IN ASSOCIATION WITH



CONFERENCE PROCEEDINGS

NESDRi–2023

INTERNATIONAL CONFERENCE ON

Numerical Methods and Experimental Techniques for Sustainable and Disaster Resilient Infrastructure

DATE

8th – 9th September 2023

ORGANIZED BY

IPS ACADEMY

Institute of Engineering & Science

(A UGC Autonomous Institute, Affiliated to RGPV)

Knowledge Village, Rajendra Nagar, A.B. Road, Indore (MP) - 452012

Civil Engineering Department

Archana Keerti Chowdhary · Amit Sharma · Mohd Nasim · Ashish Nim

Editors

Proceedings of the First International Conference on Numerical Methods and Experimental Techniques for Sustainable and Disaster Resilient Infrastructure

NESDRi-2023

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ISBN 978-93-48717-26-9

Published by: Guru Shishya Publication
Publication Date: 30 April 2025

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Preface

This volume comprises the papers presented at the International Conference on *Numerical Methods and Experimental Techniques for Sustainable and Disaster Resilient Infrastructure (NESDRi-2023)*, held on September 8–9, 2023, at the Civil Engineering Department, IPS Academy, Institute of Engineering and Science, Indore, India.

The primary objective of NESDRi-2023 was to bring together academicians, researchers, technocrats, practitioners, and students from India and abroad to exchange ideas and share research findings related to sustainable and disaster-resilient infrastructure. The conference provided a premier interdisciplinary platform for presenting recent innovations, identifying challenges, and exploring practical solutions in the field of civil engineering. To ensure systematic planning and execution, a 14-member Organizing Committee was constituted in March 2023. Leading subject matter experts from around the world were invited to contribute to the technical program, resulting in the formation of a National and International Advisory Committee comprising 28 esteemed members. Their continuous support and expert guidance played a pivotal role in shaping the scope, quality, and impact of the conference. Held in offline mode, NESDRi-2023 featured keynote addresses, invited talks, and technical presentations from more than 120 participants, including researchers, faculty members, students, and industry professionals. The conference received 50 paper submissions, including one international contribution. All submissions underwent rigorous peer review by domain experts from both India and abroad. Following the review process, comments were provided to the authors of accepted papers. A total of 21 papers were selected for offline presentation, resulting in an acceptance rate of 42%, thereby upholding the high academic standards of the conference proceedings. The inaugural session began with a welcome address and conference overview by Dr. Amit Sharma, Convener of NESDRi-2023 and Professor, Civil Engineering Department, IPS Academy, IES. This was followed by an inaugural address by Dr. Archana Keerti Choudhary, Principal, IPS Academy, IES, and the presidential address by Ar. Achal Chowdhary, President, IPS Academy, Indore. The session concluded with a vote of thanks delivered by Dr. Mohd Nasim, Assistant Professor and Organizing Secretary of NESDRi-2023. The conference was honored by the presence of the following distinguished guests: Prof. N. K. Samadhiya (IIT Roorkee) – *Chief Guest*, Dr. A. P. Singh, Honorary Secretary, Indian Geotechnical Society – *Guest of Honor*, Dr. Mahavir Bidasari, Former President, IGS; Chairman, Ferro Concrete Construction Pvt. Ltd., Indore – *Guest of Honor*, Dr. Neelima Satyam, Professor, IIT Indore – *Guest of Honor.* Their gracious presence and insightful addresses significantly enriched the conference proceedings and inspired all attendees.

NESDRi-2023 concluded with a series of technical sessions and case study presentations, showcasing innovative solutions and practical applications in the domains of sustainable and disaster-resilient infrastructure. We extend our heartfelt gratitude to all dignitaries, contributors, reviewers, participants, and volunteers whose dedicated efforts contributed to the grand success of NESDRi-2023. We also sincerely acknowledge the guidance and support of the National and International Advisory Committee members, whose expertise and involvement were instrumental throughout the planning and execution of the event. Special thanks are due to the faculty members and students of the Civil Engineering Department, IPS Academy, Institute of Engineering and Science, Indore, whose enthusiasm, teamwork, and commitment ensured the smooth coordination of all conference activities. Their efforts in managing logistics, technical support, and hospitality were vital to the seamless conduct of the event. We also express our deep appreciation to all the volunteers for their meticulous attention to detail and dedication.

We hope that readers find the research contributions in this volume both informative and inspiring. We trust that the outcomes of NESDRi-2023 will serve as a valuable foundation for future research, collaboration, and advancement in the field of sustainable and disaster-resilient infrastructure.

About the Editors

Dr. Archana Keerti Chowdhary is a distinguished academician and the Principal of the Institute of Engineering and Science (IES) at IPS Academy, Indore. With over 25 years of experience in engineering education, she has played a pivotal role in the academic and institutional development of IES since its establishment in 1999. Dr. Chowdhary has been instrumental in elevating academic standards, fostering research culture, and guiding the institution towards national recognition. Under her leadership, all eligible undergraduate programs at IES have achieved accreditation from the National Board of Accreditation (NBA), a testament to her dedication to quality and excellence in education. Holding a Ph.D. and serving as a senior professor, she has continuously emphasized the importance of innovation, interdisciplinary learning, and holistic student development. Her leadership philosophy blends administrative efficiency with a deep commitment to academic enrichment. Dr. Chowdhary's contributions have made a lasting impact on the institution, positioning IPS Academy as a center of excellence in engineering education. She remains an inspiration to both faculty and students, advocating for a future-ready education that bridges the gap between theory and real-world application.

Dr. Amit Sharma is a distinguished academician and currently serves as Professor and Head of the Civil Engineering Department at the Institute of Engineering & Science, IPS Academy, Indore. With nearly two decades of experience in civil engineering education and research, he has significantly contributed to the academic and professional development of students and faculty alike. Holding a Ph.D. in Civil Engineering, Dr. Sharma specializes in structural engineering and experimental stress analysis. He is known for promoting a curriculum that balances strong theoretical foundations with practical application, aligning with industry needs and emerging technologies. In addition to his role at IPS Academy, Dr. Amit Sharma serves as the Secretary of the Indian Geotechnical Society (IGS), Indore Chapter. In this capacity, he plays an active role in organizing technical programs, seminars, and workshops that enhance knowledge sharing and professional networking within the geotechnical community. Dr. Sharma is also deeply committed to research and innovation, with several publications and academic contributions to his credit. His leadership style focuses on fostering interdisciplinary learning, promoting skill development, and preparing students to be globally competent professionals with a strong ethical foundation.

Dr. Mohd Nasim is a respected academician and Assistant Professor in the Department of Civil Engineering at IPS Academy, Institute of Engineering and Science, Indore. He earned his Ph.D. in Structural Engineering from NIT Raipur. With over 12 years of teaching experience and one year of field experience, Dr. Nasim combines practical insights with academic excellence. His research and teaching interests encompass structural engineering, concrete technology, innovative construction materials, and finite element analysis. In addition to his academic role, Dr. Nasim serves as the I-STEM Department Coordinator, facilitating collaboration with the Indian Science, Technology and Engineering Facilities Map (I-STEM)—a national initiative aimed at strengthening R&D infrastructure by connecting researchers and institutions with access to advanced facilities and laboratories. Through this position, he actively promotes resource sharing, research transparency, and interdisciplinary innovation within the institution. Dr. Nasim is a Chartered Engineer and a Life Member of several prominent professional organizations, including: *Institution of Engineers (India), Indian Concrete Institute (ICI), Indian Geotechnical Society (IGS), Indian Society of Structural Engineers (ISSE).* Throughout his career, Dr. Nasim has taken on various leadership and academic coordination roles such as: R&D Coordinator, I-STEM Department Coordinator, Incharge, Heavy Structural Laboratory, M.Tech Structural Engineering Coordinator, NBA & NAAC Committee Member, and Academic Mentor for Civil Engineering Students. Dr. Nasim has presented his research at numerous national and international conferences and published in reputed journals. His unwavering dedication to academic advancement, research leadership, and national collaboration through I-STEM exemplifies his dynamic role in shaping future civil engineering professionals.

Dr. Ashish Nim, Associate Professor, is highly researched and experienced in the creation of environmentally-friendly walling materials and construction products out of industrial and demolition waste. As evidenced by his study outputs in the past five years, he is narrow-minded in the aspects of sustainable masonry units, slag-based binders, and alternative construction materials. He has written some papers in the reputed SCI/ESCI and Scopus indexed journals on the use of industrial waste and the sustainable building practices. In the field of SCI/ESCI, his publications concerning building blocks of slag produced in a blast furnace, industrial waste-based walling construction, and sustainable cement-slag mortars are notable, which confirms his ability to lead in developing materials, experimental validation, and sustainability evaluation. Dr. Nim has also shown good innovativeness and capabilities of conducting translational researches by filing and publication of several patents through the Intellectual Property Facilitation Centre (IPFC). Within the goals of the proposed project, these patents are paver blocks, decorative tiles, and construction blocks made by using recycled demolition waste. Moreover, he has written and co-written books with international publishers on the topic of construction risk management, RCC precast elements and structural systems due to his extensive academic and technical background.

International Conference

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IGS INDORE CHAPTER

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Civil Engineering Department

(U.G. NBA Accredited up to June 2023)

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International Conference

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"Numerical Methods and Experimental Techniques for Sustainable and Disaster Resilient Infrastructure"

(NESDRi-2023)

8th – 9th September 2023, Indore

About Academy

Indore Professional Studies Academy (IPSA) is one of the Central India's largest education hubs. It plays a major role to develop Indore as one of the most preferred educational centre. Academy is sprawled in an area of sixty acres within three campuses, housing the most intellectual & experienced educational assembly.

IPSA is a successor to Indore Public School, manifested by a renowned architect Mr. Achal Choudhary (IIT, Kharagpur). As in a traditional hierarchy of all institutions under IPS Society, IPSA is a vast universe shining with innumerable educational extravaganzas.

IPSA offers courses at all levels with curriculums designed in partnership with local employers, ensuring our students have the best possible chance of getting a job and being great at it. Our courses are designed with future employment prospects in mind and our courses also serve the region's growing industries, from Engineering and Manufacturing to IT and architecture. The College campus offers students hands-on instruction and access to the latest equipment, leading to excellent graduate placement and "degrees that work".

IPSA has established a reputation FOE excellence and visionary thinking in its efforts to improve teaching and learning across our nation, particularly within the contexts of urban and global education. The faculty remains committed to addressing the educational and physical needs of all learners across the life span and to working closely with educators, leaders and policymakers in the field.

What makes us different?

- Education that leads to good job opportunities and advancement in nation building.
- Hands-on, applied technology education
- Experienced and well qualified faculty members.
- We facilitate students with on-campus housing, sports, and activities in lush green premises.
- Ample of support services assist students during their college experience.

About Institute

IPS Academy, Institute of Engineering & Science is one of the leading private self financing institutes devoted to imparting quality engineering education with the sole motto of 'Knowledge, Skill & Values'. The institute was established in 1999 and ranked 71 among the top 100 engineering colleges in the country and 48 among the private engineering collages in the country by Times of India, it is the top preferred institute for education amongst self financing institute in MP by CSR.

NBA New Delhi accredited five UG programs i.e. Civil Engg, Computer Science & Egg, Chemical Engg, Electrical & Electronics Egg and Electronics & Communication Engg.

NESDRi - 2023

International conference on "Numerical Methods and Experimental Techniques for Sustainable and Disaster Resilient Infrastructure" aims to bring together leading academic scientists, researchers and research scholars to exchange and share their experiences and research results on all aspects of Sustainable and Disaster Resilient Infrastructure. It also provides a premier interdisciplinary platform for researchers, practitioners and educators to present and discuss the most recent innovations, trends, and concerns as well as practical challenges encountered and solutions adopted in the fields of Sustainable and Disaster Resilient Infrastructure.
During the conference, extensive deliberations on various areas are expected by way of technical presentations, invited lectures and keynote lectures through both online and in-person modes.

Key Speakers for NESDRi - 2023

- **Dr. Vasilii Golubev**, MIPT, Dolgoprudny, Russia
- **Dr. Rajesh Dhakal**, University of Canterbury, Newzeland
- **Dr. Neelima Satyam**, IIT Indore
- **Dr. Rakesh Khare**, SGSITS, Indore
- **Dr. Ankit Garg**, Shantou University, China
- **Dr. S. R. Uma**, GNS Science, New Zealand
- **Dr. Krishna R. Reddy**, University of Illinois, Chicago, USA Russia
- **Dr. Sergey Kuznetsov**, Institute for Problems in Mechanics, Moscow Russia
- **Dr. Ekaterina Beklemysheva**, MIPT, Dolgoprudny, Russia
- **Dr. Hemant B. Kaushik**, IIT Guwahati, India
- **Dr. Minu Tressa Abraham**, RWTH, Aachen University, Germany
- **Major Dr. Chaitanya S. Sanghvi,** Government College of Engineering, Modasa

Participants

- Academician
- Researchers
- Corporate Executers
- Industry Personal
- PG Students from different streams of engineering

Conference Highlights

- Inaugural Session

  The conference will be inaugurated with the release of conference proceedings and souvenir by the chief guest.

- Keynote Sessions
  Keynote sessions are scheduled to be addressed by renowned professionals from Foreign Universities, IIT's, NIT's and Institute of National repute. Authors/delegates can learn from these eminent speakers who would be with us during the days of conference.

- Skype Sessions
  Skype sessions are dedicated for the foreign authors in absentia to present their research papers through skype. Authors/delegates can attend these sessions and take advantage of learning from foreign authors.

- Special Sessions
  One special session is scheduled to be handled by experts in the industry to focus on collaborative innovation in Indian perspective. Young authors/delegates can attend the sessions and get motivated for qualitative research.

- Meet and Greet Session
  One meet and greet sessions is scheduled for the authors/delegates attending the conference to get in touch with each other thereby strengthening the technical community. Also, they would get an opportunity to exchange ideas, share resources and develop contact with experts coming from various places.

- Photo Session
  Group photo sessions are arranged for all the authors/delegates attending the conference along with the chief guest, keynote speakers, technical session chairs and the conference general chair. All authors/delegates are provided with group photograph for the respective streams at the valedictory session.

- Valedictory Session
  The closing remarks of the conference chair are presented by the conference general chair in the valedictory session. All the participating authors/delegates, technical session chairs and keynote speakers are presented with certificates by the chief guest. Cash awards are presented to the best paper awardees.

NESDRi
8 – 9 Sep, 2023

COMMITTEES FOR NESDRi 2023

Chief Patron

- Ar. Achal K. Choudhary, Founder & President, IPS Academy Indore

Patron

- Dr. A. G. Kothari, Dean Academics, IPS Academy Institute of Engg. & Sc.
- Dr. Archana Keerti Chowdhary, Principal, IPS Academy Institute of Engg. & Sc.
- Er. Mahavir Bidasari, M.D., Ferro Concrete Cons. PVT.LTD

Convener

- Dr. Amit Sharma, HOD, CED, IPSA IES

Co-Convener

- Prof. Vijay Kumar Baradiya, Assoc. Prof.CED.

Organizing Secretary

- Dr. Mohd Nasim, Asst. Prof.CED.

ORGANIZING COMMITTEE

- Dr. Ashish Nim
- Prof. Apoorv Sharda
- Prof. Arpit Sethiya
- Prof. Sonam Yadav
- Prof. Aditi Patidar
- Prof. Pallavi Gupta
- Prof. Nitya Sanghvi
- Prof. Harshit Jain
- Prof. Richa Jain

NESDRi
8 – 9 Sep, 2023

MESSAGES

President Message

It is my distinct honor and privilege to extend a warm welcome to all participants of the International Conference on **"Numerical Methods and Experimental Techniques for Sustainable and Disaster Resilience Infrastructure (NESDRi) 2023".**

As the President of IPSA, I am thrilled to see the convergence of leading scholars, researchers, practitioners, and industry experts who have gathered to engage in meaningful discourse and collaboration on the critical issues of infrastructure resilience and sustainability.

NESDRi 2023 serves as a testament to our commitment to fostering excellence in research and innovation, and to addressing the pressing challenges facing our global community. By leveraging numerical methods and experimental techniques, we have the opportunity to advance our understanding of infrastructure dynamics and develop solutions that are both resilient and sustainable in the face of environmental uncertainties and disasters.

I would like to extend my heartfelt appreciation to the organizing committee for their dedication and hard work in organizing this conference. Their efforts have been instrumental in ensuring that NESDRi 2023 provides a platform for the exchange of knowledge, ideas, and best practices.

To all participants, I encourage you to actively engage in the discussions, share your expertise and insights, and forge new collaborations that will drive positive change in our fields of study and practice. Your contributions are invaluable in advancing the frontiers of knowledge and addressing the complex challenges of our time.

As we come together to explore new avenues of research and innovation, let us embrace the spirit of collaboration and inquiry. Together, we have the power to shape a more resilient and sustainable future for generations to come.

Thank you for your participation and dedication to the success of NESDRi 2023. I look forward to the enriching discussions and fruitful collaborations that will emerge from this conference.

Warm regards,

Ar. Achal Choudhary

President, IPSA Indore

Principal Message

I extend my warmest greetings to all attendees of the International Conference on **"Numerical Methods and Experimental Techniques for Sustainable and Disaster Resilience Infrastructure (NESDRi) 2023".**.

It is with great pleasure that we gather here to explore and exchange insights on the crucial intersections between numerical methods, experimental techniques, sustainability, and disaster resilience in infrastructure development. This conference serves as a vital platform for scholars, researchers, practitioners, and industry experts to collaborate, innovate, and address the pressing challenges facing our global community.

The theme of NESDRi 2023 underscores the importance of leveraging advanced numerical modeling and experimental approaches to enhance the resilience of infrastructure systems against natural disasters and environmental challenges. By harnessing the power of technology and interdisciplinary collaboration, we have the opportunity to develop sustainable solutions that can withstand the complexities of an ever-changing world. I am deeply grateful to the organizing committee for their dedication and tireless efforts in curating a comprehensive and engaging program for this conference. Their commitment to excellence has ensured that NESDRi 2023 provides a platform for thought-provoking discussions, knowledge sharing and meaningful networking opportunities.

To all presenters, participants, and partners, I encourage you to actively engage in the exchange of ideas, share your research findings and practical experiences, and explore avenues for collaboration. Your contributions are instrumental in advancing the frontiers of knowledge and driving positive change in our communities and beyond.

As we embark on this journey of exploration and discovery, let us remain steadfast in our commitment to building resilient and sustainable infrastructure that can withstand the challenges of the 21st century. Together, we have the opportunity to shape a future where infrastructure not only serves as a catalyst for development but also fosters resilience and prosperity for generations to come.

Thank you for your participation and dedication to the International Conference on NESDRi 2023. I am confident that your contributions will enrich our collective understanding and contribute to the advancement of sustainable and disaster-resilient infrastructure worldwide.

Warm regards,

Dr. Archana Keerti Chowdhary

Principal, IPSA, Institute of Engineering & Science Indore

Dr. MAHAVIR BIDASARIA,
D.Sc., B.Sc. (Engg.), FIE, MASCE, FIGS, MICA, MIALT

Former President (2007-08 & 2009-10).
Indian Geo-technical Society, New Delhi.

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website: www.ferroconcrete.in

Message

I am delighted and honored to extend my warmest greetings to all attendees of the **'International Conference on Numerical Methods and Experimental Techniques for Sustainable and Disaster Resilience Infrastructure (NESDRi) 2023'**.

As the Guest of Honor, I am deeply privileged to be part of this esteemed gathering of scholars, researchers, practitioners, and industry leaders who are dedicated to advancing knowledge and innovation in the critical fields of numerical methods, experimental techniques, sustainability, and disaster resilience in infrastructure development.

NESDRi 2023 provides a unique platform for us to exchange ideas, share insights, and collaborate on cutting-edge solutions to address the complex challenges facing our global infrastructure. The conference theme underscores the importance of integrating advanced numerical modeling and experimental approaches to enhance the resilience and sustainability of infrastructure systems against natural disasters and environmental uncertainties.

I commend the organizing committee for their tireless efforts in orchestrating this conference, and I extend my appreciation to all participants for their dedication to advancing the frontiers of knowledge in these vital domains.

As we come together to explore new avenues of research and innovation, let us embrace the opportunity to foster meaningful collaborations and drive positive change towards a more resilient and sustainable future for generations to come.

Thank you for the privilege of serving as the Guest of Honor of NESDRi 2023. I am excited about the opportunities for learning and collaboration that lie ahead.

Warm regards,

Dr. Mahavir Bidasaria,
Former President, IGS
Chairman, Ferro Concrete Const. (India) Pvt.Ltd., Indore.

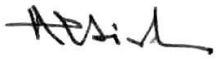
Guest of Honor Message

It gives me immense pleasure and pride in writing this message on the occasion of International conference on "**Numerical and Experimental Techniques on Sustainable and Disaster Resilient Infrastructure (NESDRI) 2023"** organized by Civil Engineering Department of IPS academy, Institute of Engineering and Science in association with Indian Geotechnical Society from 8th to 9th Sep. 2023.

On behalf of Indian Geotechnical Society (IGS), I wish to congratulate the convener and co-convener of the conference Dr. Amit Sharma and Prof. Vijay Baradiya for organising this international conference which will provide a unique platform for all the participating scholars, researchers, practitioners and industry leaders to exchange their knowledge and experience to address the complex challenges facing our global infrastructures. I believe and wish that this conference will prove to be a trend setting conference. This conference will prove to be a unique opportunity to brainstorm, cooperate and connect among all the attending participants.

My best wishes to the organisers and wishing the best for a grand success of the conference.

Yours sincerely,



Prof. A.P. Singh

Honorary Secretary, Indian Geotechnical Society

Guest of Honor Message

It is with immense pleasure and honor that I extend my heartfelt greetings to all attendees of the International Conference on "**Numerical and Experimental Techniques on Sustainable and Disaster Resilient Infrastructure (NESDRI) 2023".**

As the Guest of Honor, I am deeply privileged to be part of this esteemed gathering comprising scholars, researchers, practitioners, and industry leaders, all dedicated to pushing the boundaries of knowledge and innovation in the realms of numerical methods, experimental techniques, sustainability, and disaster resilience in infrastructure development.

NESDRi 2023 stands as a pivotal platform for us to engage in the exchange of insights, the dissemination of best practices, and the exploration of cutting-edge solutions aimed at tackling the intricate challenges that confront our global infrastructure. The conference theme resonates profoundly, emphasizing the critical need to amalgamate advanced numerical modeling and experimental approaches to fortify the resilience and sustainability of infrastructure systems against the backdrop of natural disasters and environmental uncertainties.

I extend my heartfelt commendations to the organizing committee for their unwavering dedication and tireless efforts in convening such a distinguished assemblage of experts. Moreover, I express my sincere appreciation to all participants for their invaluable contributions to this imperative discourse. As we convene to collaborate and learn from each other, let us seize this opportune moment to catalyze positive change and propel progress towards a future characterized by resilience and sustainability for all.

I am deeply grateful for the privilege bestowed upon me to serve as the guest of honor of NESDRi 2023. I eagerly anticipate the enlightening discussions and fruitful interactions.

Yours sincerely,

Dr. Neelima Satyam Devarakonda

Professor, CED, IIT Indore

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Dr. N. K. Samadhiya
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Chief Guest Message

It is with great honor and enthusiasm that I extend my warmest greetings to all attendees of the International Conference on Numerical Methods and Experimental Techniques for Sustainable and Disaster Resilience Infrastructure (NESDRi) 2023.

As the Chief Guest, I am deeply honored to be part of this significant gathering of scholars, researchers, practitioners, and industry leaders who are dedicated to advancing knowledge and innovation in the fields of numerical methods, experimental techniques, sustainability, and disaster resilience in infrastructure development.

NESDRi 2023 presents a valuable opportunity for us to exchange insights, share best practices, and explore cutting-edge solutions to address the complex challenges facing our global infrastructure. The conference theme underscores the importance of integrating advanced numerical modeling and experimental approaches to enhance the resilience and sustainability of infrastructure systems against natural disasters and environmental uncertainties.

I commend the organizing committee for their dedication and efforts in bringing together such a distinguished group of experts, and I extend my appreciation to all participants for their contributions to this vital discourse.

As we gather to collaborate and learn from one another, let us seize this opportunity to catalyze positive change and drive progress towards a more resilient and sustainable future for all.

Thank you for the privilege of serving as the Chief Guest of NESDRi 2023. I look forward to the enlightening discussions and fruitful interactions that lie ahead.

Warm regards,

Samadhiya

(N. K. Samadhiya)

Convener Message

It is my honor to welcome you all to the International Conference on "**Numerical and Experimental Techniques on Sustainable and Disaster Resilient Infrastructure (NESDRI) 2023"**.

As the convener of this prestigious event, I am thrilled to see the gathering of scholars, researchers, practitioners, and industry experts who share a common goal: to explore innovative approaches to address the challenges of sustainability and disaster resilience in infrastructure development.

NESDRi 2023 represents a unique opportunity to bridge the gap between theory and practice, bringing together cutting-edge research and practical insights from the field. Through a combination of numerical methods and experimental techniques, we aim to advance our understanding of infrastructure systems and develop solutions that are both sustainable and resilient in the face of natural disasters and environmental uncertainties.

I would like to express my sincere gratitude to the organizing committee for their dedication and hard work in planning and coordinating this conference. Their efforts have been instrumental in creating a stimulating and inclusive environment for meaningful dialogue and collaboration.

To all presenters, participants, and partners, I encourage you to actively engage in the discussions, share your expertise and experiences, and foster new connections and collaborations. Your contributions are vital in driving innovation and shaping the future of infrastructure development.

As we embark on this exciting journey together, let us embrace the opportunity to learn from one another, challenge existing paradigms, and envision new possibilities for sustainable and disaster-resilient infrastructure.

Thank you for your participation and commitment to the success of NESDRi 2023. I am confident that our collective efforts will yield valuable insights and pave the way for a more resilient and sustainable future.

Warm regards,

Dr. Amit Sharma

HOD, CED, IPSA Institute of Engineering & Science Indore

Co-Convener Message

It is with great pleasure and enthusiasm that I extend my warmest welcome to all of you as we convene for the International Conference on "**Numerical and Experimental Techniques on Sustainable and Disaster Resilient Infrastructure (NESDRI) 2023"**.

As the Co-Convener of this esteemed gathering, I am honored to be part of an event that brings together leading experts, researchers, practitioners, and stakeholders from around the world to explore innovative solutions to the complex challenges facing our infrastructure systems.

NESDRi 2023 represents a pivotal opportunity for us to leverage numerical methods and experimental techniques to enhance the resilience and sustainability of our infrastructure in the face of disasters and environmental uncertainties. Through collaborative efforts and interdisciplinary dialogue, we can advance our understanding of infrastructure dynamics and develop practical strategies for building more resilient and adaptive systems.

I would like to extend my heartfelt gratitude to the organizing committee for their diligent work and dedication in orchestrating this conference. Their tireless efforts have ensured that NESDRi 2023 provides a stimulating platform for knowledge exchange, networking, and collaboration.

To all participants, I encourage you to actively engage in the sessions, share your expertise and insights, and foster meaningful connections with your peers. Your contributions are essential in driving the conversation forward and shaping the future of infrastructure resilience and sustainability.

As we embark on this journey together, let us seize the opportunity to learn from each other, explore new avenues of research and innovation, and collectively work towards building a more resilient and sustainable future for generations to come.

Thank you for your participation and commitment to the success of NESDRi 2023. I am confident that our collaboration and collective efforts will yield transformative outcomes.

Warm regards,

Mr. Vijay Kumar Baradiya

Associate Professor, CED, IPSA Institute of Engineering & Science Indore

Organizing Secretary Message

I am delighted to extend a warm welcome to all participants of the International Conference on "**Numerical and Experimental Techniques on Sustainable and Disaster Resilient Infrastructure (NESDRI) 2023"**.

As the Organizing Secretary of this significant event, it is my privilege to play a role in facilitating an enriching and fruitful conference experience for all attendees. NESDRi 2023 brings together a diverse group of researchers, scholars, practitioners, and industry experts who are united in their commitment to advancing the field of infrastructure resilience and sustainability.

Throughout the conference, we will have the opportunity to engage in thought-provoking discussions, exchange valuable insights, and foster meaningful collaborations that have the potential to shape the future of infrastructure development. The contributions of each participant are integral to the success of NESDRi 2023, and I am grateful for your active involvement and dedication to this important endeavor.

I would like to express my sincere appreciation to the organizing committee for their hard work and dedication in planning and executing this conference. Their tireless efforts have been instrumental in ensuring that NESDRi 2023 provides a platform for high-quality presentations, networking opportunities, and knowledge sharing.

To all participants, I encourage you to make the most of your time at the conference by actively participating in sessions, engaging with fellow attendees, and seizing the opportunity to expand your professional network. Your contributions and interactions will undoubtedly contribute to the success and impact of NESDRi 2023.

As we come together to explore new frontiers in infrastructure resilience and sustainability, let us embrace the spirit of collaboration, innovation, and inquiry. Together, we can make meaningful strides towards building a more resilient and sustainable future for communities around the world.

Thank you for your participation and support, and I wish you a productive and enriching conference experience.

Warm regards,

Dr. Mohd Nasim

Assistant Professor, CED, IPSA Institute of Engineering & Science Indore

NESDRi
8 – 9 Sep, 2023

PROFILE KEYNOTE SPEAKERS



Dr. Dr. A.P. Singh

Director, Explore Engineering Consultants Pvt. Ltd
Honorable Secretary, Indian Geotechnical Society (IGS), New Delhi

Dr. A.P. Singh, Director of Explore Engineering Consultants Pvt. Ltd, is an esteemed figure in geotechnical engineering. Serving as the Honorable Secretary of the Indian Geotechnical Society (IGS) in New Delhi, India, he drives collaboration and professional development within the field. With expertise spanning academia and industry, Dr. Singh is renowned for his contributions to sustainable infrastructure development. His leadership at Explore Engineering Consultants exemplifies a commitment to innovation and excellence in geotechnical engineering, inspiring peers and shaping the industry landscape in India and beyond.

Keynote Talk: Deep Foundation for Large Infra Projects

Abstract: The keynote address at the "Deep Foundation for Large Infra Projects" technical session highlighted advancements in deep foundation techniques for expansive infrastructure projects. Emphasizing the crucial role of deep foundations, the speaker discussed various systems including drilled shafts, piles, and caissons, along with design considerations, construction methods, and quality assurance measures. Integration of innovative technologies such as advanced monitoring systems and robotics was underscored to enhance construction efficiency and safety. Case studies demonstrating successful applications of deep foundation techniques in notable projects were presented, offering valuable insights for professionals engaged in large infrastructural developments.



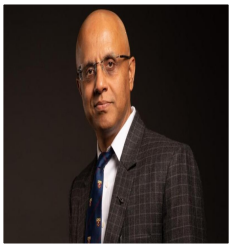
Dr. Neelima Satyam

Professor, Dept. of Civil Engineering,
IIT Indore

Dr. Neelima Satyam is a distinguished Professor at the Indian Institute of Technology (IIT) Indore, renowned for her expertise in her field. With a robust academic background and extensive research experience, Dr. Satyam is a leading authority in her area of specialization. Her contributions to academia and research have garnered widespread recognition, making her a respected figure in the academic community. Through her innovative research, mentorship of students, and participation in scholarly activities, Dr. Satyam continues to make significant contributions to advancing knowledge and fostering excellence in engineering education at IIT Indore.

Keynote Talk: Ground Improvement Methods for Expansive Sub-Grades

Abstract: This abstract encapsulates the key points presented by the keynote speaker during the technical session on "Ground Improvement Methods for Expansive Sub-Grades." The speaker emphasized innovative approaches to address the challenges posed by expansive sub-grades in infrastructure projects. Key topics included soil stabilization techniques, such as chemical stabilization and mechanical reinforcement, aimed at enhancing soil strength and reducing swell potential. Additionally, the speaker discussed the importance of site investigation, geotechnical analysis, and monitoring in selecting and implementing appropriate ground improvement methods. Case studies showcasing successful applications of ground improvement techniques in mitigating the adverse effects of expansive sub-grades were also presented. The keynote address provided valuable insights and practical strategies for engineers and practitioners involved in infrastructure development, highlighting the significance of adopting effective ground improvement methods to ensure the stability and longevity of infrastructure projects on expansive sub-grades.



Prof. Rajesh Dhakal

Structural and Earthquake Engg.

University of Canterbury, New Zealand

Dr Rajesh Dhakal is a Professor of Structural Earthquake Engineering at University of Canterbury in NZ. He received a Bachelor of Civil Engineering from Tribhuvan University (Nepal) in 1993, Master of Structural Engineering from the AIT (Thailand) in 1997 and a PhD from the University of Tokyo in 2000. His current research interests are: (i) Seismic performance of non-structural elements, (ii) Modelling, analysis, testing and design of RC structures, and (iii) Seismic loss minimization in buildings. Prof Dhakal has served in multiple panels; received more than a dozen awards for research excellence, served as an Editorial Board member for five international journals and delivered invited/keynote lectures in more than a dozen conferences. Prof Dhakal has been serving as the Chief Editor of the journal Bulletin of the NZ Society for Earthquake Engineering since 2014. In recognition of his contribution and leadership in earthquake engineering, Prof Dhakal was conferred a Fellowship of the Engineering New Zealand (since 2015) and the NZ Society for Earthquake Engineering (since 2017). In 2021, Prof Dhakal was elected the President of the International Association of SPONSE (Seismic Performance of Non-Structural Elements).

Keynote Talk: Numerical and Experimental Investigation on Out-of -Plane Buckling of Reinforced Concrete Structural Walls

Abstract: Following observations of out-of-plane instability in slender ductile structural walls in some recent earthquakes, this mode of wall failure has been, and is being, investigated by several research groups. Analytical, numerical and experimental investigations have been conducted to study this failure mechanism as well as its controlling parameters. Both singly reinforced and doubly reinforced concrete walls have been studied under unidirectional and bidirectional loading. A simplified approach making use of concrete columns representing boundary zones of rectangular walls has also been used to reduce the computational and experimental costs of the research programs. This presentation provides a state-of-the-art on the existing design practice and research conducted on this failure mechanism, in relevance with rectangular walls and under unidirectional loading.



Dr. S. R. Uma

Senior Risk and Resilience Engineer,
GNS Science, Lower Hutt, New Zealand

Dr. S. R. Uma, currently Senior Risk and Resilience Engineer at GNS Science, New Zealand, possesses extensive expertise in seismic performance assessment of buildings and functional services. With direct field experience in earthquake damage surveying and analytical modeling, she contributes significantly to international research collaborations in earthquake engineering. Dr. Uma has been instrumental in developing relevant design standards in New Zealand and conducting site-specific earthquake hazard studies based on probabilistic seismic hazard analysis. Her leadership and project management skills are evident in her role in seismic instrumentation projects for buildings and bridges. Additionally, Dr. Uma's academic background enriches her teaching experience at bachelor's and master's levels, including curriculum development and laboratory establishment. Specializing in earthquake risk assessment and resilience management, she exemplifies how water network managers worldwide can leverage science models to undertake risk assessment studies and develop resilience management plans effectively.

Keynote Talk: Planning for Resilient Infrastructure under Seismic and Cascading Hazards

Abstract: Infrastructure networks are vulnerable to earthquakes and the resulting cascading hazards, leading to disruptions in functionality and services to communities. Recent earthquakes in New Zealand highlighted prolonged service outages, prompting authorities to prioritize understanding and mitigating risks to infrastructure networks. To address this, pragmatic approaches are needed to deliver hazard, damage, and risk information effectively to stakeholders for informed decision-making and resilience planning. This study focuses on improving resilience in water networks, presenting a transparent approach to risk assessment in three key steps: defining earthquake hazard scenarios, identifying vulnerable network components, and estimating service outage durations. Using a case study of the water supply and wastewater networks of Rotorua Lakes Council, the study illustrates the process through ground motion intensity estimation, damage identification, and outage modeling based on repair strategies and crew availability. This case study serves as a model for water network managers worldwide, showcasing how risk assessment studies supported by science models can inform resilience management plans effectively.



Dr. Golubev Vasily Ivanovich

Senior Researcher & Head, Laboratory of Applied Numerical Geophysics Moscow,

Institute of Physics and Technology, Dolgoprudny, Russia

Dr. Golubev Vasily graduated in 2009 in BSc in Applied Mathematics and Informatics and in 2011 in MSC from Moscow Institute of Physics and Technology, Russia. His area of interest is the development of mathematical models, numerical methods and applied computer programs. In the research group at MIPT a new grid-characteristic method on hexahedral and tetrahedral meshes was developed that proved his robustness in wide range of scientific simulations.

Keynote Talk: Aspects of the Grid-Characteristic Methods for the Dynamic Deformation Problems.

Abstract: Numerical methods and algorithms for accurately simulating dynamic processes in layered structures, composite materials, and geological media during seismic prospecting or seismic activity initiation are actively advancing. While ray-tracing methods are widely used, they are approximate and often inadequate for understanding the behavior of real fractured geological media. Various numerical methods, such as the finite difference method and the Galerkin method, are employed for simulating seismic processes in complex media. Hybrid calculation algorithms are also developed to enhance accuracy. The grid-characteristic method, originally applied in gas dynamics, is now utilized for solving the hyperbolic system of equations governing seismic wave propagation. Initially used in unstructured triangular grids, this method was adapted for deformed solid mechanics in the 1980s. It has since been extended to simulate seismic response in multilayer geological media and account for fluid-saturated cracks. Recent developments include studying the response of clusters of fluid-saturated cracks and conducting three-dimensional simulations on unstructured grids.

Although three-dimensional calculations pose computational challenges, employing the grid-characteristic method on hexahedral grids significantly improves calculation speed. This advancement enables more efficient simulation of the formation of responses from clusters of fluid-saturated cracks in uniform media. Overall, ongoing advancements in numerical methods facilitate more accurate and detailed simulations of seismic processes in complex geological environments.



Dr. Hemant Kaushik

Professor, Dept. of Civil Engineering,
IIT Guwahati, India

Dr. Hemant Kaushik is presently working as professor in Dept. of Civil Engineering at IIT Guwahati. His area of specialization is structural engineering. Research Interests are Earthquake Resistant Design of structures, Nonlinear Behavior of Structures, Retrofitting of Structures, Seismic Vulnerability Assessment of Structures, and Earthquake Damage Surveys. He has awarded with Fellow of Institution of Engineers (India) since 2020. Professional Membership Earthquake Engineering Sectional Committee, CED, Bureau of Indian Standards, Earthquake Engineering Research Institute (EERI), USA and many more.

Keynote Talk: Reinventing the Wheel: Assam-type Housing.

Abstract: Assam-type houses are commonly found in the northeastern states of India. Generally, it is a single storey house; however, two-storey houses are also found at some places. The main function or use of this construction type is multi-family housing. These are generally single dwelling units and do not have common walls with adjacent buildings. The house is made largely using wood-based materials. Performance of Assam-type houses has been extremely good in several past earthquakes in the region. Structural strengths that influence earthquake safety of the house include good configuration, light-weight materials used for walls and roofs, flexible connections between various wooden elements at different levels, etc. However, the houses are vulnerable to fire because of use of untreated wood-based materials. When built on hill slopes, unequal length of the vertical posts leads to unsymmetrical shaking that may damage the house.



Dr. Ekaterina Beklemysheva

Senior Scientist, Institute of Physics and Technology,
Moscow, Dolgoprudny, Russia

Dr Ekaterina Beklemysheva presently working as senior scientist at MIPT, Russia. Completed her PhD in numerical mathematics and graduated from DASR MIPT in 2011. She had participated in a number of research projects on aircraft and space composites, supported by RSF. She also coordinated number of programming courses at MIPT.

Keynote Talk: Grid-characteristic numerical method for modeling of low-velocity impacts on fiber and fiber-metal laminates.

Abstract: The modern level of technology inevitably requires numerical modeling as a part of the industrial design process, but modeling of composites still requires an extensive research to be safe and reliable for engineering uses. Weak impacts play an important part in degradation of strength properties of a composite. They are mostly called low-velocity impacts, because they are reproduced by a low velocity of the impactor on standard drop-weight laboratory equipment. During exploitation, weak impacts may be inflicted by small objects like hail or gravel, moving with a high speed. The modeling data, presented in this lecture, shows the difference between strikes with the same energy, inflicted by objects of different mass. The numerical modelling was performed via grid-characteristic numerical method that shows good coincidence with experimental data for dynamic loading of deformable solids. The data provides an illustration to capabilities of the grid-characteristic method and its applicability to the problem of residual strength of fiber and fiber-metal laminates. This method is close to finite difference methods and it is faster than many other grid methods. It allows implementing various border and contact conditions, including friction contact, and complex destruction models for anisotropic materials. The homogenous orthotropic elastoplastic material model with several failure criteria and destructible contacts allows modeling the barely visible impact damage and its influence on material strength during quasi-static compressive in-plane loading. Tsai-Hill, Tsai-Wu, Drucker-Prager, Hashin and Puck failure criteria were implemented and considered.



Dr. Rakesh Kumar Khare

Professor, Civil Engineering & Applied Mechanics Department

Shri G.S.I.T. S, Indore, India

Dr. Rakesh Kumar Khare holds a Bachelor's degree in Civil Engineering and a Master's degree in Structural Engineering. His area of research focuses on Thermal Stresses in Fiber Reinforced Composite Laminated Plates and Shells. Dr. Khare's research interests encompass Finite Element Analysis and design of structures, Financial Seismic risk analysis of buildings and structures, Nonlinear and Incremental dynamic Analysis of structures, Seismic Analysis and Design of Precast Concrete Building Structures, as well as Computer-Aided Analysis and Design of Structures. With a diverse background in civil engineering and a specialization in structural engineering, Dr. Khare brings a wealth of expertise to his research endeavors, contributing to advancements in the understanding and design of resilient and sustainable structures.

Keynote Talk: Seismic Loss Estimation of Multi Storied Reinforced Concrete Frames.

Abstract: Incremental Dynamic Analysis (Ida) is an emerging tool for probabilistic seismic performance assessment. Recent studies on seismic design philosophies and financial risk assessment methodologies suggests that repairing of minor to moderately damaged structures contributes significantly in seismic financial risk. Through study it can be concluded that by adopting capacity design principles, buildings perform well at higher intensity ground motions. If columns are designed using capacity design concept in flexure incorporating contributions from floor reinforcement to beams, frames perform well even at 0.72g PGA scenario. All low rise frames are likely to partially/completely collapse in large magnitude earthquakes (i.e. annual probability > 0.0001). Smaller and frequently occurring earthquakes will pose big effect on financial risk of structures. Around 50-70% of annual financial risk is contributed by earthquakes with return period between 100-1000 years. As frequently occurring earthquakes pose small risk to buildings, owners can bear repair costs by themselves. The repairing cost for stronger earthquakes may exceed above 80% and repairing costs can be uneconomical, hence owners would like to pass this risk to insurers. It can be recommends that frames designed with capacity design concepts in shear and flexure shall be insured for stronger earthquakes with higher return periods only which in turn give rise to low insurance premiums.



Dr. Sergey Kuznetsov

Professor, Institute for Problems in Mechanics, Moscow, Russia

Dr. Sergey Kuznetsov is presently working as a professor and a leading scientist at the institute for Problems in Mechanics of Russian Academy of Science. He is the member of Scientific Committee of MICE, Russia and Editorial Board Member of various reputed research journals like International J. Computational, Civil & Structural Engineering and Bulletin of MICE.

His Research interests are Theoretical methods in surface acoustic wave studies, Surface acoustic waves in NDT, Seismic waves, Principles of seismic and vibration protection and mathematical methods in vibration analyses.

Keynote Talk: The Turkey – Syria earthquake of 06.02.2023.

Abstract: The recent devastating earthquake of Mw7.8 occurred on February 6, 2023 in the Kahramanmaraş region having extreme intensity (XI) on the modified Mercalli scale (MMS) caused the death of more than 52,800 people in Turkey and Syria, as well as severe damages to the infrastructure. The appearance of an unusually strong delta-like S-wave pulse in the seismogram of the main shock and its consequences are analysed, and possible measures to mitigate the possible future high intensity earthquakes are discussed.



Dr. Minu Tressa Abraham

Researcher RWTH, Aachen University,
Germany

Dr. MInu Tressa is presently working as a Geotechnical Research Engineer at Norway Geotechnical Institute Oslo, Norway. She had received prestigious Alexander van Humboldt Post Doctoral fellowship from RWTH Aachen, Germany in 2022. His Research interests are: Landslide forecasting model, parametric calibration of debris flows using coarse-resolution spatial data, Numerical modelling of debris flows and simulation based decision support for disaster risk reduction.

Keynote Talk: Field Investigations and Numerical Modeling of Debrisflows for Disaster Risk Reduction.

Abstract: This work summarises the previous research works carried out on detailed field investigations and numerical modelling of debris flows. Utilizing field surveys, laboratory analyses, and remote sensing data, the methodology aims to quantify similarities between different debris flow sites and using it for simulating debris flows. The field investigations revealed useful insights in understanding the similarities between four debris flow sites in the Western Ghats of India. The calibrated rheological parameters using Voellmy-Salm rheology for one site were found to be useful in simulating the shape of other debris flows satisfactorily. The major challenge in simulating the debris flows of the study area was found to be the coarse topographical input and the sparse field observations. Attempts were made to overcome these difficulties using alternate metrics for parametric calibration. The findings offer insights for identifying similar hazard-prone areas within the region and facilitate quantitative hazard assessments through debris flow simulations.



Dr. Ankit Garg

Associate Professor,
Dept. of Civil & Environmental Engineering, Shantou University, China

Dr. Ankit Garg, an Associate Professor at Shantou University, China, holds a Doctorate from Hong Kong University of Science & Technology. With international experience as a visiting scholar at the University of Leeds, U.K., and the University of Macau, his research focuses on Bio-geotechnics and sustainable materials, particularly biochar, in unsaturated soil. Dr. Garg's contributions have earned him prestigious awards like the "Telford Premium prize" from the British Civil Engineers Association for his publication in Geotechnique letters, ICE, UK. Recognized as one of the highly cited authors by ICE, UK, he also serves as an editor for esteemed journals including the International Journal of Acta Geophysica (Polish Academy of Sciences), Journal of Intelligent and Fuzzy Systems (Texas A & M University, USA), Journal of Smart Construction and Sustainable Cities (Springer), and Journal of Materials Circular Economy (Singapore). Dr. Garg's dedication to sustainable engineering solutions cements his position as a leader in the academic community.

Keynote Talk: Role of biochar and vegetation in green infrastructure.

Abstract: While biochar has been widely used in agricultural soil to enhance plant productivity, its application in green infrastructure, such as green roofs, green slopes, and landfill bio-covers, remains relatively unexplored. Soils in green infrastructure are often compacted and nutrient-deficient compared to agricultural soil. Currently, there are no design guidelines for incorporating biochar in green infrastructure projects. The type of feedstock (animal or plant waste) and the pyrolysis temperature during biochar production significantly affect its physical and chemical properties. Therefore, there is a critical need to develop suitable biochar formulations and understand the complex interactions among soil, biochar, water, roots, microbes, and the atmosphere. This study aims to develop novel biochars from both animal and plant waste and investigate their effects on soil water retention, gas flow, and cracking using experimental studies. A newly designed gas permeability setup will be utilized for this purpose. Additionally, the mechanisms underlying soil-biochar interactions will be explored in relation to the physical and chemical properties of the biochars produced from different feedstock's and pyrolysis temperatures. Furthermore, the study will explore the development of an intelligent irrigation system and a Smartphone application for estimating soil moisture based on reflection theory and unsaturated soil mechanics principles, respectively, as part of future research endeavors.

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ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

Numerical Simulation of Ice Plate Behavior under Low Impact by using Finite Element Method

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Abstract

Ice is a complex heterogeneous material. Using a mathematical model is a way to study the heterogeneity of materials. Therefore, in this study, the heterogeneity of the ice is explained by using a linear isotropic elastic model. To inspect any deformations in ice, a low impact of the velocity is considered. In this study, a three-dimensional model is considered. Both ball and ice are considered deformable. Abaqus is used for numerical modeling and simulation. A reference point is created at the center of ice, to observe deformation. The ball is allowed to strike the ice, with seven different velocities. The numerical results show that the displacement is 10 times less as compared to the experimental result. However, the force in all these cases agrees very well with experimental data. To find the precise displacement, an elastoplastic model is used and initially found in good agreement with experimental data but still this study is continuing.

Keywords: Computer simulations, Elastic and plastic media, Low impact

1 Introduction

To find the destruction process in today's modern world, modeling and simulation are used. With the increase in technology, it becomes, quite easier to solve complex problems on computers [1]. By using a powerful computer, the computational time decreases. Furthermore, oil reserves in the Arctic region have become increasingly popular for investigating heterogeneous materials. Therefore in this study, to find the heterogeneity of ice, numerical simulations are performed by using computational solid dynamics techniques (CSD). The heterogeneity of the ice is explained by using linear and non-linear mathematical models. In the current study linear elastic model is used, to find the deformation in the ice plate. The experimental study was performed by Epifanov [3] who struck a steel ball into the rectangular substrate of the ice and observed deformation shown in Figure 1. Steel ball is struck to the ice with seven different velocities. The penetration on the ice surface and force

ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

are obtained. To solve the problem numerically, Abaqus is considered for modeling and simulation. Finite Element Method (FEM)[2] is used to solve the linear elastic model.

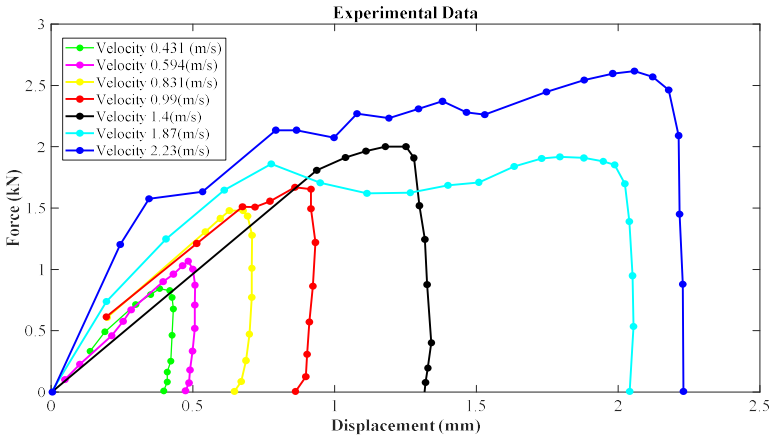


Fig.1. Experimental Resultof Ice Deformation (source: Guseva, E. K et al., 2022)[3]

2 Problem Formulation

2.1 Mathamatical Model

In this study, a three-dimensional model is considered. Both ball and ice are considered deformable. Abaqus is used for numerical modeling and simulation Linear isotropic elastics model is applied that shows the relationship between velocity$V$ and stressσ shown below [4].

$$\rho\dot{V} = \nabla.\sigma + f \tag{1}$$

$$\dot{\sigma} = \lambda(\nabla.V)I + \mu\left((\nabla\otimes V) + (\nabla\otimes V)^T\right) + F \tag{2}$$

However, $\boldsymbol{f}$ is the external force, F is additional force is equal to zero and $\boldsymbol{\rho}$ is the density of the material. Lame constant $\boldsymbol{\mu, \lambda}$ are dependent on the young's modulus$\boldsymbol{E}$ and passion ratio$\boldsymbol{\nu}$. The materialistic properties of ice and steel ball are reliant on on the pressure $\boldsymbol{C_P}$ and shear wave $\boldsymbol{C_S}$ velcoties.

$$C_P = \sqrt{\frac{\lambda + 2\mu}{\rho}} \tag{3}$$

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$$C_S = \sqrt{\frac{\mu}{\rho}} \tag{4}$$

$$\lambda = \frac{E\nu}{(1+\nu)(1-2\nu)} \tag{5}$$

$$\mu = \frac{E}{2(1+\nu)} \tag{6}$$

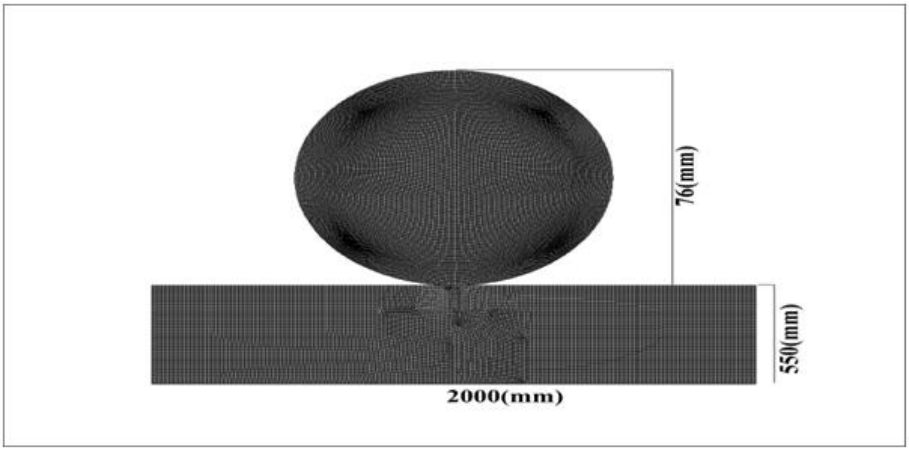


Fig.2. Geomtery and Mesh of Ice and Ball

2.2 Numerical Setup

Pressure and shear wave's velocity for ice are$C_p = 3940\frac{m}{s}$,$C_s = 2493\frac{m}{s}$ and for ball [3] $C_P = 5700\frac{m}{s}$,$C_S = 3100\frac{m}{s}$. Computational mesh is structured and has a size 0.6million shown in fig2. Dynamics solver is used with a time step of $10^{-8}s$ and total time for simulation is 0.2s. To observe deformation in the ice, a reference point is created at the center of ice.

3 Simulations Results.

The linear isotropic elastic model is solved using the finite element method (FEM). The present study demonstrates a qualitative analysis of simulation. The deformation observed at the center of ice that shows displacement is 10 times less than the experimental result. The numerical pentation amplitude is less than the experimental amplitude as shown in figs3,4.

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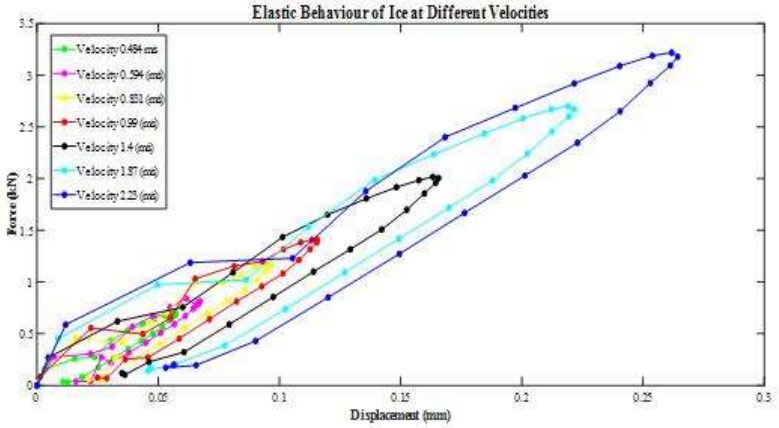


Fig.3. Numerical Result of Elastic Moidel at different Velocities

The maximum displacement in experimental cases is 2.230mm when the velocity is 2.23$\frac{m}{s}$. But numerically, the maximum displacement is 0.26mm which is 8.41 times less than experimental displacement. The comparison between displacement in different cases is shown in Table 1. However, the amplitude of force remains the same as in the experimental result, shown in figs 3, and 5. According to fig 3, it is quite clear that with the increase in the velocity of the steel ball, the depth on the surface of the ice also increases. Initially, the displacement and force increase, but when the ball loses, its all kinetics energy, it starts decreasing.

Table 1. Comparsion between Numerical and Experimental Displacement

Velocity (m/s)	**Experimental Displacement (mm)**	**Numerical Displacement (mm)**	**Error (Times)**
0.484	0.430	0.057	7.492
0.594	0.507	0.067	7.525
0.831	0.708	0.096	7.337
0.990	0.932	0.115	8.060
1.400	1.341	0.165	8.095
1.8700	2.054	0.221	9.26
2.230	2.23	0.264	8.41

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However, the amplitude of force remains the same as in the experimental result, shown in Figs 3, and 5., The maximum error between numerical and experimental force is 1.20 times when the velocity is 0.484(m/s) and the minimum error between them is 0.71 times when the velocity of the ball is 1.87(m/s). Furthermore, the relation between numerical and experimental force is shown in Table 2.

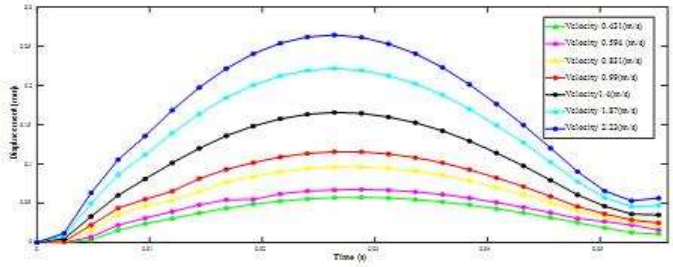


Fig.4. Displacement on the ice surface at different velocties

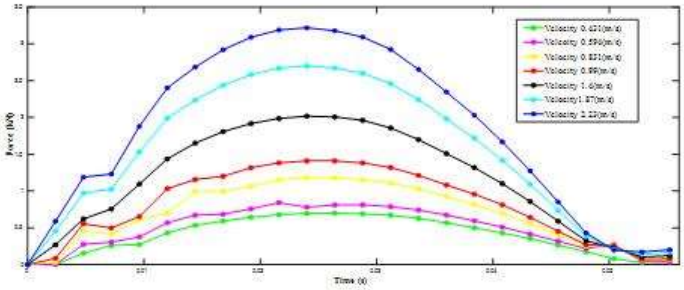


Fig.5. Behavior of Force at different velocities

Table 2. Comparsion between Numerical and Experimental Force

Velocity (m/s)	Experimental Force (kN)	Numerical Force (kN)	Error (Times)
0.484	0.843	0.699	1.20
0.594	1.066	0.841	1.26
0.831	1.480	1.180	1.25
0.990	1.669	1.408	1.18
1.400	2.002	2.016	0.99
1.8700	1.917	2.698	0.71

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2.230	2.618	3.217	0.81

4 Conclusion

In this research, the linear isotropic elastic model is applied, to find the mathematical model of the ice. The results show that the elastic model does not behave well with experimental results. The numerical displacement is ten times less than the experimental results. However, the force agrees very well with the experimental data. Furthermore, the elastoplastic model shows very well results as compared to the elastic model but still, the research continues for the model of ice.

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ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

Fly ash based Geopolymer mortar with pumice aggregate replacement

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Abstract

The present paper aims to utilize the fly ash wastes with lightweight aggregates for geopolymer concrete production process in which sodium hydroxide (NaOH) and sodium metasilicate (Na_2SiO_3) were used as alkali activators, respectively. The mix design for the research was derived from the packing density method and the geopolymer was investigated depending on the replacement of fine aggregate in the mix with pumice aggregate on a constant curing temperature and molarity of the alkali activator solution. The effects of pumice aggregates were discovered for the production of lightweight geopolymer concrete. The microstructural properties of each produced geopolymer concrete and the materials were characterized using XRD and particle size distribution. The specifications of the concrete were evaluated based on their uniaxial compressive strength (UCS), ultrasonic pulse velocity test(UPVT) and water absorption test(WAR) and sorptivity test for results. The compressive strength of geopolymer concretes were in the range of 20-70 MPa and during the research the unit weights changed from 2300 kg/m^3 to 1600 kg/m^3 . Lighter concretes were obtained on increasing the amount of pumice aggregate in the mix.

Keywords: Geopolymer, Lightweight, Pumice, Durability tests, aggregate.

1. Introduction

Geopolymer concrete is innovative and eco-friendly construction material and an alternative to Portland cement concrete. The use of a geopolymer reduces the demand of Portland cement which is liable for high CO_2 emission. Portland cement is the key component in the making of concrete as it acts as the binder between fine aggregate and coarse aggregate on the addition of

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ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

water. The Portland cement alone contributes almost 8% of the world's CO_2 emission that is it has a massive effect on the carbon footprint. Geopolymer concrete has various advantages over normal concrete such as fireproof, environmental sensitivity, low price, and permeability. It is very resistant to break down to several of the durability issues that can cause traditional concrete to crack and decay. This is often accomplished by using minimally processed natural materials or industrial byproducts. Geopolymer concretes will cure more quickly than Portland concretes. They have obtained most of their strength within 24 hours. Geopolymers are inorganic materials that are obtained from the chemical reaction of aluminosilicate oxides with sodium silicate solutions in a highly alkaline environment, complying with a polymeric Si-O-Al bond. Davidovits [1] introduced the geopolymer concrete in 1991 in which it was explained that a geopolymer consists of AlO_4 and SiO_4 tetrahedral creating poly(sialate), poly(sialate -siloxo) and poly (sialate -disiloxo) molecular structures to form three-dimensional polymeric chains Geopolymerization reaction occurs between solid aluminosilicate oxides (minerals or inorganic by-products) and alkali metal silicate solutions (NaOH, KOH, etc.) to build amorphous or semicrystalline polymeric constructs containing Si-O-Si and Si-O-Al frameworks in high alkali conditions and at moderate temperatures (20-150^{0}C) The empirical formula of Geo Polymers is as follow:

$$B_m\,[-(SiO_2)-AlO_2]_m.\,nH_2O \qquad (1)$$

Where B is a metal cation (Ca^{2+}, K^+ or Na^+), j is 1, 2 or 3, and m is the polycondensation degree. Lightweight concrete is the concrete having a unit weight between 1600 kg/m^3 to 1950 kg/m^3. Being lightweight in nature makes them advantageous at many places like it has a lesser dead load, developed thermal and sound insulation and easy to transport. Huang et al. [2] in their study compared microstructures of the lightweight concrete with the normal weight concrete, and it was found that the bonds between lightweight aggregate and cement paste are relatively tight, and there are no visible cracks at the joint interface. Lightweight concrete has an anti-earthquake effect compared to Portland cemented concretes therefore, the reduction of vertical forces results in a decrease in inertia affecting the structure. In this study, a fly ash-based geopolymer was created by replacing fine aggregate with a pumice stone in order to study the property of concrete at a constant temperature and molarity and the study of concrete's mechanical and durability properties.

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2. Materials and Methodology

2.1 Materials

Class F fly ashes (according to ASTM C618-17a) were taken from NTPC Kawas thermal power station located in Surat, Gujarat. Pumice samples were purchased from Global enterprises from Herohalli, Bangalore, Karnataka. X-ray diffraction (XRD) pattern of each sample was obtained using a Bruker, D8- Advance P-XRD-Analysis equipped with a Cu-Ka radiation in the 2ϕ range of 10°-90° and the material phases were identified through Rietveld (TOPAS) analysis software. XRD patterns of the samples are given in Fig. 1 for fly ash (black), AP (red) and peaks revealed that all the materials had amorphous silica which had confirmed by a broad peak between 15° and 45° in Fly ash and between 10° and 15° in pumice aggregate.

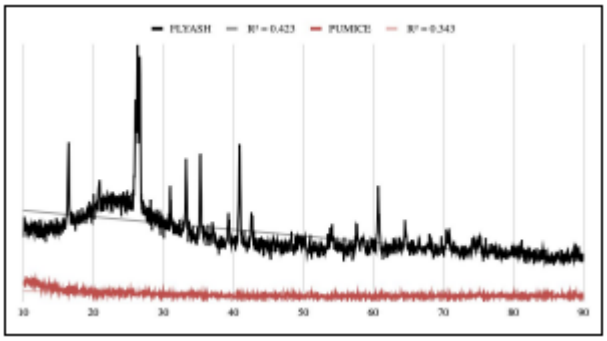


Fig.1 XRD pattern of samples (a) Fly ash (b) pumice

The particle size distribution of fly ash and pumice samples is given in Fig. 2. The size distribution of pumice samples (4.75mm) was provided to be compatible with IS 2386-1 [3].The D50 value was 4.75 mm for pumice using a dry sieving analysis, while the D50 value of the fly ash sample was found to be 150 μm.

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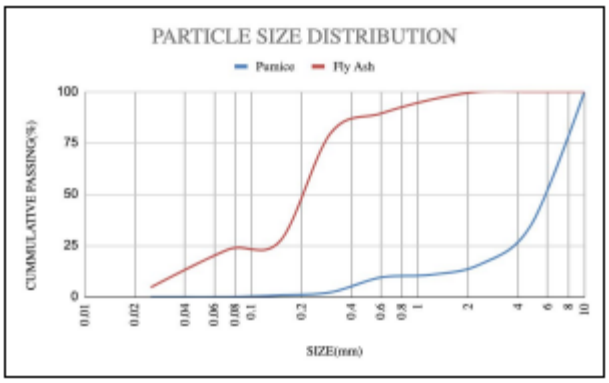


Fig 2. The particle size distribution of the sample of fly ash and pumice (logarithmic scale).

2.2 Methods

Sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3) solutions were used to provide geo polymerization and no additional water was added to the mortar. The chemicals used to create the alkali activator solution in this study [sodium metasilicate (Na_2SiO_3) solution and sodium hydroxide (NaOH) pellets] were supplied from Astrra chemicals, Chennai, Tamil Nadu. Tap water was used for the alkali (NaOH) solution preparation, the solution was prepared a day before the casting of the mortar. The mix design for the project is done via the packing density method, through which Molarity of NaOH, Alkali Activator Solution (AAS) content and alkali activator solution (AAS) ratio (NaOH: Na_2SiO_3) was decided and curing temperature and curing time were decided the binder content and the AAS to binder (Fly ash) ratio were assumed based on many literatures studied on. The priority of the project is set to on to get the best strength possible at particular molarity and with particular materials. The mortar was composed of fly ash, an alkali solution, fine aggregates, and lightweight aggregates. The mixture was manually stirred for 5 min before pouring into molds. Afterward, the mortar was poured into 50×50×50 mm^3 molds. After the casting of mortar, after about 6-7 hours which were enough for the hardening of mortar, the cubes were demolded and kept in the hot air oven for further curing of 24 hours at 90℃. After the duration, the specimens were kept in the ambient or room temperature for further curing. The compressive strength of the specimens was measured on 1 day, 3 days, 7 days and 28 days. The universal compressive testing machine's pace rate was chosen to be 0.50 KN per second and it was applied until the specimens were broken, the value

ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

at which the specimens breaks were recorded. In addition, the water absorption test and sorptivity test were performed on the mortar specimen according to the ASTM C642 [4] and ASTM C1585 [5], respectively.

3. Results and Discussions

3.1 Effect of Molarity on compressive strength of the specimen

Table 1. Indicates the compressive strength of geopolymer mixes.The effect of these factors on the compressive strength of the mortar was investigated in detail as the Na_2SiO_3 and NaOH concentration have the strongest effect on the compressive strength of the mortar. Our Experiments were carried out with mortar at 6M, 8M and 10M and cured in a hot air oven for 24 hrs and then kept for ambient curing for the rest of the curing days. We kept the molarity of the alkali activator solution at 6M, 8M and 10M. At 6M with 0% pumice replacement, 1, 3, 7, 28 days compressive strength of the mortar is 32 MPa, 44 MPa, 52 MPa and 58 MPa respectively. At 8 M with 0% pumice replacement, 1, 3, 7, 28 days compressive strength of the mortar is 65.2 MPa, 74.3 MPa, 75 MPa and 84 MPa. At 10M, the compressive strength is close to the strength coming at 8M. It is found that the highest compressive strength of the mortar is coming at an 8M solution. As the molarity of the solution increases from 6M to 8M, the compressive strength of the mortar increases and slightly decreases at 10M. It is understood that the molarity of the alkali activator solution plays a crucial role in the strength property of the concrete. Therefore, we performed our further tastings at 8M solution with 0%, 10%, 20% pumice replacement.

3.2 Effect of Percentage Pumice Replacement

We found that the workability of the specimen increases with the addition of pumice. The effect of the pumice % replacement was studied in detail. 8 M solution was giving higher strength as compared to 6M. We tested the pumice(%) replacement at 8 M solution only. At 8 M solution with 0% pumice replacement with fine aggregates, the compressive strength of the mortar at 1, 3, 7, 28 days is 65.2 MPa, 74.3 MPa, 75 MPa and 84 MPa respectively. As we added the pumice and increased its % from 0 to 10 at 8M, the compressive strength of the mortar at 1, 3, 7, 28 days is 44.1 MPa, 47.1 MPa, 48.5 MPa and 57.4 MPa respectively. The compressive strength of the

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mortar is lower at 20% as compared to the 10% pumice addition. We found that as the percentage of pumice increases, the compressive strength decreases. We also found that as the percentage of pumice increases, the weight of the specimen decreases and the details are shown in Table 2.

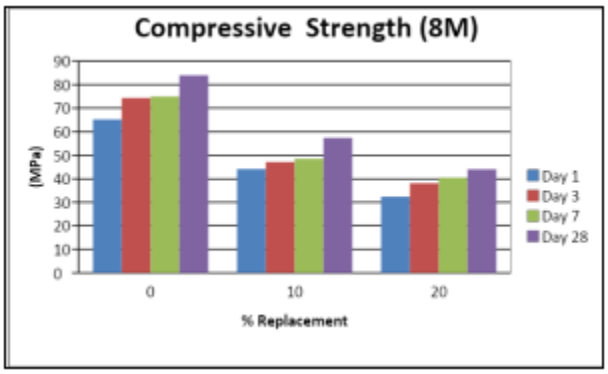


Fig 3. Compressive Strength (8M)

Table 1. Compressive strength at different molarities

S.No.	Molarity (M)	Pumice Replacement (%)	Compressive strength (Day 1) (N/mm^2)	Compressive strength (Day 3) (N/mm^2)	Compressive strength (Day 7) (N/mm^2)	Compressive strength (Day 28) (N/mm^2)
1.	6	0	32	44	52	58
2.	8	0	65.2	74.3	75	84
3.	10	0	56	62.67	74	83.5

Table 2. Compressive Strength at 0%, 10%, 20% Pumice Replacement

S.No.	Molarity (M)	Pumice Replacement (%)	Compressive strength (Day 1) (N/mm^2)	Compressive strength (Day 3) (N/mm^2)	Compressive strength (Day 7) (N/mm^2)	Compressive strength (Day 28) (N/mm^2)
1.	8	0	65.2	74.3	75	84
2.	8	10	44.1	47.1	48.5	57.4

ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

3.	8	20	32.4	38.1	40.4	44

3.3 Durability tests performed on the specimen:

Table 3. Sorptivity test reading for geopolymer concrete for 1-day test

DAY 1															
MIX 1	TIME	CUBE(g)		GAIN(g)		CUMULATIVE GAIN (g)		VOLUME OF WATER(mm3)		SURFACE AREA(mm2)		i (mm)		Sorptivity	
time	t^0.5	weight 1	weight 2	cube 1	cube 2	cube 1	cube 2	cube 1	cube 2	cube 1	cube 2	cube 1	cube 2	cube 1	cube 2
0	0	312	306	0	0	0	0	0	0	2500	2500	0	0	0	0
1	1	313.6	309.4	1.6	3.4	1.6	3.4	1600	3400	2500	2500	0.64	1.36	0.64	1.36
5	2.236	314.8	310	1.2	0.6	2.8	4	2800	4000	2500	2500	1.12	1.6	0.501	0.716
10	3.162	315.2	310.2	0.4	0.2	3.2	4.2	3200	4200	2500	2500	1.28	1.68	0.405	0.531
20	4.472	315.4	310.4	0.2	0.2	3.4	4.4	3400	4400	2500	2500	1.36	1.76	0.304	0.394
30	5.477	315.6	310.5	0.2	0.1	3.6	4.5	3600	4500	2500	2500	1.44	1.8	0.263	0.329
60	7.746	316.5	311	0.9	0.5	4.5	5	4500	5000	2500	2500	1.8	2	0.232	0.258
120	10.954	317.8	311.9	1.3	0.9	5.8	5.9	5800	5900	2500	2500	2.32	2.36	0.212	0.215
180	13.416	318	312.3	0.2	0.4	6	6.3	6000	6300	2500	2500	2.4	2.52	0.179	0.188
240	15.492	318.4	312.7	0.4	0.4	6.4	6.7	6400	6700	2500	2500	2.56	2.68	0.165	0.173
300	17.321	318.9	313.2	0.5	0.5	6.9	7.2	6900	7200	2500	2500	2.76	2.88	0.159	0.166

On Day 1, the amount of water absorbed is high and as compared to day 3 and day 7. In the sorptivity graph also, the line increase at initial hours and then smooths as time passes. That is why it is found that the sorptivity curve for day 1 and day 3 is slightly curved when compared to day 7 which is slightly linear.

4. Conclusions

The following conclusion could be drawn from the following study: 1. All the specimens of geopolymer concrete were lightweight but the lightest geopolymer concrete (1636 kg/m$^{3)}$ was obtained at 20% pumice replacement with fine aggregate. 2. As the percentage of pumice in the mix is increased the weight and the density decreases and along with that the strength decreases. 3. With the increase in molarity the strength increases but after 8M specimen there was a decrease in the strength of the specimen noticed. 4. It was seen that the sorptivity curve for the 1 day and 3-day test was slightly curved when compared with the 7-day specimen test which was

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linear in curve. 5. The gain percentage in water absorption test is decreasing as the percentage of aggregate replacement increases. 6. The XRD test done on the 28-day tested cube of 0%, 10% and 20% pumice represents: a. At 0% pumice replacement, the specimen shows amorphous behaviour all along but crystal phases can be distinguished at 27.38° and 60.57°. b. At 10% pumice replacement, the specimen shows crystal phases at many points because of the high presence of silicon dioxide and aluminium oxide in the chemical composition. The specimen shows amorphous behaviour at the beginning and at the end of the analysis. c. At 20% pumice replacement, the specimen attains highest crystal phase at 27.18° and 68.14° the specimen attains peak at many positions but at these two specific positions the specimen obtained highest and second highest value, respectively. The specimen shows amorphous behaviour especially at the end of the analysis.

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ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

An mechanical impedence Method For Structural Health Monitoring Using Piezoelectric Materials

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Abstract

The present study focuses on the mechanical impedance obtained by piezoelectric ceramic materials when used to monitor the structural health of civil engineering constructions. Due to their compact size and form, cost-effectiveness, and straightforwardness of installation, piezoelectric ceramic (PZT) patches have become popular impedance transducers for structural health monitoring (SHM) structures in recent years.Many research and industrial labs have lately shown an interest in the study of structural identification and long-term monitoring. The linked procedures will be helpful to increase dependability as well as lower maintenance and inspection costs by allowing equipment and structures to monitor their own structural integrity while in use. For this study, a 700 mm by 150 mm by 150 mm beam reinforced with Fe415 and concrete of the M20 and M30 grades will be employed. On the beam, 27 mm PZT patches are soldered at intervals of distance. The expected outcomes may be summed up as structural health monitoring assisting in lowering the cost of structural maintenance. PZT patches will track any changes in structural health and foretell them.

Keywords: Structural health monitoring, mechanical impedence, piezoelectric patches, composites.

1. Introduction

For the viewpoint of structural safety, the failure of diverse engineering components is becoming a crucial issue. These structures that fail include high-rise skyscrapers, multi-story buildings, certain private companies, airports, etc. One of the numerous causes of these sorts of failures is

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ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

natural disasters like earthquakes. As a result, it is crucial for academics to conduct thorough research, good design, and analysis to ensure the safety of these sorts of constructing structures.The impedance approach has been suggested by Cheng et al. [1] For constructing the couplings between the PZT patch and the host structure and among the PZT patches in a structure coupled with many PZT patches. The impedance methodology has a lot of promise for addressing the inverse vibration issue analytically, as shown by a method for synthesizing a specific response of a thin plate using numerous PZT patches. The inertia impact induced by the PZT patch on the host structure's vibration response is also recommended to be included in a modified structural impedance model of the host structure, which is significant for a typical intelligent structure that is typically bonded with numerous PZT patches. The force prediction for each PZT patch in creating a specified vibration response is more precise with the suggested improved structural impedance.The practical challenges surrounding the use of a wave propagation approach based on piezoelectricity in monitoring concrete curing wereaddressed by Lim et al. [2]. Concrete curing and strength development monitoring utilizing the wave propagation (WP) technology have recently found use for the smart piezoelectric material Lead Zirconate Titanate (PZT). Because a number of practical concerns have not been addressed, the technique's real-world applicability has sometimes been questioned. In order to bridge the gap between laboratory research and practical applications, a number of experimental experiments are conducted in this study to look into a variety of practical concerns relating to the use of this approach.Surface-bonded piezo-impedance transducers in two pieces are used in a novel, more straightforward approach developed by Bhalla et al. [3] to detect structural problems. A novel electro elastic PZT-structure interaction model is introduced in the first section, which is based on the idea of "effective impedance." With the help of the suggested formulas, it is simple to determine the mechanical impedance of any "unknown" structural system from the admittance signatures of a surface bonded PZT patch. The suggested model is tested using a smart system that consists of an aluminum block with a PZT patch instrumented on it. They have introduced a fresh way to assess structural deterioration using the derived impedance spectra in Part II. The suggested method is shown to be effective for identifying defects in a variety of structures, including huge civil structures as well as small precision

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machine and aerospace components.SHM is the process of putting an engineering structure's damage detection and characterization method into practice. Structure, sensors, data collecting systems, data administration, data interpretation and diagnosis, system identification, structural model updating, structural state assessment, and prediction of remaining service life are some of the components of the SHM System. The employment of sensors in aircraft and bridges is one use of this technology. This evaluation of changes in structure like stress and strain is provided by these sensors. The information obtained from the sensors is often sent to a remote data collection center when it comes to civil engineering constructions. Modern technology makes it feasible to operate structures in real time (active structural control) based on data from sensors.This concept, also known as structural health assessment (SHA) or structural health management (SHM), is often used to describe many types of infrastructure, particularly as the globe enters an even more active phase of building bridges and other types of infrastructure, including skyscrapers. Particularly when damage to structures is involved, it's important to remember that there are several instances of increasing difficulty which require for knowledge of earlier stages, such as determining whether there is damage on the structure, finding the extent of the harm, determining the types of damage, and estimating how severe the damage is.The use of signal processing and classification by statistics are required to transform sensor data on the condition of the infrastructure into damage information for evaluation. Structures are collections of members that can securely transmit the loads that are being overlaid. Throughout the course of their design lives, they are built to perform certain purposes. The structures must meet their strength and utility standards for the duration of their specified design lifetimes in order to perform their intended tasks.But over time, some wear and tear and damage are unavoidable owing to a number of circumstances, including environmental deterioration, tiredness, heavy loads, natural disasters, or rigorous use. Damage is defined as modifications to a structural system's material and/or geometric features, including modifications to the boundary circumstances and system accessibility, which have a negative impact on the system's functionality. Significant structural degradation may result in failures that compromise safety and cause annoyance. The same is explained by the next two cases.

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i. According to examinations conducted for the benefit of Eindhoven Airport and construction firm BAM, the partially collapsed structure of the parking area at Eindhoven Airport in May was caused by a construction fault. RTL Niue's claims that the parking garage's flooring, which were still being built at the precise moment of the collapse, were insufficiently strong.
ii. Prefabricated concrete slabs served as the flooring. The connections connecting the slabs weren't secure enough and didn't adhere to safety standards. The fourth story was when the collapse began. On May 27, the day of the collapse, it was quite hot. Uneven heat distribution through the slabs increased stress on the connections' already precarious state. The fourth floor gave way. The three stories below it also broke way under its weight.

A total of 900 sq. m. of space collapsed. There were no casualties at the time, and nobody had been working on the building.

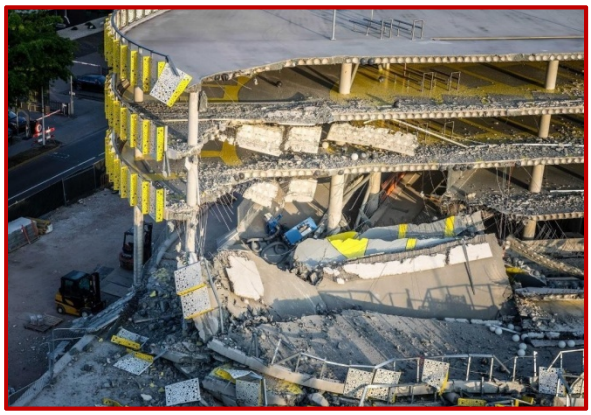


Fig.1 Eindhoven airport car park, Netherlands [3].

An electromechanical susceptibility detec tion method for online monitoring of concrete strength development utilizing smart PZT patches was investigated by Shin et al. [4]. Smart piezoelectric materials have emerged as a viable tool for the creation of a computerized system for SHM. This technology uses electro-mechanical impedance (EMI) sensing. Numerous nondestructive techniques for measuring strength gains seem to have a limited ability for doing so continuously. This research examines the viability of using EMI sensing technology for real-time strengthening monitoring for fresh concrete. On a concrete specimen using a piezoelectric patch instrument, experimental research is carried out. Kaur [5] investigated the possibility of adhesively glued thin piezo-patches functioning in D31mode for energy harvesting and integrated structural health monitoring. Up to this point, piezoelectric materials have each

ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

independently shown their effectiveness for obtaining energy and SHM. The most effective PZT patches for SHM are those that operate in the D31 mode. Built-up structures, such as stack actuators, are more preferable for energy collecting. This study's major goal was to determine if it would be feasible to utilize the same piezoelectric sensor for both SHM and energy harvesting on actual bridges.Although concrete constructions typically have a lengthy lifespan, they nevertheless need upkeep. Numerous instances of catastrophic failures serve as a reminder to the engineering community that structure monitoring is essential today for preventing the destruction of life and property as well as for efficient handling of infrastructure based on a typically limited budget. In order to provide accurate assessment findings, many methods must be employed, often in a complimentary manner, due to the wide range of structural sizes, forms, and applications, as well as the potential vulnerabilities of the various kinds of buildings.The summary of previous catastrophic events in the section before has amply shown the devastating force of structural damage once it progresses beyond the first stage. Therefore, even a little, impending harm should not be neglected since it might spread and result in failures that stop some kind of revenue-generating activity or cause a large-scale reduction in life and property, or both.This risk implies an in-depth assessment of the buildings on a regular basis, or SHM [6]. The evaluation of static and dynamic responses for layered composite arches or materials associated with flexible piezoelectric have been studied and recently it become an open area for analysis and it has been investigated by some researchers [7–10].

2. Materials and Methodology

Themethodologyto beadopted in present studyisas follows:

i. Reinforced concrete beams are the structural element being considered for the PZT patches used to monitor the health of concrete structures.
ii. Damage recognition or identifying cracks will be experimentally examined using VEEPRO software and PZT patch responses.
iii. The condition evaluation of constructions will be taken into account for various configurations as well as for various kinds of PZT patches.

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iv. Computer software will be used to do the computational analysis.

In the experimental study, a reinforced concrete beam is the object of inquiry, and PZT patches are used to measure the structure's reaction. Oscilloscopes or the VEEPRO system may be used to collect data for analysis. Variations in the responses using PZT patches will then be used to determine the extent of the damage. The project's goal is to use an LCR meter and piezoelectric patches to analyze the behavior of a structural element, in this case a slab. The cuboidal cross-section sample slabs will have dimensions of 150 mm x 150 mm x 700 mm.



Fig. 2 Reinforcement used in slabs. 8mmϕ Fe 415



Fig. 3 Cast of slabs in molds at 3 days

The separate grades of M20 and M30 are employed to strengthen the sample beam with Fe 415 8mm. The specimen was evaluated with zero faults first, then with a damaged location subsequently, and the precise differences were shown for various frequencies. The investigation was conducted using a high-end LCR meter that generated high frequencies. The specimen was soldered to the piezoelectric material.

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Fig. 4 High frequency LCR meter



Fig. 5A 27 mm patch of PZT

PZT patches were attached to the framework using industrial-grade epoxy adhesive. Because the patches are highly sensitive, a smooth surface was necessary for the connections. A metal ribbon was bonded among the exterior on the slab and the patch to provide the link between the concrete and the patch. When the connections were made, the reaction the patches had for no damage was recorded, and after that, the patches had a response around the damaged areas of the beam.



Fig. 6 Experimental setup

The light from the lasers caused four separate damage locations, prompting the necessary

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reaction. Localized methodology is the name given to the technique of damage identification.

3. Results and followed by discussions

Two beams with the same size but different concrete grades were used in the experiment. The patches were appropriately linked to the beams, and each patch's signature was collected. The beams were manually hammered with varied loads at points near the patches after the data for the undamaged condition was collected. To examine the variance in signatures collected from both scenarios, the responses and patterns obtained from the patches after causing damage to the structure were compared. With the use of VEEPRO and an Excel spreadsheet, the readings from the LCR meter were converted into numerical form. 1000 separate measurements, spanning from 1 KHz to 1000 KHz, were obtained for each patch. the PZT patch on the beam's deformation for both damaged and undamaged beams.

i. The peaks in each example were reached at various frequencies. After about 700 KHz, the conductance versus. frequency characteristic for damage 4 drastically altered.
ii. The frequency range between 160 KHz and 220 KHz was the best scenario for comparing the curves.
iii. There were little changes in the Susceptance vs. Frequency. This demonstrates that the PZT patch's health remained excellent throughout the procedure.

Table1. Conductance values for patch

Frequency	Damage1	Damage2	Damage3	Damage4	Undamaged
205000	0.00155906	0.00169889	0.00179556	0.00186962	0.00159059
206000	0.00158763	0.00170429	0.00180808	0.00186417	0.00161764
207000	0.00160929	0.00169799	0.00182587	0.00186247	0.00163416
208000	0.00162091	0.00169509	0.00183011	0.0018616	0.00164428
209000	0.00162771	0.00169875	0.00180862	0.00186065	0.00164702
210000	0.00162415	0.00168728	0.0017734	0.0018396	0.00164649
211000	0.00160862	0.00166452	0.00173842	0.00179522	0.00164541
212000	0.00159129	0.00164324	0.00170915	0.00174556	0.00163287
213000	0.00156281	0.00161331	0.00167761	0.00169867	0.00160369
214000	0.00153383	0.00157386	0.001633	0.0016605	0.00155659
215000	0.00150978	0.00153453	0.00158197	0.0016118	0.00149854

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216000	0.001478	0.00148418	0.00153716	0.00155173	0.00144363
217000	0.00142902	0.00143382	0.00148666	0.00149401	0.00139538
218000	0.00136769	0.00139207	0.0014315	0.00144195	0.00134936
219000	0.00130521	0.00134897	0.00136865	0.00138478	0.00130477
220000	0.00124944	0.00128914	0.0013058	0.00132399	0.00126288
221000	0.00120147	0.00122527	0.00125277	0.00125607	0.00122098
222000	0.00115793	0.00116484	0.0012042	0.00119617	0.00117967
223000	0.00111658	0.00111113	0.00114926	0.00114498	0.00114045
224000	0.00107811	0.00106554	0.0010912	0.00109369	0.0011053
225000	0.00103962	0.00102825	0.00103504	0.00103686	0.0010684
226000	0.00100221	0.000990269	0.000983596	0.000982765	0.00102711
227000	0.00096677	0.000954444	0.000941719	0.000932621	0.000988367
228000	0.000934708	0.000918573	0.000907735	0.000888188	0.000953637
229000	0.000902977	0.000884417	0.000874977	0.000852452	0.000919972
230000	0.000868819	0.000850869	0.000841121	0.000821943	0.000888224
231000	0.000835883	0.000820978	0.000808821	0.000790892	0.000858483
232000	0.000806356	0.000792055	0.000778709	0.0007599	0.000831536
233000	0.000778207	0.000762888	0.000751656	0.000729235	0.000806615
234000	0.000752121	0.000735248	0.000726409	0.000702086	0.000781082
235000	0.000728438	0.000709771	0.000700245	0.000678011	0.000755102
236000	0.000706792	0.000685124	0.000673377	0.000654893	0.000731034
237000	0.000688003	0.00066225	0.000649548	0.000630261	0.000709164
238000	0.000669403	0.000642084	0.000627417	0.000606605	0.000687478

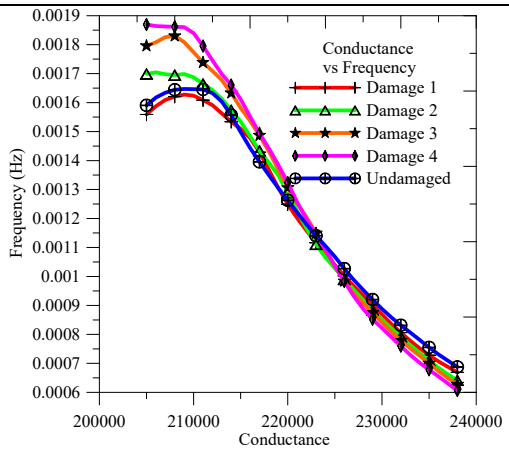


Fig. 7 Conductance(Q) vs Frequency(Hz)

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4. Conclusions

The structural health monitoring using PZTpatcheswillbemorebeneficialovertraditional approaches are concludeas follows,

i. PZT patches make it simple to establish structural health monitoring and make record data accessible as soon as it becomes available. By using PZT patches, damage recognition and crack detection will be more accurate and realistic. Due to the high frequency of the approach, noise is not a problem, therefore the signature is unaffected by noise, producing more accurate findings.
ii. The damage may be determined through research on damage detection by the vertical and lateral shifting of the peak and the changing of conductance value for healthy and various damage conditions. It is known that PZT patches may identify a variety of problems, including as fractures, scrapes, and holes.
iii. The signature curves demonstrate that when damage severity increases, the structure's conductance value rises. The best frequency range for studying a structure is between 150 KHz and 250 KHz. This is so because it is in this area that the conductance reaches its maximum value.

Acknowledgments

The authors thank the Aditya Dighe,Prakash Bhujade, Prathamesh Khobragade, and Aniket Kolpe for their help during the work (Sanjivani College of Engineering Kopargaon).

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An Experimental Investigation on Black Cotton Soil stabilization with Geogrid and Cement for Road Construction

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Abstract

The present study focuses on the soil treatment and improvement is commonly performed in the field of geotechnical engineering. Methods and materials to achieve this such as soil stabilization and mixing with cementitious binders have been utilized in engineered soil applications since the beginning of human civilization. Demand for environmentally friendly and sustainable alternatives is currently rising. Construction on problematic and soft soils has always been considered a challenging task by geotechnical engineers. Such soils can be treated with traditional cement stabilization. However, in some cases using geogrid reinforced and cement treated soil can be very effective, especially in case of loading conditions. In this research, a series of laboratory testing has been carried out to investigate properties of cement treated black cotton soil with and without geogrid reinforcing layer. The dissimilar forms of technique used for soil stabilization are soil stabilization with cement, soil stabilization with lime, soil stabilization and chemical stabilization associated an innovative promising experience of stabilization by geo textiles and geo artificial fibers.

Keywords: Geogrid, geotextile, geosynthetics, black cotton soil, cement road, etc.

1. Introduction

Geosynthetics are man-made plastics shaped in many forms (i.e. grids, textiles, nets, and cells) that possess and may contribute significant tensile strength to the bottom portion of a highway pavement section. Although geosynthetics have many applications, the focus of this report is on quantitative observations to learn more about how highways are improved with geosynthetics.

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ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

Geosynthetics are important for highway construction, since observations indicate better performance (i.e. less rutting associated with increased numbers of load repetitions) for highways constructed with geosynthetics reinforced sub-bases. A geosynthetics-reinforced sub-base is typically constructed above relatively soft subgrades and allows for thinner layers of base and surface courses above. The traditional and typically more costly alternative method for highway construction consists of replacing soft subgrades with thick granular and/or base course layers to insure support of the pavement surface. Recent explorations indicate our predecessors' strengthened walls and roads with natural materials (i.e. trees, branches, and other plant fibers). For example, the great-wall of China utilized interbedded tree branches to reinforce successive layers of earthen material. Recently, adevelopments from the natural materials having stronger, more-durable, man-made material, etc. Senthil and RajKumar et al. [1] have worked on three main components i.e., Soil, Aggregate and Geotextile Material. The subgrade soil was compacted in the CBR mould for 125mm height to its maximum dry density at the optimum moisture content found from Standard Proctor test and remaining 50mm with well graded gravel. CBR tests were carried out with 50mm plunger for soil-aggregate, soil-woven geotextile-aggregate and soil-nonwoven geotextile-aggregate systems separately. The results obtained by taking the average of three trails for each, are plotted as load versus penetration. The variation of load-penetration curve for soil-aggregate and soil-woven geotextile-aggregate is shown graphically in the paper.Oza and Gundaliyaet al. [2] have studied regarding the basic properties of Black Cotton soil, Cement and Lime powder were thoroughly studied by the researchers. They tested soil in three different conditions i.e..1) Black Cotton soil with cement dust, whose effective result was at 7%. 2) Black Cotton soil with cement dust and lime were mixed in different percentages. Effective results were found when 9% of lime and cement were mixed with soil. 3) In third condition only, lime was mixed with soil and satisfactory results were when 8% of lime mixed in sample. Gawande et al. [3] the group found one of the most effective and economical methods of stabilization are the addition of stabilizing agents like fly ash and high-density polyethylene (HDPE) to expansive soil. In this study, an expansive black cotton soil from field was stabilized using above materials i.e., fly ash in proportion of 5%, 10%, & 15% by weight of soil and HDPE strips in proportion of 0.2%, 0.4% & 0.6% by weight of soil are

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separately added and observations were taken using different preliminary and engineering tests. The results were discussed about the effect of increasing % of stabilizing materials to the respective mixture.Sune and Deshmukh et al. [4] have worked on the effect of the soil strength after the application of geotextile materials, Conducted the primary soil tests such as natural Proctor Compaction Test. Studied the results drawn from above tests for the unreinforced and reinforced soil with different percentages like 1%, 2%, 3%, 4% & 5%.Hotti et al. [5] the group studied the effect of granules on the index properties of black cotton soil stabilized with 2%, 4%, 6% and 8% granules by weight of the soil. In this study the Atterberg's limits, differential free swelling, compaction characteristics, CBR tests, were conducted as per relevant IS codes practice. The test study shows the behavior of the black cotton soil. The Atterberg limits i) Liquid limit (WL) is 51.9% ii) Plastic limit (WP) is 42.5% iii) Plasticity index (IP) is 9.65%. The swelling index of the soil is 50% and specific gravity is 2.45. Shrinkage limit (WS) is 7.46%. The optimum moisture content is 22% and maximum dry density is 1.501g/cm^3. Compaction and CBR tests were conducted as relevant IS code practice. The CBR test results show that unsoaked CBR value increases from 6.69% to 9.2% that is 2.51% increase in CBR value with addition of the granules.Ogundare et al. [6] have examined the stabilization of two soil samples (lateritic and clay) using geotextile as reinforcement. Geotechnical tests were carried out to determine Particle size analysis, Atterberg Limit test, moisture content, specific gravity, Compaction test and California Bearing Ratio test. CBR tests were conducted with and without non-woven geotextiles with the non-woven geotextiles placed at depths H/4 from the top and base surfaces of the soil in single layer under unsoaked conditions to determine the strength of the soil samples. The result showed that the strength of the soil samples increased by introducing non-woven geotextile in the soil as the one placed at depth H/4 from the base surface showed higher CBR values (15.1% and 19.6%) than when placed at depth H/4 (14.1% and 18.2%) from the top surface.

Present research study examine the soil properties vary a great deal in construction of structures depends a lot on the bearing capacity of the soil, hence it is necessary to stabilize the soil to improve the load bearing capacity. The gradation of the soil is also a very important property to

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be considered while working with soil. The soils may be well-graded which is desirable as it has a smaller number of voids or uniformly graded which though sounds stable but has more voids.

2. Materials and Methodology

This section deals with the experimental procedure to be carried out in the project, properties of various material along with there specifications. This includes the various tests to be conducted to check the properties of the material including the black cotton soil and cement in add with it. The tests are performed according to the standard recommendations given as the Indian road congress (IRC).

2.1 Geogrid

1. Product Specification - Biaxial Geogrid BX1500.
2. Product Type: Integrally Formed Biaxial Geogrid.
3. Polymer: Polypropylene.
4. Load Transfer Mechanism: Positive Mechanical Interlock.
5. Composition: 1.42% in each sample.

Table 1 Product properties of geogrid

Index Properties	**Units**	**Values**
Aperture Dimension	Inches	1.0
Minimum Rib Thickness	Inches	0.76
Tensile Strength @ 2% strain	KN/m	4.1
Tensile Strength @ 5% strain	KN/m	8.5
Ultimate Tensile strength	KN/m	12.4
Structural integrity		
Index Properties	Units	Values
Junctional Efficiency	%	93
Flexural Stiffness	Mg-cm	250000
Aperture Stability	m-N/deg	0.32
Durability		
Index Properties	Units	Values
Resistance to Installation Damage	%SC/%SW/%GP	95/93/90

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Resistance to Long Term Degradation	%	100
Resistance to UV degradation	%	100



Fig. 1 Biaxial geogrid used in experiment

2.2 Cement

Table 2 Composition percentage of Cement

Lime (CaO)	63.1%
Silica (SiO2)	20.6%
Alumina (Al2O3)	6.3%
Iron oxide (Fe2O3)	3.6%
Magnesia (MgO)	1.7%
Sulphur trioxide (SO3)	2.3%
Soda and/or Potash (Na2O+K2O)	0.7%

Table 3 Compound percentage of cement

Tricalcium silicate (3CaO.SiO2)	40%
Dicalcium silicate (2CaO.SiO2)	30%
Tricalcium aluminate (3CaO.Al2O3)	11%

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Tetra calcium aluminoferrite (4CaO.Al2O3.Fe2O3)	12%

Table 4 Properties of OPC cement

Properties	**Values**
Specific Gravity	3.12
Normal Consistency	29%
Initial Setting time	65min
Final Setting time	275 min
Fineness	330 kg/m^2
Soundness	2.5mm
Bulk Density	830-1650 kg/m^3

2.3 Black Cotton Soil

The black cotton soil sample was collected from location Sr.No.2/5, Babhulgaon Khurd Nagar - Manmad Road Yeola, Tal-Yeola, Dist-Nashik,423401, Coordinates: 20°03'53.9"N 74°28'29.3"E.

2.3.1 Sieve Analysis [IS 2720 (Part 4) – 1985]

The grain size distribution is found by mechanical analysis. If the percentage fines are more there is a need to conduct wet sieve analysis.



Fig. 2 Sieve set and Gradation sample

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2.3.2 Liquid Limit Test [IS 2720 (Part 5) – 1985]

To study the liquid limit of soil Casagrande test was conducted. Liquid limit is generally determined by the mechanical method using Casagrande's apparatus. As per this method the liquid limit is defined as the moisture content at which 25 blows or drops in standard liquid limit apparatus will just close a groove of standardized dimensions cut in the sample by the grooving tool by a specified amount.



Fig. 3 Liquid limit test apparatus

2.3.3 Plastic Limit Test [IS 2720 (part 5) – 1985]

To study the Atterberg's limit it is important to conduct plastic limit test. Plastic limit (PL) is the water content at which the soil rolled into thread of smallest diameter possible starts crumbling and has a diameter of 3 mm.



Fig. 4 Plastic limit test apparatus

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2.3.4 Compaction Test [IS 2720 (part VII) – 1980]

The Standard Proctor Test is conducted to study the density of soil and its corresponding optimum moisture content. Compaction of soil is a mechanical process by which the soil particles are constrained to be packed more closely together by reducing the air voids. Soil compaction causes a decrease in air voids and consequently an increase in dry density. This may result in an increase in shearing strength.



Fig. 5 Standard Proctor Test

2.3.5 Specific Gravity Test [IS 2750]

Knowledge of specific gravity is needed in calculation of soil properties like void ratio, degree of saturation etc. Specific gravity G is defined as the ratio of the weight of an equal volume of distilled water at that temperature both weights taken in air.

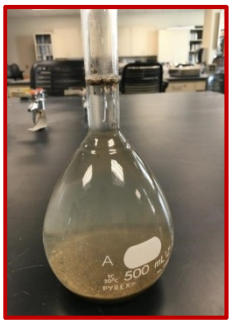


Fig. 6 Specific gravity test apparatus

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2.3.6 California Bearing Ratio (CBR) Test [IS 2720 (Part 16) – 1987]

The CBR test denotes a measure of resistance to penetration of a soil or flexible pavement material, of standard plunger under controlled test conditions.



Fig. 7 CBR test

3. Results and followed by discussions

The grain size analysis is widely used in classification of soils. The data obtained from grain size distribution curves is used in the design of filters for earth dams and to determine suitability of soil for road construction, air field etc. Information obtained from grain size analysis can be used to predict soil water movement although permeability tests are more generally used.

3.1 Plain 100% Black Cotton Soil:

Table 5 Sieve Analysis of Plain 100% Black Cotton Soil

Sr. No.	I.S. Sieve Size	Soil Retained (grams)	Percentage Retained (%)	Cumulative Percentage Retained (%)	Percentage Finer (%)
1	4.75 mm	42	4.2	4.2	95.8
2	2.36 mm	22	2.2	6.4	93.6
3	1.18 mm	54	5.4	11.8	88.2
4	600 microns	78	7.8	19.6	80.4
5	300 microns	193	19.3	38.9	61.1
6	150 microns	169	16.9	55.8	44.2
7	75 microns	41	4.1	59.9	40.1
8	Pan	401	40	100	0

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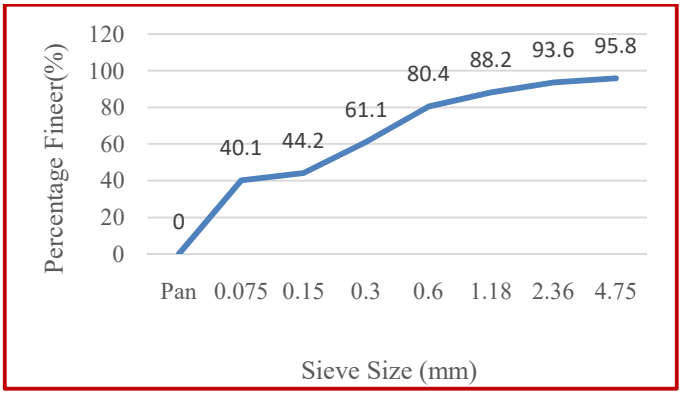


Fig. 8 Percentage finer vs sieve size for virgin soil.

Interpretation: This sample is virgin sample i.e.; it contains 100 percent Black cotton soil which has 19.33 as Uniformity Coefficient and 0.72 as Coefficient of Gradation. In this sample presence of sand is 57% whereas Silt+ Clay and Gravel are 35% and 5% respectively.

3.2 BC Soil with 2% cement:

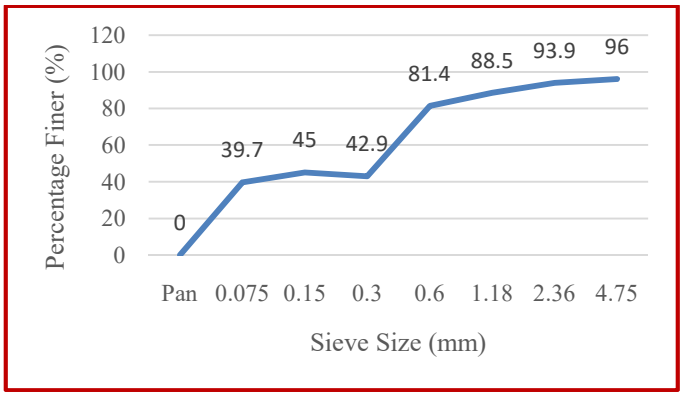


Fig.9 Percentage finer Vs Sieve for 2% Cement mixed soil

Interpretation: This sample contains 98% Black cotton soil mixed with 2% of cement. There were no marginal and satisfactory change in the gradation of cement on addition of 2% cement in black cotton soil. The results of graphical analysis of the data given below are, Uniformity coefficient and Coefficient of gradation are 22.5 and 0.57 respectively, whereas it contains 56% sand, 40% silt and clay, and 4% gravel.

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3.3 BC Soil with 4% cement:

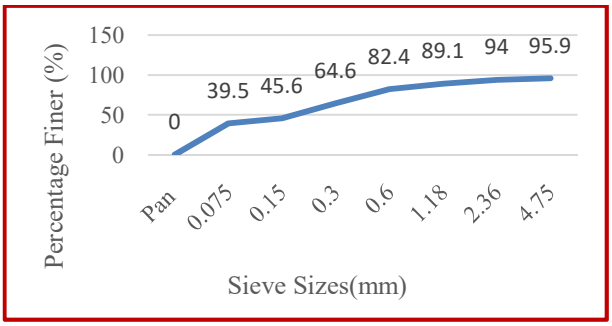


Fig. 10 Percentage finer Vs Sieve for 4% Cement mixed soil

Interpretation: This sample contains 96% Black cotton soil mixed with 4% of cement. There were no marginal and satisfactory change in the gradation of cement on addition of 4% cement in black cotton soil. The results of graphical analysis of the data given below are, Uniformity coefficient and Coefficient of gradation are 25.1 and 1.08 respectively, whereas it contains 56% sand, 40% silt and clay, and 4% gravel.

3.4 BC Soil with 6 % cement:

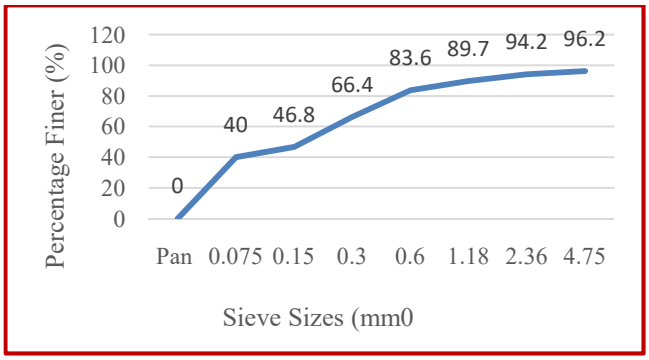


Fig. 11 Percentage finer Vs Sieve for 6% Cement mixed soil

3.5 BC Soil with 8 % cement:

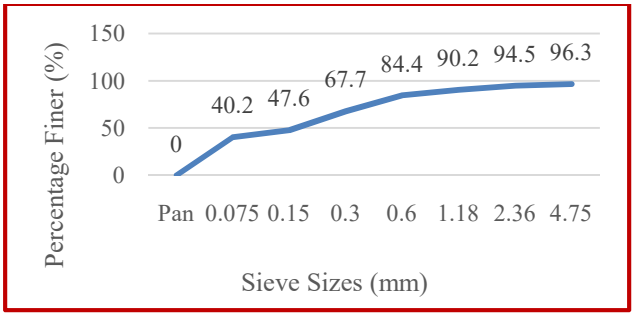


Fig. 12 Percentage finer Vs Sieve for 8% Cement mixed soil

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Interpretation: This sample contains 94% Black cotton soil mixed with 6% of cement. There were no marginal and satisfactory change in the gradation of cement on addition of 6% cement in black cotton soil. The results of graphical analysis of the data given below are, Uniformity coefficient and Coefficient of gradation are 26.08 and 0.65 respectively, whereas it contains 55% sand, 42% silt and clay, and 3% gravel.

4. Conclusions

The study regarding experiment investigating the application of woven biaxial geogrid to subgrade material in the form of reinforcement to road construction. The investigation is carried out to find the improvement in physical and engineering properties of black cotton soil which is considered problematic for road construction. Based on the experimental research, the following conclusions can be made:

i. The soil is classified under CH. Liquid limit, plastic limit and plasticity index are 61.05, 37.33 and 23.72 respectively, suggest that the soil is highly compressive, hence the results obtained shows soil falls below standard recommended for most geotechnical works, whereas the essential requirement of soil properties considered suitable for construction of subgrade are liquid limit to less than 50% and plasticity index to be less than 25%, therefore the obtained results post addition of cement with varied proportions falls within the limit of recommendations.
ii. With the increase in the addition of cement the plasticity index of soil decreases from 23.72% to 9.453% at cement percentage of 6%.
iii. The specific gravity of virgin soil was observed as 2.57 after addition of 8% cement the value raised to 2.79. For road construction, it is generally recommended to use soil with a specific gravity ranging from 2.5 to 2.8.
iv. The tests results show that there is improvement in the dry density of soil, dry density raised from 1.45 g/cc to 1.52 g/cc whereas, little increase in the optimum moisture content is observed due to cement as admixture. However, as a general guideline, the MDD of soil for road construction often ranges from 1.8 g/cc to 2.4 g/cc.
v. Interfacing the woven biaxial geogrid in road construction on especially with soft subgrade, increases the penetration resistance and hence the CBR strength increases from 7.15% to

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18.24%. Hence it is concluded that geogrid reinforced soils present better performance than traditional soil.

vi. Thickness of pavement as per IRC:37-2018 design reduced from 570mm to 530mm i.e., by 7.01%.

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Experimental Investigations of Pre-stressed Concrete Beams under Creep

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Abstract

Modern structural engineering tends to progress toward more cost-effective structures by gradually improving design methods and employing stronger materials. Such advancements are especially significant in the field of reinforced concrete; the limiting characteristics of ordinary reinforced concrete have been greatly reduced by the development of pre-stressed concrete. The post-tensioning technique is widely used in the construction industry because it simplifies the analysis and design of structures and is widely applicable to a wide range of structures. In this research work experimental work is carried out to evaluate the pre-stressed concrete beam's performance under creep. Evaluation of pre-stress creep loss is conducted using a loading Frame test; six pre-stressed concrete beams are cast and used for evaluation, consisting of three post-tension beams of the single cable profile and three post-tension beams of the double cable profile. The experimental results revealed that prestress loss is seen to be an increase in the double cable profile. Approximately a pre-stress loss of around 5% is recorded for post-tension beams respectively.

Keywords: Concrete, Prestressed Beam, Creep, Deflection, Load.

1. Introduction

Concrete is a pressure material. The preload recompresses the element, reducing or eliminating unwanted tensile stresses that would otherwise be present. Cracks under load can be minimized or avoided altogether. The applications of prestressed concrete are numerous, especially in recent times; It is widely used in bridges, buildings, railway sleepers, nuclear ships, water and other liquid resistant structures, etc. In prestressed concrete, the arrangement of the cables plays an important role in reducing stresses in the concrete. By bending, the rope exerts forces on the concrete to counterbalance the stress-inducing forces. When cables are bent, the concrete experiences an upward force that can reduce or eliminate the longitudinal and transverse forces exerted on the concrete by friction and bending. The chord is assumed to consist of multiple parabolas in continuous structures. The reason is that with a parabolic profile, the curvature becomes constant and the force of the cable can be represented as an equivalent, evenly distributed load acting in the opposite direction to the working loads. Although the parabolic hypothesis simplifies the analysis, in accordance with the intermediate supports, the hollow section becomes discontinuous, at the intersection of two parabolas.

1.1 Creep

Creep in concrete represents the dimensional change of the underlying material, in the influence of permanent mechanical stress. It is a complex phenomenon, which is not yet fully

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understood. The concrete flow is different. As metallic creep in the sense that it includes the effects of the previous one loading history. Creep has a significant impact on the performance of concrete structures, causing deflection and influence to continuously increase stress distribution up to a certain point. Creep creates not only a failsafe problem, but also economic problems such as durability, maintainability, and long-term reliability. (Bhagavan et al., 2015). The work done in the previous study relates to friction losses and anchor slip loss. Since no long-term deflection has been calculated for creep, this is the case These inelastic phenomena arise when calculating the yield loss under continuous load to significant damage to structures, including not only distributed cracks, is damage in the classic sense, but also damage in the form of a deductible arrow that disables the structure. For this reason, a chapter on crawling is included in this guide. The theory of concrete creep has become a huge field. Creeping effects are particularly important for very tall people. Prestressed concrete buildings and structures are popular because of their slenderness and high flexibility, and are indispensable for containers and nuclear reactor vessels. When exposed to high temperatures, such as fires in tunnels or tall buildings or postulates in nuclear reactor accidents, creep is very large and plays an important role.

2. Experimental Studies

The prestressing system had been developed exclusively for this research work. A wooden mold of size 100 x 150 x 1200 mm has been fabricated. The cable comprising 5 numbers of 3 mm diameter (35.34 mm2) HTS wires are used. Two categories of beams were cast, one with single cable and the other with double cable. The beam P1, Q1 and R1 fall in first category and beam P2, Q2 and R2 fall in second category. The cable profiles of these beams are shown in Figure 1 and Figure 2. The Universal Testing Machine of capacity 400 kN as shown in Figure 3 was used for post tensioning of high tension steel (HTS) wires. Since the universal testing machine is vertically oriented, vertical post tensioning has been done in the beams, Wire locking barrels to anchorage the cable. The 3 mm thick steel plates having hole of 8 mm did. to pass through tensioning cable on both ends of the PSC beams.

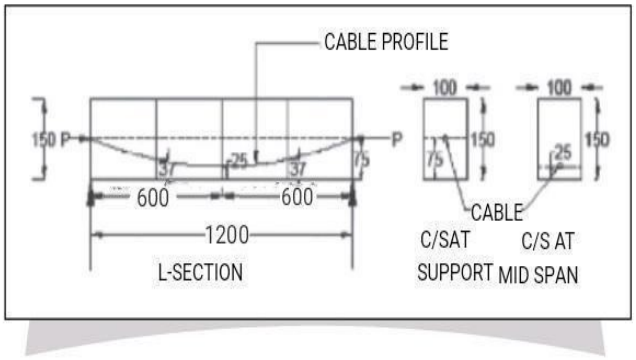


Fig.1. Cable profile of P1,Q1 and R1 (Bhargava et al., 2015).

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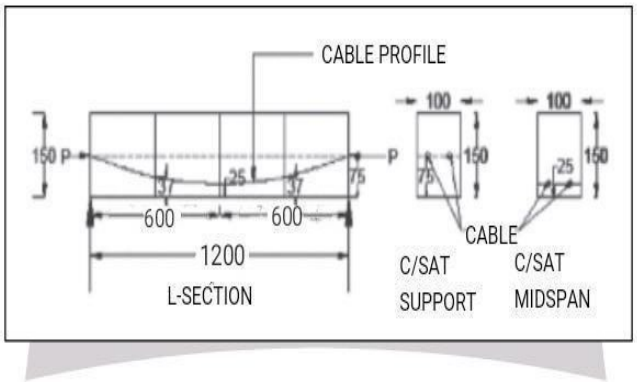


Fig.2. Cable profile of P2, Q2 and R2 (Bhargava et al., 2015).

Selected proportion for M-35 grade concrete mix as per IS code method. These beams for different pre-stressing force, loads and no of strands. The properties of the materials that were used are given in Table 1. These all 6 beams were kept in prestressed for 5 years, as result calculating of time dependent creep loss by experimental study. A detailed summary of the concrete beams that were tested is given in Table 2.

Table 1; Material properties of beam and prestressing cable.

Type	Cross Sectional Area(mm^2)	Density(kN/m^3)	Modulus of Elasticity (GPa)
Concrete beam	15000	25	20
Strand	35.34	7830.19	200

Table 2; Specimens prestressed with strand tendon and calculated losses.

Specimens	No. of strand	Prestressing force(KN)	Elongation of strand (mm)	Prestressig loss using (ultimate creep method) losses in %	Prestressig loss using ACI-ASCE method losses in %	Total losses in %
P-1	1	36	27.50	1.39	3.42	3.42

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Q-1	1	36.68	28.55	1.40	3.43	3.43
R-1	1	38.16	37.10	1.48	3.52	3.52
P-2	2	60	21.50	1.97	4.06	4.06
Q-2	2	62	9.90	2.36	4.17	4.17
R-2	2	64.4	21.50	2.69	4.29	4.29

A three point loading test was conducted on all six beams in order to evaluate the deflection at mid-span. A Loading Frame was used to apply loading on each beam. In order to measure the deflection of beams, a dial gauge of the least count 0.002 mm was installed at the mid-span of each beam, as shown in Figures 6 to 11. The beams obtained experimentally are given in Tables 2 to 7. The load increment is taken 2 kN, and it is applied on mid-span section. Simply supported conditions are created for testing. The load displacement results from experimental are recorded. From (Bhagavan et al., 2015).



Fig.3. Experimental Analysis of Single Strain Beam P1

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Fig.4. Experimental Analysis of Single Strain Beam Q1



Fig.5. Experimental Analysis of Single Strain Beam R1



Fig.6. Experimental analysis of Double Strain Beam P2

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Fig.7. Experimental analysis of Double Strain Beam Q2



Fig.8. Experimental analysis of Double Strain Beam R2

3. Calculation of Creep Loss

3.1 Creep calculation by Ultimate Creep Coefficient Method: - According to IS 1343:2012, N Krishna Raju book on prestressed concrete.

3.1.1. Loss of stress in steel due to creep of concrete = ε**CC** $*f$**C*** **ES**Where, ε**CC** = Ultimate creep strain for a sustained unit stress

f**C** = Compressive stress in concrete at the level of steel

ES = Modulus of Elasticity

Creep Coefficient Method: - According to IS 1343:2012, N Krishna Raju book on prestressed concrete. 1.2.Creep Coefficient Method :-

$$\frac{\textit{Creep strain}}{\textit{Elastic strain}} = \varepsilon_c/\varepsilon_s$$

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Therefore loss of stress in steel = $\mathscr{E}$**C * ES** = $\boldsymbol{\phi}$ *$\mathscr{E}$**e* ES =**$\boldsymbol{\phi}$∗ (**fc**) ∗**ES =**$\boldsymbol{\phi}$***** f***** ae

Where, $\boldsymbol{\phi}$ = Creep Coefficient
$\mathscr{E}$**C** = Creep Strain
$\mathscr{E}$**e** = Elastic Strain
ae = Modular Ratio
f**c** = Stress in Concrete
EC = Modulus of Elasticity of Concrete
ES = Modulus of Elasticity of Steel

3.2 In present study ACI ACI-ASCE method model recommendation 1971 is adopted for creep coefficient because of its simplicity and reliable predictions (Kawano et al.1996, Pathak et al. 1999 etc.). Creep coefficient due to ACI is given by- 2.1.

$$C(t) = \frac{(t)^{0.6}}{[10 + (t)^{0.6}]} \quad Cu$$

Where the value of **Cu** ranges between 2 and 4, **Cu** has been taken equal to 2.35 in this study.

$$\Delta f_{pCR} = Ct * \frac{Eps}{Ec} * fcs = Ct * m * fcs$$

$\boldsymbol{m}$= Modular Ratio
f**c** = Stress in Concrete
EC = Modulus of Elasticity of Concrete
ES = Modulus of Elasticity of Steel

The creep losses are calculated given in Table 2.

4. Result & Discussions

Using above methodology testing of PSC beam P1 is done on applying pre- stressing force of 36 kN, for different loads corresponding deflections are obtained. The load deflection data considering total pre-stressing loss using Experiment is given in Table 3.

Table 3; Deflections under various loads for Single Cable Beam P1.

Load in (kN)	Deflection in (mm)
0	0.0000
2	0.0225
4	0.0410
6	0.0592
8	0.0786
10	0.0945
12	0.1121
14	0.1285
16	0.1465
18	0.1630

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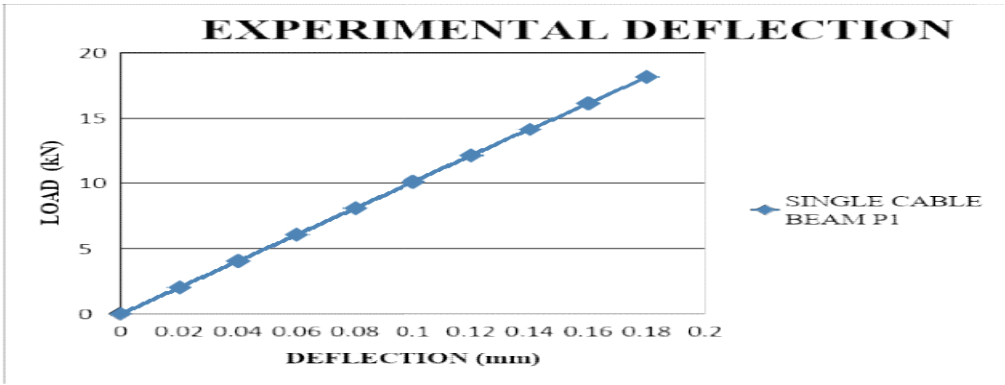


Fig.9. Graph of Single Cable Beam P1

Testing of PSC beam Q1 is done on applying pre-stressing force of 36.68 kN, for different loads and corresponding deflections obtained. The load deflection data considering total prestressing loss using Experiment is given in Table 4.

Table 4; Deflections under various loads for Single Cable Beam Q1

Load in (kN)	Deflection in (mm)
0	0.0000
2	0.0225
4	0.0410
6	0.0592
8	0.0786
10	0.0945
12	0.1121
14	0.1285
16	0.1465
18	0.1630

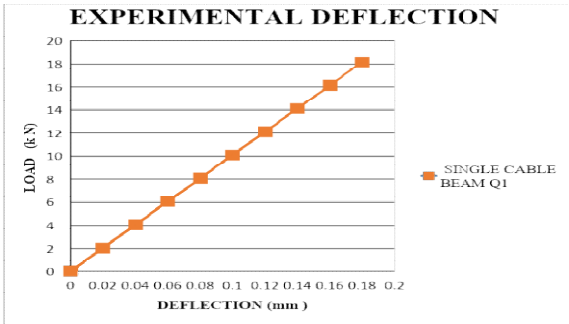


Fig.10. Graph of Single Cable Beam Q1

Using above methodology testing of PSC beam R1 is done on applying pre-stressing force of 38.16 kN, for different loads corresponding deflections are obtained. The load deflection data considering total pre-stressing loss using Experiment is given in Table 5.

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Table 5; Deflections under various loads for Single Cable Beam R1.

Load in (kN)	Deflection in (mm)
0	0.0000
2	0.0230
4	0.0415
6	0.0599
8	0.0790
10	0.0945
12	0.1125
14	0.1290
16	0.1469
18	0.1635

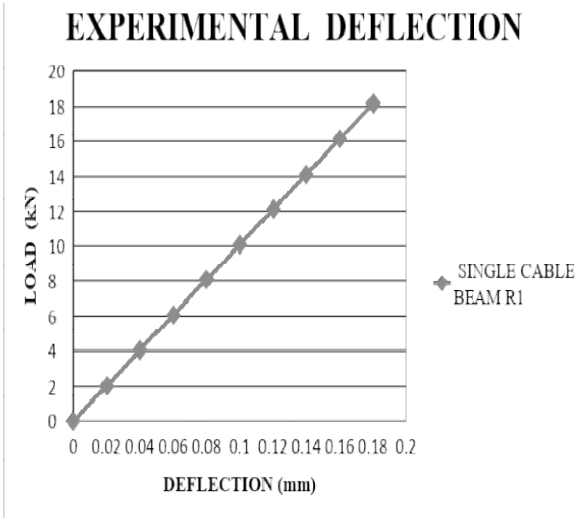


Fig.11. Graph of Single Cable Beam R1

Using above methodology testing of PSC beam P2 is done on applying pre-stressing force of 60 kN, for different loads corresponding deflections are obtained. The load deflection data considering total pre-stressing loss using Experiment is given in Table 6.

Table 6; Deflections under various loads for Double Cable Beam P2.

Load in (kN)	Deflection in (mm)
0	0.000
2	0.0267
4	0.0450
6	0.0648
8	0.0840
10	0.0980
12	0.1160
14	0.1340
16	0.1516
18	0.1684

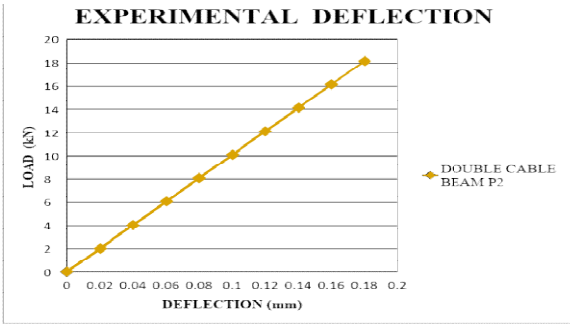


Fig.12. Graph of Double Cable Beam P2

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Using above methodology testing of PSC beam Q2 is done on applying prestressing force of 62 kN, for different loads corresponding deflections are obtained. The load deflection data considering total pre-stressing loss using Experiment is given in Table 7.

Table 7; Deflections under various loads for Double Cable Beam Q2.

Load in (kN)	Deflection in (mm)
0	0.000
2	0.0272
4	0.0455
6	0.0652
8	0.0845
10	0.0980
12	0.1161
14	0.1341
16	0.1520
18	0.1690

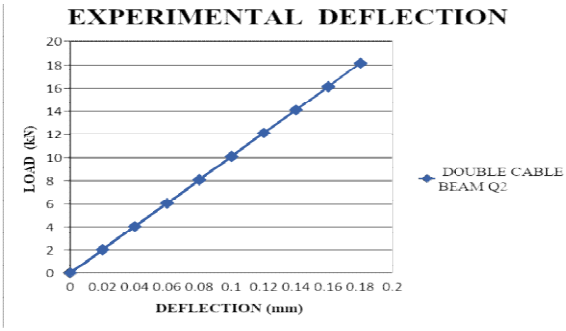


Fig.13. Graph of Double Cable Beam Q2

Using above methodology testing of PSC beam R2 is done on applying pre-stressing force of 64.4 kN, for different loads corresponding deflections are obtained. The load deflection data considering total pre-stressing loss using Experiment is given in Table 8.

Table 8; Deflections under various loads for Double Cable Beam R2.

Load in (kN)	Deflection in (mm)
0	0.000
2	0.0280
4	0.0458
6	0.0655
8	0.0850
10	0.0982
12	0.1160
14	0.1346
16	0.1525
18	0.1692

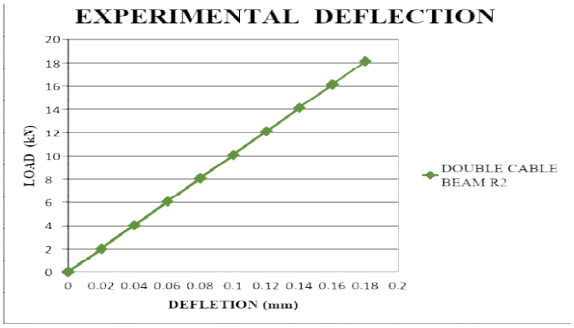


Fig.14. Graph of Double Cable Beam R2

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5. Conclusion

The experimental investigations of PSC beams are performed in this study. For experiment, PSC beams are tested in laboratory. The beam models are loaded for different loads, while deflections on the external concrete surface are monitored. Creep losses are calculated, as result prestress losses are seen to be increased in double cable profile P2, Q2, R2. Approximately for post-tension beams a prestress loss of around 5% is recorded respectively. As per IS 1343:2012 & N Krishna Raju book, limit for creep of concrete must be up to 5 % & for total losses allowed in post tensioning is 20%. In both the cases our calculated losses are below the limit hence it is safe .

Creep not only creates problem of safety against failure but also creates economic problem such as durability, serviceability and long term reliability. The rate of creep depends on various factors such as: time, magnitude of stress, water-cement ratio, amount and type of cement, ambient relative humidity, and aggregate properties.

Future Scope

1. Research can be extended for heavy and large beams which is possible with higher version and updated software's in near future.
2. The reinforce material and its property is having wide range and compositions, it can be varied to analyze beam behavior and performance.
3. Nonlinear analysis can also be performed in future cases. The results can also be comparing with existing cases and boundary conditions.
4. Various analyses like Modal analysis can also be performed for same cases.
5. Voided beam can also be designed and analyzed for advanced buildings.

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ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

Optimizing Time and Cost in Road Construction: A Novel Approach Using the Teaching-Learning-Based Optimization (TLBO)

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Abstract

The India's economy is currently expanding at the fastest rate in the world, and infrastructure improvements are ongoing. The development of a country's infrastructure is crucial, and it is decisive to manage cost and time, to create excellent infrastructure. This research aims to optimize the cost and time of a road construction project. For the optimization of the project cost, a new approach Teaching Learning Based optimization (TLBO) technique is used and the optimization of time is computed by scheduling. TLBO is a new concept based on learning and interaction between teacher and students. This method of optimization does not require any control parameter and derivative. It gives effective results, easy to use, more accurate, with an easy concept of optimization. Finally, it is concluded that TLBO algorithm could generate the most optimal solution with less number of iterations, establish the fitness function and minimizes the total costs of the project.

Keywords: Road construction project; Teaching Learning Based Optimization (TLBO); Time and Cost Optimization.

1. Introduction

India depends heavily on road transportation since it connects rural areas to cities and provides infrastructure for the agricultural and industrial sectors. Indian roads account for a significant portion of passenger and freight traffic, with highways carrying an uneven share. Road transport is expected to continue handling a majority of passenger and freight traffic in the future. It also plays an important role in connecting remote and underdeveloped areas and contributes to the country's GDP. Additionally, road construction and maintenance create employment opportunities and improve fuel efficiency and productivity in the transport sector. In a road construction project, Time and Cost are very important factors. Both are dependent on each other. These factors directly deal with the project and affect every aspect of the project. Therefore, time and cost optimization is very important in the Road construction industry. Optimization of these factors helps to reduce the cost of the project and helps to complete the project within the time or before the time. Lots of work was carried out in this field but still, the research in Indian conditions can be carried out where the time and cost optimization is uncertain for different construction modes.

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ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

Maji and Jha (2008) proposed a multi-objective approach to optimize highway alignment using genetic algorithm based multi-objective optimization algorithm. Rao and Patel (2012) developed teaching learning based optimization algorithm which does not requires any specific control parameters. Shanmugapriya and Subramanian (2013) studied major factors causing Time and Cost overruns in Indian construction projects. Joshi and Patil (2013) analysed the project management techniques by scheduling various construction activities and resource-levelling using Microsoft Project 2013. Dehmourdi (2014) studied the use of linear programming in optimization of transporting cost of equipment and finding the best solution for reducing the functional costs of the equipment. Salunkhe and Patil (2014) studied the external and internal factors that influence the construction process and the effect of delays in large construction projects. Subramani (2014) identified major causes of cost overruns in construction projects including slow decision-making, poor schedule management, increased material/machine prices, poor contract management, poor design, rework, land acquisition problems, incorrect estimation methods, and long period between design and bidding. Balaji and Shankar (2015) developed a schedule for a Highway Project using both CPM and Linear Scheduling Techniques. Kumar and Samuel (2015) introduced Teaching–Learning-Based Optimization (TLBO) as a new optimization method for mechanical design problems. The method was tested on unconstrained benchmark test functions and found to be 244% more effective than the Genetic Algorithm. Rajguru and Mahatme (2015) studied the various factors that affect the cost of construction projects and the various techniques and materials used for cost optimization. Sivanagaraju and Kumar (2016) studied the effect of high-potential parameters in Primavera software on Metro Rail construction projects. They emphasized the importance of proper planning and scheduling to reduce delays and waste of resources in the project. Kumar and Antony (2018) used project management software to pre-plan and schedule road projects to reduce and control delays. Baviskar and Devalkar (2018) emphasized that time and cost are critical factors in construction project planning, highlighting the importance of Time-cost optimization to achieve project objectives and minimize costs. Togan and Eirgash (2018) proposed a multi-objective optimization model based on TLBO and MAWA to solve Time-Cost Trade-off Problem (TCTP) in construction projects. The model was found to be effective and efficient in finding Pareto front solutions, making it a valuable tool for construction engineering and management. Sinha and Tripathi (2019) used Genetic Algorithm (GA) to optimize time and cost in a highway project and found that the GA technique can produce the most optimal solution for time-cost optimization. Wagh and Fulse (2021) conducted a study to identify factors causing cost overruns in Indian construction projects and provided solutions and recommendations to reduce cost overruns in construction projects.

This case study provides a review of highway construction scheduling and optimization of cost and

ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

time by the TLBO algorithm. TLBO is a new and easy concept of optimization. In the construction industry, it is not widely used. So research on this algorithm is needed. The present study aims to use the Teaching-Learning-Based Optimization (TLBO) algorithm to optimize the time-cost and scheduling of a highway project

2. Study Area and Data Acquisitions

As a case study Indore (Super corridor) Ch.6+900 of Indore - Depalpur Road to 4 Lanning of Gomatgiri - Pitra Parvat Ch.10+900 Road,Indore (MP) is chosen as shown in Fig.1.

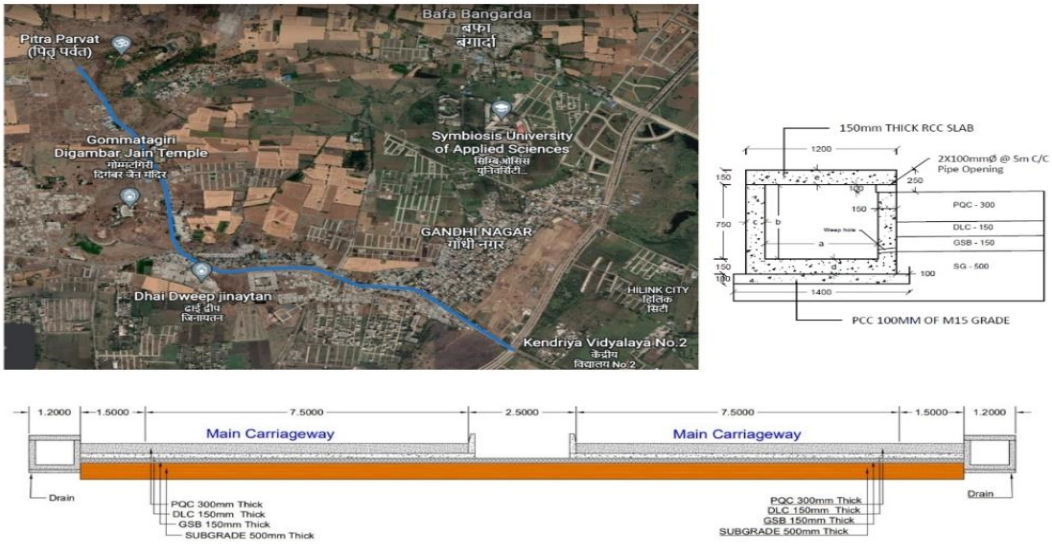


Fig.1. Location of road construction site and section of road

The terrain of the proposed alignment is plain and the length of the road is 4 kilometres. The details of the project were collected from the Madhya Pradesh Road development corporation (MPRDC), office – Indore (MP). The detailed information of the case study is shown in Table 1.

Table 1. Actıvıtıes detials of road project.

S.No.	Activity Name	Original Duration	Predecessors	Successors	Cost (Rs)
1	Site clearance	66			165506.37
2	Earthwork (Excavation)	247	1	3	990574.37
3	Earthwork (Embankment, Subgrade)	252	2	4, 7,10	4985054.37
4	Granular Sub-Base (GSB)	236	3	5	10659689.4
5	Rigid Pavement (DLC)	227	4	6	26489203.3
6	Rigid Pavement (PQC)	226	5	8, 9	121740611
7	HP Culverts.	90	3		791206.37
8	Crash Barrier	205	6		22349054.4
9	Kerb	85	6		3365054.37
10	RCC Drain & Stone Pitching	236	3	11, 12	38760880.4
11	Road Marking & Stone Work	59	10		982278.37
12	Traffic Sign Boards.	59	10		418113.37

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			Direct Cost	231697226	
			Miscellaneous	131274	
			Total Project Cost	23,18,28500	

3. Methodology

For the present study construction activities has been scheduled through primavera to manage costruction delays, to determine float and slack, by which continously monitouring of construction should help for decsion making in construction site. Also the updating of scheduling, WBS and profile of Gantt chart representation helps in finding delays, work breakdown and time duration. Hence to minimize the total porject cost and to complete the project in target duration project modelling is necessary. Despite to achieve the minimization of total project cost, achievement of target duration required optimization. In past various techniques used for the optimization of the cost and time in construction projects such as Genetic Algorithm, particle swarm optimization (PSO), ABC algorithm, NSGA-II, Fuzzy Systems, and many more. Each method has its own set of benefits and drawbacks. Out of these methods, Teaching-Learning-Based Optimization (TLBO) is selected for the present case study. The Teaching-Learning-Based Optimization (TLBO) algorithm is a type of optimization method that simulates the teaching-learning process in a classroom to solve multi-dimensional, linear, and nonlinear problems efficiently. It does not require any specific control parameters and is a new and easy concept of optimization. The TLBO algorithm is useful for solving optimization problems in industrial environments, such as the optimization of time and cost in a construction project.It is not widely used in the construction industry, but research on this algorithm is needed to fully understand its capabilities.

3.1 Problem Formulation

$$C=\sum_{d=1}^{n}(X_d)-R(D_{tar}-D_{act})+X_i.D_{act} \quad (1)$$

Subject to:

$$R_p = (D_{tar}-D_{act}) <0 \quad (2)$$

$$R_{in} = (D_{tar}-D_{act}) >0 \quad (3)$$

$$\therefore R= R_p = R_{in} \quad (4)$$

Where,

C = Project total cost;

X_d = Actual direct cost of each construction activity from 1 to 'n'.

X_i = Project daily indirect cost

D_{tar} = Project target duration.

D_{act} = Project actual duration.

R = Sharing ratio.

ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

R_p= penalty ratio.

R_{in}= incentive ratio.

Each stage of the construction activities has been transformed into work breakdown structure (WBS). The particulars of every activity durations are required to evaluate the risks of construction schedule for highway project. The duration for each activity is that the time taken which is required to complete the activity, if the construction progress on site is operating smoothly in estimated time with schedule. But if it is not in schedule then we have to find out the completion time of the project using PERT analysis. In this analysis the optimistic time, most likely time, and pessimistic time estimates of all activities must be decided. Afterwards expected duration and variance for each activity should be computed.

3.2 Teaching Learning Based Optimization Technique

Rao et al. (2011) introduced the Teacher-Learning-based Optimization (TLBO) algorithm. The TLBO algorithm is a new conceptual algorithm that is based on the teaching-learning process. It is inspired by the transmission of knowledge in a classroom setting, where students first learn from a teacher and then interact with one another. The TLBO algorithm is a population-based optimization algorithm that uses a group or class of students as the population and different subjects offered to the learners are considered as different design variables of the optimization problem and a learner's result is analogous to the 'fitness' value of the optimization problem. The best solution in the entire population is considered as the teacher. The design variables are the parameters involved in the objective function of the given optimization problem and the best solution is the best value of the objective function. The working of TLBO is divided into two parts, 'Teacher phase' and 'Learner phase'.

Teacher Phase

The Teaching-Learning-Based Optimization (TLBO) algorithm is a method for optimization where learners learn from a teacher. In the teacher phase, the teacher tries to increase the mean result of the class in the subject taught by him or her. In iteration i, the algorithm considers 'x' number of subjects (i.e., design variables), 'y' number of learners (i.e., population size), and Xa,i as the mean result of the learners in a particular subject 'a'. The best overall result, Vtotal-ybest,i, considering all the subjects together obtained in the entire population of learners is considered as the result of the best learner, ybest. The teacher is considered as a highly learned person who trains learners so that they can have better results, the best learner identified is considered by the algorithm as the teacher. The difference between the existing mean result of each subject and the corresponding result of the teacher for each subject is given by,

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$$\text{Difference Mean: } X_{a;y;i} = r_i(V_{a;ybest;i} - T_f X_{a;i}) \quad (5)$$

Where, Va;ybest;i is the result of the best learner in subject a. T_f is the teaching factor which decides the value of mean to be changed, and ri is the random number in the range [0, 1]. The value of Tf can be either 1 or 2 and T_f is not a parameter of TLBO algorithm. The value of T_f is taken 1 or 2 because these value simplify the algorithm.Based on the Difference Mean $X_{a,y,i}$, the existing solution is updated in the teacher phase according to the following expression.

$$V'_{a;y;i} = V_{a;y;i} + X_{a;y;i} \quad (6)$$

Where, $V'_{a;y;i}$ is the updated value of $V_{a;y;i}$. $V'_{a;y;i}$ is accepted if it gives better function value.
All the accepted function values at the end of the teacher phase are maintained and these values become the input to the learner phase. The learner phase depends upon the teacher phase.

Learner Phase

The second part of the algorithm is where learners increase their knowledge by interacting with one another. A learner interacts at random with other learners in order to expand his or her knowledge. If another learner has more knowledge than the learner, the learner learns new things. The learning phenomenon of this phase is explained below, assuming a population size of 'y'. Randomly select two learners C and D such that $V'_{total\text{-}c,i} \neq V'_{total\text{-}D,i}$

Where,$V'_{total\text{-}c,i}$and $V'_{total\text{-}D,i}$ are the updated function values of $V_{total\text{-}c,i}$ and $V_{total\text{-}D,i}$ of C and D respectively at the end of teacher phase.

$$V''_{a,C,i} = V'_{a,C,i} + ri(V'_{a,C,i} - V'_{a,D,i}), \text{ if } V'_{total\text{-}C,i} < V'_{total\text{-}D,i} \quad (7)$$

$$V''_{a,C,i} = V'_{a,C,i} + ri(V'_{a,D,i} - V'_{a,C,i}), \text{ if } V'_{total\text{-}D,i} < V'_{total\text{-}C,i} \quad (8)$$

$V''_{a,C,i}$ is accepted if it gives a better function value.The eqs. (7) And (8) are for minimization problems. In the case of maximization problems, the eqs. (9) And (10) are used.

$$V''_{a,C,i} = V'_{a,C,i} + r_i(V'_{a,C,i} - V'_{a,D,i}), \text{ if } V'_{total\text{-}D,i} < V'_{total\text{-}C,i} \quad (9)$$

$$V''_{a,C,i} = V'_{a,C,i} + ri(V'_{a,D,i} - V'_{a,C,i}), \text{ if } V'_{total\text{-}C,i} < V'_{total\text{-}D,i} \quad (10)$$

Teaching-learning-based optimisation (TLBO) is a population-based algorithm that simulates the classroom teaching-learning process. This algorithm requires only the common control parameters, such as population size and generation number, and no algorithm-specific control parameters. The following are the Steps of TLBO algorithm and general flowchart of TLBO as shown in Fig.2.

Steps of Teaching Learning Based Optimization (TLBO)

Based on the above discussion steps of TLBO algorithm are as follows:

Step1: Initialization

- Initialize the optimization parameters

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- Population size (the number of students or learners
- Number of design variables or parameters (Subjects)

Step2: Teacher Phase

- Modify solution according to the concept: the learning of the students by the teacher

Step3: Student Phase

- Modify solution according to the concept: the learning of the students by their mutual interaction

Step4: Repeat

- Go to Step 2 until the stopping criteria (maximum iteration: optimum solution) is not met

Step5: Stop

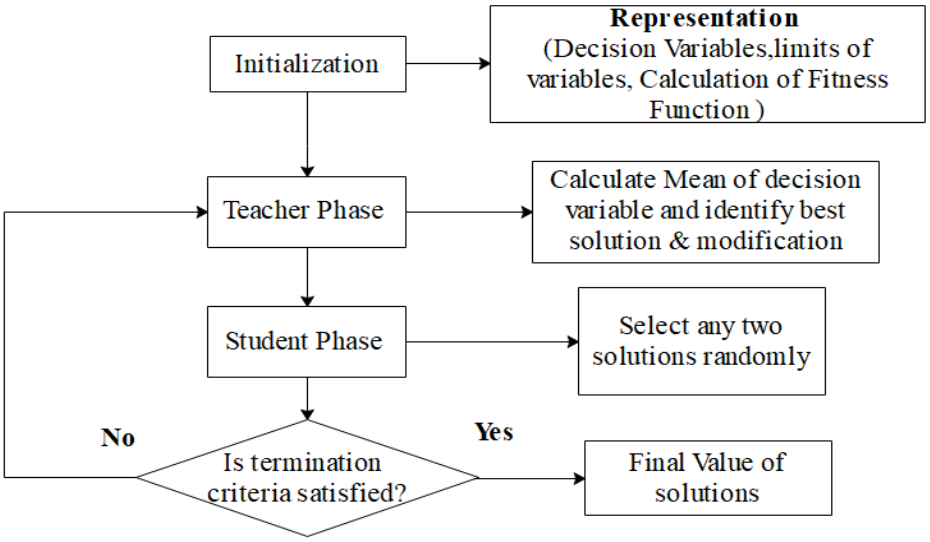


Fig.2. General flowchart of TLBO algorithm

4. Results and Discussion

The collected data of construction activities underwent analysis thorough scheduling in primavera for the proposed study as shown in Fig.2. The results of primavera includes "predecessor" and "successor" which are used to define the relationships between activities such as such as Finish-to-Start (FS), Start-to-Start (SS), Finish-to-Finish (FF), and Start-to-Finish (SF). in a construction schedule of project. These relationships establish the sequence and dependencies between activities. Overall using this relationship helps to create accurate schedules and manage dependencies between actvities effectiviely, ensuring smooth work flow throughout the construction project of raod construction.From the analysis of primavera results the original duration is 353 days. Despite from duration the primavera analysis also includes direct cost, indirect cost of construction project with total original estimated cost of 231828574/-Rs.

Let's Take 5 learners (5 different costs) and 2 Subjects (Direct and Indirect costs).

So, Learners = 5 and Decision variables = 2 (X_1 and X_2).

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First iteration of TLBO:

Teacher phase:

In Table-2 contains an initial population of 5 learners and 2 subjects (5 rows and 2 columns). In the objective function, compute the fitness value of X1 and X2. In Table-2 contains an initial population of 5 learners and 2 subjects (5 rows and 2 columns). In the objective function, compute the fitness value of X1 and X2. The values of C(x) will then be obtained by plugging these values into the objective function C(x). To minimise the function, choose the smallest (best) value, 268438906, and make it the teacher. Then compute the mean of each column for X_1 and X_2, which are 231697226 and 130693.8, respectively.

Table 2. Initial Population

	X_1	X_2	D_t	D_a	R	$C(x) = X_1+(X_2*D_a)-(R*(D_t-D_a))$
	231697226	**115849**	**353**	**320**	**10000**	**268438906 (Teacher)**
	231697226	125242	353	340	10000	274149506
	231697226	131274	353	353	0	278036948
	231697226	136293	353	370	-10000	281955636
	231697226	144811	353	400	-10000	289151626
Mean	231697226	130693.8				

Now, apply the following formula to each subject to determine the difference mean:

Difference Mean of $x_1 = r_1 * T_f * (X_1$ from Teacher – Mean of $X_1)$

(11)

Difference Mean of $X_2 = r_2 * T_f * (X_2$ from Teacher – Mean of $X_2)$ (12)

In this case, r_1 and r_2 are randomly generated values between 0 and 1. The teaching factor, or T_f, can be either 1 or 2. Assume, $r_1 = 0.58$, $r_2 = 0.49$ and $T_f = 1$.

Therefore,

Difference Mean of X_1

$= 0.58*(231697226 - 231697226) = 0$

(13)

Difference Mean of X_2

$= 0.49*(115849 - 130693.8) = -7273.952$

(14)

Table 3. Calculation of Difference Mean of X_1 to each value in the x_1 column and the DM of X_2 to each value in the X_2 column;

X_1	X_2	D_t	D_a	R	$C(x) = X_1+(X_2*D_a)-(R*(D_t-D_a))$
231697226	**108575.048**	**353**	**320**	**10000**	**266111241.4**
231697226	117968.048	353	340	10000	271676362.3
231697226	124000.048	353	353	0	275469242.9
231697226	129019.048	353	370	-10000	279264273.8
231697226	137537.048	353	400	-10000	286242045.2

After adding, the new fitness values for each learner have obtained. Maintain that value and proceed to the next step. The succeeding step is to compare each learner's new and previous

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fitness values. Keep the learner's X_1 and X_2 values for which the fitness value is minimum after comparison. After completing all of the steps, the following table is obtained:

Table 4. Comparison of Fitness values (Table 2 and 3)

X_1	X_2	D_t	D_a	R	$C(x) = X_1+(X_2*D_a)-(R*(D_t-D_a))$
231697226	**108575.048**	**353**	**320**	**10000**	**266111241.4**
231697226	117968.048	353	340	10000	271676362.3
231697226	124000.048	353	353	0	275469242.9
231697226	129019.048	353	370	-10000	279264273.8
231697226	137537.048	353	400	-10000	286242045.2

Now, the Teacher phase is completed of this algorithm.

Learner phase:

Learners will interact with one another during the learner phase. Assume Learner 1 interacts with Learner 2, and then compare their fitness levels. The knowledge will be transferred from the person with the best fitness. In this case, learner 2 has a higher fitness level than learner 1. As a result, knowledge will be transferred from learner 2 to learner 1.

Now, calculate the new values of x_1 and x_2 for learner 1 by the formula:-

New x_1 for L_1 =

Current x_1 of L1 + r_1 * (X_1 of L_2 — X_1 of L_1)

… (15)

New x_2 for L_1 =

Current x_2 of L_1 + r_2 * (X_2 of L_2 — X_2 of L_1) … (16)

In this case, r_1 and r_2 are random numbers between 0 and 1. r_1 is set to 0.81, and r_2 is set to 0.92.

Table 5. Calculation of interactions between L_1 and L_2, L_2 and L_4, L_3 and L_5, L_4 and L_1, L_5 and L_3 is shown in this table. The new values of X_1 and X_2 are computed in each Interaction.

X_1	X_2	D_t	D_a	R	$C(x) = X_1+(X_2*D_a)-(R*(D_t-D_a))$	Iteration
231697226	117216.608	353	320	10000	268876540.6	1 & 2
231697226	128134.968	353	340	10000	275133115.1	2 & 4
231697226	136454.088	353	353	0	279865519.1	3 & 5
231697226	110210.568	353	370	-10000	272305136.2	4 & 1
231697226	125083.008	353	400	-10000	281260429.2	5 & 3

Both the Teacher and Learner phases are now complete. Now, compare the finesses of the learner and teacher phases and keep only the best fitness value and its corresponding X_1 and X_2 values:

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Table 6. Comparison of Fitness values of Teacher phase (Table 4) and Learner Phase (Table 5)

X_1	X_2	D_t	D_a	R	$C(x) = X_1+(X_2*D_a)-(R*(D_t-D_a))$
231697226	**108575.048**	**353**	**320**	**10000**	**266111241.4**
231697226	117968.048	353	340	10000	271676362.3
231697226	124000.048	353	353	0	275469242.9
231697226	110210.568	353	370	-10000	272305136.2
231697226	125083.008	353	400	-10000	281260429.2

This marks the completion of the first iteration of the TLBO algorithm. Use this table as the initial population for the next iteration. The process then continues through the Teacher and Learner phases, repeating until the minimum value is reached for five soulitions as illustrated in Table 7.

Table 7. Evaluation of Objective Function vs. No of iteration.

Iteration \ Duration (D_a)	320	340	353	370	400
1	266111241.4	271676362.3	275469242.9	272305136.2	281260429.2
2	264763969.3	267818346.1	273983033.5	270190621.9	279177809.9
3	263718941.4	266043217.2	272830237	268937769.8	277839642.6
4	262741504.7	264913854.7	271752002.1	267804045.5	276615296.1
5	261772948.2	263874484.4	270683563.3	266683867.1	275404396.5
6	260805380	262845379.9	269616214.6	265565093.6	274194919.9
7	259837913.1	261817341.9	268548977.7	264446458.1	272985585
8	258870456.1	260789409	267481751.7	263327835.8	271776263.6
9	257903000	259761485.9	266414526.7	262209214.7	270566943.5
10	256935544	258733563.9	265347301.8	261090593.7	269357623.5
11	255968088	257705641.8	264280076.9	259971972.7	268148303.5
12	255000632	256677719.8	263212852	258853351.7	266938983.5
13	254033176	255649797.8	262145627.1	257734730.7	265729663.5
14	253065720	254621875.8	261078402.2	256616109.7	264520343.5
15	252098264	253593953.8	260011177.3	255497488.7	263311023.5
16	251130808	252566031.8	258943952.4	254378867.7	262101703.5
17	250163352	251538109.8	257876727.5	253260246.7	260892383.5
18	249195896	250510187.8	256809502.6	252141625.7	259683063.5
19	248228440	249482265.8	255742277.7	251023004.7	258473743.5
20	247260984	248454343.8	254675052.8	249904383.7	257264423.5
21	246293528	247426421.8	253607827.9	248785762.7	256055103.5
22	245326072	246398499.8	252540603	247667141.7	254845783.5
23	244358616	245370577.8	251473378.1	246548520.7	253636463.5
24	243391160	244342655.8	250406153.2	245429899.7	252427143.5
25	242423704	243314733.8	249338928.3	244311278.7	251217823.5
26	241456248	242286811.8	248271703.4	243192657.7	250008503.5
27	240488792	241258889.8	247204478.5	242074036.7	248799183.5
28	239521336	240230967.8	246137253.6	240955415.7	247589863.5
29	238553880	239203045.8	245070028.7	239836794.7	246380543.5
30	237586424	238175123.8	244002803.8	238718173.7	245171223.5
31	236618968	237147201.8	242935578.9	237599552.7	243961903.5
32	235651512	236119279.8	241868354	236480931.7	242752583.5
33	234684056	235091357.8	240801129.1	235362310.7	241543263.5
34	233716600	234063435.8	239733904.2	234243689.7	240333943.5
35	232749144	233035513.8	238666679.3	233125068.7	239124623.5
36	231781688	232007591.8	237599454.4	232006447.7	237915303.5
37	230814232	230979669.8	236532229.5	230887826.7	236705983.5
38	229846776	229951747.8	235465004.6	229769205.7	235496663.5
39	228879320	228923825.8	234397779.7	228650584.7	234287343.5
40	227911864	227895903.8	233330554.8	227531963.7	233078023.5
41	226944408	226867981.8	232263329.9	226413342.7	231868703.5
42	225976952	225840059.8	231196105	225294721.7	230659383.5
43	225009496	224812137.8	230128880.1	224176100.7	229450063.5

44	224042040	223784215.8	229061655.2	223057479.7	228240743.5
best	224042040	223784215.8	229061655.2	223057479.7	228240743.5
worst	266111241.4	271676362.3	275469242.9	272305136.2	281260429.2
Mean	243899178.9	244902474.5	250966561.5	246018492.5	253063023.2
S.D	12307076.39	13241819.83	13576243.64	14255999.37	15402352.49

Fig.3 illustrates the behavior of an objective function over multiple iterations for various $D_a$values (measured in days). The consistent downward trend across all curves indicates an optimization process, where the objective function improves with each iteration. Each curve represents a distinct D_a value, with higher D_a values starting at elevated objective function levels but ultimately converging in a similar pattern as the iterations proceed.

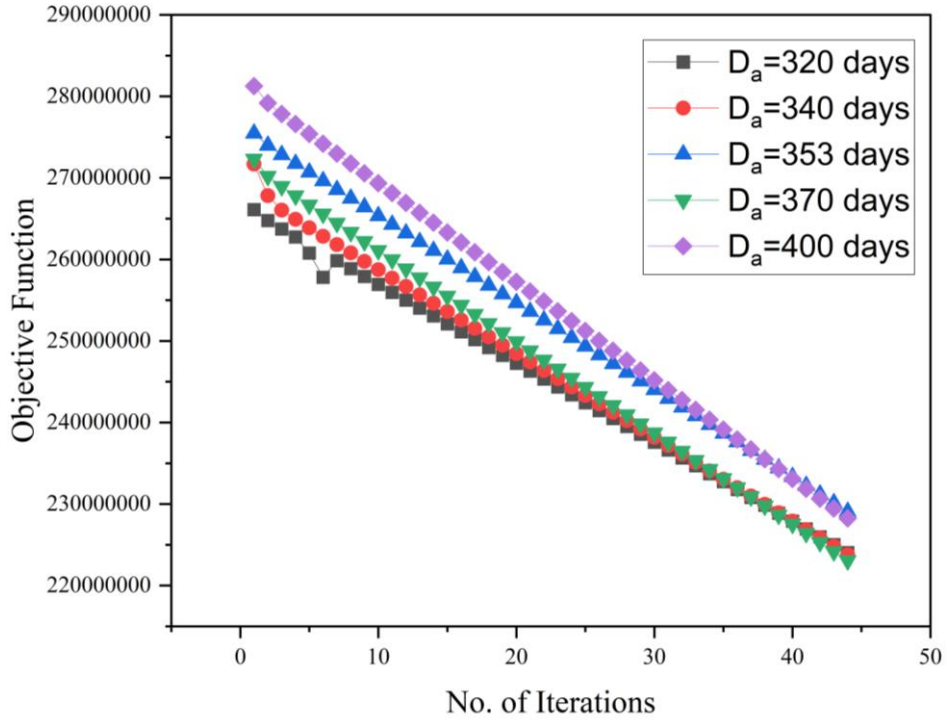


Fig.3 Evaluation of Objective Function vs. No of iteration by TLBO Algorithm

V. CONCLUSIONS

The following are the conclusions of the study:

1) By Primavera the scheduling of the project has been done.
2) Description of our project as scheduled through primavera is 353 days.
3) The objective function was optimized over a period of 320 days and 340 days, starting with a value of 231813075 and 231822468, and reducing to 225009496 and224812137.8 respectively after the Forty-Fourth iteration. The optimization process involved continuously decreasing the objective function value.

ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

4) For period of 353 days, starting with a value of 231828500 and reducing to 230128880.1 after the Forty-Fourth iteration.
5) For period of 370 days and 400 days, starting with a value of 231833519 and231842037, and reducing to 224176100.7 and 229450063.5 after the Forty-Fourth iteration.
6) The objective function, representing the balance between time and cost, was optimized over different periods of time and the results showed a decrease in the objective function value after each iteration.
7) The results showed that after each iteration, the objective function value decreased and reached its minimum value.

The study concludes that the TLBO algorithm was applied to optimize the scheduling of a construction project using Primavera software. The results indicate that the TLBO algorithm can effectively optimize the balance between time and cost in construction projects.

ACKNOWLEDGEMENT

The authors extend their heartfelt appreciation to the Madhya Pradesh Road Development Corporation Limited, Indore for their invaluable contribution of data and other project-related information, as well as to the Principal of IPS Academy Institute of Engineering and Science, Indore for their support.

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ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

Analyzing Risks in Construction: A Comprehensive Study

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Abstract

Risk is an inherent aspect of every construction project, manifesting in diverse forms with the potential to impact project objectives. This paper delves into the multifaceted nature of risk within the construction industry, encompassing threats that pose negative impacts, opportunities that yield positive outcomes and business risks that can sway either way. Offering insights into risk definition and various risk types, it also provides a comprehensive overview of risk management processes. Effective risk management necessitates a two-fold approach: mitigating negative risks through meticulous identification, classification and thorough analysis, while also capitalizing on potential opportunities. By conducting detailed analyses encompassing all facets including stakeholder perspectives, projects can proactively manage risks, translating challenges into tangible benefits for future endeavors.

Keywords: Risk; Management; Threat; Construction; Project objective; Impact; Uncertainty

1. Introduction

In the era of progressive globalization, it is hard to avoid risk, which has become an indispensable part of everyday life. Risk is present everywhere, in every aspect of our life. One of such aspects is the construction industry, where risk is an inherent element. Effective risk management does not mean the removal of risk, which would seemingly be the cheapest option. From economic point of view this option is pointless because what is potentially profitable is by definition risky and activity that does not pose a risk is not economically interesting, and thus, does not bring tangible benefits [1, 2].

All over the world today, the construction industry is the main engine of development, social welfare, and national economy. It contributes greatly to the jobs market by providing many jobs and in different specialization such as Engineers, Accountants, different labors and many other titles. Additionally, with regard to the urban and industrial development, it supports both by providing the feasibility studies, conceptual design, cost estimate, construction and maintenance services [3]. Therefore, we agree that construction deserves more attention and

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ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

researches in order to decrease the uncertainty as much as possible, which will maximize the likelihood of achieving the objectives of the different projects within the construction industry. Uncertainty range differs from project to another based on the project`s circumstances [1, 4].

There are many sources of uncertainty and on the other hand, we can manage this uncertainty by using some tools and processes. Uncertainty comes from the undefined scope, undefined project objectives, project constraints, improper design, ambiguous contract, and other unknowns. This uncertainty is always translated into risks because both are causing events with a probability of less than 100%, which is defined as a risk [6, 7]. The above discussion indicates that there are some tools and processes to manage risk either proactively or reactively. By the way, the difference between proactive and reactive can be summarize data the time of managing the risk. If we manage the risk before occurring, definitely it`s a proactive approach. On the other hand, the reactive approach is managing the risk after occurring. Risk management is a collaborative effort to drive the project forward the targeted success through some processes. It's not means or aim to avoid all project risks. Definitely, it aims to determine the probable events and maximize the probability or the impact of opportunities and minimize the probabilities or the impact of the threats. Every day, the construction parties are requested to make decisions, which definitely have great impacts on their project. Risk management is very important to make an informed decision. An informed and proactive decision means basing the decision on clear information even it includes an amount of uncertainty [8].

2. Risk Definition

A risk is a probable event that has a probability, a cause or more and an impact or more. Usually, the probability is not a fixed number and it`s changed along the project period. It may be very high at a time and becomes very low at another time based on the project circumstances [10]. The cause of risk is something that converts the probability of occurring into a hundred perfect. It may be one cause and may be a group of causes. Furthermore, the occurred risk may represent a cause for another risk. Also, the response of the risk may represent a cause for a new risk which called a secondary risk. The impact of the risk can be positive or negative or a mix between both. The highest number of risks are mostly existed on the initiation phase because of the big uncertainty, after that the uncertainty begins to be

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ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

decreased along the project period because of the information received noted through the execution phase.

2.1 Risk Names According to the Time of Risk Identification

Each project passes through some phases until reach the closure phase. The project phases are initiation, planning, execution, monitor and control, and closure. Risks are may be discovered at any phase and it can be identified ether before taking placing or after that. Accordingly, one of the risk classifications is mainly based on the identification times as follows:

I. Known risk
II. Unknown risk.

3. Factors of Risk

The typical risk on a construction project is as: occurrence of accidents, failure to complete within the specified time, failure to obtain the expected outline, unforeseen adverse conditions, unexpected rises for labor and materials, force majeure, and failure to complete the project within the client's budget. All construction projects carry some level of risk. Being able to identify and manage risks requires skill, careful planning, and being able to make good decisions quickly. When risks become reality, they can be detrimental to the successful completion of your project. Properly managed risks can lead to higher profits, stronger relationships with clients, and the ability to grow and expand your business [9, 11].

4. Common Risk in Construction Projects

4.1 External risk

External risks are not directly related to the construction process, but they have a significant weight in terms of the completion of the project. We have seen the common types of risk a construction project can face. But we still haven't discussed the most random of them- External Risks.External risks are the troubles affecting the construction project from the outside. They can be categorized as follows.

4.2 Environmental risk

Climate change has an adverse effect on projects all around the world. Although environmental risk cannot be eliminated, it can be decreased by taking the required actions. Environmental risk plays a significant role in large building projects, notably transportation projects. To avoid

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ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

material durability being reduced owing to climatic change, construction supplies should be appropriately stocked. During the construction material selection process, the material that is most suited to the site location and climatic circumstances should be consider. Environmental risk can show up in bad weather, continuous rainfall, landslides, earthquakes, and many others. The construction process should be aptly planned to complete the major chunk of the onsite work in amiable environmental conditions.

In the case of severe environmental calamities, one has no choice but to suspend the construction activity. Also, an efficient risk management plan is always prudent

4.3 Political risk

Political risk definitions can be divided into two categories. The first approach focused on the causes of political risk, such as the possibility of negative consequences from political events (such as wars, regime changes, revolutions, political violence, riots, insurgencies, terrorist attacks, and coups) and government activities (e.g., expropriations, unfair compensations, foreign exchange restrictions, illegal interferences, changes in laws, corruption, poor enforcement of the contract, and labor restrictions). The second approach focused on the repercussions of political risk, which was characterized as negative effects on businesses as a result of a deterioration in the political environment.

4.4 Economic risk

In terms of economic risk, inflation and unexpected price fluctuations are the most significant. Currency fluctuations are an economic risk to consider when designing a significant construction project, especially for international enterprises. Many countries have recently used foreign cash to build privately financed infrastructure, putting their local currencies in danger of depreciation. International lenders are rarely willing to take such a risk, preferring to get payments in foreign currency. In the past, public corporations or governments were willing to absorb currency risk; but now, with the increased need for private financing, the risk of currency depreciation now falls mostly on the project promoter, and the lender is unwilling to assume it. This risk factor refers to challenges or concerns about the project's macroeconomic impact on the community and region in which it will be built.

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4.5 Legal and order

Some of the legal and order-related risks include project partner breach of contract, lack of enforcement of legal judgment, improper verification of contract documents, lack of knowledge of arbitration, and uncertainty and unfairness of court justice.

4.6 Labor Shortages

The labor shortage is spreading around the construction industry, just like the Covid pandemic. Without the workers, a construction project simply can't progress. Labor shortages can arise due to many reasons. But social, political, and economic disturbances can be mostly held responsible for the scarcity of workers. Some instances of labor shortage demand the company to hire even inexperienced workers. This increases the safety concern and decreases productivity.

5. Internal risk

Internal risks in large building projects are frequently linked to the management team's control. They can be categorized as follows.

- Design risk

Defects in the design that cause the asset to be built yet fail to meet the specified standards, legal requirements, and any environmental or other constraints. Such situations necessitate a revision to the project, resulting in delays and, most importantly, cost increases. Defects or failures in the design that cause the project to fall short of the contract's service standards, or that cause a rise in operation and maintenance (O & M) expenses to fulfill the contract's service requirements.

Some design risks include design flaws and omissions, the design process taking longer than expected, stakeholders requesting late revisions, and failing to complete the work in line with the contract. Mistake in design is often extremely costly. Sometimes, the whole face of the building has to change, literally. Transparency in the project objective, i.e., the uses, applications, and requirements of the building, with the designer will be a deciding factor in these kinds of costly mistakes.

- Technical risk

Anything that prevents from creating a product that fits a customer's desire is considered a technical risk. This can be due to a lack of funding and materials, a lack of site assessment, or

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ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

an imperfect design. Changes in project scope and needs, as well as design flaws or omissions, are major causes of these risks. Material shortage, poor quality of procured material, unknown site physical condition, obsoleteness of building equipment, wastage of materials by work are also some of the technical risks.

- Loss of Paperwork

These days everything is done online, limiting the use of printed pages. But don't be fooled by the digital revolution! At the end of the day, it can never match the authority of a printed paper. Be it legal, contractual, or any other business-related agreement. The paperwork is essential everywhere. Losing a signed contract is another nuisance one should avoid at all costs. Also, missing the contract leaves one at the mercy of the party at the other end of the contract. Carelessness, misplacement, and theft are the common excuses given for the loss of paperwork.

- Construction risk

Contractors and subcontractors are more likely to be the sources of most construction risks. Experienced contractors must be involved in the project as early as possible to make sound preparations for generating legitimate construction programs in order to keep the construction activity on schedule. Construction phase risks include machinery, delays due to rain and other factors, uncertain market conditions, contractor productivity issues, time. Construction risks also include labor productivity, labor disputes, site conditions, equipment failures, design revisions, too high-quality standards, and new technologies.

- Management risk

The wrong project team selection, lack of a proper project manual, lack of procedures, a project being too complex for the available resources, inability to take prompt remedial actions, poor quality control, poor control of status review, lack of an experienced person in the project team, and inadequate communication infrastructure are some of the construction management risks. Short tendering time, improper project feasibility study, time constraint, and no past experience in similar projects, are also some of the management risks.

- Delays in Completion

Delays aren't new phenomena. It happens everywhere. It is the same in the case of construction contracts too! Delays in project completion can happen due to a wide variety of reasons. The typical excuses for delays are: Adverse Weather, Poor scheduling, miscommunication with any subcontractor, Socio-political changes. Delays can be catastrophic

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to the project as they can shoot up the project cost, expire the validity of permits, and increase the chance of facing environmental and political setbacks.

- Finance risk

The ability to overcome the project's financial risk all the way to ultimate completion and operation is referred to as "financial risk." This risk factor refers to challenges or concerns about the project's funding, such as the execution period, operations, or equity financing.

- Cost Overrun

Construction is always based on a contract. And, there are different types of contracts for the project owners to choose from. Many of these construction contracts are flexible in the payment option. In other words, the total project cost will depend upon the contractor or the construction manager. In such instances, the incidence of cost overrun is as old as the civilizations. The project owner will lose money if the construction company doesn't abide by the contract. Therefore, a cost risk analysis is a must-do procedure. To avoid every unpleasant financial risk, our best advice will be to sign only contracts which have a fixed contract price, such as EPC Contracts.

- Subcontractor Default

Another significant construction risk is a contractual risk. The construction of a building contains many procedures and requires experts from different disciplines. Hence, subcontractors of varied expertise are essential for the perfection of the construction project. But some of the subcontractors may not be true to their words. And they might abandon the project or do it in an incompetent fashion, lessening the quality of the building. Now, defaulting isn't desirable to either of the parties. The subcontractors will lose their jobs. And the general contractor will have to account for the losses due to delay and poor quality.

- Incompetent Contractors

An incompetent contractor is like a cow chewing cud. They prolong the construction project unnecessarily and shoot up the construction cost. We have already seen how delays can be catastrophic to the project. An unprofessional contractor can also stir troubles in the paperwork and relations with subcontractors. So, having a motivated and competent project team is of the utmost importance. In our opinion, the project owners should not be ready to waver the quality of construction and must choose an experienced or well-qualified general contractor.

- Safety Hazards

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The construction industry is no stranger to safety hazards. The construction site is filled with hazardous materials, steep drops, sharp objects, and heavy machinery. Implementing the innovations in construction technology such as exoskeletons and smart wearables helps in reducing safety hazards. Hence, the construction manager or the general contractor needs to be aware of the industry's risk identification and risk mitigation processes. Some of the construction site safety tips include using personal protective equipment and keeping the workplace clean.

6. How to Reduce the Impact of Construction Risks

Though it is not possible to eliminate many of the risks faced by the owners, contractors, and workers that contribute to construction projects; many construction risks can be dramatically reduced with dedicated effort and the right set of tools.

7. Conduct a Construction Risk Assessment

Though the obvious goal of a risk assessment is the prevention of injuries and incident on-site, there are a few additional reasons to conduct one, such as:

- Determining who is at risk, and which of the risks above pertain to them
- Creating awareness around the risk through orientations and other training materials,
- Fulfilling any legal or state/federal regulatory duties surrounding risk,
- Meeting insurance requirements regarding loss prevention, and much more.

Table 1: Phase of risk management process.

Process Phase	Proposed Actions
Risk identification and early warning system	Determining the causes of risk; Determining possible consequences ; Identifying entities affect by risk..
Risk analysis	Determining the probability of event; Determining the consequences of event.
Formulating variants	Identifying possible alternatives; Analyzing expenditures and costs in different variants.

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Risk assessment	Declaring readiness and determining ability of the entity to make decisions; Determining the actual level of risk; Qualifying the use of possible alternative to manage risk.
Decision and action in the area of risk (risk control)	Choosing tools; Setting priorities; Using optimal combination.
Control monitoring and evaluation of undertaken activities	Checking and ex post evaluation impact of undertaken actions; New formation of risk management process in the case of wrong decision; Further use of tool which ensured success in risk management.

Breaking a risk down into manageable segments allows more strategic and logical thinking, to apply contingency action where it is practical and realistic. This should involve as many key people as possible, because this exposes the issue

to the best and most experienced personnel with the most comprehensive knowledge of processes, procedures, materials and equipment. This should then lead to the best possible solutions and control measures. It is never ideal for an independent person to undertake a full risk assessment in isolation.

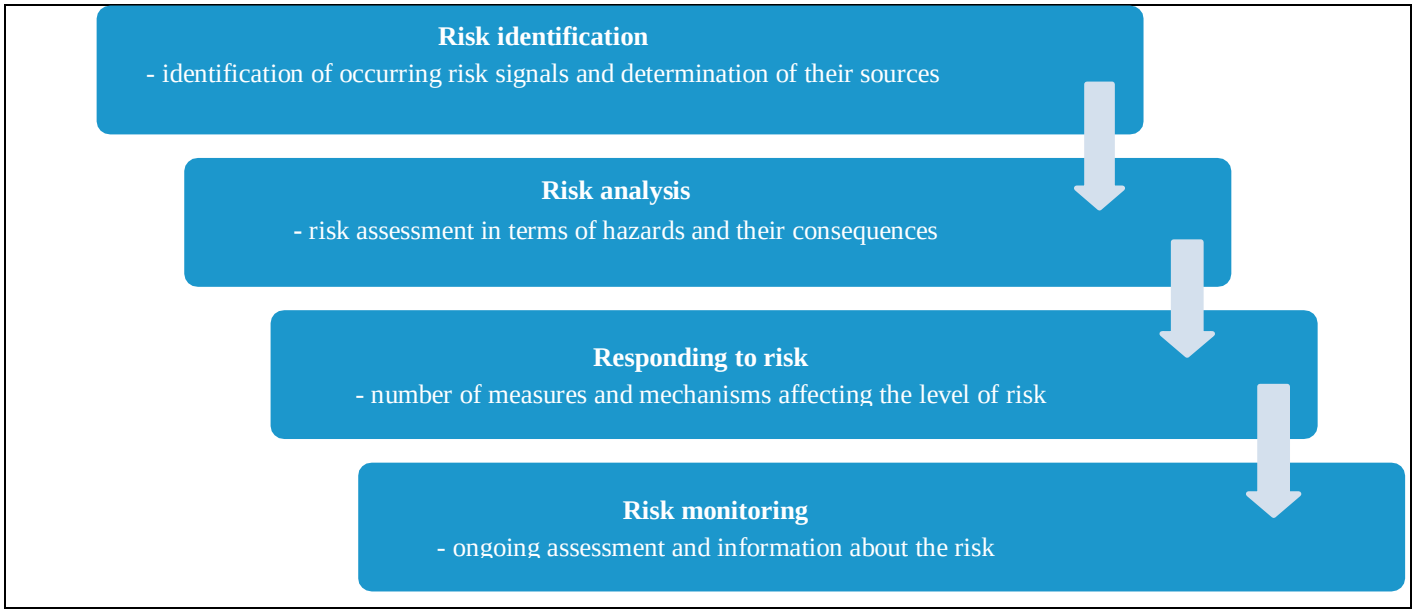


Figure 2: Example risk management cycle.

9. Conclusion

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ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

Risk is existed in each project especially the construction industry due to the big amount of complexity and uncertainty. Theses risk has several and various impacts on the project objectives ranging from high impact and low impact, therefore shall be managed closely and deeply. Risk management can be managed in two ways are formal and informal. The informal management of risk is to manage risk not following a specific process. Usually, in this case, the contractor allows contingency either a fixed amount or a percentage to absorb any arise risks during construction. It`s clearly seen that this way does not need effort but it`s very risky and doesn`t support the decision making. Moreover, it does not alert the project manager toward the probable risks.

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ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

A Sustainable Approach for Waste Reduction and Enhanced Strength for Industrial Application

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Abstract

The world has, by now, identified the seriousness and challenges regarding the sustainability of resources amid major environmental concerns that are part of modern problems today. The construction industry all over the world has been explicitly using concrete owing to its quality, strength, and adaptability to various construction needs and situations. However, in the last few decades, increased awareness, legislation, and global initiatives to combat pollution, energy consumption, waste disposal, and global warming have pushed industries, researchers, engineers, and other stakeholders to substitute virgin materials with alternative construction materials. Construction and demolition account for about 30% of the total solid waste generated worldwide. The top ten countries including India and China which are contributing heavily to this waste stream, together generating about 2.5 billion metric tonnes every year. The C&D waste poses a significant strain on landfill sites, contributes to energy waste, and adds additional costs for its disposal. However, through careful sorting, processing, and recycling processes, a significant chunk of it can be reused and help minimize environmental impact. The work presented here involves fractional replacement of C&D waste aggregates viz., RCA and RA in amounts ranging from 05-25% as coarse and fine aggregates, respectively. Most of the previous works have not aimed at higher grades like M35 and M40, which form the subject matter of this paper. Several tests were conducted to estimate the fresh and hardened state properties of concrete, most important being compressive and tensile strength as well as slump test for workability.

Keywords: C&D Waste, Sustainability, Recycled Aggregates, Compressive Strength, Concrete, Split Tensile Strength.

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ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

1. Introduction

Concrete is by far, the most used construction material worldwide. There are so many factors which makes concrete almost irreplaceable as construction material anytime soon. Concrete is a highly durable material that can withstand heavy loads and resist the effects of weathering, erosion, and chemical attacks. Concrete is versatile material with ability to be moulded and cast in any shape and size, the local availability of constituent materials also makes it cost effective. It has high thermal mass, good fire resistance and better sound insulation and acoustic comfort.

Every year, about 12 billion tonnes of concrete is produced world over, which amounts to per capita consumption of 1 m^3, hardly any material would reach anywhere near this number, in terms of production. The annual demand for concrete is expected to exceed 18 billion tonnes by 2050. With such huge demand forecast, it is vital to look for sustainable practices to balance environmental impacts associated with the extraction and manufacturing of its components, as well as carbon emissions from cement production.

China is the largest producer and consumer of concrete, followed by India and the United States and unarguably these are the chief contributors to construction related waste. These wastes can be managed with sustainable mindset by incorporating recycled materials such as aggregates coming from Construction and Demolition (C&D) waste and other industrial waste by-products which causes considerable nuisance for municipal authorities and put pressure on landfill sites for disposal, such practices can relax the demand for virgin resources to a good extent and reduce carbon footprint of the associated processes.

Construction and Demolition waste is largely composed of materials which comes from debris from demolished structures, waste generated from construction and renovation projects, road construction and repairs, construction of bridges and other infrastructure works. C&D materials generally include concrete, asphalt, wood, metals, gypsum, plastics, and reclaimed building materials. Rapid construction is often viewed as an indicator of improving lifestyle and economic growth.

Recycling of waste developed as a concept in late 20th century, since then efforts are being taken to use recycled aggregates (RA) to produce recycled aggregate concrete (RAC). The absence of proper recycling facilities, inconsistent government policies and regulations, quality issues in recycled aggregates, impurities, and contamination etc. are proven limitations for the use of it on large scale, maybe this is why it has not gained popularity

ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

except in works of minor importance such as base and sub-base course in road construction, as filler in foundation work and sanitary structures. However, recent studies have shown that these recycled aggregates have enough potential to be reused in conventional concrete grades with replaced component ranging from anything between 0-100%.

A detailed study was carried out to know the exact amount of C&D waste generated in India, it was done by Technology Information, Forecasting and Assessment Council, TIFAC. Overall C&D waste output was approximately 13-15 million tonnes for the year 2000. Several findings reported in this study is highlighted through the following points:

1) The total Construction and Demolition (C&D) waste output generated in the year of study was 14.69 million tonnes.
2) The waste generated per unit area in construction and renovation/repair work was 40-60 kg/$m^2$and 40-50 kg/m^2 respectively.
3) Out of different sources of waste generation, the waste stream from demolition of buildings, was estimated to be 425 kg/m^2 of waste.

It also gave rule of thumb for C&D waste generation for different types of construction and repair work. However, as per C&D Waste Management Rules 2016, the C&D waste generated can be assumed to be 25% of total municipal solid waste, total output lying between 10-750 million tonnes per year as reported by different government agencies, this figure could be a gross underestimate given the absence of special measures to collect C&D waste separately. As per Annual report on Solid Waste Management 2020-2021 in conformance with Solid Waste Management (SWM) Rules 2016, about 50% of waste is recycled and 18.4% goes to landfills. The load on landfills seems to be decreasing due to improved collection efficiency. The policy roadblocks and economic viability are slowly giving way for better data accumulation and inclusion of C&D waste in construction industry. IS:383 which only allowed for 'naturally sourced' virgin materials for aggregates got revised in 2016 and allowed for usage of C&D waste in conventional concrete mix with certain limits. The latest stipulations in IS:383 allows for use of recycled aggregates with 25% replacement limit in plain concrete, 20% in RCC mixes of M25 and below grades, with up to 100% replacement in lean concretes of grades smaller than M15. Similar changes were incorporated in other technical institution such as National Building Code of India (NBC) which added a chapter on 'sustainability' and made certain provisions to allow recycled aggregates to replace natural aggregates.

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2. Material and Methods

2.1 Materials

2.1.1 Cement

Cement is the most basic material in concrete production, it acts as a binder and imparts strength. In this study OPC 43 Grade cement was used which complies with IS 8112: 1989. Several properties of concrete such as setting times, fineness, consistency etc. are used to judge the quality of cement, these tests were carried out to ascertain quality of cement, properties, and test results are listed in Table I.

Table I: Physical Properties of OPC 43 Grade Cement

Physical Properties	Test Results	IS 8112-1989 Stipulations
% Fineness (90 µm IS Sieve)	4.25	⊁10
Soundness (mm) Le Chatelier's Method	1.20	⊁10
Normal Consistency (%)	31	-
Initial Setting Time (mins.)	220	≥ 30
Final Setting Time (mins.)	335	≤ 600
Specific Gravity (Le-Ch-atelier's Method)	3.15	-

2.1.2 Fine aggregates

We have taken fine aggregates which are part of demolished concrete structure, it was subjected to cleaning with running water and manually sorted for impurities, it is labelled as recycled fine aggregate (RFA). Sieve analysis was carried out and based on fineness modulus it falls into Zone III, control mix i.e., a reference mix was designed with natural river sand having nominal size of 4.75 mm.

2.1.3 Coarse aggregates

In this study, coarse aggregates of 10 mm and 20 mm were chosen and combined grading was done to work out the proportion in which they need to be mixed, sieve analysis was done to match the grading requirements given in IS 383:2016 and recycled concrete aggregate (RCA) was used substituted with natural coarse aggregates; the recycled aggregates were sourced from a local construction waste processing plant. Physical properties of coarse and fine aggregate are listed in Table II.

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Table II: Physical Properties of Fine & Coarse Aggregates

Properties	Fine Aggregates		Coarse Aggregates		Admixture (Conplast SP430G8)
	Natural Fine Aggregate	Recycled Aggregate (RA)	Natural Coarse Aggregate	Recycled Concrete Aggregate (RCA)	
Maximum Size (mm)	4.75	4.75	20	20	-
Bulk Density (loose) in kg/m^3	1656	1435	1480	1155	-
Bulk Density (compacted) in kg/m^3	1865	1600	1570	1316	-
Specific Gravity	2.60	2.63	2.65	2.45	1.24
Free Moisture (%)	1.55	1.38	0.30	2.25	-
Water Absorption (%)	14.6	16.3	0.34	5.065	-

2.1.4 Water

The various limits of impurities to be allowed in water used for mixing the ingredients of concrete are given in IS 456:2000 and samples used in our study have been made with clean source of potable water at room temperature for mixing and curing and conforms to IS 456 limits.

2.1.5 Chemical Admixture

Conplast SP430G8 was used in the experimental investigation for both the grades. This admixture is to produce pumpable concrete and high-grade concrete of M30 & above by substantial reduction in water resulting in low permeability and high early strength. Also, it helps in producing high workability concrete requiring little or no vibration during placing. Its dosage was fixed as 0.5% by weight of cement as stipulated in the mix design.

2.2 Methods

In the present investigation M35 grade of concrete was used. The mix proportion concrete was 1:1.45:2.91 at water cement ratio of 0.38. The specimen concrete was tested for density and workability green concrete and compressive, Split Tensile Strength & flexural in hardened state after 7 days and 28 days of moist curing. Mix Design details of M35 Grade Concrete are tabulated in Table III.

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Table III: Mix Design details of M35 Grade Concrete

Cement	Fine Aggregate	Coarse Aggregate	Water
420	607.1	1222.9	159.6
1	1.45	2.91	0.38

2.2.1 Mix Design and Experimental Work

2.2.1.1 Design Mix details of M35 Grade of Concrete

The mix proportions were worked out for the two grades as per IS 10262:2009 and IS 456:2000 and details are tabulated in Table IV.

Table IV: Replacement Details with Number of Samples*

Percentage replacement	No. of cubes for Compressive Strength Test		No. of cylinders for Split Tensile Strength Test		No. Of beams for Flexural Strength Test	
	7 Days	28 Days	7 Days	28 Days	7 Days	28 Days
0	3	3	3	3	3	3
5	3	3	3	3	3	3
10	3	3	3	3	3	3
15	3	3	3	3	3	3
20	3	3	3	3	3	3
25	3	3	3	3	3	3
Total	36 Cubes		36 Cylinders		36 Beams	

***The total number of samples as indicated in Table IV is for both the grades i.e., 108 samples for M35.**

2.2.2 Methodology

In fresh state; the workability parameters such as slump value and compacting factor were studied. In hardened state; the strength tests such as compressive strength, split tensile strength and flexural strength were studied and were conducted for each mix. The obtained results are tabulated. The conclusions were made from the results and discussions.

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3 RESULT AND DISCUSSION

The experimental programme was designed to determine the fresh and hardened characteristics of concrete mixes. The results obtained at the end of various tests conducted are presented here. Control mixes of M35 were prepared and then the recycled aggregates were replaced in different percentages equally spaced from one another. The impacts of replacing aggregates on different concrete properties are studied through tests such as workability and density estimation for the fresh properties and compressive strength, splitting tensile strength and flexural tensile strength for matured state of concrete.

The ease of mixing of control mix and concrete prepared with replaced recycled aggregates of both the grades are evaluated using slump test in conformance with IS 1199:1959.

The slump test is most used procedure for measuring the consistency or workability of fresh concrete. The test determines the degree of deformation the concrete undergoes under its own weight after being placed in a cylindrical mould and then removed. The slump test signifies the consistency of various batches of concrete. The shape of the concrete slumps provides information about the workability and quality of the concrete. The slump cone's shape demonstrates concrete's workability and it is suitable for low to high workabilities.

Initially, the inner surface of the mould was cleaned and oiled. The non-porous base plate was then covered with a mould, which was then filled with approximately four layers of prepared concrete mixture. Each layer was tamped with 25 strokes, and excess concrete was removed by slowly lifting it upward in a vertical direction. The slump was then known by measuring the height difference between the mould and the highest point of the test specimen mixture.

Table V: Slump Variation With % Replacement for M35

S. No.	Level of replacement (%)	Obtained Slump Value (mm)
1	0	70
2	5	65
3	10	63
4	15	68
5	20	62
6	25	60

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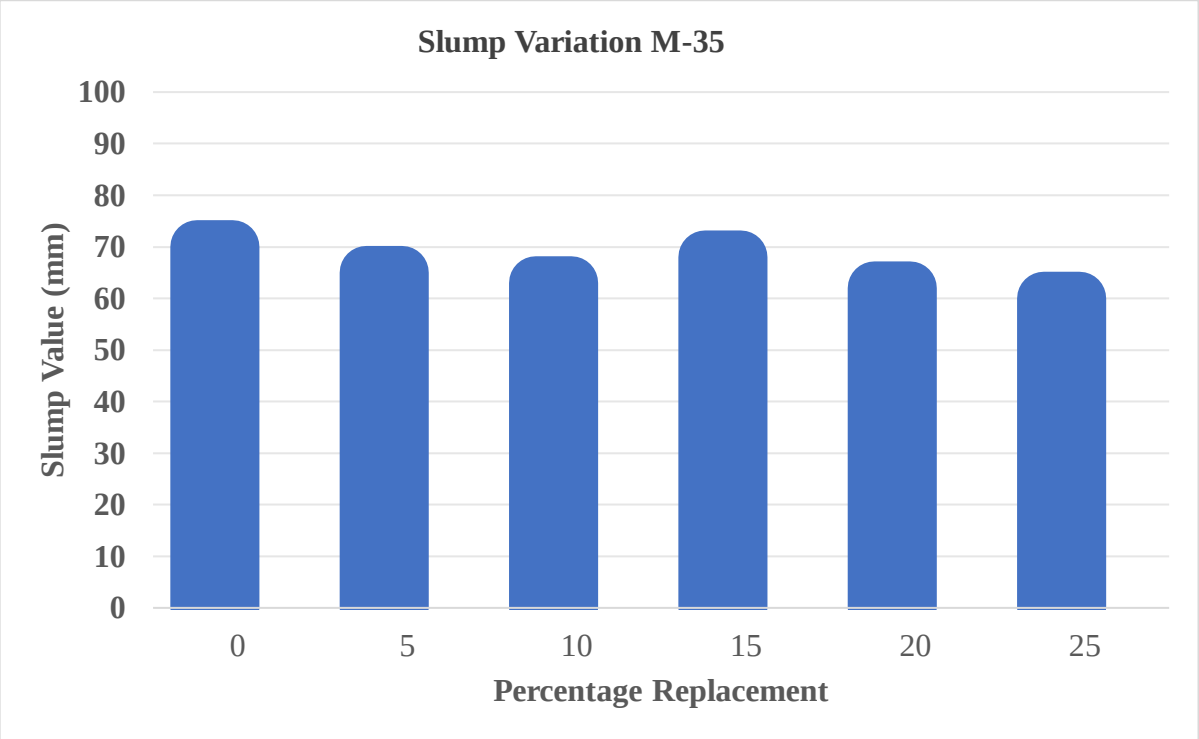


Figure I: Slump variation with percentage (%) replacement for M35

Table VI: Results of different types of Strengths Tests conducted on M35 Grade Concrete

S. No.	% Replace-ment	Grade	Average Compressive Strength (in MPa)		Average Split Tensile Strength (in MPa)		Average Flexural Strength (in MPa)	
			7 Days	28 Days	7 Days	28 Days	7 Days	28 Days
1.	0	M35	34.05	39.62	2.55	4.14	3.88	6.37
2.	5		30.65	37.30	2.23	3.50	5.71	6.22
3.	10		32.95	39.90	3.02	3.66	5.82	6.48
4.	15		31.14	42.95	3.66	4.14	6.22	7.06
5.	20		30.10	40.95	3.34	3.82	6.10	6.60
6.	25		28.70	39.20	2.86	3.42	5.70	6.08

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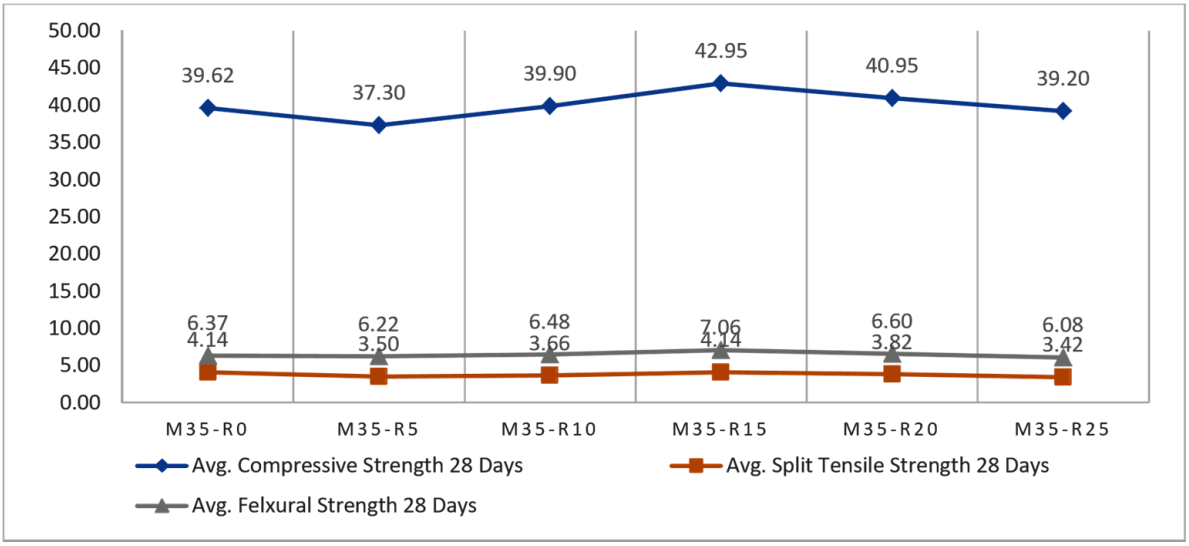


Figure II: Line Graph showing variation in Split Tensile Strength, Flexural and Compressive Strength at 28 days

4 CONCLUSION

recycled aggregates have quality issues even when sourced from highly mechanized sorting and cleaning process. The surface imperfections result in decreased strengths as we increase the percentage of replacement to the control mix, however average strength mostly lies between characteristic and target strength .

The fresh and hardened properties of concrete both seems to indicate that at higher grades such as M35 and M40 which are standard grades as per IS 456 and are dense enough and needs careful supervision both during design and casting. During mix design process, effort was taken to limit w/c ratio to as low as practically feasible.

The compressive strength, split tensile strength and flexural strength have all shown a similar trend of strength variation that as soon the control mix is replaced with recycled aggregates, there is dip in values which starts rising gradually till 15% replacement level (RL) and it starts decreasing from 15 to 25% RL, the greatest fall recorded from 20 to 25% replacement level (RL). From observations at the time of casting, such decrease at 25% replacement level (RL) was quite apparent as the work-ability, appearance and surface finish of the concrete were decreasing rapidly. From our study, it is therefore concluded that the ideal level of replacement at these grades with chosen recycled aggregates lies at 15% replacement level (RL) as at this point, peak strength is achieved.

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It was also concluded, based on experience that coarse aggregates contribute more to strength than fine aggregates as fine aggregates have large surface area, so there should be greater cohesion and hydration reactions occurring on its surface but since the aggregate was already subjected to loads before and contains impurities on it surface hence it hampers the strength development appreciably. Also, the water absorption of recycled aggregates is higher and requires at least 10-15% more water to not hamper the work-ability, fine aggregates being porous absorbs most of it and this may necessitate use of admixtures. Therefore, the quality and source of recycled aggregates play a vital role in overall performance of such recycled concrete.

Use of recycled fine aggregate (RFA) can be substituted with other alternatives like Industrial by-products (IBP) such as blast furnace slag, wood ash (WA), waste foundry sand (WFS), etc. and effect of such material in conjunction with recycled coarse aggregate can be studied. Results of this study can be conveniently used for future studies on C&D waste (recycled coarse and recycled fine aggregates) concrete.

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ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

Characterization of Cement Mortar Incorporating Silica-Based Materials Derived from Diverse Waste Sources: A Review

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Abstract

The cement production process is notorious for its high energy consumption and significant contribution to global carbon dioxide emissions, accounting for approximately five percent of worldwide emissions. With a growing demand for sustainable construction practices, there's an increasing emphasis on integrating naturally occurring materials into building projects. One pressing challenge faced by the construction industry is reducing the reliance on cement while maintaining the performance of cementitious materials. There's a critical need for durable cementitious products that offer economic and environmental advantages to support modern infrastructure development. This review focuses on the utilization of silica-based materials sourced from various waste streams in cement mortar formulations, aiming to demonstrate their efficacy in waste utilization. The study investigates the chemical properties of diverse silica-based materials and evaluates the mechanical properties of mortar specimens prepared with these materials. Results indicate that silica-based materials can effectively substitute cement and complement naturally occurring fillers like river sand and dolomite across different replacement percentages. This approach holds promising potential for enhancing the technical feasibility of mortar manufacturing processes while promoting sustainable waste management practices.

Keywords: Cement, Silica, Mortar, Fly ash, Fillers, Environmental friendly, Sand, Non-biodegradable, Sustainable.

ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

1. Introduction

Cement, mortar and concrete are the prime materials for construction work. The roles of these materials are always being of great influence for infrastructural development. As compared with many industrial materials, production of cement also consumes a huge amount of energy and originates lots of exhaust gases contributing global warming. With the production of 1 tone cement, CO_2 emission was also found to be 1 tone which promotes harmful actions for environment [1, 2].

The most common filler used in cement mortar is river sand. Use of cement into mortar is very limited because most of the portion is occupied by fillers. For example, in 1:3 mortar, 1 part is consumed by cement and 3 parts are by filler. The need of investigating novel and affordable binders which consumes low energy and emits less amount of CO_2 is applaud able, but same time it is also required to find suitable alternates for fillers that are dependent to nature.

Disposal of non-biodegradable wastes is one of the prime challenges in the world. Scarcity related to landfilling, depletion of natural resources and water contamination are the main consequences of improper waste disposal. Most of the non-biodegradable wastes are generated through construction industries. The wastes materials containing higher silica may found suitable to use as fillers in cement mortar due to its inherent and pozzolanic properties [3]. Pozzolanic reactions are one of the reasons for raise in strength and durability of cementitious products [3], and hence wastes with higher silica can be considered to use with naturally occurring fillers to form cement mortar.

The aim of this research is to observe behavior of silica based non-biodegradable wastes with cement and to promote the same in favor of reducing the use of natural resources for the benefit of environment. Various verities of such wastes had been utilized by many researchers like SSA (Sewage Sludge Ash), GBS (Granulated Blast Furnace Slag) [3], brick waste [1], heat-treated boron derivative waste [4], quarry waste [5], ground waste glass [2, 8], green waste glass [6], GS (Granite Sludge waste) [7] etc.

2. Characterization of Silica Based Materials

2.1 Chemical Properties

ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

Yen et al. [3] reported that the chemical composition of SSA (Sewage Sludge Ash), GBS (Granulated Blast Furnace Slag) and FA (Fly Ash) was determined using microwave assisted digestion method by means of atomic emission spectrometer. Authors observed that the SSA and FA were includes with higher percentage of $SiO_2$and Al_2O_3 and hence SSA can be treated as pozzolan like FA. GSB also comprises higher SiO_2 and CaO content.

Kaman et al. [4] used X-ray fluorescence (XRF) technique to determine chemical compositions of boron derivative waste and found SiO_2, CaO, MgO, B_2O_3, Na_2O, and Al_2O_3 as major enclosure in the waste. Balbuena et al. [5] characterized the mineralogical properties of quarry waste by XRD and Fluorescence to infer that due to presence of 76% SiO_2 in the waste, itcan be used in the form of stone aggregate.

Corinaldesi et al. [8] conducted the chemical analysis of waste glass and reported that the waste is composed of higher amount of SiO_2 up to 72%,while Matos and Coutinho [2] observed 70% SiO_2 in glass waste through X- ray diffraction and Scanning electron microscopy (SEM).Marmol et al. [7] examined chemical properties of granite sludge waste by using X- ray fluorescence(XRF), X- ray diffraction (XRD), laser diffraction, and scanning electron microscope (SEM) and obtained that the waste contains up to 60% SiO_2.Table 1 shows the chemical compositions of silica based materialsstated in various researches.

Table 1: Chemical compositions of silica based materials

Silica based materials type	Compositions wt (%)in terms of oxides								References
	Si	Al	Fe	Ca	Mg	Na	K	S	
SSA	48.0	13.7	6.2	3.6	1.9	1.0	2.1	1.7	[3]
FA	41.8	17.0	5.3	5.9	1.6	0.2	0.6	0.7	[3]
GBS	31.3	1.7	0.1	34.2	0.5	ND	0.1	1.8	[3]
BD	18.92	2.31	0.91	18.4	13.55	5.30	0.71	0.76	[4]
QW	75.95	10.79	-	2.42	0.15	0.96	8.51	0.32	[5]
GW	72.50	1.7	-	12.0	0.2	12.2	1.0	-	[8]
WGP	70.0	1.2	0.65	8.7	3.7	16.0	0.35	<0.05	[2]
GWG	75.06	6.65	-	-	-	10.7	4.49	3.1	[6]
GS	50-60	10-40	6-28	3-6	0.5-2	2-2.6	2.9-3.6	-	[7]
FA, fly ash; SSA, sewage sludge ash; GBS, granulated blast furnace slag; BD, boron derivative									

waste; QW, quarry waste, GW, ground waste glass; WGP, waste glass powder; GWG, green waste glass; GS, granite sludge waste; ND, not detected.

2.2 Preparation of Silica Based Mortar and Their Characteristics

Yen et al. [3] demonstrated the effect of pozzolana based mixed waste materials in cement mortar production. Several combinations of SSA, FA and GBS were used to prepare blended cement mortar and their properties are examined as per control cement mortar specimens. Total six specimens each of size 5 cm^3 were prepared and tested. Table 2 shows the proportion of various blended cement mortar used in the research. Authors concluded that the 56 days compressive strength recorded for dual and triple replacement blended cement mortar at total 50% cement replacement was 93.7% and 92.9% of control cement mortar. With 70% replacement of cement by modified SSA and GBS, the 56 days compressive strength was found 92.4% of the control mortar. The pozzolanic reactions between pozzalance were also found expressive and hence that can be replaced with cement to form cement mortar.

Table 2: Mixtures of the blended cement mortars [3].

Binder Combination	Binder (g)				Total cement replacement ratio (%)
	Cement	SSA	FA	GBS	
Control	500	0	0	0	0
D-I	250	125	125	0	50
D-II	250	62.2	187.5	0	50
D-III	250	125	0	125	50
D-IV	250	62.5	0	187.5	50
T-I	250	62.5	125	62.5	50
T-II	250	62.5	62.5	125	50
M-I	150	175[a]	175	0	70
M-II	150	175	175	0	70
M-III	150	175[a]	0	175	70
M-IV	150	175	0	175	70

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Mohamed and Djamila [1] researched on application of brick waste into cement mortar and its effect on engineering properties. A combination of two types of sand i.e., roller and crushed sand had been used with the constituent of brick waste replaced with cement in various percentage from 0 to 30%. To compare the results, control cement mortar specimens were also prepared using cement and sand mix. Authors concluded that at 5, 10 and 15% replacement of brick waste from cement, the improvement of mechanical properties in terms of compressive strength and flexural strength was observed. The addition of brick waste into mortar also decreases the rate of water absorption therefore brick waste can be technically replaced with cement to make ordinary mortar.

Kaman et al. [4] reported the use of heat treated boron waste to prepare cement mortar and identified its mechanical properties at elevated temperatures. Cement was partially replaced with waste that treated at 800 and 900^0C temperatures in definite percentage of 15, 25 and 35% by weight rations. Mix proportions of cement mortar prepared are shown in table 3.

Table. 3: Mix proportions of prepared cement mortars [4].

Sample code	Mass in grams				
	cement	**waste**	**sand**	**Initial water**	**Final water**
Control mortar	740.00	0.00	2035.00	359.00	364.00
800°C-15% - WDCM Mortar	629.00	111.00	2035.00		359.00
900°C-15% - WDCM Mortar	629.00	111.00	2035.00		
800°C-25% - WDCM Mortar	555.00	185.00	2035.00		
900°C-25% - WDCM Mortar	555.00	185.00	2035.00		
800°C-35% - WDCM Mortar	481.00	259.00	2035.00		

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900°C-35% - WDCM Mortar	481.00	259.00	2035.00		
WDCM, waste-doped cement mortars.					

Authors concluded that the compression strength for specimen denoted by sample code WDCM-800°C-25% was found proximate as compare to other mortar samples. (Figure 1) shows the graph between 28 days compressive strength and waste replacement for various samples.

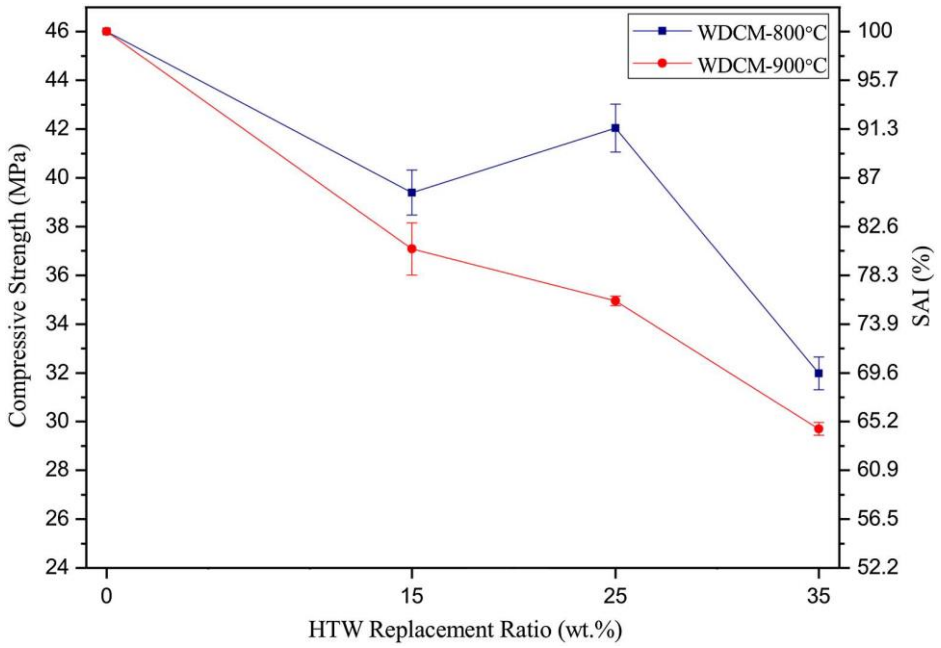


Fig. 1 Compressive strength and SAI (strength activity index) values after 28 days curing [4].

Corinaldesi et al. [8] investigated the properties of cement mortars based on aggregates derived from glass waste. Three categories of glass waste in terms of their particle size ('glass A' particle size up to 36 µm; 'glass B' particle size ranged between 36 to 50 µm; and 'glass C' with particle size ranged between 50 to 100 µm) were utilized to prepare prismatic specimen of mortar sized 40 X40 X 160 mm. Along with Ref (reference) mortar, three mortars were prepared for 70% replacement of total aggregate by glass waste (denoted as A-70, B-70 and C-70) and three were prepared by replacing 30% of total aggregate (denoted as A-30, B-30 and C-30) respectively. The mixture proportions are shown in table 4. The mortar

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specimens were tested for compression and flexure to observe the mechanical properties. Authors concluded that the maximum 180 days compressive strength was found for mixture A-30 and flexure strength for C-70 but all other specimens were also found better in mechanical properties as compare to reference specimen. In order to achieve higher performance mortar, glass waste with particle size up to 100 µmmay suitably replace with aggregate.

Table. 4: Mortar proportions [8].

<table>
<tr><th rowspan="3">Mortar type</th><th rowspan="3">Water-cement ratio</th><th colspan="5">Mortar ingredients in grams</th></tr>
<tr><th rowspan="2">Cement</th><th rowspan="2">Natural aggregate</th><th colspan="3">Type of glass waste with particle size</th></tr>
<tr><th>A: up to 36 µm</th><th>B:36 to 50 µm</th><th>C: 50 to 100 µm</th></tr>
<tr><td>Reference</td><td>0.56</td><td rowspan="7">450</td><td>1350</td><td colspan="3">-</td></tr>
<tr><td>A-70 mortar</td><td rowspan="3">1.00</td><td rowspan="3">405</td><td>945</td><td colspan="2">-</td></tr>
<tr><td>B-70 mortar</td><td>-</td><td>945</td><td>-</td></tr>
<tr><td>C-70 Mortar</td><td colspan="2">-</td><td>945</td></tr>
<tr><td>A-30 mortar</td><td rowspan="3">0.67</td><td rowspan="3">945</td><td>405</td><td colspan="2">-</td></tr>
<tr><td>B-30 mortar</td><td>-</td><td>405</td><td>-</td></tr>
<tr><td>C-30 mortar</td><td colspan="2">-</td><td>405</td></tr>
</table>

Matos and Coutinho [2] researched on effect of glass powder waste in the form of cement replacement on durability of mortar. Crushed glass was replaced with cement (as 0, 10 and 20%) to prepare mortar specimens and was tested for mechanical resistance after 7, 28, 90, 180 and 562 days curing. Authors concluded that attractive strength activity indexes were obtained at 90 days of curing in mortars containing waste glass powder. (Figure 2) shows the compression and flexural strength of mortar.

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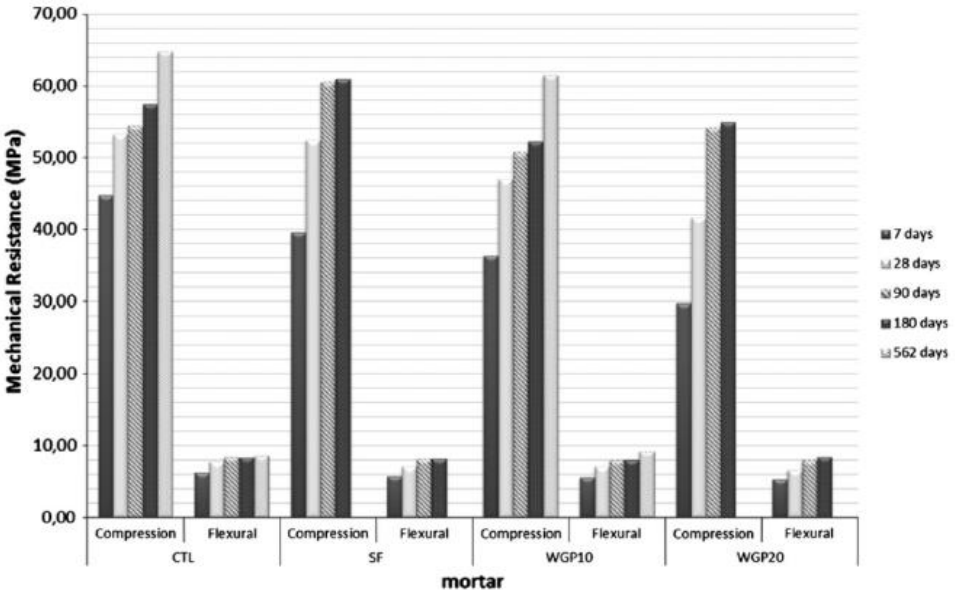


Fig. 2 Compression and flexural strength [2].

Marmol et al. [7] reported the use of granite sludge waste for the production of coloured cement-based mortar. Experimental work was carried out on two different types of mortar. The standard mortar was also prepared by adding natural silica and dolomite sand with limestone. The 90% grain size of waste used was less than 500 µm. First type of mortar was obtained by replacing cement with waste was termed as (samples A-D), whether the second mortar (samples E-G) was prepared by replacing natural filler with waste. Prismatic samples of size 40X40X160 mm were tested to determine 28 days compressive strength. Authors concluded that gradual replacement of filler with waste shows improvement in compressive strength and 10 % replacement of cement with waste demonstrated no changes in 28 days compressive strength as compare to standard mortar. (Figure 3) shows the compressive strength after 7 and 28 days curing of mortars with cement and filler replacement.

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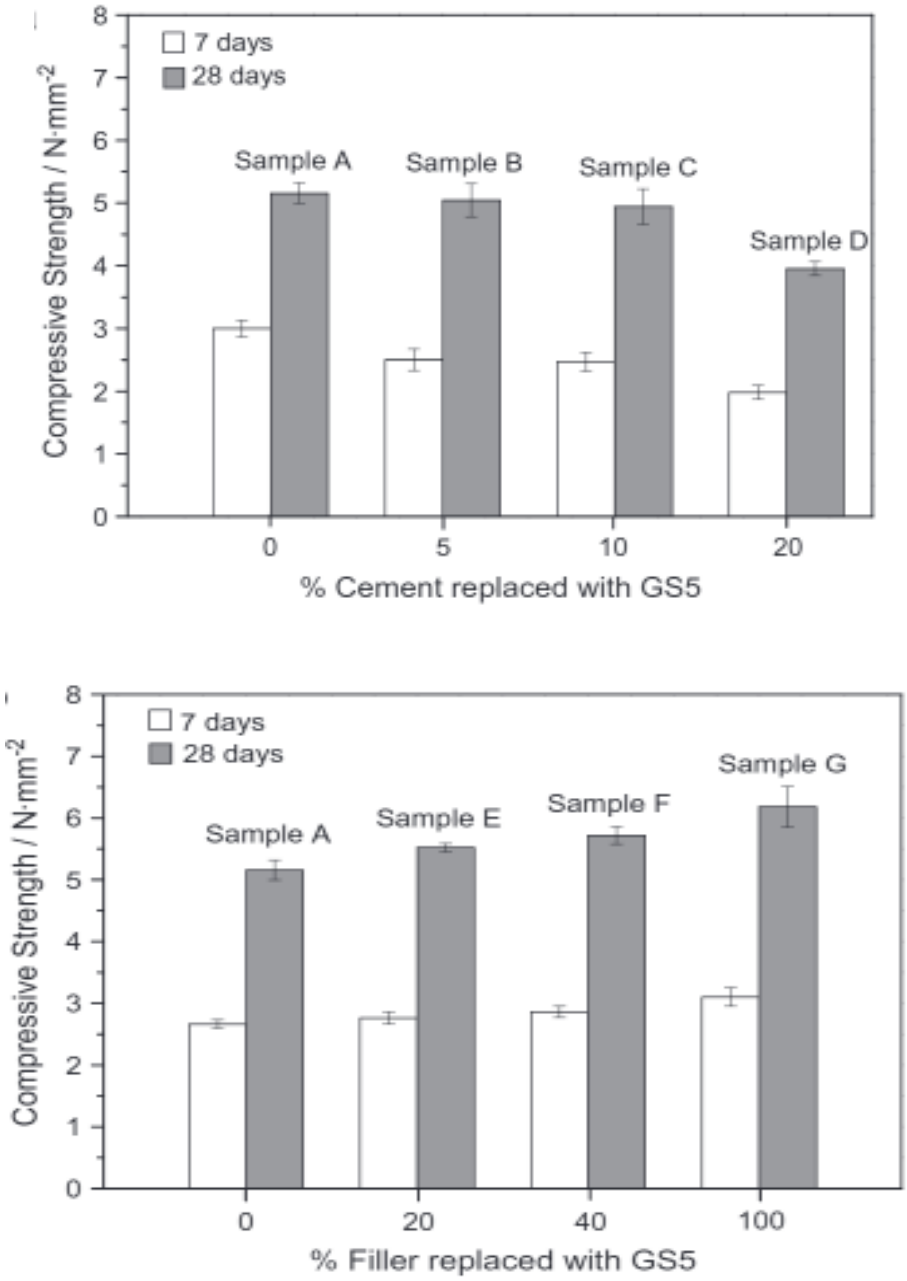


Fig. 3 Compressive strength of different mortars [7].

3. Conclusions

The main objective of this research was to observe the efficacy of silica based materials in cement mortar. Following collusions drawn for this purpose are shown below:

- The process of using silica based waste materials in mortar manufacturing is environment and nature friendly.

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- Use of such materials leads to reduce the spread of greenhouse gases and pollution generated by cement manufacturing industries.
- Silica based wastes materials like fly ash, quarry dust, brick debris, boron waste, slag, granite waste, glass waste etc. are abundantly available and their reuse into cement mortar may reduce the scarcity of landfill and problem of unnecessary dumping.
- Engineering parameters like adequate durability and strength required for cement mortar can be achieved using silica based materials.
- Use of silica based materials may be a better alternative for sustainable and nature saving development.

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High Rise Building with Electric Vehicle Charging Station Infrastructure

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Abstract

An urban development approach embraces sustainability through a modern high-rise building featuring EV infrastructure in its parking area. This innovative concept amalgamates towering structures with the pressing demand for electric vehicle integration. By fusing EV facilities within the building's parking zone, a greener, less polluting urban landscape emerges, fostering sustainable mobility. This amalgamation provides occupants with accessible charging stations, thereby promoting electric vehicle adoption. These stations boast swift-charging technology, conveniently energizing vehicles while idle. Though scheduling a G+5 high-rise with EV integration necessitates meticulous coordination, the resultant benefits outweigh the minimal delay. Comparative analysis indicates slightly extended construction periods due to specialized installations. Nonetheless, the long-term advantages encompass advancing eco-friendly urbanization, elevating property value, and harmonizing with the global electric mobility trend. This reinforces the enduring potential of EV-facilitated structures in a swiftly evolving urban sphere.

Keywords: High rise building, Electric vehicles, Charging infrastructure, Electric vehicle charging stations

1 Introduction

Introduce the increasing significance of sustainable urban development and the role of electric vehicles (EVs) in reducing carbon emissions and enhancing transportation efficiency. The 21st century is witnessing an unprecedented wave of urbanization, with more than half of the world's population now residing in cities. This rapid urban growth has brought forth numerous challenges, most notably the strain on resources and the environment (Singh et.al 2022). As a response to this pressing issue, sustainable urban development has emerged as a pivotal concept, aiming to harmonize the needs of growing urban populations with the preservation of our planet's finite resources. One of the linchpins of sustainable urban

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ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

development is the adoption of clean and efficient transportation systems, and in this regard, electric vehicles (EVs) have emerged as a transformative solution.

The primary objective of this research is to conduct a comprehensive analysis of the integration of Electric Vehicle (EV) infrastructure in high-rise buildings and to examine its profound impact on construction scheduling. As urban centers continue to grapple with the imperative of sustainable development, the integration of EV infrastructure within high-rise buildings emerges as a critical solution at the intersection of transportation efficiency and environmental stewardship and how the presence of EV charging provisions affects the overall construction scheduling of high-rise buildings (Yujuvan et.al 2020). This research endeavours to illuminate the intricate interplay between sustainable urban development, electric mobility, and construction efficiency. By shedding light on the complexities of integrating EV infrastructure in high-rise buildings, aim to provide valuable insights for urban planners, architects, and developers, contributing to informed decision-making and the advancement of greener, more future-oriented urban landscapes.

2. Methodology

The research paper employs a comprehensive methodology for the design and implementation of a G+5 high-rise building integrated with electric vehicle (EV) infrastructure. The study encompasses three main aspects: architectural and structural planning, EV-enabled parking area design, and project scheduling using Primavera software. Initially, the architectural and structural considerations are meticulously addressed to ensure the building's stability and functionality while accommodating EV charging facilities. Subsequently, an innovative layout for the EV charging stations within the parking area is developed, optimizing space and accessibility. Finally, Primavera is leveraged for efficient project scheduling, ensuring seamless coordination of construction activities and EV infrastructure integration. The methodology holistically combines architectural, engineering, and project management principles to create a sustainable and technologically advanced high-rise building with EV capabilities.

3. Impact and Implications

The impact of ev infrastructure on construction scheduling and its implications for sustainable urban development.

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The integration of Electric Vehicle (EV) infrastructure into construction projects, particularly in high-rise buildings, has a notable impact on construction scheduling, with far-reaching implications for sustainable urban development. This intersection holds the potential to reshape the urban landscape, enhance environmental sustainability, and advance the adoption of electric mobility. The impact and implications can be understood through the following:

3.1. Construction Scheduling Impact:

a) Time Variance: The introduction of EV infrastructure can lead to modifications in construction activities, such as installing charging stations, electrical upgrades, and adapting parking layouts. These additional tasks can influence project timelines, potentially extending certain phases of construction.

b) Coordination Complexity: Integrating EV infrastructure necessitates coordination among various stakeholders, including architects, engineers, electrical contractors, and charging technology providers. This coordination effort can introduce complexities that impact construction scheduling and seamless collaboration.

c) Permitting and Approvals: The process of obtaining necessary permits and approvals for EV infrastructure installation can introduce delays in construction timelines. Regulatory requirements related to electrical work and charging station may need to be navigated, potentially affecting project progression.

3.2. Implications for Sustainable Urban Development:

a) Promotion of Green Transportation: The integration of EV infrastructure aligns with sustainable urban development goals by promoting eco-friendly transportation option. By facilitating electric mobility, high-rise building contribute to reducing carbon emissions and mitigating air pollution, fostering a more sustainable and livable urban environment.

b) Enhanced Market Value: High-rise buildingwith EV infrastructure are likely to attract environmentally conscious residents and businesses. The presence of convenient charging facilities enhances property value, catering to a growing demand for sustainable amenities in urban areas.

c) Urban Resilience: EV-equipped buildings contribute to urban resilience by supporting the transition to cleaner transportation alternatives. This resilience is particularly relevant as cities seek to reduce their carbon footprint and enhance their preparedness for future mobility trends.

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d) Technological Innovation: The integration of EV infrastructure reflects technological innovation within urban design and construction. This showcases a commitment to forward-thinking urban planning and aligns with the evolution of smart cities and sustainable urban development paradigms.

The integration of EV infrastructure in high-rise buildings carries a significant impact on construction scheduling, influencing various project phases and introducing coordination challenges. However, the implications for sustainable urban development are profound. As urban areas worldwide strive for greener, more resilient, and technologically advanced cities, the incorporation of EV infrastructure within construction projects serves as a catalyst for positive change, aligning with the vision of a more sustainable and eco-friendly urban future.

4. High rise building wıth ev infrastructure

Integrating Electric Vehicle (EV) infrastructure in a high-rise residential building's parking area requires a comprehensive approach to ensure functionality, convenience, and sustainability. Here are the essential components and considerations for successful integration:

1. Charging Station:
   - A mix of Level 2 (AC) and potentially Level 3 (DC fast) charging stationto accommodate different EV charging needs.
   - The optimal number of charging points based on projected occupants.
   - Future-proofing by selecting charging station that can handle evolving EV technologies and standards.
2. Electrical Infrastructure:
   - The building's electrical capacity and potential load distribution.
   - Installation distribution panels and circuits to provide sufficient power to the charging points.
   - Incorporating safety measures, such as circuit breakers and surge protection devices, to ensure reliable and safe charging.
3. Layout:
   - Designate parking spaces with appropriate signage for EV charging to prevent confusion.
   - Ensuring proper spacing between charging stations to allow for maneuverability and user convenience.

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4. Networking and User Management:
    - Implementing a networked charging system for residential people authentication, monitoring, and remote management.
    - Provide multiple user access methods, such as RFID cards, mobile apps, or touchscreen interfaces in a parking area.
5. Safety and Compliance:
    - Adhering to NFPA 70, National Electric Codefor safety and regulations of electrical installations and charging equipment.
    - Installing clear signage indicating EV charging points and safety instructions for users.
6. Aesthetic Integration:
    - Conceal wiring and cable management systems to maintain a clean and organized appearance.
7. Future-Proofing and Scalability:
    - Planning for scalability by designing the EV infrastructure in a high rise building to accommodate potential future expansions.
    - Consider the ability to upgrade charging stations and add more units as EV adoption increases.
8. Sustainability Integration:
    - Renewable energy options, such as solar panels, to power the charging stations and reduce environmental impact.

By addressing these essential components and considerations, high-rise residential building can successfully integrate EV infrastructure in their parking areas, promoting sustainable transportation options and contributing to a more environmentally friendly and forward-thinking urban community.

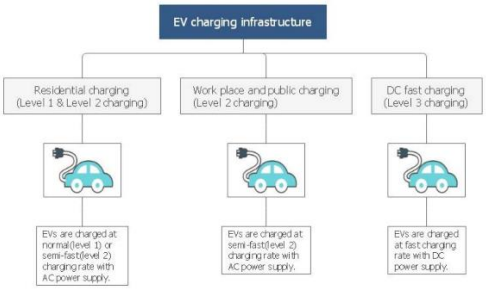


Fig.1 EV Charging Infrastrcuture

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5. Benefits of EV Infrastructure

Benefits of ev parking, including reduced environmental impact, increased property value, and support for electric mobility.

EV parking in a residential building offers a multitude of compelling benefits that encompass environmental, economic, and social dimensions. The key advantages of implementing EV parking in a residential setting:

1. Reduced Environmental Impact
2. Increased Property Value
3. Support for Electric Mobility
4. Energy Efficiency and Grid Management
5. Technological Advancement
6. Economic Savings
7. Community Engagement

In conclusion, EV parking in a residential building yields a range of advantages that extend beyond individual vehicle charging. It contributes to reduced environmental impact, enhances property value, supports electric mobility growth, and aligns with the broader goals of sustainable urban development. As communities seek to create more livable, environmentally friendly neighborhoods, the integration of EV parking emerges as a pivotal step toward a greener and more future-oriented residential landscape.

6. DEMAND-BASED TARGET SETTING FOR EV CHARGING INFRASTRUCTURE IN BENGALURU

Using forecasts for the adoption of electric vehicles across various vehicle categories, the anticipated need for charging, and the proportion of charging to be met through public charging facilities, the calculation of the quantity and categories of public chargers necessary for Bengaluru has been outlined for the future periods of 2025 and 2030.

6.1 EV projectıons for horizon years, by segment

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VEHICLE SEGMENTS	Annual growth rate	EV penetration rate - 2025	Total number of EVs - 2025	EV penetration rate - 2030	Total number of EVs - 2030
E-2W	5.88%	10%	1,00,477	30%	6,12,353
E-3W (passenger/cargo)	5.57%	40%	30,376	70%	1,15,804
E-car (personal)	3%	3%	4,519	15%	42,561
E-car (commercial)	15.80%	10%	4,775	30%	41,992

Fig.2 EV projectıons for horizon years, by segment

6.2 Chargıng demand by vehicle segment

VEHICLE SEGMENTS	Daily kms driven	Battery capacity in kWh	Driving range in km/full charge	Daily charging demand in kWh	Total daily charging demand in kWh - 2025	Total daily charging demand in kWh - 2030
E-2W	40	2.5	80	1.25	1,25,596	7,65,442
E-3W (passenger / cargo)	120	7	100	8.4	2,55,162	9,72,757
E-car (personal)	40	30.2	312	4	17,498	1,64,786
E-car (commercial)	100	21.2	181	12	55,931	4,91,838

Fig.3 Chargıng demand by vehicle segment

7. Construction Scheduling

The construction scheduling process for a high-rise residential building with parking, including both EV infrastructure and normal parking, involves a detailed and coordinated approach to ensure the successful completion of the project.

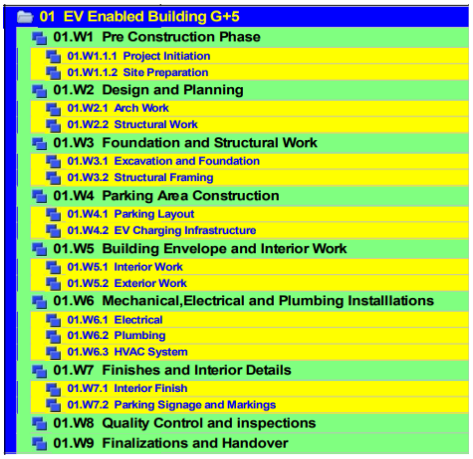


Fig.4 Construction Scheduling

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Throughout the construction scheduling process for a high-rise residential building with both EV infrastructure and normal parking, effective project management, collaboration among various stakeholders, and adherence to construction timelines are crucial to ensure the successful delivery of a modern, functional, and sustainable living space.

8. Results and Conclusion

The comparative analysis between buildings with Electric Vehicle (EV) infrastructure in their parking areas and those with conventional parking areas reveals notable differences in construction scheduling:

1. EV Infrastructure Integration:

   EV Parking Area: Buildings incorporating EV infrastructure necessitate additional design and planning time for the placement of charging stations, electrical wiring, and load distribution, contributing to slightly extended design phases.

   Conventional Parking Area: Conventional parking areas require less specialized planning, potentially leading to a streamlined design phase.

2. Electrical Work and Load Management:

   EV Parking Area: The installation of EV charging stations and related electrical systems introduces an extended electrical work phase, including wiring, panel upgrades, and load management strategies.

   Conventional Parking Area: Traditional parking areas involve standard electrical installations with comparatively fewer modifications, resulting in a shorter electrical work phase.

3. Coordination and Stakeholder Involvement:

   EV Parking Area: Integrating EV infrastructure involves coordination between architects, engineers, electrical contractors, and EV technology providers, contributing to longer coordination periods.

   Conventional Parking Area: Coordination may be simpler and more streamlined without the need for specialized EV technology involvement.

4. Potential Construction Timeline Extension:

   EV Parking Area: The introduction of EV infrastructure, while generally leading to a modest extension of the construction timeline, brings sustainable and future-oriented benefits to the building.

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Conventional Parking Area: Construction schedules for buildings with conventional parking areas may be slightly shorter due to fewer specialized considerations.

5. Sustainable Features and Market Appeal:

   EV Parking Area: Buildings with EV infrastructure enhance market appeal by aligning with sustainable trends and catering to environmentally conscious residents, potentially justifying the minor construction timeline extension.

   Conventional Parking Area:While construction timelines may be slightly shorter, buildings with conventional parking areas may have fewer sustainability-driven amenities.

This research investigates the integration of Electric Vehicle (EV) infrastructure in high-rise residential buildings' parking areas and its impact on construction scheduling. By comparing buildings with EV infrastructure to those with conventional parking, the study highlights the complexities and considerations introduced by EV charging facilities. The research underscores the importance of early planning, coordination, and collaboration among stakeholders to mitigate potential construction timeline extensions. This study contributes to the field of sustainable urban development by emphasizing the positive implications of EV infrastructure for environmentally conscious mobility, market competitiveness, and future-oriented urban planning, furthering the integration of clean energy technologies within modern urban landscapes.

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ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

Effect of Wheat Husk Ash as Mineral Admixtures on Concrete Durability

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Abstract

Concrete's durability may suffer if it is exposed to a harsh environment. Previously, people were more concerned with the strength of concrete rather than its endurance. However, the longevity of concrete and concrete constructions has recently become a serious problem. The effect of sulphate on concrete generated from wheat husk ash was examined in this experimental investigation. In terms of compressive strength, the optimal replacement level of Ordinary Portland Cement (OPC) with wheat husk ash was determined to be 25%. After determining the best replacement level, 150 mm cubes of Normal Concrete (NC) and wheat husk ash Mixed Concrete were cast for future research. The strength and durability of all concrete samples were evaluated in a sulphate environment. In this context, it was determined that WHA Mixed Concrete was more durable than Normal Concrete.

Keywords: Wheat Husk Ash, Sulphate Environment, Ordinary portland cement, Durability, Normal Concrete.

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ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

1. Introduction

In the past few years, the construction sector has implemented a number of novel strategies to reduce its carbon footprint. These initiatives include incorporating waste and recyclable components as aggregates and binders into concrete mixtures. However, the majority of these programmes combine the use of environmentally friendly components with less energy-efficient concrete production processes. The obligation to use conventional components and processes in its production, resulting in higher consumption of energy and carbon dioxide emissions into the atmosphere.[1] Because cement made from Portland cement has the highest carbon and energy content in control mix concrete, looking for alternate ways can drastically lower the carbon footprint of concrete. Many years of research and development have demonstrated that industrial/agricultural waste can be turned into concrete mixtures as cementitious supplemental substitution materials. Because many types of agricultural debris are generated in large quantities, particularly in developing nations like Pakistan, they pose several hazards to durability and aesthetics in the environment. The recycling of these agro wastes into concrete mixtures entails burning agricultural waste and using the resulting residues (i.e., ash) to replace the PC in the concrete mix. Because of the high silica content in pesticide residual ash, it exhibits pozzolanic qualities and can be used as a PC alternative. The pozzolanic properties of such ashes lead the silica in the ash to react with the calcium hydroxide in the concrete mixture to generate high hydration products.[2] Furthermore, agro wastes in the form of ashes, such as coconut shell ash, corn cob ash, rice husk ash, sugarcane bagasse ash, wheat straw ash and millet husk ash, have been used as supplemental alternatives for PC in concrete mixtures. It was discovered that the use of such ashes in concrete mixes can improve the mechanical qualities of the concrete. However, the ideal ash content at which ash can replace PC without causing harm differs depending on the type and source of ash. Agricultural residue ashes(ARAs) pose a huge threat to the environment because the majority of them end up in landfills. Wheat husk ash, sugarcane bagasse ash, and corn stover ash contain a large amount of silica, making them an efficient pozzolanic material. The silica in these materials combines with calcium hydroxide (CH), a cement hydration product, to produce further hydration products. Because of its high silica

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ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

concentration and inexpensive cost, rice husk ash (RHA) is the most commonly utilized ARA.[3] A number of investigations have been carried out to examine the pozzolanic activity of WHA. The findings show that the high specific surface area, rich silica content, and porous microstructure of well-burnt WHA are the reasons for its raised pozzolanic activity. The addition of WHA resulted in improved compressive strength, low permeability, and boosted resistance to penetration of chlorides and acid damage.[3] In recent years, there has been a surge of interest in "green composites." Some of the effort has been focused on the utilization of novel waste sources in order to create biologically active chemicals that can be used in a variety of fields and applications. These natural lignocelluloses grain residues (by-products) are environmentally friendly and could be used to produce specialty chemicals.[2] Cereal waste product is a yearly recyclable fiber that is abundantly available around the world. Traditional applications for these husks and straws include livestock bedding and animal feeding. According to April 2009, global wheat production was 682 million metric tonnes, with the European Union producing 150 million metric tonnes.[2]. This experimental work aimed to analyze the mechanical and durability properties of concrete mixtures using different contents of WHA to replace OPC .

2. Materials

Wheat husk was collected from the local agriculture area; wheat husk screening was not performed because this work aimed to use any type of WHA. After accumulating it, the wheat husk was burned under monitored temperature ranges of 500 C to 750 C for 6 h to be transformed in ash form, and then WSA was sieved through #300 sieve before being used as substitute cement ingredients in concrete. Portland cement (PC) was obtained from a nearby vendor and utilized as a binder in the mixture; the composition of PC oxides, WSA, Additionally, stones used for this research work were ground up as coarse aggregates (CAs) with a size of 20 mm, and fine aggregates were passed through a #4 sieve.[1,2]

3. Mixture design

The mechanical qualities (compressive strength) and durability features of concrete were explored in this research study on concrete mixtures blended with 25% WHA to replace OPC component. Ninety concrete samples were prepared with water-cement ratios of 0.35, 0.40, and 0.45.

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ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

4. Procedures for Testing

The compressive strength test was performed on a cubical specimen with dimensions of 150mm,150mm,150mm, mixed with varied amounts of substitution of PC with WHA as BCM in the mixture using the BS EN 12390-3.These specimens of concrete were allowed to cure and analyzed after 7 , 28 and 56 days of curing.



Fig. 1. Cube on Compressive Testing Machine

5. Result and Discussion

5.1 Mechanical properties of a blend agro-waste ash system

Figure 1 depicts the test done on a cube specimen built of concrete with the addition of WHA as BCM. The highest compressive strength determined is 67.25 MPa at 25% WHA with 0.35 % water cement ratio, while the lowest strength is 39.26 MPa at 0% WHA with 0.45 % water cement ratio in concrete after 28 days . The test findings revealed an increase in hard concrete strength when using up to 25% WHA due to the fineness of WHA particles that occupied micropores left by other concrete materials when using up to 25% WHA [4].

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ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

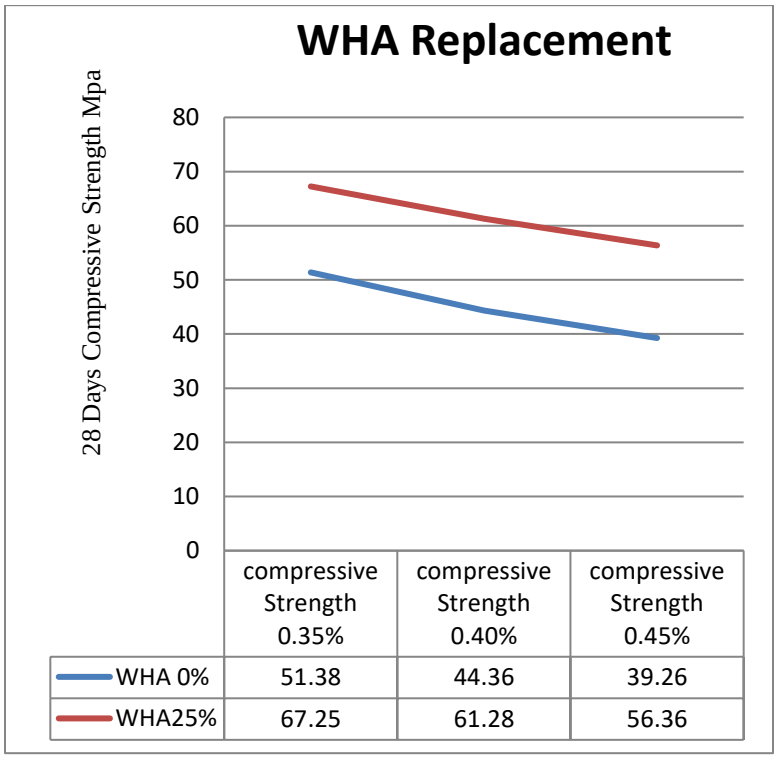


Fig.2.Compressive Strength at 28 days

5.2 Agro-waste ash blended cementitious system's durability qualities

5.2.1 Susceptibility to sulphate attack

After demoulding and after 7, 28, 56, and 90 days of immersion in water and 5% sodium sulphate solution, the weights of both Regular Concrete and WHA Blended Concrete were calculated.

Figure 3 depicts the results. Weight loss of 6.26, 7.65, and 8.65 is recorded for Regular concrete specimens cured in water at 28 days, respectively, but for WHA Mixed Concrete the values are 5.153, 5.89, and 6.23. This is consistent with the findings [3].

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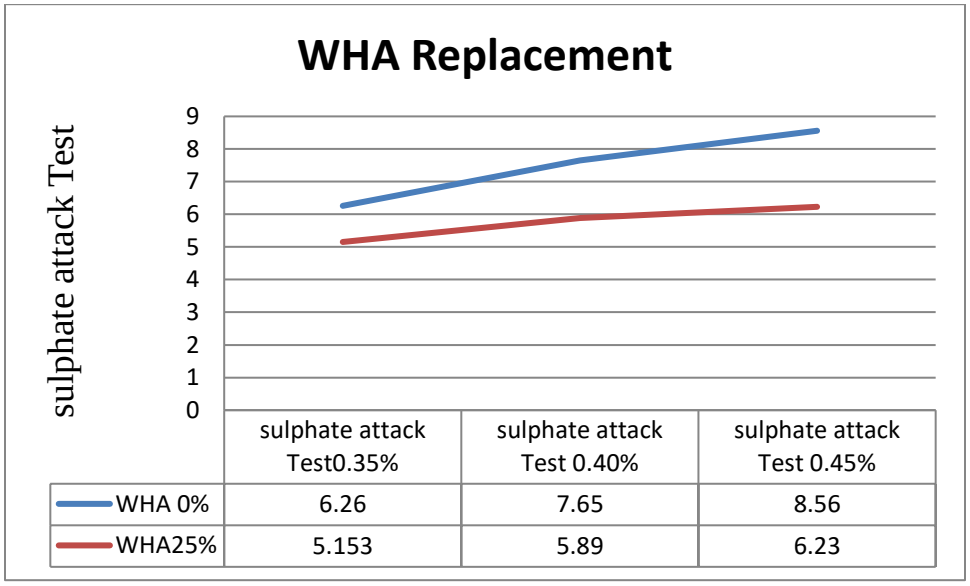


Fig.3.Sulphate Resistance for C, WHA 25%

5.2.2 Non Destructive Testing

All concrete cube specimens compressive strength were measured using a rebound hammer and direct compression tests.

The compressive strength findings for the concrete samples are shown in Table 1.



Fig.4.Rebound Hammer Test on Concrete Cube

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ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

Table .1. Compressive strength results by rebound hammer

Sample	Strength	*Number of readings									
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	Rebound Reading	**38.2**	**34.3**	**34.6**	**36.3**	**31.9**	**35.1**	**37.5**	**33.6**	**30.9**	**37.9**
	Equivalent computed compressive strength (MPa)	**31.5**	**29.6**	**28.6**	**31.4**	**28.9**	**30.5**	**33.1**	**29.3**	**28.6**	**24.8**
2	Rebound Reading	**36.8**	**38.3**	**32.5**	**37.4**	**32.6**	**32.9**	**35.9**	**35.9**	**32.5**	**35.2**
	Equivalent computed compressive strength (MPa)	**30.9**	**28.6**	**31.6**	**30.9**	**31.5**	**32.6**	**32.8**	**32.5**	**27.3**	**26.4**
3	Rebound Reading	**37.5**	**36.8**	**33.8**	**35.3**	**33.5**	**34.6**	**36.8**	**34.6**	**33.7**	**36.7**
	Equivalent computed compressive strength (MPa)	**31.9**	**30.8**	**29.4**	**31.9**	**29.5**	**31.6**	**30.5**	**30.9**	**29.7**	**27.6**

6. Conclusion

Water-cured WHA Mixed Concrete has a higher compressive strength than normal concrete. The incorporation of AWAs increased compressive strength by up to an appropriate replacement level. Ashes can be used as an alternate cementitious material up to 25% of the time. At 28 days, the weight loss in Normal Concrete samples in water is 6.26, 7.65, and 8.65, respectively, but in WHA Mixed Concrete, the changes are 5.153, 5.89, and 6.23. The compressive strength of concrete increases by up to 25% when WHA is added. All mixtures' compressive strength, splitting tensile strength, and flexural strength properties improved as curing regimes were enhanced. The study found that modified concrete gained its strength faster than control mix. The mixture with the highest strength contained 25% more cementitious material. As SCM

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ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

content approaches 25%, the strength does, however, somewhat drop. In general, contrary to the manufacturer's standards, the rebound readings were not closely associated with the actual compressive strength values. Although the rebound hammer test had a poor forecast of the real compressive strength of concrete, the device is good enough to estimate the compressive strength of concrete provided it is calibrated and periodically maintained in excellent condition.

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ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

Experimental Investigation on Concrete Using Distillery Waste as Partial Replacement to Potable Water

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Abstract

The by-product of sugar industry- distillery spent wash, is the hazardous and unwanted residual liquid waste generated during alcohol production and pollution caused by it is one of the most critical environmental issue because it poses a serious threat to the human life as well as aquatic life as water quality degrades by a huge amount because of high amount of COD and BOD present in distillery waste. Despite of setting various standards on effluent quality, untreated or partially treated effluent are freely released into rivers, nalas, canals etc. The generation of distillery spent wash on the one hand and stringent legislative regulations of its disposal on the other has stimulated the need for developing new technologies to process this effluent efficiently and economically. This paper presents an overview on experimental study on usage of distillery waste in concrete with various percentages and its alternative use in various sectors. The contribution of distillery waste i.e., spent wash on the properties of concrete is high compared to conventional concrete. In this study partial replacement of potable water has been done at 0 %, 10 %, and 20% with distillery waste.An optimum amount of replacement is observed at 10 %. Compressive as well as split tensile tests on concrete replaced with distillery waste has been compared with conventional concrete of grade M25.

Keywords: Concrete, Spent wash, Distillery waste, Partial replacements, etc.

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ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

1. Introduction

Water is the Elixir of life. Our earth seems to be unique among the other known celestial bodies as it has water, which covers three fourth of its surface and constitutes life (60-70 wt %) of the living world. Industrialization is a process of social and economic change whereby a human society is transformed from a pre-industrial to an industrial state. The rapid industrialization has now increased the pollution potential. Different types of wastes are generated from various industrial processes. The characteristics of the wastewater depend on the industrial operation and nature of the raw materials. When water bodies and lands are used for ultimate disposal of the wastewater it may pose a threat to the aquatic life in the receiving water and may affect the ten-crutial ecosystems. So wastewater treatment is utmost essential for any type of industry (www.lndustrialization.com). Nowadays a large amount of waste that has the adverse potential of causing water contamination is being emitted to the environment. One of the industries which discard this effluent is molasses-based distilleries. Spent wash is a dark brown color that contributes to the dominant source of most molasses-based liquor factories. This toxic liquid is removed from the distillation unit during the separation of the fermented mash from ethanol. Spent wash is well known for its dark brown color and obnoxious odor.

Today, the demand for energy is increasing at an alarming rate, which necessitates much work in the concerned field. With the tremendous urbanization and population explosion the fuel consumption has increased to a maximum, thereby posing a threat to the non-renewable resources. Currently much importance is being given to select suitable renewable energy resources. One such resource happens to be the product of distillery i.e., ethanol. With an increase in the demand for ethanol, the problem of utilization of distillery effluent also enlarges into a major problem. The current condition also makes us feel the importance of water to a greater extent. Any method or idea that facilitates the reuse of any effluent will be highly appreciated. Of the various industries, which uses higher amount of water for the processes, distillery plays a major and an important role. These industries concentrate on the production of valuable ethanol accompanied with the discharge of spent wash, which has importance. During the recent years, India has emerged as one of the largest sugarcane producers in the world. The cane-growing states of Uttar Pradesh and Maharashtra have the highest installed capacity constituting more than 40% of the total installed capacity followed by Madhya Pradesh (14.2%) and Tamil Nadu (9.7%).The type of wastewater and its

ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

components is dependent on the source from which this water is brought, each type of wastewater causes different effects on properties of concrete. The consistency and loss of strength may be there as a result of the product of sulfuric acid with the metabolism, this product may attack the cement matrix of the concrete. The present study simplified the comparison of concrete properties produced by different types of wastewater. Compared with control concrete, it is focused on fresh concrete properties, hardened properties, and durability aspects of wastewater concrete. More studies are required for wastewater use in the production of concrete. Durability check is the most important. concern for the concrete structure but insufficient data is available on durability. There is a wide research gap in sulfate resistance, acid attack, water absorption, chloride permeability, and carbonation which require more research work to check the compatibility of different wastewater in the production of concrete structures.All the effluents from households, commercial complex hospitals, institutions are referred to as wastewater. Stormwater and urban runoff are also considered as effluent. Sewage originated from toilets, bathing, kitchen, and laundry is also a category of wastewater. Globally, the demand for water in the coming decades is expected to rise substantially. The industry and energy production projected to see significant increases in water demand. The United Nations World Water Development Report (UN-WWDR) published a report on wastewater in 2017. According to this report, 80% of the world's wastewater is being discharged into the environment without treatment. Similar things are with 95% least developed countries. Two-thirds population of the world lives in areas where water scarcity occurs at least a month annually. On an average, high-income nations treat approximately 70% of the wastewater generated in municipal and industrial areas. This is down to 38% in countries with a higher middle income and 28% in countries with smaller middle incomes. In countries with low incomes, just 8% receive some form of care.Notably, the use of wastewater from a ready mix concrete plant causes an insignificant change in rheological property but no change inconsistency. Mixing water suitable to be used concrete is necessary to obey standard recommendations. Turbidity, pH value, chloride ions, total solids, and sulfate content are the key variables that must be within the permissible limits to be used in concrete production. The standards recommended for several aspects of water never represent the right representation of their impacts on properties of concrete. It is noticed that limited work has been done related to the various effects on concrete when impurities are present in the wastewater.Satyawali Y et al. presented a review of the existing

ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

status and advances in biological and physico-chemical methods applied to the treatment of molasses-based distillery wastewater [1]. Both laboratory and pilot/industrial studies have been considered. Furthermore, limitations in the existing processes have been summarized and potential areas for further investigations have been discussed.Chandra et al. [2] Experiments were carried out to study the effect of distillery sludge amendments with garden soil (10, 20, 40, 60, 80 and 100%) on seed germination and growth parameters of Phaseolus mungo L. Germination percentage and index values decreased with rise in sludge concentration. Soil amended with 10% (w/w) sludge showed favorable growth while >10% was inhibitory for plant growth. Soil amended with 10% (w/w) distillery sludge induced the growth in root length, shoot length, number of leaves, biomass, photosynthetic pigment, protein and starch while 20% (w/w) sludge amended soil had variable effects on the root, shoot, leaves and nodules of P. mungo L. At concentrations (>40%) reduced all the growth parameters, viz., root length, shoot length, number of leaves, biomass, photosynthetic pigment, protein and starch of P. mungo. Malondialdehyde (MDA) product of lipid peroxidation was also enhanced in both root and leaves of sludge amended soil grown P. mungo at all the sludge amendments and exposure periods. A coordinated increase in cysteine, non-protein thiol and ascorbic acid antioxidants was up to 40 days of growth. After this period a decrease was observed.Malik et al. [3]studied that composting is a biological process in which the organic matter is degraded by the mixed population of microorganisms in a moist aerobic environment to more stable and humidified end products. The composting process involves an interaction between the organic waste, microorganisms, moisture and oxygen. The molasses-based biomethanated distillery wastewater is presently effectively utilized with sugarcane pressmud through the composting process. The aim of present work was to evaluate the effect of ozone pretreatment on the rate of composting process and the quality of compost obtained. Manwatkar et al.[4]studied Co-combustion of coal with distillery sludge waste (DSW) was investigated in a laboratory-scale Drop Tube Furnace (DTF) plant. This study examined the feasibility of combustion of sludge with coal using preliminary testing methods, such as thermogravimetric, ultimate and proximate analysis followed by combustion experiments. These methods helped to identify burnout efficiency, emitted pollutants, and metal constituents in the bottom/fly ash. Hoarau et al. [5] Industrial production of biodiesel from microbial catalysts requires large volume of low-cost feedstock for lipid production. Vinasse, also known as distillery spent wash (DSW),

ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

is a liquid waste produced in large amounts by ethanol distilleries. This effluent is particularly rich in organic matter, and may be considered as a potential resource for the production of fungal lipids. The present study aimed at evaluating the potential of vinasse from a distillery located in Reunion Island for yeast and fungal growth, lipid production, and suitability for biodiesel requirements.

2. Materials and Methodologies

Following methodology will be adopted for the present study.

1. Comprehensive review of literature, collection of materials, availability of equipment and study of proposed methodology for investigation.
2. Experimentation to identify properties of distillery waste and potable water in laboratory.
3. Conduction of different tests on concrete by partial replacement of potable water by distillery waste (10%).
4. Comparative study of distillery waste added concrete and ordinary concrete.
5. Applying modelling techniques to validate results.

2.1 ConcreteMixDesign

Concrete Grade = M25

Type of cement = OPC 53 grade (UltraTech)

Maximum nominal size of aggregate = 20mm(Angular)

Type of Exposure = Severe

Degree of quality control = Good

Degree of workability = 0.9 Compaction factor

2.2 Test Data for Material

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Fig. 1. Laboratory test on potable water sample

Cement used = OPC 53 grade

Specific gravity of cement = 3.15

Specific gravity of :

Coarse aggregate = 2.60

Fine aggregate = 2.38

Water Absorption:

Coarse aggregate = 0.81%

Fine aggregate = 3.98%

Free (surface) moisture:

Coarse aggregate =Nil

Fine aggregate = 2.0%

Sieve analysis as shown below:

Coarse Aggregate

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Table 1. Sieve analysis of coarse aggregate

Sieve size (mm)	**Analysis of coarse aggregate fraction(% passing)**		**Percentage ofdifferent factors**			**Remark**
	1	2	1	2	combined	
20	100	100	60	40	100	Conforming to
10	0	78.70	0	26.4	26.4	table 2
4.75	-	10.30	-	4.1	4.1	IS 383:1970
2.36	-	-	-	-		

Table 2. Sieve analysis of fine aggregate

Sieve Sizes	**Fine aggregate% Passing**	**Remark**
4.75mm	100	
2.36mm	87.9	
1.18mm	50.6	Conforming to grading zone 3
600µ	20.1	of table – 4 IS383- 1970
300µ	4.8	
150µ	1.8	

Target mean strength of concrete:

The target mean strength for specified characteristic cube strength is 25+65*5=33.25Mpa (refer table)

Selection of water cement ratio: Adopt water cement ratio as 0.4

Selection of Water and Sand Content

Using IS Code for 20mm maximum size aggregate sand conforming to grading zone 2nd , water content per cubic meter of concrete = 186 kg and sand content as percentage of total aggregate by absolute volume =35%

For change in value in water cement ratio compact factor for sand belonging to zone 3rd Following adjustment is required.Therefore, required sand content as % of total aggregate by absolute volume 35-3.5 = 31.5%.

Required water content = 186+6/100 x 186

=197.16 lit/m3

Determination of cement content

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W/C ratio = 0.4

Water = 197.16 lit/m3 Cement = 197.16/0.4

=495 kg/ m3

This cement is adequate for mild exposure condition (refer table)

Determination of volume of coarse and fine aggregate

From IS 10262:2009 volume of course aggregate corresponding to 20mm size aggregate and fine aggregate W/C ratio of 0.50=0.64

Actual W/C ratio – 0.40

It is less by (0.5-0.4) = 0.10 to increase the course aggregate

As the W/C ratio is reduced it is desirable to increase the course aggregate proportion to reduce the fine aggregate

The course aggregate is increased at the rate of 0.01 for every decreased in W/C ratio of 0.05

So for decrease every 0.10 W/C ratio = course aggregate increased by 0.02

Corrected proportion of volume of course aggregate = 0.64+0.02 =0.66

Volume of fine aggregate = 1-0.66=0.34

Design mix calculation (IS 10262:2009)

The mix calculation per unit volume of concrete shall be as follows

a) Volume of concrete = 1 m3

b) volume of cement = (mass of cement / sp gravity of cement) x 1000

= (495 / 3.15) x1000

= 0.157 m3

c) volume of water

= mass of water / sp gravity of water x 1000

= (198 / 1) x1000

= 0.198 m3

d) volume of all aggregate =[a-(b+c)]

= [1-(0.157+0.198)]

= 0.645 m3

e) mass of course aggregate = volume of all aggregate x volume of course aggregate x sp.gravity x 1000

= 0.645 x 0.66 x 2.60 x 1000

= 1106.82 kg

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f) Mass of fine aggregate = volume of all aggregate x volume of fine aggregate x sp gravity x 1000

= 0.645 x 0.34 x 2.38 x 1000

= 521.934 kg

Mix proportion Ratio

Cement	= 495 kg/m3	=	1
Fine aggregate	= 521.934 kg/m3	=	1.05
Course aggregate	= 1106.82kg/m3	=	2.23
Water content ratio	= 0.40		

3. Results and discussion

3.1 Test on water

Table 3. Properties of water sample

Sr. No.	Description	Value
1	Ph	7.33
2	Alkalinity	Carbonate – 62mg/lit Bicarbonate – 3mg/lit
3	Hardness	225.35mg/lit

Table 4. Test on cement

Sr. No.	Description	Value
1	Fineness of cement	2%
2	Standard consistency of cement	31.25%
3	Setting time of cement	Initial = 45 Minutes Final = 450 Minutes
4	Soundness of cement	3mm
5	Compressive strength of cement	After 3 days = 34.98N/mm2 After 7 days = 45.27N/mm2

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Table 5. Test on aggregate

Sr. No.	Description	Value
1	Specific gravity of fine aggregate	2.58
2	Specific gravity of coarse aggregate	2.70
3	Water absorption in coarse aggregate	0.81%
4	Water absorption in fine aggregate	3.98%

Table 6. Test on distillery waste

Sr. No.	Description	Value
1	COD (Before Treatment	104255 mg/lit
2	pH (Before Treatment)	3.81
3	COD (After Treatment)	42565 mg/lit
4	pH (After Treatment)	7.50
5	BOD (Before Treatment)	46682 mg/lit
6	BOD (After Treatment) 11337mg/lit	11337mg/lit



Fig. 2 Distillery waste sample

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Fig. 3 Development of Cracking after applied load.



Fig. 4 Sample casting and curing

Table 7. Tests on concrete sample (potable water)

Sr. No.	Description of sample	Size of sample	Load taken
1	Beam 1	750MM X 150MM X150MM	3275kgf
2	Beam 2	750MM X 150MM X150MM	3350kgf
3	Beam 3	750MM X 150MM	4300kgf

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		X150MM	
4	Cube 1	150MM X 150MM X150MM	560 KN
5	Cube 2	150MM X 150MM X150MM	580 KN
6	Cube 3	150MM X 150MM X150MM	565 KN
7	Cylinder 1	DIA – 150MM DEPTH – 300MM	360 KN
8	Cylinder 2	DIA – 150MM DEPTH – 300MM	260 KN
9	Cylinder 3	DIA – 150MM DEPTH – 300MM	240 KN

Table 8. Tests on concrete sample (partial replacement of potable water by 10% distillery waste)

Sr. No.	**Description of sample**	**Size of sample**	**Load taken**
1	Beam 1	750MM X 150MM X150MM	3575kgf
2	Beam 2	750MM X 150MM X150MM	3450kgf
3	Beam 3	750MM X 150MM X150MM	4275kgf
4	Cube 1	150MM X 150MM X150MM	630 KN
5	Cube 2	150MM X 150MM X150MM	620 KN
6	Cube 3	150MM X 150MM X150MM	635 KN
7	Cylinder 1	DIA – 150MM DEPTH – 300MM	420 KN

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8	Cylinder 2	DIA – 150MM DEPTH – 300MM	295 KN
9	Cylinder 3	DIA – 150MM DEPTH – 300MM	290 KN

Table 9. Tests on concrete sample (partial replacement of potable water by 20 % distillery waste)

Sr. No.	Description of sample	Size of sample	Load taken
1	Beam 1	750MM X 150MM X150MM	3320kgf
2	Beam 2	750MM X 150MM X150MM	3370kgf
3	Beam 3	750MM X 150MM X150MM	3940kgf
4	Cube 1	150MM X 150MM X150MM	535 KN
5	Cube 2	150MM X 150MM X150MM	565 KN
6	Cube 3	150MM X 150MM X150MM	595 KN
7	Cylinder 1	DIA – 150MM DEPTH – 300MM	330 KN
8	Cylinder 2	DIA – 150MM DEPTH – 300MM	285 KN
9	Cylinder 3	DIA – 150MM DEPTH – 300MM	230 KN

4. Conclusion

This research study mainly focuses on the utilization of distillery spent wash as a partial replacement of portable water in order to reduce the waste.This research will help to reuse

ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

distillery waste which is hazardous in nature for human as well as aquatic life.This research will create a substitute to potable water which in turn will save potable water which is very precious for human being.Result shows increment in load carrying capacity of concrete if potable water is replaced by 10 % distillery waste. Result also shows that load carrying capacity is increased by partially replacing potable water with 10 % distillery waste. Optimum percentage of distillery waste is 10%.

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ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

Analyzing the Impact of Delay Factors on Construction Industry Project Timelines

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Abstract

The construction industry holds significant economic importance in India, ranking second only to agriculture. However, construction project delays pose a widespread problem globally. These delays can stem from various factors, ranging from straightforward issues to more intricate challenges. To effectively address and mitigate project delays, a thorough analysis and management of the underlying causal factors are crucial. This report focuses on exploring the causes of construction project delays, presenting a comprehensive list of 63 factors classified into seven distinct categories. A questionnaire was designed based on these factors and disseminated among owners, consultants, and contractors within the industry. The responses obtained from the participants were utilized to calculate the frequency index, severity index, and importance index for each delay factor. The primary objective of this study was to compile diverse perspectives from researchers, highlighting the variations in their assessments of factors contributing to project delays. Subsequently, the results were computed, and the factors were ranked based on their probability and impact on project delays. The study revealed the top five factors responsible for construction project delays, namely equipment breakdown (Rank 1), labor shortages (Rank 2), delays in sub-contractor work (Rank 3), equipment shortages (Rank 4), and low productivity levels of labourers (Rank 5). This abstract summarizes the key findings of the study, emphasizing the critical factors that significantly influence construction project delays.

Keywords: Delay, Construction, Frequency Index, Questionnaire.

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ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

1. Introduction

Construction is a significant economic activity in India, but delays in construction projects pose challenges for the industry and the economy. Delays can be simple or complex, resulting in time and cost overruns, disputes, and legal actions. [1] These delays can be excusable or non-excusable, with adverse effects on project outcomes.Various factors contribute to construction delays, including issues related to owners, consultants, contractors, materials, labor, projects, and external events.[2] Owner-related delays stem from changes in project requirements and delayed approvals, while consultant-related delays result from design errors and coordination issues. Contractor-related delays can occur due to poor project management and resource allocation. Material-related delays are caused by procurement and delivery issues. Labor and consultant-related delays may arise from a shortage of skilled labor or inefficient consultant services. Project-related delays are due to unforeseen events, and external-related delays are beyond stakeholderscontrol.[3] To analyze and mitigate construction delays, techniques like Critical Path Method, As-planned expanded technique, Collapsed but for technique, Windows technique, and Bar chart are commonly employed. Effective project management practices, improved coordination among stakeholders, and proactive measures to address delay factors can help mitigate construction delays.Addressing construction delays is crucial as they lead to increased costs, financial losses, missed opportunities, and reduced investor confidence.[4] Timely completion of construction projects is essential for economic growth and infrastructure development.

Construction Delay Analysis Techniques—A Review of Application Issues and Improvement Needs (Nuhu Braimah, 2013): This study identifies critical issues overlooked in delay analysis and emphasizes their impact on results. Factors like software functionality, resource loading, resolving concurrent delays, and delay-pacing strategy significantly affect delay analysis outcomes. Evaluating common Delay Analysis Techniques (DATs) through a case study reveals varying delay responsibility allocations. The study stresses the importance of choosing suitable techniques based on project circumstances.[6] Delay Management in a Construction Project (B. Indhu and P. Ajai): The research identifies major causes of delays, including issues caused by the contractor, owner, and natural factors like rain. Important causes highlighted are delay in payment, frequent staff changes, poor site management, engineer mismanagement, material supply delays, and lack of skilled manpower. Though specific recommendations are not provided, addressing these factors can help mitigate

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ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

delays.[7]

Understanding Construction Delay Analysis and the Role of Preconstruction Programming: This study, published in 2014, focuses on common delays in modern construction projects, aiming to improve delay claim resolutions. Detailed findings are not available.[8]

Analysis of Causes of Delay and Time Performance in Construction Projects (Pablo Gonzalez et al., 2014): The research presents a comprehensive methodology examining both qualitative (delay causes) and quantitative (time performance) aspects of construction delays. The objective is to gain a holistic understanding of delay causes and their impact on project timelines.[9][10]

Delay Analysis Methods for Construction Projects: Mathematical Modeling (Alenas Vasilyeva-Lyulina et al., 2015): The paper concludes that various factors contribute to construction project delays, resulting from complex interdependencies among tasks. The research formalizes common delay analysis methods, including impacted as-planned, time impact analysis, and collapsed as-built. Mathematical modeling enhances the understanding and application of these methods.[11]

2. Methodolgy

The purpose of this study was to conduct a critical review of previous research studies on time delays and cost overruns in construction projects and identify their applicability to current projects. The researchers collected data through questionnaire surveys distributed to industry professionals involved in construction projects. The first phase involved a literature search that identified 63 potential causes of delays. In the second phase, a questionnaire was developed using these causes, and responses were gathered from 20 industry experts. The analysis aimed to rank and understand the relative importance and impact of each delay cause on project delays. The specific findings and rankings resulting from the analysis were not provided, but the study aimed to gain insights into the frequency and significance of various delay causes in construction projects.

3. Results and analysis

Total 20 responses have been collected from the various researchers and engineers and frequency index, severity index and importance index has been ranked according to the ranking given. Total 20 responses has been collected from the various researchers and

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engineers and frequency index, severity index and importance index has been ranked according to the ranking given.

Delay analysis will be based on the following factors:

- Frequency Index
- Severity Index
- Importance Index

Frequency Index= $\frac{\sum an}{N \times A} \times 100$

Where a= constant expressing the weight assigned to each responses from 1 to 5.N=frequency of each response

N=total number of responses

A=highest weight (i.e.,5 in this case)

Severity Index= $\frac{\sum an}{N \times A} \times 100$

Where a= constant expressing the weight assigned to each responses from 1 to 5.N=impact of each response

N=total number of responses

A=highest weight (i.e., 5 in this case)

Importance Index=Frequency index x Severity index

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ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

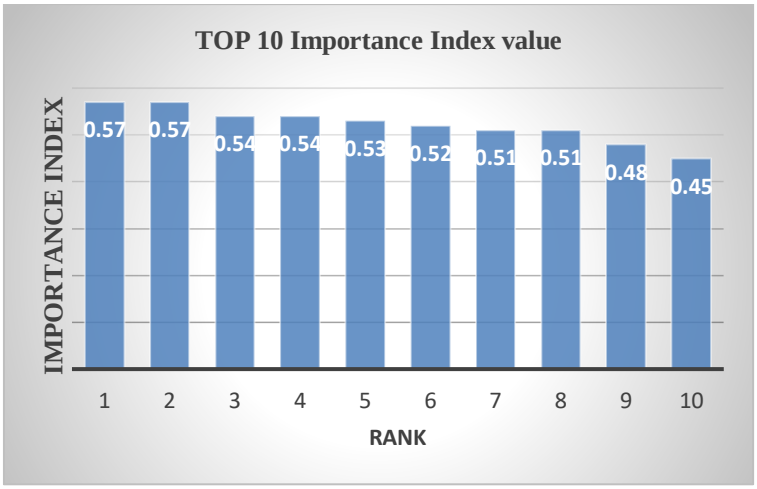


Fig. 1. Top Importance Index factors value

4. Statistical equation

The below R^2 value clearly show positive regression whose value is between -1 to 1.

$$y = -0.0119x + 0.5873$$

$$R^2 = 0.9268$$

5. Conclusion

The research study employs a robust methodology by combining a comprehensive literature review with a well-structured questionnaire survey, leading to a holistic understanding of the multifaceted factors causing delays in construction projects. The incorporation of indices such as Importance Index (I.I), Frequency Index (F.I), and Severity Index (S.I) enhances the analysis, allowing for a nuanced assessment of these factors' significance across various project stages. The study's standout outcome is the identification of the top five major contributors to project delays: equipment breakdown, shortage of labor, delay in sub-contractor work, shortage of equipment, and low productivity level of labor. These findings are pivotal for project managers and stakeholders, guiding their efforts towards effectively mitigating and managing delays. Additionally, the utilization of MS Project software to quantify delay duration pragmatically translates these identified factors into measurable impacts on project timelines. This tangible measurement aids decision-making and facilitates a proactive approach to project management. By disseminating these research insights, a better grasp of the challenges underpinning construction project delays is attainable. This knowledge forms a cornerstone for refining project strategies, optimizing resource allocation,

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ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

and bolstering risk management protocols, ultimately contributing to the success of construction endeavors.

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ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

Driving Productivity growth: A Partial Least Square-Structural Equation Modeling Based Framework for Criterion Prioritization

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Abstract

Productivity is an important factor in an organizational growth. Productivity shows the ratio of outputs generated on the inputs used for this specific task. This paper is based on a detailed study on developing a relation between the factors affecting to the total productivity of an organization. The study employs a quantitative research approach, utilizing PLS-SEM to analyse the relationships between various factors and organizational productivity. PLS-SEM is a powerful statistical technique that is particularly well-suited for exploratory research, complex models, and smaller sample sizes. It allows researchers to examine multiple relationships simultaneously, making it an ideal choice for this study. The model was developed and analysed using SmartPLS 4.0, a widely used software tool for PLS-SEM that offers advanced capabilities for model estimation, validation, and interpretation. This model adopts partial least square approach of structural equation modelling and developed in SmartPLS4.0 software. The data for this model was derived form 100 valid responses of a questionnaire survey among various organizations. The result shows the influence of various factors on productivity of an organization.

Keywords: Productivity, AVE, Path Coefficient, Reliability, Discriminant validity, R-square, P-value, T-value

1. Introduction

Productivity is a cornerstone of project success, as it reflects the efficient use of resources such as labour, materials, and equipment. By optimizing resource utilization, productivity not only reduces production costs but also enhances profitability and project outcomes (Jha, 2011). Defined as the volume of work completed within estimated costs, quality standards, and predefined timelines, productivity is a critical measure of project performance (Jha, 2011). However, research has shown that poor resource management often leads to inefficiencies such as delays, cost overruns, low productivity, and material wastage, which can significantly hinder project success (Enshassi et al., 2007; Abd El-Razek et al., 2008;

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ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

Ahmadian et al., 2015). As a ratio of output to input, productivity serves as a vital indicator of how effectively production systems utilize available resources (Kumar, 2022). Achieving timely project completion is often difficult without addressing key success factors, among which productivity is paramount (Belasi & Tukel, 1996; Hatush & Skitmore, 1997). Recognizing its importance, this study aims to investigate the relationship between productivity and the factors that influence it in project environments. By identifying and analyzing these factors, the research seeks to provide actionable insights for improving productivity and ensuring successful project outcomes. Timely project completion is a common challenge in many industries, and achieving this goal is often difficult without addressing the key factors that influence productivity. Among these factors, productivity stands out as a critical determinant of project success (Belasi & Tukel, 1996; Hatush & Skitmore, 1997). Recognizing its importance, this study aims to explore the relationship between productivity and the various factors that impact it within project environments. By identifying and analyzing these factors, the research seeks to provide actionable insights that can help improve productivity and ensure successful project outcomes.

The findings of this study are expected to contribute to a deeper understanding of the dynamics of productivity in project management and offer practical recommendations for optimizing resource utilization and enhancing overall project performance.

Factors Affecting Productivity

Productivity is shaped by a range of factors, each contributing to the efficiency and effectiveness of project execution. Increased productivity implies higher output within a defined timeframe without compromising per-unit costs. The following factors have been identified as critical determinants of productivity in projects (Jha, 2011):

1. Well-Planned Work (WPW): Systematic planning ensures that tasks are executed efficiently, reducing production time, minimizing delays, and enhancing overall productivity.
2. Skilled Manpower (SM): Employing skilled and suitable workers reduces material wastage, rework, and corrective efforts, thereby improving productivity.
3. Good and Suitable Equipment (G&SE): Utilizing high-quality and well-maintained equipment enhances productivity by ensuring smooth and uninterrupted operations.
4. Description of Materials (DM): Providing detailed material specifications and lists minimizes delays, reduces errors, and improves productivity.

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5. Right Type of Hand Tools (RTHT): Selecting appropriate tools for specific tasks ensures efficiency and reduces time wastage, contributing to higher productivity.
6. Neat and Tidy Workplace (N&TW): A well-organized and accessible workspace reduces delays and accidents, indirectly boosting productivity.
7. Staff Productivity (SP): Proactive supervisors and staff who adopt modern methods and tools play a vital role in enhancing productivity.
8. Other Parameters (OP): Additional factors, such as environmental conditions and external influences, may also impact productivity.

The data is collected in this whole process is done through forming a questionnaire survey. These survey results are collected on a specific scale known as Linkert's scale, with the range of 1 to 5, where 1 indicates very week and 5 indicates very strong. This survey is performed on an industrial area of Pithampur city located near Indore city Madhya Pradesh. This survey was conducted by distributing 130 questionnaires, where only 100 valid responses were received by us and used for complete analysis. In this analysis the technique used is known as Partial Least Square-Structural Equation Modelling (PLS-SEM).

Result and analysis: This paper represents all the detailed results of data analyzed by PLS – SEM using the tool SmartPLS4.0. It includes the assessment of Measurement model and Structural model. The measurement model establishes the validity and reliability of the construct. The structural model shows various relationship among the constructs as per our hypothesis;

H1: The significant impacts of various factors on overall productivity of a project.

2. Methodology

2.1 Measurement model analysis:

It assesses the reliability and validity of the construct. For assessing the reliability, we have to check the value of Combrach alpha & composite reliability, and for assessing the validity we have to assess the average variance extractor (AVE) with two parameters: Convergent validity and Discriminant validity.

- **Path coefficient:** It is also known as beta coefficient. It shows the weight of impact from your independent variable to your dependent variable. The higher the weight of impact the stronger the relationship between two variables. Its significance can be checked by P-value.

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- **Factor loadings:** It also known as outer loadings. Factor loading means the correlation of each item (which is representing its underlined construct) with the principal component. It can be in the range of -1.0 to +1.0, normally cutoff is taken as 0.70. We can conclude that, if the value of factor loading is closer to one then the representation is better.

Table 1: Factor Loadings

	DM	G&SE	N&TW	OP	RTHT	SM	SP	WPW
DM1	0.889							
DM2	0.77							
GSE2		0.855						
GSE3		0.804						
NTW2			0.823					
NTW3			0.901					
NTW4			0.832					
OP1				0.693				
OP2				0.675				
OP3				0.714				
OP4				0.737				
OP5				0.74				
OP6				0.765				
RTHT1					0.879			
RTHT2					0.938			
SM1						0.738		
SM2						0.885		
SM3						0.817		
SP1							0.81	
SP2							0.808	
SP3							0.661	
WPW1								0.662
WPW2								0.685

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WPW3								0.667
WPW4								0.885

2.2 Reliability analysis: Reliability means consistency. The two most commonly used methods for establishing reliability include Cronbach Alpha and Composite Reliability (CR). These values should be more than 0.70 in researches. The results are shown in table below. Cronbach Alpha is a measure of internal consistency reliability; it assumes equal internal loadings. Composite reliability is not assuming equal internal loadings.

Table 2: Construct Reliability Analysis

	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)
DM	0.683	0.745	0.797
G&SE	0.634	0.676	0.804
N&TW	0.85	0.945	0.87
OP	0.815	0.814	0.867
RTHT	0.745	0.868	0.821
SM	0.744	0.747	0.855
SP	0.64	0.66	0.805
WPW	0.765	1.08	0.818

Construct Validity: In PLS-SEM, it is established using convergent validity and discriminant validity.

- **Convergent Validity** is established in the form of AVE (Average Variance Extracted). It is a criterion of showing the reliability of underline constructs. The recommended value of AVE should not be less than 0.50.

  Calculation of AVE = $\frac{Sum\ of\ Square\ of each\ loadings}{Total\ no.\ of\ indicators}$ … 1

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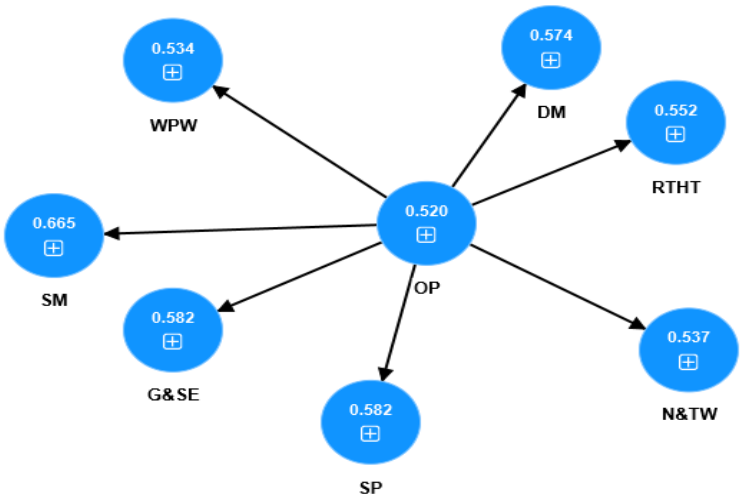


Fig. 1: Average Variance Extracted (AVE)

- **Discriminant validity** refers to the extent to which constructs in a research model are distinct and do not overlap with one another. It ensures that each latent variable in the model is unique and not excessively correlated with other constructs. Establishing discriminant validity is essential to confirm that the constructs being measured are statistically independent and do not share overlapping characteristics. This is typically evaluated using three main methods: The **Fornell-Larcker criterion**, **cross-loadings**, and the **Heterotrait - Monotrait Ratio (HTMT)**.

Method: 1 Fornell-Larcker Criterion

This approach involves comparing the square root of the Average Variance Extracted (AVE) for each construct with the correlations between that construct and all other constructs in the model. To establish discriminant validity, the square root of the AVE for each construct must exceed its correlations with any other construct (Fornell & Larcker, 1981). This indicates that a construct shares more variance with its own indicators than with other constructs, ensuring its distinctiveness.

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ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

Table 3: F&L Method

	DM	G&SE	N&TW	OP	RTHT	SM	SP	WPW
DM	***0.758***							
G&SE	0.195	***0.763***						
N&TW	0.135	0.449	***0.733***					
OP	0.288	0.521	0.604	***0.721***				
RTHT	0.202	0.32	0.518	0.78	***0.743***			
SM	0.26	0.492	0.413	0.871	0.434	***0.815***		
SP	0.349	0.668	0.341	0.493	0.378	0.399	***0.763***	
WPW	0.169	0.416	0.267	0.583	0.213	0.656	0.44	***0.731***

Note: Bold and Italic represents the square root of AVE.

Method 2: (**Heterotrait - Monotrait Ratio (HTMT):** The HTMT method evaluates discriminant validity by comparing the average correlations of indicators across different constructs (heterotrait-heteromethod correlations) to the average correlations of indicators within the same construct (monotrait-heteromethod correlations). An HTMT value below a specified threshold (typically 0.85 or 0.90) confirms that the constructs are distinct from one another (Henseler et al., 2015). This method is considered more reliable than the Fornell-Larcker criterion, particularly in complex models.

Table 4: HTMT method

	DM	G&SE	N&TW	OP	RTHT	SM	SP
DM							
G&SE	0.29						
N&TW	0.324	0.56					
OP	0.337	0.708	0.586				
RTHT	0.276	0.459	0.83	0.909			
SM	0.311	0.706	0.421	1.114	0.514		
SP	0.501	0.993	0.387	0.674	0.503	0.575	
WPW	0.28	0.61	0.236	0.54	0.173	0.682	0.531

Method 3: (Cross Loadings) – Loading of indicator must be higher and significant well with its parent construct instead of another construct. It shows the discriminant validity. When the above two methods not showing significant discriminancy than you check your validity with the help of this method. The difference is taken as less than 0.10 than trait it, if the difference increases than you have to eliminate the indicators.

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Table 5: CL method

	DM	G&SE	N&TW	OP	RTHT	SM	SP	WPW
A	0.156	0.332	0.085	0.223	0.019	0.319	0.462	0.667
AA	-0.077	0.052	0.619	0.201	0.246	0.124	0.002	0.034
AB	0.144	0.519	0.823	0.471	0.352	0.351	0.292	0.201
AC	0.213	0.441	0.901	0.693	0.543	0.457	0.377	0.371
AD	0.053	0.329	0.832	0.481	0.337	0.368	0.311	0.212
B	0.163	0.104	0.072	0.157	0.038	0.21	0.174	0.662
C	0.149	0.116	0.159	0.268	0.048	0.282	0.123	0.685
E	0.11	0.457	0.301	0.675	0.292	0.738	0.432	0.885
E	0.11	0.457	0.301	0.675	0.292	0.738	0.432	0.885
F	0.221	0.395	0.26	0.714	0.318	0.885	0.345	0.439
G	0.296	0.355	0.444	0.737	0.445	0.817	0.207	0.306
K	-0.022	0.607	0.506	0.309	0.158	0.299	0.112	-0.042
L	0.156	0.855	0.237	0.473	0.254	0.494	0.537	0.551
M	0.281	0.804	0.356	0.391	0.309	0.307	0.81	0.33
M	0.281	0.804	0.356	0.391	0.309	0.307	0.81	0.33
N	0.158	0.482	0.203	0.423	0.265	0.358	0.808	0.506
O	0.406	0.181	0.223	0.303	0.303	0.233	0.661	0.115
R	0.889	0.249	0.059	0.288	0.169	0.265	0.333	0.225
S	0.77	0.063	0.172	0.203	0.189	0.189	0.25	0.064
T	0.581	0.028	0.164	0.045	0.038	-0.022	0.143	-0.084
V	0.214	0.3	0.27	0.74	0.879	0.421	0.414	0.256
W	0.196	0.279	0.387	0.765	0.938	0.435	0.346	0.207
X	0.061	0.134	0.622	0.337	0.569	0.154	0.067	0.022
Y	0.046	0.224	0.63	0.267	0.48	0.138	0.168	0.019
Y	0.046	0.224	0.63	0.267	0.48	0.138	0.168	0.019
Z	-0.039	0.048	0.508	0.066	0.272	-0.031	-0.021	-0.014

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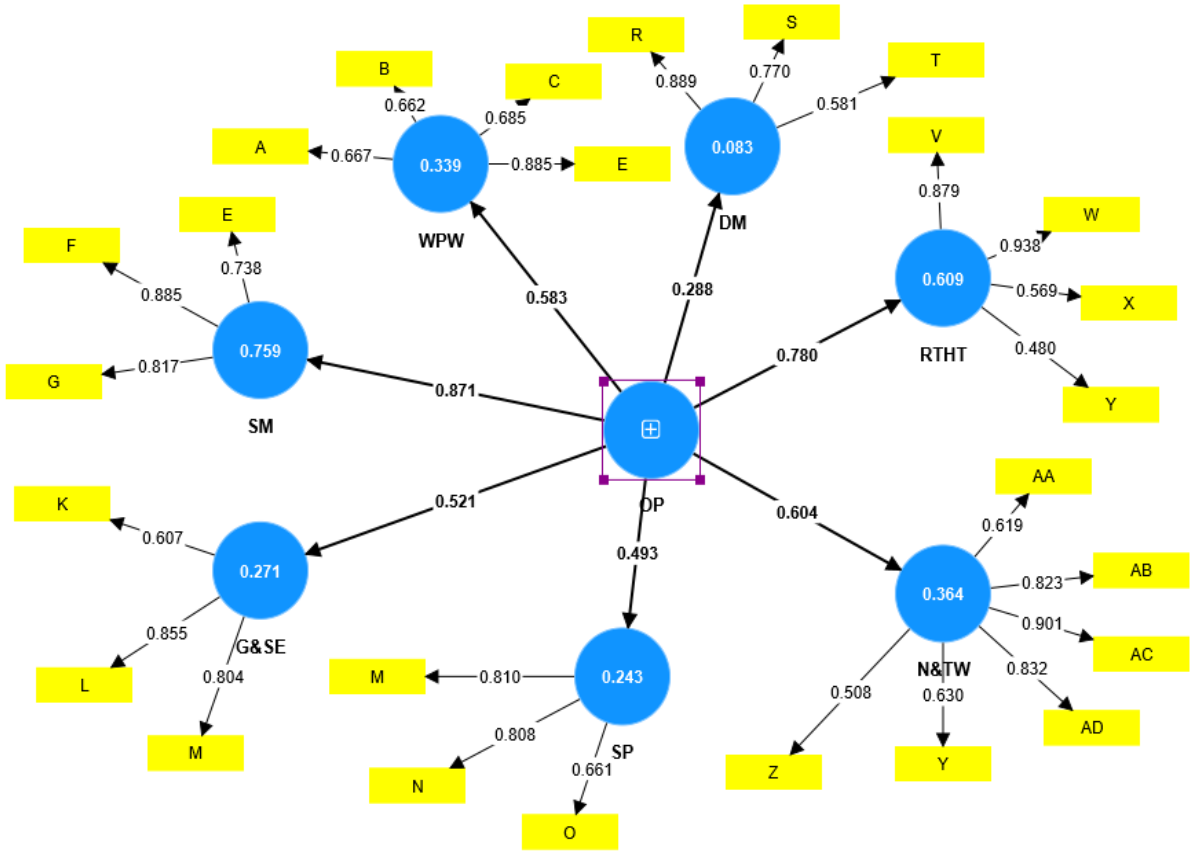


Fig. 2: Measurement model analysis

Structural model analysis:

Structural Equation Modelling (PLS-SEM) involves evaluating the relationships between latent variables in the model. PLS-SEM is a variance-based approach that is particularly useful for predictive analysis and when dealing with complex models, small sample sizes, or non-normal data.

For the assessment of structural model, firstly we have to asses inner model or measurement model. After that we start the bootstrapping calculation. After that we asses all the results as well as the relationship between the latent variables or constructs.

Structural Model involve:

- Path Coeficient
- R-Square value
- P-value & T-value

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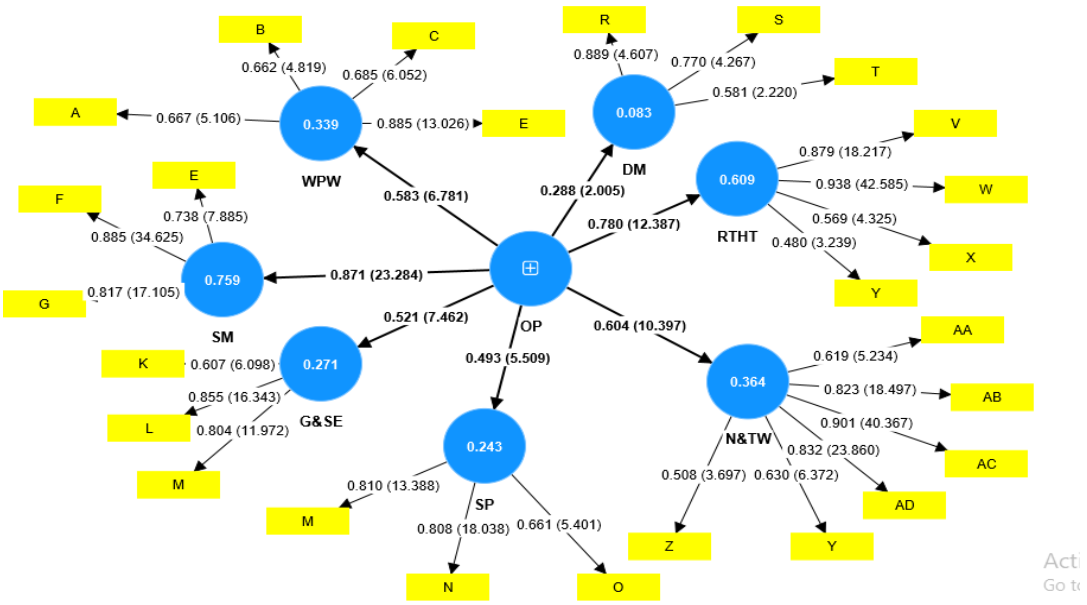


Fig. 3: Path coefficient with T- value

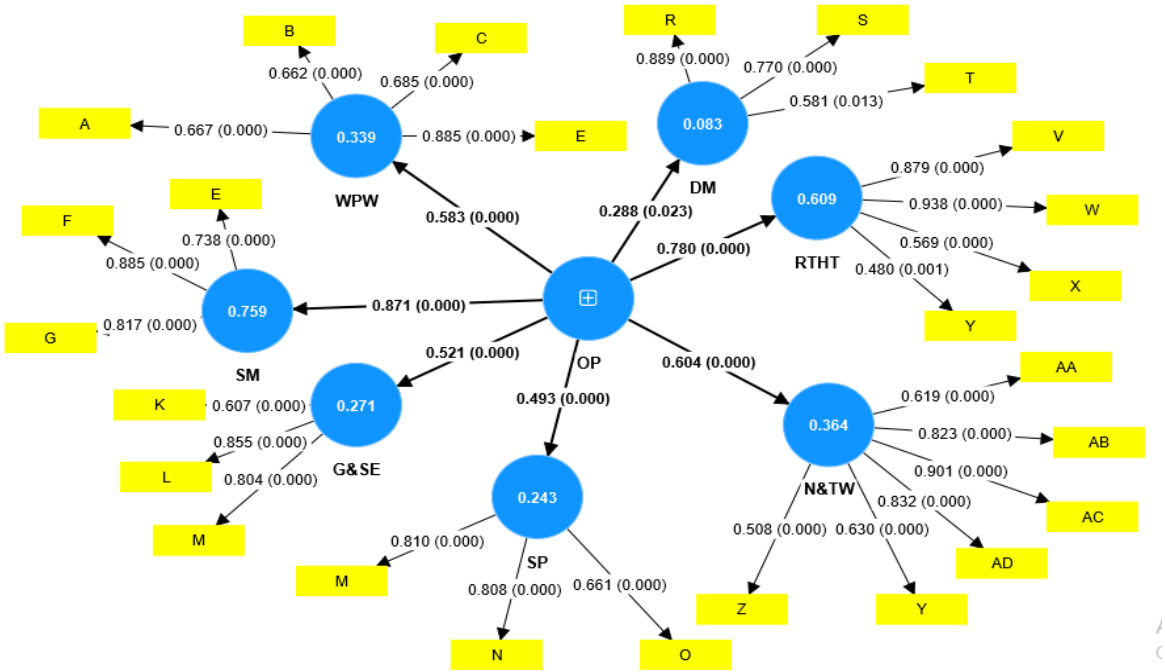


Fig. 4: Path coefficient with P- value

- **Beta coefficient:** It is also known as original sample value. It shows the higher impact of construct. If the value is closer to 1 the significance or impact is higher.

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- **Sample mean:** It is calculated acc. to bootstrapped samples.
- **Standard deviation:** It shows the standard error comes in the calculation.
- **T Statistics:** It is the ratio of beta coefficient to the standard deviation. It shows significant relationship between constructs. it can be calculated according to the direction of relationship such as; For one tailed- Considering value should be greater than **1.645**, and for two tailed- Considering value should be greater than **1.96**. (Field, A. 2018).

$$\text{T Statistics Value} = \frac{Beta\ coefficient}{Stand.\ deviation} \quad \ldots\ldots\ldots\ldots 2$$

- **P value:** If the value is less than 0.05, it would mean the significant relationship.

Table 6: Shows the P- value and T- value

	Original sample (O)	Sample mean (M)	Standard deviation	T statistics	P values	Check T>1.96 and P<0.05
OP -> DM	0.288	0.294	0.143	2.005	0.023	Significant
OP -> G&SE	0.521	0.527	0.07	7.462	0. 000	Significant
OP -> N&TW	0.604	0.617	0.058	10.397	0. 000	Significant
OP -> RTHT	0.78	0.779	0.063	12.387	0. 000	Significant
OP -> SM	0.871	0.87	0.037	23.284	0.000	Significant
OP -> SP	0.493	0.495	0.09	5.509	0.000	Significant
OP -> WPW	0.583	0.598	0.086	6.781	0.000	Significant

Coefficient of determination (R SQUARE): R-Square statistics explains the variance in the endogenous (dependent) variable explained by the exogenous (independent) variable(s). (Falk and Miller 1992) recommended that R^2 values should be equal to or greater than 0.10 in order for the variance explained of a particular endogenous construct to be deemed adequate. (Cohen 1988) suggested R2 values for endogenous latent variables are assessed as follows: 0.26 (substantial), 0.13 (moderate), 0.02 (weak). Chin (1998) recommended R^2 values for endogenous latent variables based on: 0.67 (substantial), 0.33 (moderate), 0.19 (weak). (Hair et al. 2011 & Hair et al. 2013) suggested in scholarly research that focuses on

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marketing issues, R^2 values of 0.75, 0.50, or 0.25 for endogenous latent variables can, as a rough rule of thumb, be respectively described as substantial, moderate or weak.

Table 7: Shows the value of coefficient of determination

	Standard deviation	T statistics	P values	R - square
DM	0.055	1.509	0.066	0.083
G&SE	0.071	3.794	0	0.271
N&TW	0.07	5.228	0	0.304
RTHT	0.09	6.778	0	0.609
SM	0.063	11.97	0	0.759
SP	0.086	2.833	0.002	0.243
WPW	0.1	3.401	0	0.339

F-Square: A variable in a structural model may be affected/influenced by a number of different variables. Removing an exogenous variable can affect the dependent variable. F-Square is the change in R-Square when an exogenous variable is removed from the model. f-square is effect size (>=0.02 is small; >= 0.15 is medium;>= 0.35 is large) (Cohen, 1988).

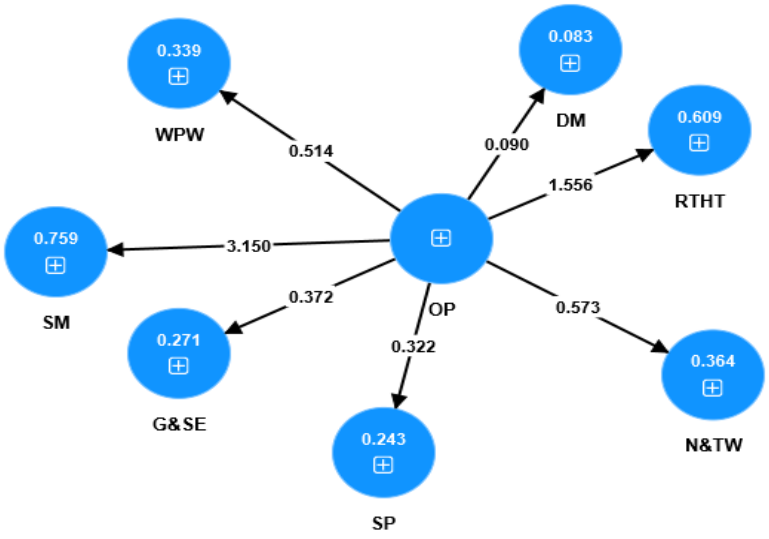


Fig. 5: Value of F square for each construct

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3. Conclusion:

In this study all the seven factors (WPW, DM, RTHT, N&TW, SP, G&SE, SM) affecting productivity is taken as latent variables, and the overall productivity depends on these factors. The whole analysis is done in two major parts: one is measurement model analysis and another is structural model analysis. Measurement model asset's reliability and structural model is about strength and significance of construct relationships. Fig 2 shows the measurement model with the significant path coefficients and outer loadings of various constructs. Fig. 3 and 4 shows the significant T- value and P- value respectively of the structural model. Fig. 5 shows the value of F square for the constructs. Table 6 shows the significance impact of various factors on overall productivity. Table 7 shows the extracted value of R square from the structural model analysis with significant effects.

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ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

Methods of Assessment of Flood Impact and Floodplain Mapping on Urban Area.

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Abstract

Urban calamity is Increasing problem due to various factors like flood, changing land use and land develop strategies. To build up a vigorous municipal civilization, real urban river control is also required. A flexible disaster management is to mentioned design infrastructure, flood management prevention and to develop several computational simulation for existing river catchment area. The basic points studied in this paper is major reasons for flood disaster. The paper focuses on climate changing effects on catchment area. The paper highlighted the flood events and causes of flood events in India. The efforts of this paper for improve the water system and the important objective is to reconcile human activities and flood risks to reduce these risks. According to this study of near about maximum 17.5 million hector land affects due to heavy rain and averagely 7.1 million hector land affected per year and damages of crop, houses, cattle, human live, damage of public utility is also mentioned in this study. The purpose of this study is, the risk of urban disaster increased due to unequal progress of urbanization. Improper planning, indiscipline city development and some amount of climate change condition is also effect on river catchment flow due to which simultaneously flood events are happened.

Keywords: Flood, Disaster, River. (Max Keyword 6)

1 Introduction

In this paper we are going to show flood effect approach for identify flood impact that is based events study. Flood assessment term is used in metrological engineering. Flood is form due to course of subjected due to high rainfall as compare to previous history. Flood is predisposed by several issues like rainfall, stream flow and due to High tide condition, various geographical factors, barriers and failure of flood control systems, and changes in land use and land covered conditions(Rafiq et al. 2016). Floods is one of the natural calamity that make severe impact on human being, Infrastructural disaster and most of the times human and animals deaths also happens(Afifi et al. 2019). The surface drainage is also major issue in rural and urban area. For flood controls and reduce the effect of flood hazards

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ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

effective flood impact analysis and advance flood mapping plays very important role(Radmehr and Araghinejad 2014).

An enormous numbers of flood mapping evolved in last few years which is helpful for flood impact analysis and out of them set a margin to do a flood impact analysis(Rangari et al. 2019). The flood mapping tools and land modelling is limited from last few years. Now a day's various software available to make flood plain map and it assist to analyse critical flood plain map(Eric Tate et al. 1999). When there are increases in population in rural areas, it is often difficult for the standard of living to improve beyond basic sustenance. The living standards of people alter as a consequence of increased population and urbanisation in metropolitan areas, which has an impact on both infrastructure and way of life(Ranjan 2016).

Calculate of disaster effects may help to design the guidelines and standard operating process. The best reason for design flood map and flood assessment is to finding out future investment and to decide the nature or flow of development which will economical and find the future threats(GoI 2017), The guideline related to flood disaster, economic and financial losses is given by Queensland government (Emergency Management Australia 2002).

2 Literature Review of flood events

The prominent example of flood in India from last some decades that makes disaster in term of economical and life of human being is Chennai in 2015, Srinagar in 2014, Mumbai in 2005 and Kolkata in 2013 and Hyderabad in 2016. The many authors make study of urban flooding and they try to make effective flood model by using various software, tools and advanced techniques like flood assessment and modeling of Hyderabad city (Surwase and Manjusree 2019). The study of Oshiwara River Basin of Mumbai Uncover the effect of Urbanisation and changing pattern of city development that effect on flood path and result in high flood.

The Land use and land cover (LULC) pattern studied from 1966 to 2009 by use of flood plain map and various satellite photograph. The analysis of Land use and land cover (LULC) In a growing urban watershed of the Oshiwara River in Mumbai, India, the effects of land use-land cover (LULC) change and urbanisation on floods are being investigated. By utilising the topographic map and satellite pictures for the research region, the change in land usage between 1966, 2001, and 2009 was calculated. According to the examination of LULC change, there was a slower rate of change between 1966 and 2001 than between 2001 and 2009(Zope et al. 2016).

Similarly in Surat city urbanisation changing by LULC pattern, which shown effect in 2006

ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

cause financial, damaged Surat city and other surrounding village. The flood management plan for Surat city, also known as a portion of the Lower Tapi Basin, Gujarat, India, and this study aims to evaluate the flood risk in urban systems and governance. The subject region is examined using topographical maps from 1968 and a satellite picture of Resources-1 from 2006. According to the study, the key factor behind the study area's increased flood risk is a shift from a low to a high urbanisation pattern(Waghwala and Agnihotri 2019). The Thirusoolam sub watershed, an urban watershed in Chennai, Tributary flow regime changes brought on by urbanisation in the watershed always mirror changes in land use. The study natural flood level is disturbed by the growth of impermeable surfaces. Reduced infiltration causes runoff to rise, which raises flood peaks and volumes even during brief periods of light rain. Through suitable interventions to change the water regime and adaptation of human behaviour, Integrated Flood Management (IFM) seeks to balance human activities and flood hazards, therefore lowering such risks(Suriya and Mudgal 2012).

Flood impact assessment is a critical task in emerging guidelines for flood hazard managing. As discussed in previous paragraphs, there is various flood assessment study was done in past but not mentioned in this literature(Nkwunonwo et al. 2020),

One can anticipate improvement and promise in simulating urban floods in emerging nations as a result of the growing accessibility of global flood risk models. Sadly, the issue of uncertainty and the model's susceptibility to outside datasets and test sites still exists.

Therefore, the research community should concentrate emphasis on calibration through uncertainty and sensitivity studies in order to promote a wider application of flood modelling processes that benefits particularly the developing nations. More research is required to create custom models that can simulate flood inundation risk without heavily relying on dispersed topography and friction statistics.

3 Methodology

The aim of this paper to make an outline a framework that assess the flood impact and ability to measure on urban area, To pinpoint the essential elements that can result in actual (possible) success and to illuminate a route for sustainable urban development.

3.1Methods of flood assessment

The following factors should be taken into account when estimating economic losses due to urban flood damage to building units: the damage ratio of buildings, building damage costs, flood victims, damage costs of industry, and costs of casualties. In other words, the cost of

ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

property destruction and the cost of human life are added together to determine the economic loss brought on by floods. The expenditures associated with property damage cover damage to the building itself, its contents, its industry, and its infrastructure. The cost of human loss includes both individual losses and the financial losses incurred by flood victims (Eem et al. 2018).

Assessing floods typically involves a combination of data collection, analysis, and modeling to understand the extent, severity, and potential impacts of flooding events(Bansal et al. 2015). Here is a general methodology for flood assessment:

3.1.1. Define the study area: Determine the geographic scope of the flood assessment. This could be a specific region, river basin, or a particular area prone to flooding(Emergency Management Australia 2002).

3.1.2. Collect data: Gather relevant data from various sources(National Disaster Management Authority Government of India 2015), including:

a. Topographic data: Obtain elevation models, digital elevation maps, or topographic surveys of the study area. This data helps identify low-lying areas, water flow patterns, and potential floodplain locations(Pina et al. 2011).

b. Hydrological data: Collect information on river flow rates, precipitation data, historical flood records, and water level gauges. This data is crucial for understanding the hydrological characteristics of the area(Emergency Management Australia 2002).

c. Land use and infrastructure data: Obtain maps or spatial data indicating land use patterns, urban infrastructure, drainage systems, and existing flood control measures. This data helps assess vulnerability and potential impacts(Ramkumar et al. 2018).

d. Climate data: Gather information on weather patterns, including rainfall intensity, storm events, and climate change projections. Climate data is valuable for understanding flood frequency and magnitude(Turkington et al. 2016).

3.1.3. Perform hydraulic modeling: Use hydraulic models to simulate the behaviour of water flow during flood events. These models take into account factors such as topography, river geometry, rainfall data, and land cover. Hydraulic modeling can help estimate flood extents, flow velocities, and flood depths.

3.1.4. Validate models: Validate the accuracy of the hydraulic models by comparing the model predictions with historical flood events or available field measurements.

ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

Calibration and validation ensure that the model accurately represents the actual flood conditions.

3.1.5. Assess flood risk and vulnerability: Evaluate the potential impacts of flooding on various elements at risk, such as human settlements, infrastructure, agriculture, and ecosystems. Assess the vulnerability of these elements based on factors like exposure, sensitivity, and adaptive capacity.

3.1.6. Develop flood hazard maps: Utilize the hydraulic modeling results to create flood hazard maps, which depict areas at different levels of flood risk. These maps help identify high-risk zones, flood-prone areas, and areas requiring specific flood management strategies.

3.1.7. Analyse potential mitigation measures: Identify and evaluate potential flood mitigation measures, such as flood control infrastructure, land use planning, early warning systems, and community preparedness. Assess the cost-effectiveness and feasibility of different strategies.

3.1.8. Communicate and disseminate findings: Present the results of the flood assessment in a clear and accessible manner to stakeholders, policymakers, and the public. Effective communication helps raise awareness, support decision-making, and encourage proactive measures to reduce flood risk.

It is important to note that flood assessment methodologies can vary depending on the scale and resources available. More advanced techniques, such as remote sensing, real-time data monitoring, and advanced modeling, can enhance the accuracy and timeliness of flood assessments. Following are some measures referred from ISO 31000:2018.

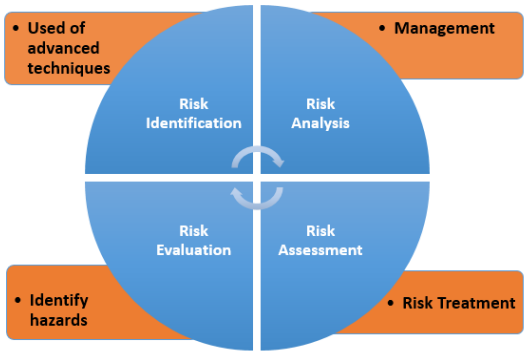


Fig. 1. Risk assessment (Source: ISO 31000:2018 identification)

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4. Hazardous Scale

The flood hazard generally count along the criteria of flow characteristics and type damage. Hydrological events also count for flood damage but measure in terms of Rainfall, Runoff, Discharge and other flow characteristics. The flow hazards measures in following manner.

Table 1. Flood hazard classification

Hazard Classes	Hazard Description
Very low	Flood does not affect to human and animal survival.
Low	During flood situation there is difficult to rescue children and old age person.
Medium	Humans may dead in flood depth; but they safe inside to their houses
High	Even people are their home but they not safe, rescue operation is running and instructed them to go on safe position.
Extreme	Manmade structure may submerged into water, even they go to safe position they faced other issues like flood, food, health and living.

5. Flood Plain map

In the following figure flood hazardous categorised in five level like very low to very high level. The map is prepared for Mumbai basin.

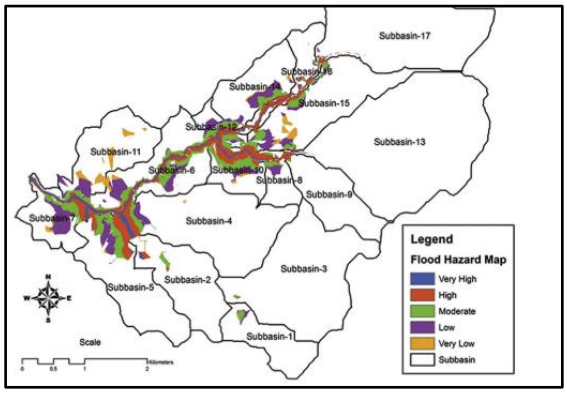


Figure 2. Flood hazard maps for LULC

In various study, schematic flood plain maps prepared for extreme flood condition at different stream situation, slope condition, length of river, soil type and distance for the study area are generated by using various tools like HEC-HMS, HEC-RAS, and ArcGIS. The result shows the effective figure to analyse flood hazardous area(Zope et al. 2016).

6. Conclusion

In conclusion, the assessment of flood impact and floodplain mapping in urban areas is a

ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

crucial task that requires careful consideration and reliable methods. This topic has been extensively studied and various approaches have been developed to mitigate the devastating effects of floods on urban areas. By employing advanced technologies, such as remote sensing, Geographic Information Systems (GIS), and hydrological modeling, researchers and policymakers can accurately assess the impact of floods and create comprehensive floodplain maps.

The methods discussed in this study highlight the importance of integrating both qualitative and quantitative data to assess the extent and severity of flood impacts on urban areas. These methods provide valuable insights into flood risk management, land use planning, and emergency response strategies.

Furthermore, the development of reliable floodplain maps is essential for urban planning and infrastructure development. Accurate floodplain mapping allows for the identification of high-risk areas and assists in the implementation of appropriate flood management strategies. By considering factors such as topography, land cover, and hydrological characteristics, floodplain maps provide valuable information for decision-makers, helping them to allocate resources effectively and reduce the vulnerability of urban areas to flooding.

It is important to note that the methods discussed in this study are continually evolving, driven by advancements in technology and research. Future studies should aim to integrate emerging technologies, such as artificial intelligence and machine learning, to enhance the accuracy and efficiency of flood impact assessment and floodplain mapping. Additionally, interdisciplinary collaborations among researchers, policymakers, and communities are essential to ensure the successful implementation of flood management strategies and the resilience of urban areas.

In conclusion, the assessment of flood impact and floodplain mapping on urban areas is a complex task that requires the integration of various methods and data sources. Through continuous research and innovation, we can improve our understanding of floods and their impacts, leading to more effective flood risk management and resilient urban planning. By implementing these methods, we can strive towards building safer and more sustainable cities that are better prepared to withstand and recover from the challenges posed by flooding events.

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ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

"A Review on study of Seismic Response of Multistorey Plan Irregular building with Shear Wall & Bracing System"

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Abstract

Multistory plan irregular buildings with shear wall and bracing system are commonly used in high-rise construction due to their structural efficiency and architectural flexibility. However, these structures are vulnerable to seismic events due to their complex geometry and irregular distribution of mass and stiffness. Therefore, evaluating the seismic response of multistory plan irregular buildings with shear wall and bracing system and enhancing their seismic resilience is crucial to ensure the safety and sustainability of these structures. This review paper aims to provide a comprehensive overview of the recent studies on the seismic response of multistory plan irregular buildings with shear wall and bracing system, highlighting the current state of knowledge, research gaps, and future directions in this field.

Keywords: Seismic analysis, Multistory, Bracing system, Shear wall system.

1 Introduction

The topic of seismic response of multistory plan irregular buildings with shear wall and bracing system is crucial for ensuring the safety and sustainability of these complex structures commonly used in high-rise construction. This review paper provides a comprehensive overview of the recent studies on this topic, highlighting the current state of knowledge, recent research, and potential research gaps. While significant progress has been made in understanding the seismic behavior of these structures, further research is needed to address the identified research gaps and enhance their seismic resilience. This review paper serves as a useful resource for researchers, practitioners, and policymakers interested in advancing our understanding of the seismic performance of multistory plan irregular buildings with shear wall and bracing system.

2 CONTRIBUTION OF RESEARCHERS

Taranath (1975) [1] conducted research to determine the optimal location for single bracing in high-rise buildings. The midpoint of the structure was identified as the best location to reduce lateral sway under wind loadings. They also proposed a straightforward analytical technique for the bracing structural system. Building upon Taranath's work, McNabb (1975) [2] further investigated the effects of bracing on reducing lateral drift. He confirmed Taranath's findings and suggested that placing bracings at approximately 0.445 times the height of the structure from the top is beneficial for drift and displacement control.

In a study by Chan and Kuang (1988) [3], the concept of stiffening the structure through the placement of stiff beams at various locations was explored. They found that the positioning of stiff beams significantly influences the overall performance of high-rise structures against lateral loads.

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ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

Qi and Chen (1996) [4] investigated the suitability of bracing systems using two-dimensional models. Their model consisted of a channel-shaped core and two columns connected by bracing beams. The study revealed that the inclusion of three bracings substantially reduced lateral displacement.

Sadjadi et al. (2007) [5] presented a methodological approach for seismic evaluation of reinforced concrete (RC) frames using push-over and nonlinear time history analysis. The study examined 5-story RC frames and validated the analytical models against experimental data. The results indicated that the gravity load-designed (GLD) structure did not perform well during the earthquake, while the ductile and less ductile frames exhibited superior behavior. Notably, the modified GLD frame demonstrated improved seismic performance.

Duan et al. (2012) [6] conducted numerical analyses and found that structures designed according to GB50011-2010 exhibited the intended inelastic behavior and response specified by the code. The structures also met the inter-storey drift and maximum plastic rotation limits recommended by ASCE/SEI 41-06. However, the push-over analysis indicated the potential for a soft first-story mechanism under significant lateral demands.

Poonam et al. (2012) [7] conducted numerical analyses and concluded that no storey, particularly the first storey, should be weaker or softer than the storeys above or below. They also found that irregular mass distribution contributed to increased building response. If irregularities are necessary, they should be addressed through appropriate and thorough analysis and design processes. Moehle's research supported the effectiveness of standard limit analysis and static inelastic analysis in evaluating strength and deformation characteristics during strong earthquake motions.

K.K. Sangle et al. (2012) [8] investigated the performance of steel framed structures under seismic loadings by incorporating different types of bracings. They used Northridge earthquake data for time history analysis. The study considered six different configurations, including a bare frame model without bracing and models with diagonal, X-bracing, K-bracing, and knee bracing. The displacement at the top of the steel framed building was reduced by 43% - 60% with different bracing patterns, indicating an increase in flexural stiffness. The study observed a reduction in the time period with different types of bracings, and diagonal bracing was found to be the most efficient.

Divyashree M et al. (2014) [9] compared the effectiveness of two methods for strengthening irregular buildings. They used ETABS software to model and analyze eight-story buildings using response spectrum and pushover analysis methods. Different configurations of bracings and shear walls as strengthening elements with varying stiffness were analyzed. The results indicated that increasing the stiffness of the strengthening elements reduced roof top displacement. Additionally, a cost comparison analysis showed that shear walls were more cost-effective than bracings for achieving a similar level of performance.

Junais Ahmed AK and Yamini Sreevalli (2014) [10] conducted a study to investigate the change in the fundamental time period of buildings with bracing placed at different locations in structural models. Using FEM-based ETABS software, they created structural models of 30, 40, 50, and 60 storeys. The models were subjected to lateral loads based on IS 1893(PART 1) - 2002 for earthquake loads and IS 875(PART 3) - 1987 for wind loads. The study found that the maximum reduction in the fundamental time period occurred when bracing was placed at one-third of the building height from the top and bottom. The results also indicated that the plan dimension of the structure plays a role in its stability. Increasing the structural height with the same plan dimensions led to an increase in the fundamental time period, suggesting an inverse relationship between lateral stability and the height of the structure

M.R. Suresh and Shruti Badami (2014) [11] investigated the most suitable structural configuration for structures of different heights under gravity and wind loads. They considered the "Rigid Frame," "Shear Wall/Central Core," "Wall-Frame Interaction," and "Bracing" systems. The study focused on G+15, G+30, G+45, and G+60 storey models with symmetrical plans. The findings showed that for buildings up to 40 storeys, the Rigid Frame with Shear Wall system was suitable, while for buildings over 40 storeys, the bracing structural system was efficient in controlling excessive displacement and inter-storey drift at the top of the building.

Abdul Karim Mulla and Shrinivas B.N (2015) [12] considered both regular and vertically irregular structures in their study. They used 20 storey building models with vertical irregularities but symmetrical plans. The linear

ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

static method and response spectrum method according to IS codes were employed. The researchers observed a considerable reduction in time period and base shear in models with bracing. Bracing efficiently enhanced the stiffness of vertically irregular buildings and effectively controlled displacement. Concrete bracings were found to be more efficient than steel bracings in controlling lateral displacement.

H.S. Sukesh et al. (2017) [13] investigated bracing systems with varying relative stiffness at different locations in a 35-storey building model. Bracings were placed at 0.25H, 0.5H, 0.75H, and H heights of the building, and the relative stiffness of the bracing beams was varied by changing dimensions. The study used six different models, including a bare frame model without shear walls and bracings, as well as models with shear walls and bracing concrete beams of varying stiffness. Analysis was performed for seismic zones 2 to 5 using ETABS software. The findings showed that increasing the relative stiffness of the concrete beams led to a decrease in lateral displacement and an increase in base shear in all seismic zones.

Mohammad Noor Jan Ahmadi1 and Prof. Dr C. S. Sanghvi (2017) [14] The L-shape plan of a G+7 storey reinforced concrete building was chosen for this study. The models are analysed in two phases: the first phase analyses the building without shear walls and soft-storey on the ground floor, and the second phase analyses the same building with shear walls and soft-storey on the ground floor. The shear walls are also added to the model in two different cases in the Second Phase to study the best location of shear walls in the building. STAAD Pro V8i SS6 software is used to analyse the models, which are based on the IBC-2012(9) code (International Building Code 2012) and the Linear Static Method.

Prajyot A. Kakde and Ravindra Desai (2017) [15] conducted a study comparing the performance of structures with steel bracings and concrete beam bracings. They analyzed a tall building with plan dimensions of 30m x 30m and a height of 70 storeys, which included a central core. Wind load was considered in the analysis using ETABS 2016 software, focusing on parameters such as displacement, drift, and base shear. The study found that steel bracings were more effective in controlling lateral displacement and storey drift compared to concrete bracings. Additionally, the base shear was lower with steel bracings than with concrete bracings. The combination of the bracing system and the peripheral belt made of structural steel proved to be more efficient than using concrete deep beams.

Rohan Chavan & Prachi Sohoni (2018) [16] conducted an analysis on G+11 irregular reinforced concrete (RC) buildings with and without a cross bracing system. The cross-bracing system was considered as one of the best concentric bracing systems. Non-linear time history analysis using ETABS 2016 software was employed to assess the structure's response to ground motions. Performance measures such as story drifts, lateral displacements, bending moments, axial forces, and base shear were evaluated.

Surender Kumar et al. (2018) [17] emphasized the importance of shear walls in resisting lateral loads in high seismic areas. The positioning of shear walls plays a crucial role in the overall behavior of the building. The study focused on the response of G+8 RCC buildings with different shear wall positions, utilizing the Equivalent Static Method and IS 1893 (PART - I): 2002. The critical aspects of seismic building design, namely story drift and lateral displacements, were considered.

Saurabh Mishra & V.K. Singh (2018) [18] highlighted the significance of properly designing and locating shear walls to resist lateral loads. The study aimed to optimize the placement of shear walls on an irregular 'H'-shaped plan building by analyzing story drift, story displacement, and torsion. ETABS software was used to compare parameters between models with varying shear wall locations and a model without shear walls.

Sajjad Baygi and Amin Khazaee (2019) [19] investigated the optimal number of bracings for reducing top storey displacement. They utilized MATLAB to formulate the base moment and top displacement of a structural model under lateral loads. The study found that he optimum number of bracings depends on factors such as axial rigidity of columns, bay length, structure height, and bracing stiffness. It was observed that using four or more bracings does not significantly reduce lateral displacement beyond a certain limit and may result in uneconomical configurations.

P A Krishnan and N Thasleen (2020) [20] conducted a study on the response of irregular buildings to lateral loads, particularly focusing on the impact of re-entrant corners. The analysis was performed using Pushover analysis and followed the codal provisions of IS 1893 (Part 1): 2016. Ten models with re-entrant corners were analyzed using

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ETABS v16.2.0 software and seismic Match 2018 software. The study considered parameters such as storey displacement, stress concentration, and performance levels. Strengthening techniques for improving the resilience of vulnerable models were also discussed, and the results were compared to those of a regular structure.

Vishal N, Ramesh Kannan M, and Keerthika L (2020) [21] highlighted the importance of considering sequential analysis in multi-storey buildings, as each storey is subjected to specific loads during the construction process. Ignoring sequential analysis can lead to variations in structural members between different storeys, affecting the distribution of forces within the structure. The study focused on a 20-storey building with vertical setback irregularity and compared the structural behavior and response using response spectrum method with and without Construction Sequence Analysis (CSA). The analysis was conducted using CSI ETABS V16 software, following BIS 1893:2016 (Part 1) provisions. The results included axial force, shear force, bending moment, storey displacement, storey shear, and storey drift for different structural systems.

Shobha Ram, Syed Kaleem AZ, and Naveen Kumar (2021) [22] addressed the challenge of designing seismic-resistant buildings considering irregularities. The study focused on incorporating bracing into the structure to resist lateral forces such as earthquakes and wind loads, which can reduce lateral deflection. A G+10 storey building with vertical and horizontal irregularities was analyzed using different types of steel bracing systems, including v-type steel bracing and diagonal type buckling restrained bracing. The results were compared to a bare frame model, and the steel braced models demonstrated better performance compared to the buckling restrained bracing models.

Karthik Prabhakar (2021) [23] conducted a study on exoskeleton structures, which are external self-supporting structural systems connected to the primary inner structure of a building. The study optimized the exoskeleton structure by removing intermediate bracing between the corners of the building. The seismic performance of the optimized exoskeleton structure was analyzed and compared with shear wall buildings and normal exoskeleton buildings. Nonlinear static analyses were performed using ETABS 2016 software. The study demonstrated that shear walls can improve the seismic performance of reinforced concrete frame buildings, and the optimized exoskeleton RC building was compared to this system. The seismic behavior of G+5 storey buildings with horizontal irregularity was compared to regular buildings with and without shear walls using ETABS software. The comparison was based on parameters such as lateral displacement and storey drift.

Abdul Wasey Abdul Wahab & Dr. P. B. Ullagaddi (2021) [24] focused on the design of multi-story buildings subjected to lateral forces, particularly in seismic zones. Irregular structures require special consideration during analysis and design to ensure their stability and safety. The study utilized a C-shaped building as the subject of research and installed a bracing system for lateral loading resistance. The behavior of the structure, including base shear, story drift, stiffness, and lateral displacements, was monitored. Three types of bracing systems (X, V, and Diagonal) were employed in four different models, including one moment-resisting frame (MRF) and three models with unique bracing systems. The study used the response spectrum method for dynamic analysis of the structure to assess its performance and determine the most appropriate bracing system.

3 RESEARCH GAP

Lack of studies on the effectiveness of different retrofitting and strengthening measures for improving the seismic performance of multistory plan irregular buildings with shear wall and bracing system.

- Limited research has been conducted on the seismic performance of multistory plan irregular buildings with shear wall and bracing system under extreme seismic events, such as near-fault earthquakes.
- Insufficient investigation of the long-term durability and effectiveness of energy dissipation devices used to enhance the seismic resilience of multistory plan irregular buildings with shear wall and bracing system. Limited research on the cost-effectiveness and practicality of different retrofitting and strengthening measures for multistory plan irregular buildings with shear wall and bracing system, particularly in developing countries where financial resources may be limited.
- Need for further experimental investigations to validate the accuracy and reliability of analytical models used to evaluate the seismic response of multistory plan irregular buildings with shear wall and bracing system.

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- Lack of studies on the social and economic impacts of seismic events on multistory plan irregular buildings with shear wall and bracing system, such as displacement of residents, disruption of economic activities, and recovery and reconstruction efforts.
- Need for further investigation of the interactions between the different structural elements of multistory plan irregular buildings with shear wall and bracing system under seismic loading, and their effects on the overall seismic performance of the structure.

4 CONCLUSIONS

The studies conducted by various researchers have highlighted the significance of incorporating bracing and shear walls in the seismic design of buildings to enhance their resistance against lateral forces such as earthquakes and wind loads. These lateral load-resisting systems play a crucial role in controlling lateral displacement, story drift, and base shear, thus ensuring the overall stability and safety of structures, especially in high seismic zones.

The research has explored different types of bracing systems, including diagonal, X-type, V-type, and buckling restrained bracing, as well as the use of shear walls in various configurations. It has been observed that the placement and relative stiffness of bracings influence the structural behavior and seismic performance of buildings. The optimal location of bracing systems and shear walls has been investigated, with studies indicating that specific placements can significantly reduce the fundamental time period and improve lateral stiffness.

Research conducted till date has addressed irregularities in building design, such as vertical and horizontal irregularities, re-entrant corners, and exoskeleton structures. Efficient designing and selection of appropriate locations of bracing systems and shear walls is found to be useful in mitigating the adverse effects of these irregularities, improving the overall performance of buildings under lateral loads.

Furthermore, cost-effectiveness has been an essential consideration, numerous studies have been done for comparing the efficiency of different lateral load-resisting systems and highlighting the economic benefits of specific configurations. In some cases, steel bracing systems have shown to offer better performance in reducing lateral displacement compared to concrete bracing, while the optimization of exoskeleton structures has demonstrated promising results in terms of seismic performance.

Overall, the research presented a comprehensive understanding of the behavior of structures under lateral loads and emphasized the importance of implementing effective bracing and shear wall systems in seismic design. By considering the findings from these studies, engineers and designers can make informed decisions to enhance the seismic resilience of buildings, ensuring the safety of occupants and protecting critical infrastructure in earthquake-prone regions. Continued research in this field will further advance our understanding of lateral load-resisting systems, contributing to the development of more robust and sustainable structures for the future.

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ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

Structural Strength Assessment, Seismic Evaluation and Strengthening of Non-engineered R.C.C. Building - Case Study

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Abstract

Every large-scale earthquake causes many casualties and huge property damage. Casualties and damage in developing countries are far worse compared with those in developed countries, especially casualties. The main cause of human casualties is the collapse of non-engineered buildings. They are usually called "non-engineered houses" or "non-engineered construction" as they are usually constructed without any involvement of engineers. In spite of this situation, non-engineered construction attracts far less attention from the engineering community and policymakers. The evaluation and retrofitting of buildings damaged by earthquakes is a critical issue for ensuring the safety of people and minimizing property loss. The hazards associated with non-engineered buildings include structural instability and earthquake vulnerability. This study covers the structural assessment and strengthening of the building by reinforced concrete jacketing of the non-engineered building. The structural strength assessment and design of a strengthening residential building at Musakhedi Indore. This case study is mainly conducted in two steps: first, a structural audit and assessment. This investigation shall include a preliminary visual survey and collection of data on the prevailing environment, its geometry, existing material strengths, such as in-site concrete strengths and grades of various important load-carrying elements, reinforcement detailing, structural condition assessment, and non-destructive evaluation tests (NDTs), followed by a seismic evaluation of the existing structure and the design of required strengthening.

Keywords: Retrofitting, RC Jacketing, Strengthening, Non-Engineered Building.

1 Introduction

A building is considered to be safe, only when both of the following can resist earthquake ground motions occurring at its base without any loss, namely a) People in the building, and b) Structural safety of the building Here, the safety of people means no collapse of the whole or part of the building that causes danger to life, and structural safety of the building means the building is able to continue to offer the function the way they are expected to even after the earthquake. (Charleson, A. et al. 2016) in this document the dissemination of technical guidelines and good practices for non-engineered construction, specifically focusing on the importance of seismic design and earthquake-resistant low-cost houses. (Pajgase, P. S. et al. 2000) this study focuses on ductile detailing for the primary members of the structure to withstand stress reversal from earthquake loads. Lateral confinement can be achieved by providing closely spaced stirrups to prevent brittle failure. Buildings with a flexible first story,

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such as those on stilts, require retrofitting measures such as jacketing columns, providing additional columns, and shear walls to meet ductility requirements. (Jain, S. K. et al. 2000) this study focuses on the earthquake in Jabalpur and reveals several important issues and recommendations. The performance of RC frame buildings with brick infills was satisfactory, highlighting the positive contribution of unreinforced masonry. However, RC frame buildings with insufficient member sizes and insufficient reinforcement showed poor performance, which is concerning given their prevalence in modern India.

The safety of people in a building depends first on whether or not the building is capable of resisting earthquake shaking and then on standing upright after the earthquake. Significant attention has been drawn to the safety of the building during an earthquake, the only way possible to do that is to design the building earthquake resistance, but there is a significant increase in non-engineered building construction as seen from past earthquake studies these non-engineered building doesn't behave well, cause structure failure and loss of life. In the present scenario, there is a number of non-engineered building already constructed, to reduce loss of life and increase structural performance strengthening/ retrofitting is suggested. Objective – Structural strength assessment and design suggested retrofitting technique of the residential building at Musakhedi, Indore.

2 Methodology

The methodology adopted for this case study is as follows –

a) Data Collection – The investigation includes a preliminary visual survey, its geometry, determination of existing member strength, geotechnical investigation, presence of any sign of distress/ deterioration, size of a structural member, reinforcement detail, foundation type, and year of construction.

b) Structural condition assessment - The assessment includes, identifying the cause of distress/ deterioration in the building, identifying the vertical and lateral load-resisting system, to assessing the extent of distress if any.

c) Non-destructive tests (NDTs) - The investigation method involves in-situ tests and data collection by NDT. The strength of the structural member is most important for the further steps, this also includes the verification of main structural members like concrete, rebar, masonry, and general data of other perimeters like corrosion in rebars, damping, carbonation, seepage, and spalling of concrete is also collected.

d) Evaluation of existing building – The determination of existing capacity and demand of the building. Analysis of the building to check the structural integrity and stability.

e) Design Basis – To check the existing building for the current building code and current seismic parameters.

f) Unsafe structural condition – A structural assessment is performed to determine the following structural condition- instability, likely to collapse members. Assessment criteria for the unsafe structural condition of seismic resistance are checked by IS 15988 (2013).

g) Evaluation and Strengthening – To meet the seismic demand the strengthening method is selected and designed as per requirement. İt also includes the repair and rehabilitation of damaged/ cracked members.

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3 Case study

This case study is based on a real-life project in which a residential non-engineered building at Musakhadi, Indore is studied, and suggested the required retrofitting/ strengthening method, front elevation of the building shown in Figure 3.1.



Fig. 3.1 Front elevation of a residential building at Musakhedi Indore

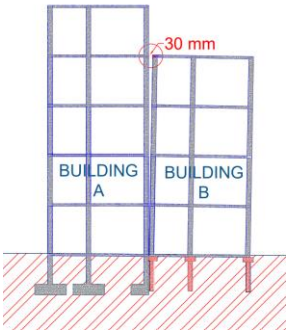


Fig. 3.2 The type of foundation used in both buildings and at the top of building B is a 30 mm tilt towards the right.

3.1 Building information

- Building Name: Residential Building
- Address: Ajay Bagh Colony, Musakhadi, Indore, Madhya Pradesh 452003
- Building Use: Residential
- No. of stories: Ground Floor + 3, and ground + 4 (Refer to Table 3.1)
- Story height: 3.3 m
- Year of Construction: 2016 and 2020 (Refer to Table 3.1)
- Total built-up area (Sqm): 182 sq.m
- Building Structural System: Moment Frame (Beam-column system)
- Foundation Type: Pile footing and isolated footing (Refer to Table 3.1)
- Geo-Technical Report available: No
- Structural drawings available: No
- Special confining reinforcement in beam/column joints: No
- Original Structural design calculation available: No
- Any other information like past repairs/ remodeling details: No
- Seismic Zone (As per IS 1893 (Part-1)): Zone III
- Seismic safety importance factor: 1.2
- Special Hazard Vulnerability: No
- High water table: No
- Land Slide Prone site: No

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- Severe Plan Irregularity: No, as per IS 1893 (Part-1)
- Severe Vertical Irregularity: No, as per IS 1893 (Part-1)
- Building having structural dampness/ cracks: No
- Building having non-structural dampness/ cracks: No

There is two adjacent building as shown in figure 3.2. The foundation of Building A is isolated footing and building B has pile footing. The pile of building B settles down due to which the building is tilting towards the right. There is a visible gap between the buildings of about 30mm at the top of building B. The gap between the buildings increases continuously. There is only one pile below every column of 300 mm diameter of about 2 meters in depth.

Table 3.1. Number of Stories, Type of Foundation, and Year of Construction of Building A and B

S. No.	Type	Building A	Building B
1.	Number of stories	G+4	G+3
2.	Foundation type	Isolated foundation	Pile foundation
3.	Foundation Problem	No foundation problem	Foundation settlement
4.	Year of Construction	2016	2020

Existing material strength is fairly good there are no visible cracks and distress due to weathering and corrosion is seen at the structural member. The concrete strength is M20 and steel of Fe500 is used in the construction. In column size is 230X300, having 6 bars of 12 mm diameter are used.



Fig. 3.4 Gap between the building on the ground floor.



Fig. 3**.5** Gap between the building on the First Floor.



Fig. 3.6 Gap between the building on the second floor.



Fig. 3.7 Gap between the building on the third floor



Fig. 3.8 Gap between the building at Terrace

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Fig. 3.10 Gap between the building on the third floor.



Fig. 3.9 Gap between the building at mummty level

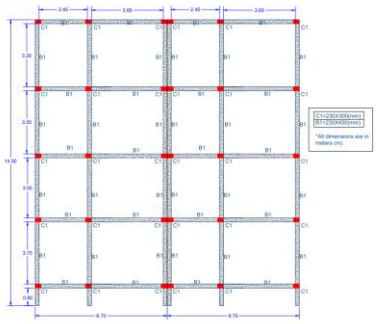


Fig. 3.3 Column and Beam Layout of the building.

3.2 Structural Condition Assessment

There is an important assessment finding after the visual survey:

1. There is a visible tilt of the building as shown in Figures 3.4, 3.5, 3.6, 3.7, 3.8, 3.9, and 3.10, the deflection of the building is caused by foundation settlement.
2. After investigation, it is clear that the building has one pile of 300mm diameter below every column, which is the main reason for the deflection of the building.
3. There is no irregularity in the load path of the building, and it is an ordinary moment-resisting frame building.
4. The structural member beam, column, and footing do not show any signs of distress, but the column size and reinforcement in the column are insufficient to carry the load of the building.
5. The main cause of such problems is deficiencies in the design of buildings and foundations. Differential settlement of the foundation is caused by foundation settlement.

3.3 Non Destructie test (NDTs)

A non-destructive test of the concrete with a rebound hammer is conducted on the concrete structural members, which shows 18–20 MPa of strength.

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3.4 Seismic Evaluation of Existing Building

It is a process of determining whether the entire structure or any individual component thereof, is structurally adequate for its current intended use or performance goal. The structural analysis is performed using ETABS software.

3.4.1 Building classification

The structure is an ordinary moment-resisting frame structure, this frame structure acts as a vertical and lateral load-resisting system. There is an infill wall in the building but for simpler analysis, we are considering the infill effect of the wall will not take part in the lateral load-resisting system.

3.4.2 Applicable Indian/ International Standards

Table 3.2 List of Codes and Guidelines Used

S. No	Code	Description
1.	IS-875 (Part 1) - 1987	Code of Practice for Design Loads (other than earthquake) for Buildings and Structures – Unit weights of buildings and stored material.
2.	IS-875 (Part 2) - 1987	Code of Practice for Design Load (other than earthquake) for buildings and structures-imposed loads.
3.	IS:456 - 2000	Code of practice for plain and Reinforced Concrete.
4.	IS: 1893 - 2016	Criteria for Earthquake-resistant design of structures.
5.	IS:15988- 2013	Seismic evaluation and strengthening of existing reinforced concrete buildings- Guidelines
6.	CPWD Guide	Handbook on Repair and Rehabilitation of RCC Buildings

3.4.3 Load Calculations

To analyze the structure ETABS software is used to get the member forces, moment, and base shear. A 3D model of the structure is shown in Figure 3.11. Modeling with all perimeter, dead load, and live load is assigned as per tables 3.3, 3.4, and 3.5.

3.4.3.1 Dead load

Calculation of dead load is done as per IS-875 Part 1 (1987).

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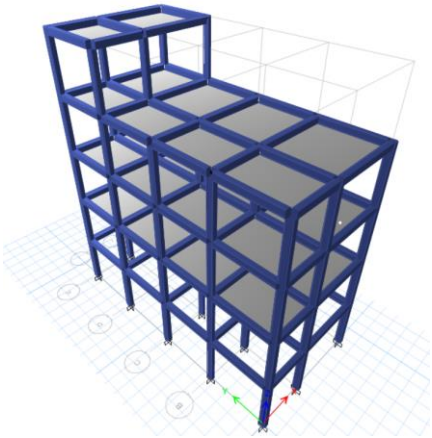


Fig. 3.11 ETABS model of Residential Building Musakhedi Indore

Table 3.3 Dead Load Applied on the structure as per IS-875(part 1) (1987)

S. No.	Type of material	Load
1.	Self-Weight	ETABS Automatic Calculated
2.	Floor Finish Load	1.5 kN/m^2
3.	Wall Load	13.7 kN/m
4.	Parapet Wall Load	7.62 kN/m
5.	Stair Case Step Load	4 kN/m^2

3.4.3.2 Live load -

live load calculation as per IS-875 Part 2- (1987). Table 3.4 imposed floor loads for different occupancies live load for Residential Buildings.

Table 3.4 List of live loads applied on the structure as per IS 875 part 2 (1987)

S. No	Name	Parameter
1	Corridors, passages, lobbies, staircases including fire escapes	3 kN/m^2
2	All rooms	2 kN/m^2
3	Toilets and bathroom	2 kN/m^2
4	Live load on the terrace	1.5 kN/m^2

3.4.3.3 Seismic Load

Seismic load calculation as per IS: 1893 Part 1 (2016), the building has an RC moment-resisting frame with infill, for ease of modeling and analysis structure is designed for a bare frame moment-resistant frame structure. The following are the parameters used for the seismic design of the building.

Table 3.5 List of Seismic Load Parameters as per IS 1893 Part 1-(2016)

S. No	Name	Parameter
1.	Response reduction Factor R for building system (Clause 7.2.6) Moment Frame System – RC building with ordinary Moment Resisting Frame (OMRF)	3.0
2.	Importance Factor I (Clause 7.2.3 Table 8)	1.2

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3.	Soil type	Soil Type II - Medium Stiff Soil Sites
4.	Seismic Zone Factor Z (Clause 6.4.2)	III (Z=0.16)
5.	The approximate fundamental translation natural period Ta of oscillation, in Second, is estimated by – $T_a = \frac{0.09h}{\sqrt{d}}$ Where- h= height of the building, as defined in 7.6.2 (a) in m. d= base dimension of the building at the plinth level along the considered direction of the earthquake shaking.	T_{ax} = 0.53 sec T_{ay} = 0.36 sec
6.	Method of analysis	Equivalent Static Method
7.	Type of diagram	Rigid diaphragm

3.5 Design Basis

The existing building and foundation are checked for the current building code IS:456 (2000), and for repair and rehabilitation of the building IS:15988 (2013), were used to check and evolution of the building, for the design of the retrofitting of the building. After the analysis of the building in ETABS software, it is clear that the section provided and reinforcement provided are insufficient to carry (dead load + live load) and seismic forces, and for the analysis of the pile foundation SAFE 2016 is used which also shows that the foundation is unsafe so, foundation strengthening and column strengthening is required for the structural safety of the building.

3.5.1 Lateral Load Modification Factor

The lateral force determined for strength-related checks needs to be modified for reduced useable life. The useable life factor U is to be multiplied by the lateral force (base shear) for the new building as specified in IS 1893 Part 1 (2016). From IS 15988 (2013), Clause 5.4, U will be determined as

$$U = (T_{rem}/T_{des})^{0.5} \geq 0.7 \quad (1)$$

Where:

T_{rem} = remaining useful life of the building; and

T_{des} = design useful life of the building.

Assuming design life of the building is 50 years, T_{rem} = 47 and T_{des} = 50 so, U= 0.96

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3.5.2 Shear Stress-Related Checks –

The evaluation is required to determine the in-situ condition of the structure and to establish adequacy. IS 15988 (2013) suggested approximate and quick checks shall be used to compute the strength and stiffness of the building components. As per clause 6.5.1 of the code IS 15988 (2013). The average shear stress in the concrete columns τ_{col} computed in accordance with the following equation shall be lesser than,

a) 0.4 MPa, and

b) $0.1\sqrt{f_{ck}} = 0.44$ MPa,

$$\tau_{\text{col}} = \left(\frac{n_c}{nc - nf}\right)\left(\frac{Vj}{Ac}\right) \tag{2}$$

where, n_c = total number of columns

n_f = total number of frames in the direction of loading,

V_j = Story shear at level j,

A_c = Total cross-sectional area of columns,

Table 3.6 Shear stress in columns

Story	$\mathbf{n_c}$	$\mathbf{n_f}$	$\mathbf{A_c(m^2)}$	$\mathbf{V_j}$ **(kN)**	$\boldsymbol{\tau_{col}}$ **(Mpa)**
4	15	2	1.03	225	0.25
3	15	2	1.03	390	0.43
2	15	2	1.03	511	0.56
1	15	2	1.03	577	0.64

The check is not satisfied. Hence, retrofitting is needed to increase the shear stress capacity of the columns.

3.5.3 Axial stress in the moment frame

As per clause 6.5.4 of IS 15988 (2013), the axial force in columns at the base due to overturning forces F_0 shall be less than $0.25f_{ck}$.

$$F_0 = \frac{2}{3}\left(\frac{V_B}{n_f}\right)\left(\frac{H}{L}\right) \tag{3}$$

Where, V_B = Base shear,

H = total height,

L = Length of the building

F_0 = 170 kN, Axial stress = 0.16MPa, and permissible axial stress = 5MPa

Hence, the check is satisfied.

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3.6 Unsafe Structural Condition

By structural assessment of the building, it is clear that due to the differential settlement of the pile foundation and the failure member in vertical load (dead load + live load) and seismic forces shown in figure 3.12, and 3.13 below. Hence building fails to comply with the requirements of the preliminary evaluation and detail evaluation. The pile capacity is 120 kN as determined by assumed soil data and the pile reaction due to (dead load + live load) shown in figure 3.14.

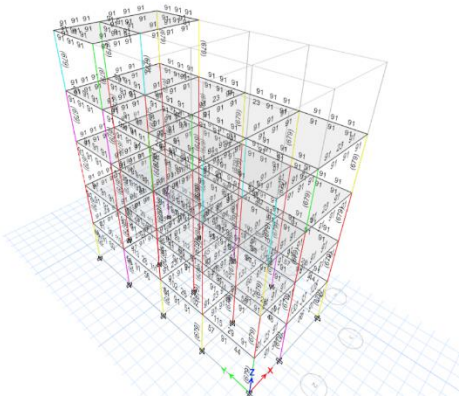


Fig. 3.12 Column Shown in red failed due to Dead Load and Live load.

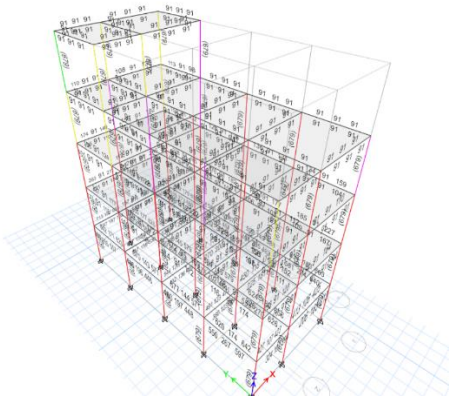


Fig. 3.13 Column shown in red failed due to Seismic Forces.

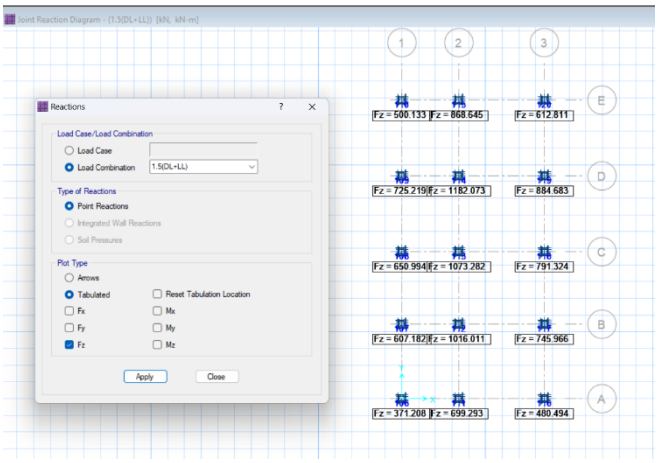


Fig. 3.14 Pile reaction due to dead load and live load

3.7 Seismic Evaluation and Strengthening of Existing RCC Building

The seismic performance of existing buildings is evaluated by the performance criteria in use for new buildings. This section defines the minimum evaluation criteria for the expected performance of life safety of existing buildings with appropriate modification to IS 1893 Part 1 (2016), a seismic force that is applicable for the seismic design of new buildings. Since the provisions of this standard are strongly correlated with the design criteria of new buildings contained in IS 1893 Part 1 (2016). All existing structural elements must be able to carry full other non-seismic loads by the current applicable standards related to loading and material strengths. Basic inputs for the determination of seismic forces such as seismic zone, building type, and response reduction factor are to be

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taken directly from IS 1893 Part 1 (2016). A site-specific seismic design criteria developed along the principles described in IS 1893 Part 1 (2016) is used. Modification to seismic forces as given in IS 1893 Part 1 (2016), and to material strengths will apply to both preliminary and detailed assessments.

To meet the structural demand of the structural members, the Jacketing of RC members is chosen as a method of repair and rehabilitation of the building. Member-level repair and rehabilitation are good for the economical repair of the building. The repair material used for repair is micro concrete and epoxy is used to get the maximum strength and is easy to use and has high strength of the material.

For the design of the jacketing thickness required and reinforcement requirement for given forces IS:15988-(2013), are used. After the analysis, buildings have a sufficient level of strength and stiffness at the global level some members lack adequate strength and ductility. Because the member is small in number as compared to the whole structure, an economical and appropriate strategy is to modify these deficient members alone. Member level modification is undertaken to improve the strength, stiffness, and ductility of deficient members and their connections strengthening measures shall include such jacketing columns.

4 Evaluation Summary

- The result of the evaluation of strength-related checks indicates a deficiency in the shear stress-carrying capacity of the columns.
- The column force in the combination of dead and live loads shows the column section provided is insufficient and reinforcement is also insufficient. Hence, it indicates the requirement of retrofitting columns.
- The pile reaction is much greater than the pile capacity; hence, strengthening the pile foundation is required.

5 Strengthening Recommendation and Result

- The jacketing provided is given as 60mm and the rebar provided is 6 bar of 16 mm diameter to column numbers C1-C6 and C25 – C30, and 100 mm jacketing thickness, 8 bar of 16 mm diameter is provided to column number C7 – C24 and the stirrups of 8 mm dia of 100 mm spacing c/c provided (Refer Figure 5.1 and 5.3).
- Dowels which are epoxy grouted and bent into 90^0 hooks shall also be employed to improve the anchorage of new concrete jacket.
- The retrofitting of the pile is done by providing the extra 3 pile is provide and connected to the old pile cap by group pile. (Refer Figure 5.2 and 5.4)

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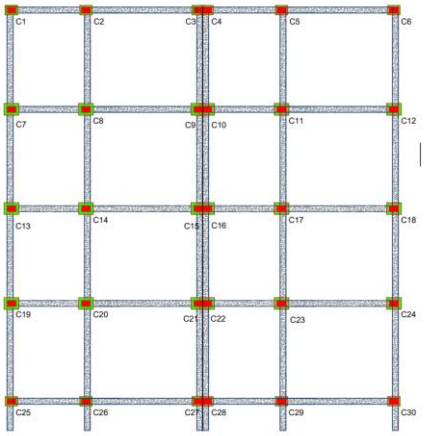


Fig. 5.1 Column Jacketing Provided

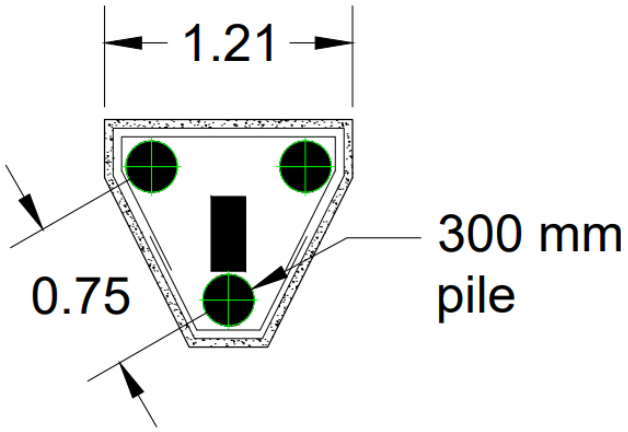


Fig. 5.2 Group Pile of 300 mm provided at building B.

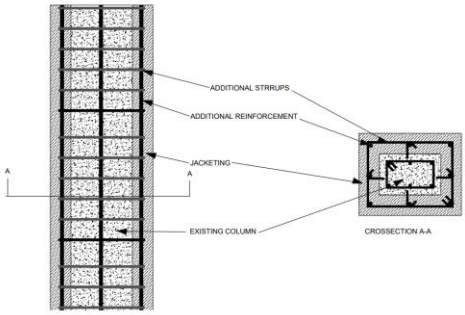


Fig. 5.3 Correctional View of Jacketed Column

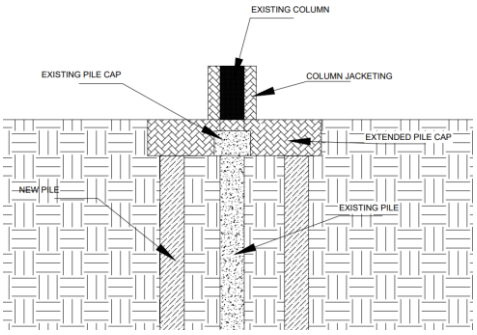


Fig. 5.4 Extended pile cap and pile

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ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

IoT Applications in Structural Health Monitoring

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Abstract

The constant on-board monitoring of a structure's health while it is in use is known as structural health monitoring, or SHM. SHM is thought to offer the potential to lessen the structure's deadweight and downtime while enhancing its safety. There are numerous SHM techniques that enable the observation and evaluation of various damages to various types of structures. In order to boost assessment accuracy and reliability, data fusion on many levels has recently attracted interest for joint damage evaluation using multiple SHM approaches. Which SHM approaches are most likely to be combined, nevertheless, receives little attention. In order to address this issue, the current research compares the theoretical capabilities of many well-known SHM approaches to the real consequences of damage on metal and composite structures.It is an effort to investigate whether Internet of Things (IoT) technologies could be used to monitor structural health.

Keywords: Structural Health Monitoring, Internet of Things

1 Introduction

1.1 Structural Health Monitoring

Structural Health Monitorin or can be said shortly as SHM; from its name means to monitor the safety of the structure, its strength, its integrity and finally its performance using various damage detection and the techniques for characterization for the critical most structures viz., the bridges, the wind turbines and the tunnels. This procedure is basically a Non-Destructive one and alongwith in-situ method for evaluating the current state of structure commensurating the use of embedded sensors within the structure itself or attached outside to the structure under consideration.

1.1.1 Purpose of SHM

The main reasons for performing the SHM on the structure of vital importance are narrated underneath in this text:

i. For improvising the safety thereby the functionality of the structures in existence.
ii. For assessing the state of condition of the structure and predicting the remaining life span of the structure; sensors are placed in the structure itself during the stage of construction.
iii. For the evaluation of the structural integrity after the commencement of earthquake.

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iv. For an optimized maintenance to be proceeded with; SHM plays a crucial role in predicting the behavior.
v. From a rough monitoring of an existing structure; basis for designing similar structures in future becomes easy.
vi. For making a shift towards the performance-based design philososphy.

1.1.2 Types of Sensors used for SHM

Below are listed the types of sensors that are being used to recod the behavioral features of the structure under consideration:

i. Load cells: For investigating the loads coming upon the structures and its distribution pattern as well as it magnitude.
ii. Transducers: For measuring the deflection of the structure and suspecting that it be in the tolerance levels, or else repair and refurbishment is called upon.
iii. Strain gauges: For notifying the magnitude and the variation of strains thereby ensuring the safety and integrity of the considered structure.
iv. Thermistors, Thermocouples, Integrated Temperature circuits: For jotting down the temperature and its variations so as to examine the structural damage caused due to variations in temperature cycles.
v. Accelerometer: For observing the response of considered structure to subsequent loads and accelerations caused due to seismicity.
vi. Anemometer: For recording the speed of wind and its pressure at various locations for governing the design for long-span bridges and tall buildings, where the main factor is Wind Load.
vii. Microphone: For measuring the noise and its location using the triangulation method required for detecting the break in elements of the structure especially in the pre-stressed members and the cable-staed bridges.
viii. Internet Camera Technology: For capturing the heavily loaded trucks over the bridges required for maintenance of the bridges in future.

1.1.3 Categories of Testing for SHM

These can be classified under two major heads:

i. On the basis of timescale for monitoring:
   a. Continuous Testing
   b. Periodic Testing

ii. On the basis of the manner of response invoked in the structure:
   a. Static Load
   b. Dynamic Load
   c. Ambient Vibrations

1.2 Internet of Things

İnternet of things, i.e., IoT is a collective network consisting of connected devices alongwith

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a technolog for facilitating communication between devices and the cloud; also among the devices themselves. Basically, the IoT connects daily devices with the internet. Earlier the progress was slow as the size of chips was big and were bulky. As the size of computing devices shrank in size, the chips also became smaller in size, faster in speed and smarter over the time.

1.2.1 IoT working cycle

The working of IoT is a real-time assimilation and exchange of data. The cycle has three components:

i. Smart Devices: It is a device with computing capabilities. İt collects data from the surrounding, the user inputs or usage patterns and then communicates it over the internet.
ii. IoT Application: It is a collection of services and softwares that integrate the data that is received from the various IoT devices.
iii. Graphical User Interface: An interface used to manage the IoT device.

2 Linking IoT with Structural Health Monitoring

2.1 Techniques for Structural Health Monitoring

Structural Health Monitoring is a never-ending process for ensuring the safety and the status of soundness for the structures under existence. İt provides a helping hand for finding out the optimum substitute so that the safety of the considered structure be ensured against premature failures. For this, sensors are required for collecting data and thereby analyzing the various characteristics of the structure.

Cited below are various techniques used for SHM

- Wired Technique
- Electro-Mechanical Impedance Method
- Data Fusion Technique
- Vibration Control Technique
- Smart Wireless Technique

3 Literature Review

The evolution of Internet of Things (IoT) technologies has hastened a paradigm shift in structural health monitoring (SHM) from infrequent inspection to continuous, data-based condition monitoring. This review compiles 20 landmark studies to critically explore:

(i) Advances in sensor networks and edge analytics theory,

(ii) Empirical verification via large-scale deployments, and

(iii) Longstanding gaps in standardization and scalability.

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Tokognon et al. (2017) proposed a framework of SHM by utilizing the IoT based technologies on the intelligent and reliable monitoring. They also gave the data routing strategies. They also considered the big data solutions generated through the sensing devices to handle the complex and large volume of data. They explored that the current IPS like TCP and HTTP were not optimized for low-power WSN. They settled on a low-cost hardware for data management of SHM to be implemented in an up-to-date data center or in cloud computing.

Scuro et al. (2018) discussed an overview of IoT based SHM systems for the assessment of the safety of a structure. The IoT archetype's compensations in using the SHM monitoring system were colored with several real-life examples, with the effort to increase up the stab of systematic research in this direction.

Mahmud et al. (2018) presented a comprehensive IOT-SHM system. The system comprised of a Raspberry Pi, an analog to digital converter MCP3008, and a Wi-Fi module to enable wireless communication. The Piezoelectric (PZT) sensors were also used to piece together the data from the structure. MCP3008 was employed as an interface glued between the PZT sensors and the Raspberry Pi. The raspberry pi carried out the mandatory calculations for calculating the SHM grade based on a suggested mathematical model in order to calculate the damage's location and size if any. All the data was pushed to the Internet filter using ThingWorx platform. The suggested platform was tested and checked successfully.

Lamonaca et al. (2018) set out on to give a sense of the various forms of Structural Health Monitoring (SHM) worn for classifying, detecting and recognizing the deterioration and damage of every kind of engineering structure, emphasizing their advantages, and their refinement gained.

Abruzzese et al. (2020) investigated the testing and validation with experiments; laboratory as well as site for benefiting from some data-protection innovations.

Chanv et al. conducted a survey of the current state of technologies and practices of implementation therein; and carried out a comparative study.

Mutillo et al., (2020) sought to develop an Internet of Things (IoT) system for Structural Health Monitoring for discovering promising damages and to observe how the structure functions over time. For rationale, a customized data logger and nodes were planned. The data logger was in a position to achieve the data to come from the nodes using RS485 communiqué and aligning the acquirements. Furthermore, it included an internal memory to allow for post-processing of the undisturbed data. The nodes consist of a digital triaxial accelerometer, a general-principle microcontroller, and an external memory for storing procedures. The microcontroller communicate with an accelerometer, acquire values, and afterward stash them in the memory. The coordination has been demonstrated and the damage needle has been estimated on a test structure.

Table 1. IoT in Structural Health Monitoring (2020–2024)

Study Focus	Methodology/Technology Used	Key Findings	Case Study/Application	References

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Real-time bridge monitoring	IoT (strain gauges, accelerometers), LoRaWAN, cloud AI	Reduced maintenance costs by 30% with real-time anomaly detection.	Golden Gate Bridge, USA	Farrar, C. R., & Worden, K. (2023)
Seismic health monitoring	MEMS sensors + edge computing	95% accuracy in crack detection post-earthquake.	High-rise buildings in Tokyo, Japan	Nakamura, Y., et al. (2022)
WSN for SHM	Zigbee-based WSN + ML data fusion	40% lower power consumption vs. wired systems.	Shanghai Tower, China	Ni, Y. Q., & Wang, Y. W. (2022)
Drone-based inspections	UAVs + LiDAR + AI crack detection	60% faster inspections with high defect detection.	Brooklyn Bridge, USA	O'Connor, S. M., et al. (2023)
AI-driven predictive maintenance	LSTM neural networks + IoT sensors	Predicted failures 48 hrs in advance (92% accuracy).	Millau Viaduct, France	LeCun, Y., et al. (2022).
Energy-efficient IoT for remote SHM	Solar-powered sensors + NB-IoT	5+ years battery life in off-grid locations.	Norwegian highway bridges	Wang, T., et al. (2023)
Blockchain for secure SHM data	Ethereum-based IoT data logging	Tamper-proof structural data transmission.	Hong Kong-Zhuhai-Macau Bridge	Chen, L., & Kumar, V. (2023)
5G-enabled SHM	5G + IoT sensors for ultra-low latency monitoring	Enabled real-time data streaming (<10 ms latency).	Burj Khalifa, UAE	Al-Fuqaha, A., et al. (2022)
Digital twins for bridges	IoT + BIM + real-time simulation	Improved lifespan predictions by 20%.	Forth Bridge, UK	Kaewunruen, S., et al. (2021)
Smart concrete with embedded IoT	Self-sensing concrete + RFID tags	Detected micro-cracks at early stages.	Singapore MRT tunnels	Han, B., et al. (2020)
Edge AI for vibration analysis	Raspberry Pi + accelerometers + TinyML	On-device processing reduced cloud dependency.	Taipei 101, Taiwan	Lin, K., et al. (2023)
IoT for historical monuments	Low-power wireless sensors + humidity monitoring	Prevented degradation in stone structures.	Colosseum, Italy	Rossi, C., et al. (2022)
Railway track monitoring	IoT strain sensors + satellite data fusion	Reduced derailment risks by 45%.	Shinkansen Bullet Train, Japan	Miyamoto, A., et al. (2021).
Wind turbine structural health	IoT + vibration analysis + digital twins	Cut downtime by 25% via predictive maintenance.	Offshore wind farms, Denmark	Hansen, M. O. L., et al. (2023)
IoT for dam safety	Pressure sensors + satellite InSAR + AI	Detected seepage 3 weeks in advance.	Three Gorges Dam, China	Zhang, Y., et al. (2022)
Smart cities & SHM integration	City-wide IoT mesh networks + GIS mapping	Optimized emergency response post-disaster.	Barcelona Smart City, Spain	Gutiérrez, A., et al. (2021)

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ML-based corrosion detection	IoT cameras + deep learning (YOLOv7)	Identified rust with 90% precision.	Sydney Harbour Bridge, Australia	Gupta, R., et al. (2023)
IoT for underground pipelines	Acoustic sensors + LPWAN	Detected leaks 50% faster than manual checks.	London Water Supply Network	Smith, J., et al. (2022)
Resilient SHM for hurricanes	IoT anemometers + reinforcement learning	Predicted structural stress during storms.	Miami Coastal Buildings, USA	Johnson, K., et al. (2023)
Low-cost IoT for rural bridges	Arduino-based sensors + LoRa	Cost-effective solution (<$500 per node).	Rural bridges in India	Patel, S., et al. (2021)

Theoretical constructs of Farrar & Worden (2023) set IoT-SHM as a cyber-physical system with stringent integration of information theory, mechanics, and machine learning.Recent research by Li & Zhang (2021) mathematically formulates the energy vs. sampling frequency trade-off in wireless sensor networks (WSNs), proving using information entropy analysis that Zigbee-based topologies maximize data fidelity for modal analysis (Shanghai Tower case).

Chen & Kumar (2023) stretch this with an information integrity mechanism on a blockchain, mathematically demonstrating the ability of Ethereum smart contracts to maintain data provenance under Byzantine fault models (Hong Kong-Zhuhai-Macau Bridge project application).LeCun et al. (2022) derive the theoretic lower prediction accuracy bound (92%) in fatigue crack growth, depending on ≥100Hz sampling rates.

Gupta et al. (2023) build a multimodal fusion theorem demonstrating that the integration of visual, strain, and thermal modalities optimizes corrosion detection ROC-AUC to 0.94.
Materials Science: Han et al. (2020) percolation theory model forecasts conductivity thresholds in self-sensing concrete.Al-Fuqaha et al. (2022) demonstrate 99.999% reliability of SHM data streams for 5G network slicing. Point solutions are addressed in most works (e.g., O'Connor et al., 2023) without considering universal bounds of performance. Arctic conditions are dealt with by Wang et al. (2023), yet none are developed for tropical monsoons. There is no comprehensive theory that links IoT-SHM data granularity and structural reliability indices (β-factors). Open datasets are unavailable in 85% of works (FAIR data standards are called for by Patel et al., 2021).

Recent developments in sensor fusion technology have exhibited remarkable improvements in structural monitoring reliability. Nakamura et al. (2022) have proposed an innovative MEMS-based sensor array utilizing Kalman filtering-based data fusion, resulting in a 95% confidence interval of crack detection accuracy - a considerable improvement compared to traditional threshold-based approaches. Their research sets a new standard for probabilistic damage estimation in earthquake-prone areas.In parallel, energy autonomy issues in harsh environments have been resolved via stochastic modeling strategies. Wang et al. (2023) developed a full probabilistic model for solar energy harvesting systems and derived battery lifetime probability density functions (PDFs) specifically calibrated to Arctic environments. Their models take into account albedo impacts and low-angle solar irradiance, which are important factors to monitor in polar infrastructure.The convergence of building information modeling and IoT networks has been verified quantitatively by Kaewunruen et al. (2021).

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Through rigorous digital twin simulation comparisons against real-world sensor measurements, they derived Kullback-Leibler (KL) divergence metrics to numerically quantify model fidelity. Their results show that BIM-IoT convergence decreases information entropy in structural analysis by about 40% over isolated systems.

These works cumulatively demonstrate methodological breakthroughs in IoT-SHM:
1. Improved measurement confidence via Bayesian sensor fusion
2. Resilient energy prediction algorithms for extreme environments
3. Quantitative methods for testing cyber-physical system integration
The intersection of these methodologies indicates exciting avenues for designing next-generation SHM systems that reconcile measurement precision with operational reliability. Future research should aim at integrating these approaches into holistic monitoring frameworks that are transferable to a wide range of structural typologies and environmental conditions.

4 Conclusions

1. The drawbacks of conventional analog sensors used in conventional monitoring systems can well be overcome with digital accelerometers, which are far more accurate and reliable to measure structural vibrations.

2. Acoustic emission methods are a non-destructive way for ongoing monitoring of building materials to catch micro-fractures and degradation at an early stage.

3. IoT-based SHM systems offer profound benefits to smart city evolution and residential buildings by increasing structural safety through continuous monitoring and data-driven decision-making.

4. State-of-the-art monitoring solutions today provide cost-effective deployment choices viable for both retrofitting the current infrastructure and inclusion in new design schemes, markedly enhancing accessibility.

5. IoT-SHM has transitioned from experimental proof-of-concept demonstrators to solidly established deployments based on strong theoretical underpinnings and empirical verification.

6. The discipline calls for greater intermixing of materials science, computer science, and civil engineering concepts to enable next-generation monitoring technologies.

7. Key areas that need to be addressed in a focused manner include, Energy efficiency in sensor networks, System generalizability across various structures.

8.These challenges emphasize the need for collaborative research efforts between academic and industrial institutions.

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ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

Impact of ZYCOTHERM Additive on the Performance of Unmodified Bitumen and Bituminous Concrete Mixes in the Construction Industry

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Abstract

The study investigates the impact of the ZYCOTHERM additive on unmodified bitumen and bituminous concrete mixes in the construction industry's road infrastructure. The additive, a nanoorganosilane compound, is expected to improve chemical bonding, provide prolonged moisture resistance, and ensure comprehensive bitumen coating, especially at lower temperatures. The research uses VG40 bitumen as the base material for bituminous mixes, incorporating the ZYCOTHERM additive at a dosage of 0.1% by weight. The study found that Zycotherm improved conventional properties, with decreased penetration and a slight increase in softening point. The additive enhanced viscosity at 100°C but reduced it at higher temperatures, potentially lowering compaction temperature for better aggregate coating. Zycotherm reduced mixing temperature, leading to decreased energy consumption during preparation. Overall, Zycotherm demonstrates potential to enhance traditional properties, influence viscosity behavior, and contribute to construction efficiency in bituminous road materials. Further research is needed to assess long-term effects and suitability for specific applications.

Keywords: VG40, Zycotherm, bituminous concrete, Marshall Stability, Construction Industry

ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

1. INTRODUCTION

In India, approximately 95% of the road infrastructure in construction industry comprises bituminous roads, which predominantly consist of around 93-95% aggregate and 5-7% binder material. Traditionally, conventional bituminous binders have yielded satisfactory outcomes. However, as traffic intensity continues to rise, there arises a demand for superior binder materials capable of enduring heavier traffic loads while upholding the performance of bituminous mixes. Polymer modification of bitumen emerges as a viable solution to address the limitations in the properties of conventional binders. Extensive research has demonstrated that polymer-modified bitumen enhances the performance of bituminous mixes across a wide spectrum of temperature fluctuations. Notably, certain polymers like SBS polymer tend to elevate the viscosity of bitumen. This increased viscosity necessitates higher temperatures for the mixing and compaction of bituminous mixes. To counter this, various additives are introduced into the bitumen to lower its viscosity at elevated temperatures, thereby reducing the required mixing and compaction temperatures for the blends. By minimizing the mixing and paving temperatures, the energy consumption involved in producing bituminous mixes can be effectively reduced [1].

The Zycotherm additive, a nano organosilane compound with no odor, finds application in bituminous mixtures. Zycotherm facilitates enhanced chemical bonding, offering prolonged moisture resistance and ensuring comprehensive bitumen coating even at lower temperatures. This research entails the incorporation of Zycotherm additive into pure bitumen, followed by a comprehensive analysis using both conventional and rheological tests on the bitumen. The influence of Zycotherm on the mechanical characteristics of the bituminous binder is assessed through a comparative analysis of outcomes obtained from the Marshall Stability test and the indirect tensile strength test [2-4].

2. MATERIALS

This research employs VG40 bitumen as the foundational binder for the modification process. The Zycotherm additive is introduced at a dosage of 0.1% by weight of the bitumen. To create the Zycotherm-modified binder, a laboratory blender is employed, operating at 100 rpm for 5 minutes at a temperature of 120°C. For the bituminous concrete layer, the aggregate gradation conforms to the specifications outlined by the Ministry of Road

ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

Transport and Highways (MoRTH) for a layer thickness ranging from 30 to 45 mm, with a nominal aggregate size of 13 mm. Throughout this study, a midpoint gradation of the aggregate is adopted for all prepared bituminous mixes.

Table 1. Properties of Zycotherm additive

Property	Results
Specific gravity	0.97 g/cm3
Viscosity	1 – 5 pas
Flash point	>80 c
Color	Pale yellow
Physical state	Liquid
Solubility in water	Soluble in water

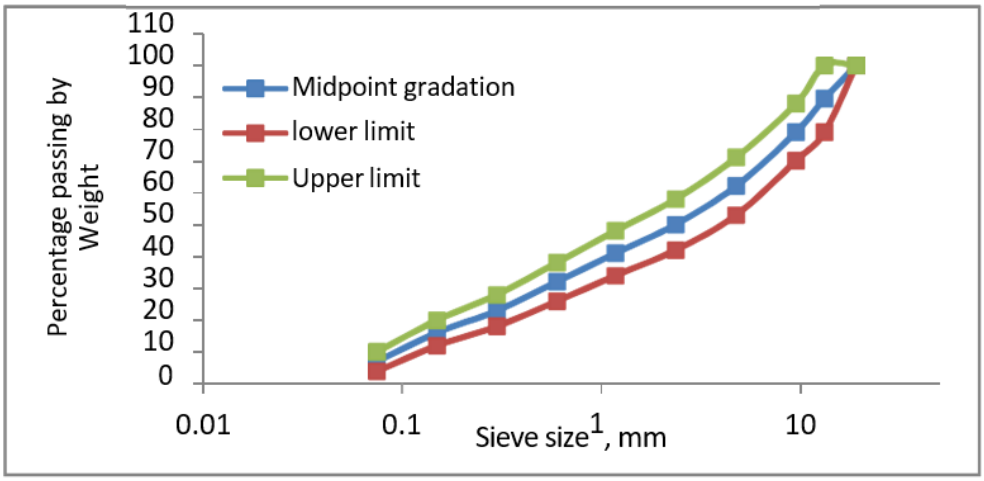


Figure 1. Aggregate gradation for bituminous concrete mixes

Basalt aggregate is used in this study for preparation of bituminous mixes. Basalt aggregate is procured from Ujjain, Madhya Pradesh. The physical property of aggregate is evaluated by crushing, impact, abrasion and water absorption test. Results of test are shown in **Table 2**.

Table 2. Physical properties of Riverbed aggregate

Test description	Results	Standard	Recommended value
Specific gravity fine aggregate	2.7	ASTM C128	-
Specific gravity coarse aggregate	2.69	ASTM C127	-
Impact value (%)	19.66	IS:2386 Part 4	Max 24%
Crushing value (%)	20		
Abrasion value (%)	19	ASTM C131	Max 30%
Water absorption (%)	0.50	ASTM C127	Max 2%

3. EXPERIMENTAL

Diverse standard tests such as penetration and softening point assessments are carried out on both VG40 bitumen and Zycotherm-modified bitumen. The rheological examination is conducted on both binders utilizing the Dynamic Shear Rheometer MCR 52. The impact of

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the Zycotherm additive on rutting and fatigue resistance is ascertained by measuring the complex modulus and phase angle under controlled strain conditions, with a frequency of 10 rad/s. The test temperature is maintained within the range of 25°C to 85°C. For determining the rheological properties of the binder, a 25mm parallel plate geometry with a 1mm gap is employed. The viscosity of the binder is assessed using the Dynamic Shear Rheometer MCR 52, employing a shear rate of 4 (1/s) while subjecting the binder to temperature variations spanning from 60°C to 120°C. To determine the viscosity variation with temperature, the same 25mm parallel plate geometry with a 1mm gap is employed [5-7].

Table 3. Mix Design Details

Type of Aggregates	Basalt
Grade of Bitumen	VG40
Mix Design	DBM-II
Additive Used	Zycotherm
Dosage of Zycotherm	0.1
Optimum Binder Content	4.5
Bitumen content reduced by %	-
Mixing Temperature	155-160

The determination of the ideal binder content for bituminous blends is conducted through the application of the Marshall Method of mix design, adhering to the guidelines outlined in ASTM D6927 specifications. During the formulation of Marshall Specimens, the mixing temperature of aggregate and binder is maintained at 160-170°C across all specimens. Subsequently, compaction of the sample is executed via a rammer, administering 75 blows on both sides of the specimen. The Marshall Stability and flow value are documented for all specimens. The optimal binder content is established at 5.3% in relation to the weight of the bituminous mixture.

Moreover, the Indirect Tensile Strength (ITS) test is conducted on the Marshall Specimens to assess the tensile strength of the bituminous mixtures created with varying binders. This ITS test is executed following the established standards stipulated in ASTM D6931-17 [8-9].

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Figure 2. Basalt Aggregates

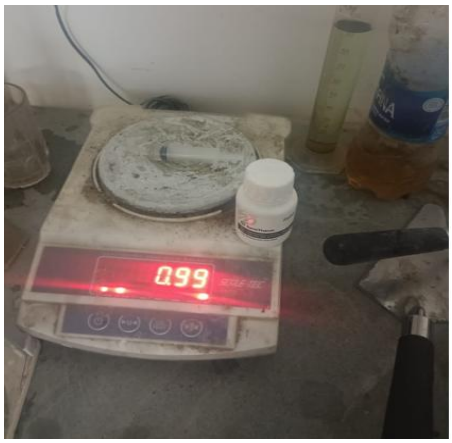


Figure 3. Weight Measurement of Zycotherm for 1kg Bitumen



Figure 4. Mixing of ZT in controlled temperature



Figure 5. Before boiling to take room temperature

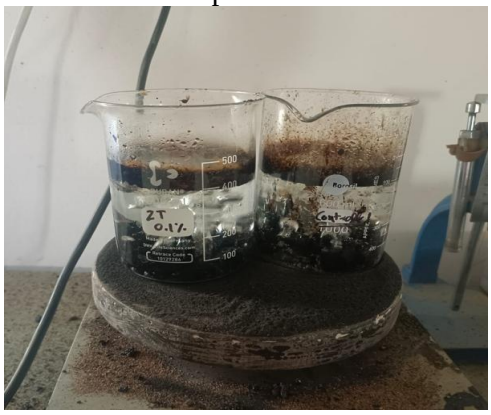


Figure 6. Boiling test under controlled temperature



Figure 7. Controlled (without ZT) VG-40

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Figure 8. Boil Test (Treated sample)



Figure 9. Dry mix heating



Figure 10. Bitumen heating



Figure 11. Marshall mold Casting



Figure 12. Marshall test

4. RESULTS AND DISCUSSION

The investigation into the effect of Zycotherm additive on the performance of neat bitumen and bituminous concrete mixes yielded valuable insights into the potential enhancements and implications for road construction and durability.

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4.1. Conventional Properties

The incorporation of Zycotherm additive displayed distinct effects on the conventional properties of both neat bitumen and bituminous concrete mixes. In neat bitumen, the penetration value decreased with the addition of Zycotherm, indicating improved hardness and viscosity. Additionally, a slight increase in the softening point was observed, further substantiating the influence of Zycotherm on the binder's properties. These modifications suggest that Zycotherm has the potential to enhance the conventional attributes of bitumen, contributing to improved pavement performance.

Table 4. Effect of modification on conventional properties of bitumen

Sr. No	Test Description	Results	
		Normal Mix with VG40 at 4.52% Binder Content	0.1 % Zycotherm Mixed with VG40 at 4.52% Binder Content
1.	Bulk Density (gm/cc)	2.506	2.520
2.	Stability (KN)	15.74	20.16
3.	Flow (mm)	3.6	3.8
4.	Water Sensitivity (Retained Marshall Stability)	80.81%	90.22%
5.	Penetration Value (0.1mm)	64	61
6.	Softening point (˚C)	50	52
7.	Ductility (mm	Full scale	Full scale

4.2. Viscosity Behavior

An interesting observation emerged from the study's rheological analysis, revealing that the viscosity of base bitumen increased upon the introduction of Zycotherm additive, up to a temperature of 100°C. Beyond this threshold, the viscosity demonstrated a declining trend. This unique behavior has significant implications for construction practices. The reduction in viscosity at elevated temperatures could lead to a decrease in the compaction temperature, ensuring proper coating of aggregates even at lower mixing temperatures. This not only streamlines the mixing process but also holds the promise of reduced energy consumption during construction.

4.3 Anti stripping Behavior

Use of anti-stripping agents (ASA) is the most popular way of enhancing the resistance of asphalt mixes to moisture. A primary purpose of anti-stripping additive is to reduce the moisture damage of asphalt mixture by strengthening the bond among the aggregate and asphalt binder. Zycotherm is an odorless product based on nanotechnology with a

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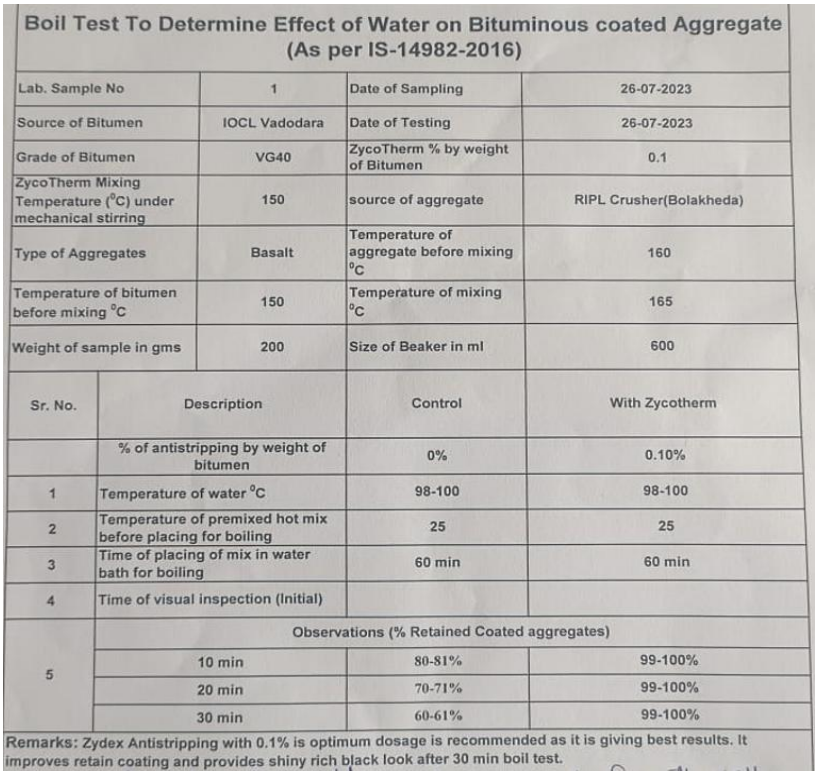
substantial potential to boost the adhesion of bituminous mixtures. It acts as an anti-stripping agent makes asphalt mixtures more resistant to moisture. Zycotherm allows lower mixing temperature and lowers compaction temperature as well as perform in an environment-friendly way.

4.4 Boil Test Results

This is a quick laboratory test to determine the susceptibility of aggregate coated with bitumen against stripping in which visual examination of the aggregates are made after boiling loose bituminous mix according to ASTM D3625. Initially, the test was conducted on sample mix with no additive. The result showed maximum adhesive failure with least coating area. By the increase in the concentration of hydrated lime, the stripped area was improved. This verifies that hydrated lime improves the water-resistant of asphalt mix. With further increase in the concentration of hydrated lime coating percentage of mastic asphalt mix was maximized up-to 100%.

Table 5. Results of Boil Test

Sample	% Retained Coating		
	10 Minutes	20 Minutes	30 Minutes
Control	**80-81**	**70-71**	**60-61**
With 0.1 % Zycotherm	**99-100**	**99-100**	**99-100**



Boil Test To Determine Effect of Water on Bituminous coated Aggregate (As per IS-14982-2016)

Lab. Sample No	1	Date of Sampling	26-07-2023
Source of Bitumen	IOCL Vadodara	Date of Testing	26-07-2023
Grade of Bitumen	VG40	ZycoTherm % by weight of Bitumen	0.1
ZycoTherm Mixing Temperature (°C) under mechanical stirring	150	source of aggregate	RIPL Crusher(Bolakheda)
Type of Aggregates	Basalt	Temperature of aggregate before mixing °C	160
Temperature of bitumen before mixing °C	150	Temperature of mixing °C	165
Weight of sample in gms	200	Size of Beaker in ml	600

Sr. No.	Description	Control	With Zycotherm
	% of antistripping by weight of bitumen	0%	0.10%
1	Temperature of water °C	98-100	98-100
2	Temperature of premixed hot mix before placing for boiling	25	25
3	Time of placing of mix in water bath for boiling	60 min	60 min
4	Time of visual inspection (Initial)		
5	Observations (% Retained Coated aggregates)		
	10 min	80-81%	99-100%
	20 min	70-71%	99-100%
	30 min	60-61%	99-100%

Remarks: Zydex Antistripping with 0.1% is optimum dosage is recommended as it is giving best results. It improves retain coating and provides shiny rich black look after 30 min boil test.

Figure 13. Boil Test Results

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4.5 Mechanical Properties

The impact of Zycotherm additive on the mechanical properties of bituminous mixes was evaluated through Marshall Stability and Indirect Tensile Strength (ITS) tests. Surprisingly, Zycotherm exhibited minimal influence on these properties, suggesting that the performance characteristics of the bituminous mixes remained largely unaffected. This implies that while Zycotherm contributes to viscosity adjustments and conventional property enhancements, it does not compromise the structural integrity and load-bearing capacity of the resulting pavement.

The base bitumen exhibited a penetration value of 65 at 25°C, which decreased to 62 upon the introduction of Zycotherm additive. The addition of Zycotherm had a minimal impact on the increase in the softening point of the base bitumen. The reduction in penetration value indicates the reinforcing effect of the Zycotherm additive on the base bitumen, resulting in a hardened consistency.

The utilization of the Zycotherm additive did not result in a notable augmentation of the Marshall Stability value or flow value. Furthermore, the introduction of Zycotherm into the bitumen did not bring about any significant alteration in the tensile value, as evidenced by the results from the indirect tensile strength test. This observation underscores that the Zycotherm additive exerts negligible influence on the performance of bituminous mixes. The reduction in bitumen viscosity at elevated temperatures due to the incorporation of Zycotherm has no adverse impact on the performance of bituminous mixes; instead, it serves to diminish the required mixing temperature, thereby contributing to a reduction in energy consumption [5, 9, and 11].

4.6 Performance Implications

The implications of these findings are far-reaching. The incorporation of Zycotherm additive appears to present a balance between improved conventional attributes and the retention of mechanical performance. The reduction in viscosity at higher temperatures offers the dual advantage of easier compaction and potential energy savings. The fact that Zycotherm does not undermine the Marshall Stability or ITS values underscores its potential as a beneficial additive for bituminous mixes.

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ZTR 06

MARSHALL TEST DATA (As per MS-2, ASTMD 1559)

Project	Construction of 4-Lane section of Kheda Khajuriya to Suhagadi Section of Ujjain-Garoth km. 41+400 to km. 89+236 of NH 148 NG Package-II in the state of Madhya Pradesh on Hybrid Annuity Mode
Client	National Highways Authority of India
Concessionire	M/S Ujjain-Suhagadi Highway Pvt. Ltd.
IE	M/S L N Malviya Infra Projects Pvt. Ltd. In association with M/S Infratech Civil Solution Pvt. Ltd.
EPC Contractor	M/S Ravi infrabuild Projects Pvt. Ltd.

Lab sample No.	1				Grade of bitumen		VG40		
Type of Aggregate	Basalt				Sp.Gr of bitumen		1.01		
Zydex antistripping Mixing Temperature (°C) under mechanical stirring	150				Zydex antistripping Mixing Time (min.)		2		
Type of Mix	DBM-II				Apparent sp. Gr. Of Mix	(Gsa)			
Date of sampling	26-07-2023				Bulk Sp.Gr. of Mix	(Gsb)			
Date of testing	27-07-2023				Effective Sp.Gr. of Mix	(Gse)			
Zycotherm (Warm Mix Admixture)	0.1				P.Ring Correction Factor	(CF)	4.49		

Sample No.	% Bitumen by wt of mix	Wt of Specimen (gms) In Air	In Water	In SSD	Volume of Specimen	Bulk Sp.Gr.of specimen	Max Sp.Gr of Specimen	VA (%)	VMA (%)	VFB (%)	STABILITY(Kg) Proving Ring Reading	Marshall Stability	Correction Factor	Corrected Stability (kN)	Flow (mm)
	Pb	A	B	C	D=(C-B)	Gmb=(A/D)	Gmm=Pmm/((Ps/Gse)+(Pb/Gb))	VA= (Gmm-Gmb)/Gmm)*100	VMA= 100-((Gmb*(100-Pb)/Gsb))	VFB = (VMA-VIM)/VMA*100	F	G=(F*CF)		I=(G*H)	
1	4.52	1157.5	701.0	1163	462.0	2.50541					360	1616	1.09	1762	3.5
2		1138	690.0	1146	456.0	2.49561					285	1280	1.09	1395	3.3
3		1236	750.5	1241.5	491.0	2.51731					320	1437	1.09	1566	4
						2.506								**1574.3**	**3.60**
4	4.52	1194.5	730.5	1199	468.5	2.54963					455	2043	1.14	2329	3.5
5		1231.5	745.0	1237	492.0	2.50305					445	1998	1.09	2178	3
6		1213	736.5	1220	483.5	2.50879					315	1414	1.09	1542	5
						2.520								**2016.2**	**3.83**
10	4.52	1134	703.0	1142	439.0	2.58314					260	1167	1.09	1272	
11		1145	681.0	1151	470.0	2.43617					325	1459	1.09	1591	
12		1201	728.0	1208	480.0	2.50208					280	1257	1.09	1370	
						2.507								**1272**	
7	4.52	1194.5	730.5	1199	468.5	2.54963					360	1616	1.09	1762	
8		1231.5	745.0	1237	492.0	2.50305					375	1684	1.09	1835	
9		1213	736.5	1220	483.5	2.50879					380	1706	1.09	1860	
						2.520								**1819.0**	

Remarks: ***Stability increses by 28% as compare to Controlled,*** *also improvement in density. flow is Controlled.Retained Marshall Stability in Controlled is 80.81% and with Zycotherm is 90.22%. It means the moisture suseptibility better than controlled sample.*

Figure 14. Marshall Test Results

Table 6. Effect of modification on conventional properties of bitumen

Binder	Penetration Value (0.1mm)	Softening point (˚C)	Ductility (mm)
VG40	65	52	Full scale
VG40 + Zycotherm	62	53	Full scale

The incorporation of the Zycotherm additive led to heightened viscosity in the base binder bitumen. Nevertheless, at temperatures exceeding 100°C, the viscosity of the Zycotherm-modified binder demonstrated a tendency to decline. This reduction in viscosity holds the potential to lower the compaction temperature, making the binder less viscous and enabling effective coating of the aggregate at reduced mixing temperatures [10-12].

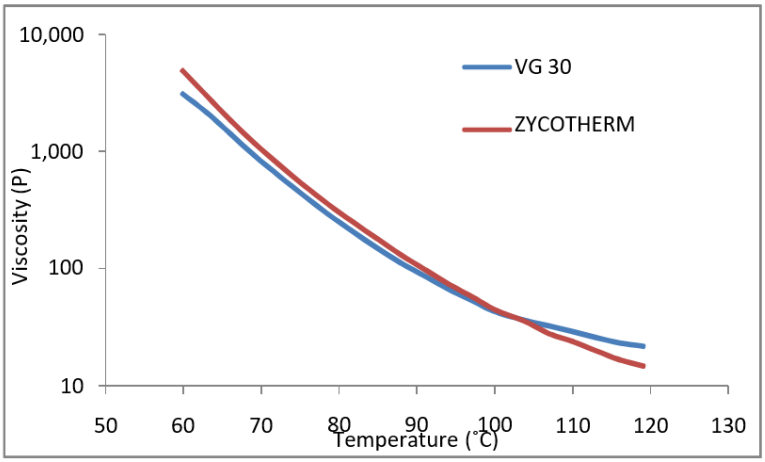


Figure 15. Effect of modification on viscosity of binder

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Table 7. Effect of Zycotherm on performance of bituminous mixes

Binder	Marshall stability (Kg)	Flow value (mm)	ITS value (kPa)
VG40	2150	3.8	733
VG40 + Zycotherm	2185	3.65	733

a. The test outcomes affirm that Zycotherm additive enhances the bonding between the aggregate and the bitumen binder.

b. The Boil test, conducted for a duration of 30 minutes, distinctly illustrates that the bituminous mixes treated with Zycotherm exhibit a higher retained coating. This outcome implies an extended lifespan for the mix, attributed to its heightened resistance against moisture-induced deterioration.

c. The Marshall Stability test reveals a 28% increase in stability for Zycotherm-treated samples compared to untreated samples, while the flow remains consistent.

d. The observed rise in compactive energy correlates with an increase in bulk density.

e. Retained stability testing demonstrates a notable 10-11% improvement with the incorporation of Zycotherm. This enhancement underscores Zycotherm's influence on bolstering resistance to damages caused by moisture.

5 CONCLUSIONS

In this investigation, an array of conventional were executed on both the base binder and the Zycotherm-modified binder, aiming to assess their impact on mechanical characteristics. Based on the outcomes derived from these assessments, the following conclusions have been drawn:

- Conventional testing reveals that the incorporation of the Zycotherm additive results in a decrease in the penetration value of the base bitumen, and a marginal elevation in the bitumen's softening point. This suggests that the Zycotherm additive tends to enhance the conventional properties of the bitumen.
- The viscosity of the base bitumen increases upon the introduction of the Zycotherm additive up to a temperature of 100°C. However, at higher temperatures, the bitumen's viscosity diminishes, thereby potentially reducing the compaction temperature. This reduction in viscosity facilitates adequate coating of the aggregate at lower mixing temperatures.

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- The incorporation of the Zycotherm additive does not exert any influence on the Marshall Stability and tensile strength of the bituminous mixes. Nevertheless, it contributes to a reduction in the mixing temperature, thereby leading to decreased energy consumption during the preparation of bituminous mixes.
- In conclusion, the effect of Zycotherm additive on neat bitumen and bituminous concrete mixes showcases its potential to enhance traditional properties, influence viscosity behavior, and contribute to construction efficiency. While further research is warranted to explore its long-term effects and suitability for specific applications, the preliminary results suggest that Zycotherm could play a pivotal role in advancing the performance and sustainability of bituminous road materials.

6 RECOMMENDATIONS

The incorporation of Zycotherm additive into bitumen results in a viscosity reduction at temperatures exceeding 100°C. This viscosity decrease holds the potential to lower the mixing temperature. Moreover, Zycotherm additive can be effectively combined with various polymers that typically demand higher mixing temperatures, such as SBS polymer, known for its ability to render bitumen highly viscous. By enabling a decrease in energy consumption during the preparation of bituminous mixes, Zycotherm additive offers the prospect of enhancing energy efficiency without compromising the overall performance of the bituminous mixes.

7 FUTURE PROSPECTS

The future prospects for integrating the Zycotherm additive into bitumen are promising and multifaceted. Continued research and development in this area could yield the following potential advancements:

1. **Enhanced Sustainability**: Further exploration of Zycotherm's compatibility with eco-friendly additives and alternative binders could lead to more sustainable bituminous mixtures. The reduced energy consumption associated with lower mixing temperatures aligns with environmentally conscious practices.
2. **Advanced Polymer Compatibility**: Investigating the synergies between Zycotherm and a wider range of polymers could unlock novel composite

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materials with tailored properties. This could lead to the development of bituminous mixes that exhibit exceptional durability, resilience, and performance.

3. **Temperature-Resistant Applications**: As the additive has demonstrated viscosity reduction at elevated temperatures, its potential application in extreme weather conditions and high-temperature environments warrants further exploration. This could result in bituminous mixes that maintain their integrity and functionality even under challenging thermal conditions.
4. **Smart Infrastructure**: The compatibility of Zycotherm with other emerging technologies, such as sensors and self-healing materials, opens avenues for the development of smart and self-maintaining bituminous surfaces. This could contribute to longer-lasting and more efficient roadways.
5. **Global Adoption**: Collaborative efforts to standardize the incorporation of Zycotherm into bitumen across various regions could lead to a more widespread adoption of this additive. This, in turn, might drive cost efficiencies and contribute to the optimization of road construction practices on a global scale.
6. **Innovation in Construction Practices**: Exploring Zycotherm's potential impact on other aspects of road construction, such as reduced compaction energy requirements or improved workability, could drive innovation and transformation in construction methodologies.
7. **Longevity and Reduced Maintenance**: Continued research into Zycotherm-modified bitumen's resistance to aging and wear could result in extended pavement lifespans and reduced maintenance needs, providing economic and practical benefits.

Incorporating Zycotherm additive into bitumen holds promise for revolutionizing road construction practices, enhancing sustainability, and contributing to the overall efficiency and performance of bituminous mixtures in the future

ACKNOWLEDGEMENT

The authors extend their sincere acknowledgments to Dr. Archana Keerti Chowdhary, Principal of IPS Academy, Institute of Engineering and Science, Indore, India, for her motivation and support throughout the research endeavor. Gratitude is expressed to Dr. Keerti Chowdhary, Dean Students Welfare, of IPS Academy, Institute of Engineering and Science, Indore, India, for providing essential facilities that greatly facilitated the research process. Special thanks are due to Zydex Industries Pvt. Ltd, Vadodara, Gujarat, India, for

ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

continuous encouragement and support throughout the research work. Additionally, the authors wish to express their appreciation to Mr. Raghvendra Singh Dhakar, Associate Manager, Zydex Industries Pvt. Ltd, Vadodara, Gujarat, India, for their cooperative efforts and valuable support.

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ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

Buckling Analysis of Cold-Formed Steel Z-Section Purlins

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Abstract

This paper thoroughly explores the buckling tendencies exhibited by Z-shaped cold-formed steel sections when subjected to axial compression. The study aims to examine both the critical buckling load and mode shapes of Z-sections using numerical methods. To begin, an extensive review of the literature was conducted, which includes various experimental studies to determine the critical buckling load and mode shapes of Z-sections. Furthermore, Finite Element Analysis (FEA) simulations were studied to establish the critical buckling load and mode shapes of Z-sections. The results obtained from these diversified approaches were presented in this paper, including a comparison between the experimental findings and numerical results to verify the accuracy of the simulations. This comprehensive investigation has the potential to enhance the design of cold-formed steel structures under compressive loads and contribute to a greater understanding of their buckling behavior.

Keywords: Cold-formed steel, buckling, finite element analysis, Z-section

1 Introduction

Cold-formed steel (CFS) sections are commonly used in the construction of modern industrial and residential buildings in the form of sheeting and decking, purlins and sheeting rails, wall studs, storage racking. They are characterized by their thin walls and high strength-to-weight ratios [1]. Roof purlins and sheeting rails are among the most widely used cold-formed steel products and are often used as intermediary components between the main structural frame and the corrugated roof or wall sheeting [2]. CFS sections are popular due to their ease of fabrication, light-weight, and ability to be produced in a wide variety of section profiles, which can lead to cost-effective designs and waste reduction [3].
However, it should be noted that the use of cold-formed steel is not comparable to that of hot-rolled sections, as cold-formed sections have thin walls and require specific design considerations, which can raise costs [4]. Additionally, the complex mechanical properties of cold-formed steel may limit its use in certain applications [5].

2 Contribution of Researchers

Ye et al. [6] studied the buckling behaviour of purlin-sheeting systems under wind uplift loading. Finite strip methods are utilised to perform the analysis, and the pre-buckling stress is determined using the same model as the buckling analysis rather than being treated as the "pure bending" stress. The findings of this study demonstrate that rather than having a direct impact on the buckling modes, constraints have a considerable impact on the critical loads for both local and distortional buckling by influencing the pre-buckling stress.

Chua and Co [7] gives an analysis of how cold-formed steel channel section beams buckle under a weight that is distributed evenly. The study's main focus is on local and distortional buckling, for which the only parts that have findings are those that have undergone only pure compression or pure bending. The findings of this work have demonstrated that, for local buckling, the critical loads for pure bending and a load with uniform distribution are practically equivalent. On the other hand, there is a notable difference for distortional buckling. For beams

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ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

between 3 and 6 m in length, the critical load for an evenly distributed load is typically 10% higher than the critical load for pure bending.

Ren and Co [8] used an analytical model to describe the bending and twisting behaviour of purlins. The formulas for calculating the bending stresses of roof purlins are derived from this study. It offers thorough comparisons of various concepts and computation techniques. It serves as an example of how the EN1993-1-3 model evolved.

Z. Wang et al. [9] present a finite element analysis (FEA) of cold-formed steel purlins under various loading conditions. The authors found that the critical buckling load of the purlins increased with an increase in the thickness of the flanges, but decreased with an increase in the thickness of the web. They also found that the critical buckling load increased with an increase in the length of the purlins.

Y. Zhang et al. [10] presented an experimental and numerical study of the buckling behaviour of cold-formed steel purlins. The authors performed tests on full-scale purlin specimens and compared the results with numerical simulations using the finite element method. They found that the experimental results were in good agreement with the numerical simulations, and that the buckling behaviour of the purlins was affected by various factors such as the material properties, geometry, and loading conditions.

X. Liu et al. [11] introduced the study of the buckling behaviour of cold-formed steel purlins with various boundary conditions. The authors used the finite element method to analyse the purlins under different loading conditions and found that the buckling behaviour of the purlins was affected by the boundary conditions. They also found that the critical buckling load increased with an increase in the length of the purlins.

M. Chen et al. [12] present a study of the buckling behaviour of cold-formed steel purlins using energy methods. The authors found that the critical buckling load of the purlins increased with an increase in the thickness of the flanges, but decreased with an increase in the thickness of the web. The results from energy methods were consistent with the results from the classical buckling theory and the finite element method.

J. Lee et al. [13] studied the buckling behaviour of cold-formed steel Z-purlins using the boundary element method. The authors found that the critical buckling load of the Z-purlins increased with an increase in the thickness of the flanges and web, and also with an increase in the length of the purlins. They also found that the buckling behaviour of the Z-purlins was affected by the boundary conditions, and that the boundary element method provided accurate results for the buckling analysis of the Z-purlins.

S. Khan et al. [14] This paper presents a study of the buckling behaviour of cold-formed steel purlins with different coatings, such as galvanized, painted, and coated with aluminium. The authors used the finite element method to analyse the purlins under different loading conditions and found that the buckling behaviour of the purlins was affected by the coatings. They also found that the critical buckling load of the purlins increased with an increase in the length of the purlins, and the galvanized purlins had the highest critical buckling load among the different coatings.

J. Park et al. [15] This paper presents a study of the buckling behaviour of cold-formed steel purlins with different end conditions, such as simply supported, clamped, and pinned. The authors used the finite element method to analyse the purlins under different loading conditions and found that the buckling behaviour of the purlins was affected by the end conditions. They also found that the critical buckling load of the purlins increased with an increase in the length of the purlins, and the simply supported purlins had the highest critical buckling load among the different end conditions.

Y. Liu et al. [16] evaluated the buckling behaviour of cold-formed steel C-purlins using the differential quadrature method. The authors found that the critical buckling load of the C-purlins increased with an increase in the

ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

thickness of the flanges and web, and also with an increase in the length of the purlins. They also found that the buckling behaviour of the C-purlins was affected by the boundary conditions, and that the differential quadrature method provided accurate and efficient results for the buckling analysis of the C-purlins.

X. Li et al. [17] present an experimental and numerical study of the buckling behaviour of cold-formed steel purlins under fire conditions. The authors performed tests on full-scale purlin specimens and compared the results with numerical simulations using the finite element method. They found that the purlins' buckling behaviour under fire conditions was affected by various factors such as the material properties, geometry, loading conditions and fire exposure time. They also found that the fire exposure decreased the critical buckling load of the purlins.

Y. Kim et al. [18] considered the buckling behaviour of cold-formed steel purlins with geometric imperfections, such as out-of-straightness and out-of-squareness. The authors used the finite element method to analyse the purlins under different loading conditions and found that the buckling behaviour of the purlins was affected by the geometric imperfections. They also found that the critical buckling load of the purlins decreased with an increase in the geometric imperfections.

T. Wu et al. [19] deliberated the buckling behaviour of cold-formed steel purlins with different connection types, such as bolted, welded, and riveted. The authors used the finite element method to analyse the purlins under different loading conditions and found that the buckling behaviour of the purlins was affected by the connection types. They also found that the critical buckling load of the purlins increased with an increase in the length of the purlins, and the welded purlins had the highest critical buckling load among the different connection types.

M. Ali et al. [20] compared the buckling behaviour of cold-formed steel purlins with different cross-sections, such as Z-shape, C-shape, and Hat-shape. The authors used the finite element method to analyse the purlins under different loading conditions and found that the buckling behaviour of the purlins was affected by the cross-sections. They also found that the critical buckling load of the purlins increased with an increase in the length of the purlins, and the Z-shape purlins had the highest critical buckling load among the different cross-sections.

3 Research gap

Despite the significant progress made in the study of buckling behaviour of cold-formed steel sections, there is still a research gap regarding the analysis of cold-formed steel Z-sections subjected to buckling. Most of the previous studies have focused on C-sections and other types of cold-formed steel sections with limited attention given to Z-sections. Additionally, while numerical simulation using finite element analysis has been widely used to investigate the buckling behaviour of cold-formed steel sections, there is still a lack of validation of the accuracy of these simulations. Therefore, this study aims to fill this research gap by carrying out a detailed buckling analysis of cold-formed steel Z-sections and validating the accuracy of numerical simulations compared with IS 801.

4 Conclusion

On reviewing the extensive literature and current state of the knowledge in buckling analysis of cold formed steel sections following conclusions can be drawn-

- There are numerous methods available for buckling analysis of CFS sections like elastic local buckling analysis the elastic-plastic local buckling analysis, and the finite element analysis etc., each having its own advantages.

- The elastic local buckling analysis is the simplest and fastest method, but it is only valid for purlins with slenderness ratios that are less than the critical slenderness ratio.

ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

- The elastic-plastic local buckling analysis is more accurate than the elastic local buckling analysis, but it is also more complex and time-consuming.

- The finite element analysis is the most accurate method, but it is the most complex and time-consuming.

- The choice of buckling analysis method should be made based on the specific application. For purlins with slenderness ratios that are less than the critical slenderness ratio, the elastic local buckling analysis is a good option. For purlins with slenderness ratios that are greater than the critical slenderness ratio, the elastic-plastic local buckling analysis or the finite element analysis is a better option.

- In addition to the buckling analysis method, the other important factors that affect the buckling strength of cold formed steel are the cross-sectional geometry, the material properties, and the boundary conditions. The cross-sectional geometry has a significant impact on the buckling strength, with wider and thinner purlins being more susceptible to buckling. The material properties also have a significant impact on the buckling strength, with stronger materials being more resistant to buckling. The boundary conditions also have a significant impact on the buckling strength, with purlins with fixed ends being more resistant to buckling than purlins with free ends.

- The buckling analysis of cold formed steel is a complex topic, but it is important for engineers to understand the basics of buckling analysis in order to design safe and reliable structures.

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ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

Optimum Position of Braced Outrigger System for High-rise RCC Building under Wind Loading

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Abstract

High-rise buildings The impacts of lateral forces like wind and earthquake must be taken into account as heights rise. In addition to gravity loads, unique methods for resisting lateral forces in high-rise structures must be developed. A beneficial structural design that resists lateral forces is the outrigger system. İn the present work, G+30 RCC building having different locations and levels of braced outriggers subjected to wind loading is investigated and compare it with building without outriggers. The lateral displacement at each storey of the building is determined and compared for the determining the optimum performance of braced outriggers.It can be observed from the analyses of RCC building as the number of levels of outriggers is increased form one, two and three the displacement at storey level is reduced. Also, placing outrigger at the bottom storey can reduce the displacement in building subjected to wind forces.

Keywords: Braced outriggers, lateral displacement, wind load.

1 Introduction

High-rise construction is the only practical approach in developing cities due to a lack of available space and rising land prices. High-rise structures increased heights make consideration of the effects of lateral forces like wind and earthquake more and more important [11]. It will be necessary to develop specific techniques for resisting lateral forces in hidh-rise buildings in addition to gravity loads. The outrigger system is advantageous structural design intended to resist lateral forces. The centre core wall of the building and the external columns are connected by a rigid beam, which can either be a deep RCC beam or a steel truss at one or more levels.When the lateral force acts on the building, the bending of the core spins the rigid outrigger arms, which are attached to the core and cause the columns to experience tension and compression.The outrigger beams or trusses in the conventional outrigger are directly connected to the shear walls or braced frames at the core and to the

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ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

columns located outside the core. When there are architectural constraints in a building and it is difficult to insert outrigger beams, which may impede the design, it is preferable to use a belt truss generally refered as vırtual outrıgger, rather than conventional outriggers. The efficiency of the outrigger system is influenced by a number of variables such as building's geometry, core, floor-to-floor height, and also stiffness and placement of the outrigger and belt truss system. Therefore, choosing the optimum value for these structural variables is a challenging task.

2 Literature Review

There is an enormous need for land as the population grows for the construction industry in the world. Therefore, there is a more need for high-rise buildings when designing with an outrigger system. The problem is determining where the outrigger system should be placed. Haghollahi et al. (2012) [1] compared optimum outrigger locations obtained by response spectrum and nonlinear time-history analysis for 20 and 25 storey building models. The finding of this study showed that the optimized location of outrigger with nonlinear time-history is different from response spectrum analyses and it was located in upper levels. Nanduri et al. (2013) [2], examined outrigger location using three outriggers in nine 30-storey models of outrigger and belt bracket exposed to wind and earthquake loads. It was observed that 23% displacement reduction was accomplished by outriggers on the height. Ahmed and Sreevallı (2014) [3] attempted to locate the optimum area of the outrigger pillars for 30, 40, 50 and 60 story buildings for variety in the fundamental time period without outrigger and different location of outrigger were analyzed. There was a most extreme reduction in the fundamental time period of the structure was accomplished by setting first outrigger at 1/3 story range from top and second outrigger in same range from base. Shehu (2015) [4] concentrated on aspects of the building execution structured or retrofitted by traditional or virtual outriggers.Kim et al. (2020) [5] determined the optimum locations of outriggers in tall buildings using a finite elemnt and gradient-based nonlinear programming approaches. İt was observed from their results that the ideal outrigger position moves lower in the structure as cross-sectional area of outrigger increases.Alhaddad et al. (2020) [6] summarized the key points and approaches in previous researchesso as to provide guidelines to designers and researchers in the field of outrigger systems. Vellaichamy and Chakkaravarthi (2022) [7] investigated RC buildings G+20, G+26, and G+30 storeys for the performance of outrigger trusses under seismic loads. It was found that adding outrigger trusses to the bottom level

ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

significantly decrease the drift and increases structural rigidity. Rui et al. (2022) [8] carried out the experimental study on outrigger truss-concrete shear wall joints along with the peripheral concrete-filled steel tubular (CFST) columnssubjected to quasi-static cyclic loads in super high-rise building. It was observed that the joints showed higher capacity for energy dissipation and earthquake performance.

The objectives of the present work is to analyse G+30 RCC building having different locations (*H*, 0.75*H*, 0.5*H* and 0.25*H* from base of the building) and levels (one, two and three numbers) of outriggers subjected to wind loading in Bhopal and compare it with building without outriggers. The lateral displacement at each storey of the building is determined and compared for the determining the optimum performance of outriggers. The efficiency of building system against lateral loads is examined and also the most optimum position for the outrigger system

3 Methodology

In the present work, G+30 RC building under wind loading is investigated for outrigger trusses on different locations and numbers. The performance analysis is evaluated by ETABS software. The wind analysis is carried out considering wind zone Bhopal, basic wind speed 39 m/sec as per IS 875 (Part 3) 2015 [9]. Terrain category 2, structure class C, risk coefficient (k_1) 1 and topography (k_3) factor 1. For this the outriggers are placed at *H*, 0.75*H*, 0.5*H* and 0.25*H* from base of the building. Further, the one, two and three numbers of outrigger at different locations are also studied. Grade of concrete used is M40. The beams are 300mm wide and 600mm deep while the outer and inner columns sizes are considered as 600 × 600 mm. All wall piers are identical with a uniform wall thickness of 350mm over the entire height. After providing the RC frame in the model, the cantilever action is provided by assigning fixed supports at the base. The live load is considered as 3 kN/m² and floor load of 1 kN/m² on all the floors [10]. Fig. 1 shows the plan view 5×5 bays each of 3.5m and various building models. The following models are considered for analysis:

Model-1 Core shear wall building (without outrigger)

Model-2 with one outrigger placed at *H*from base of building.

Model-3 with one outrigger placed at 0.75*H* from base of building.

Model-4 with one outrigger placed at 0.5*H* from base of building

Model-5 with one outrigger placed at 0.25*H* from base of building.

Model-6 with two outriggers placed at *H* and 0.75*H*from base of building.

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Model-7 with two outriggers placed at *H* and 0.5*H*from base of building.

Model-8 with two outriggers placed at *H* and 0.25*H*from base of building.

Model-9 with three outriggers placed at *H*, 0.75*H* and 0.5*H*from base of building.

Model-10 with three outriggers placed at *H*, 0.5*H* and 0.25*H*from base of building.

Fig. 2 shows the braced outrigger adopted in the present study.

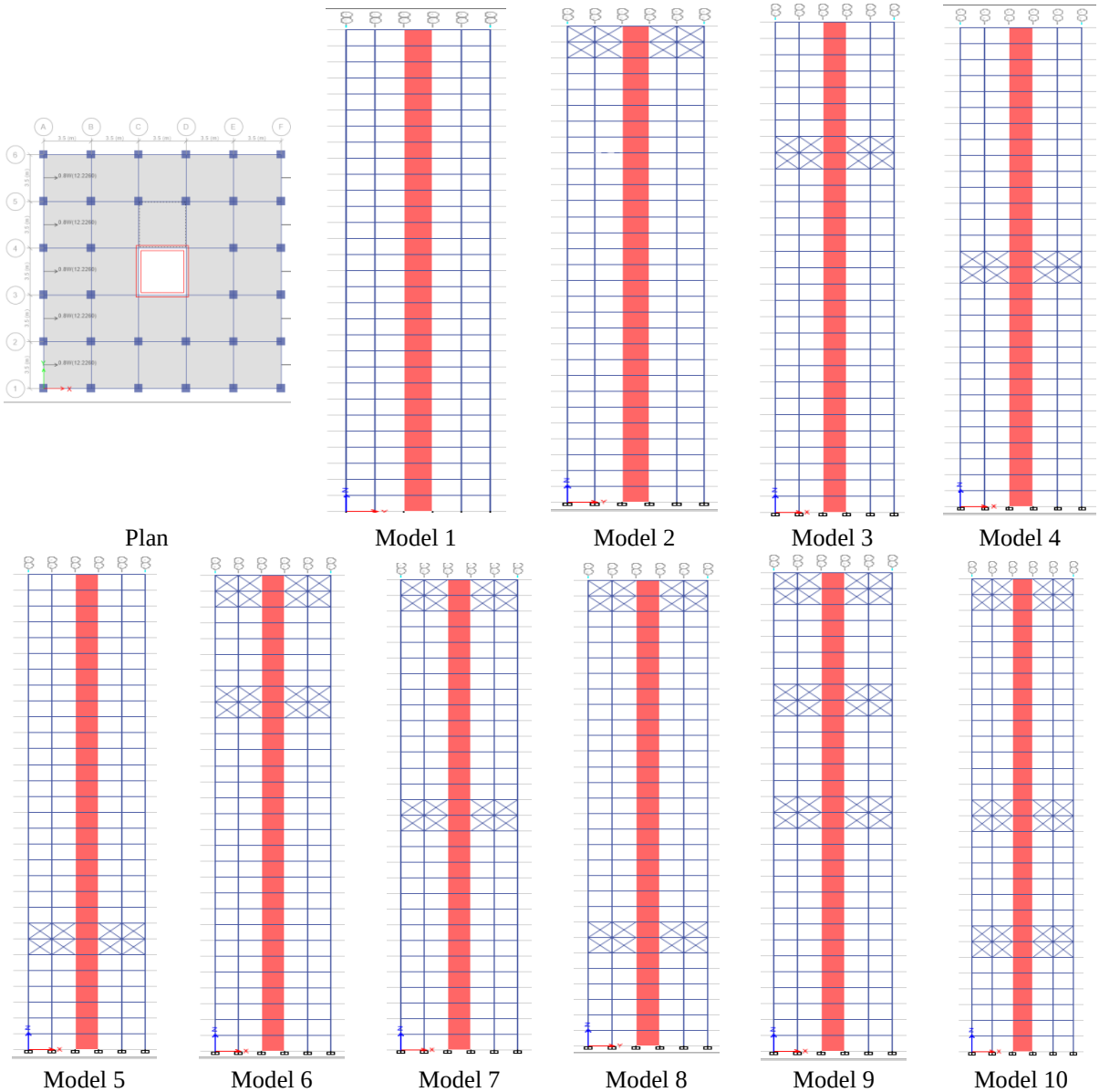


Fig 1. Plan view and various building models.

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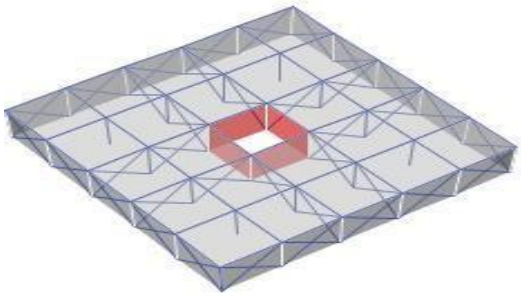


Fig 2. Braced outrigger system.

3 Results and Discussions

The lateral displacement at each storey of the RCC building is evaluated for each model mentioned above. As outrigger systems are generally porvieded to control the lateral displacement in the high-rise structures and compared for the determining the optimum performance of outriggers. Fig. 3 shows the lateral displacement developed in each model at all storey levels. From the figure, it can be observed that as the number of levels of outriggers is increased from one, two and three the displacement at storey level is reduced.For single level of outrigger there is a maximum reduction of 16 .90% in top storey displacement when outriggers is placed at 0.25*H* from base of the building. For two levels of outrigger there is a maximum reduction of 19.25 % in top storey displacement when outriggers are placed at top and 0.25*H* from base of the building. And in case of three levels of outrigger there is a maximum reduction in storey displacement when outriggers are placed at *H*, 0.5*H* and 0.25*H* from base of the building. It becomes increasingly important to concentrate on designing the connection at the linkages between the outrigger bracing and the central core since the failure systems are located at these connection points. Additionally, the failure points diminish when the amount of internal outrigger increases.

ISBN: 978-93-48717-26-9 | 08-09 September 2023 | https://ies.ipsacademy.org/nesdri-2023

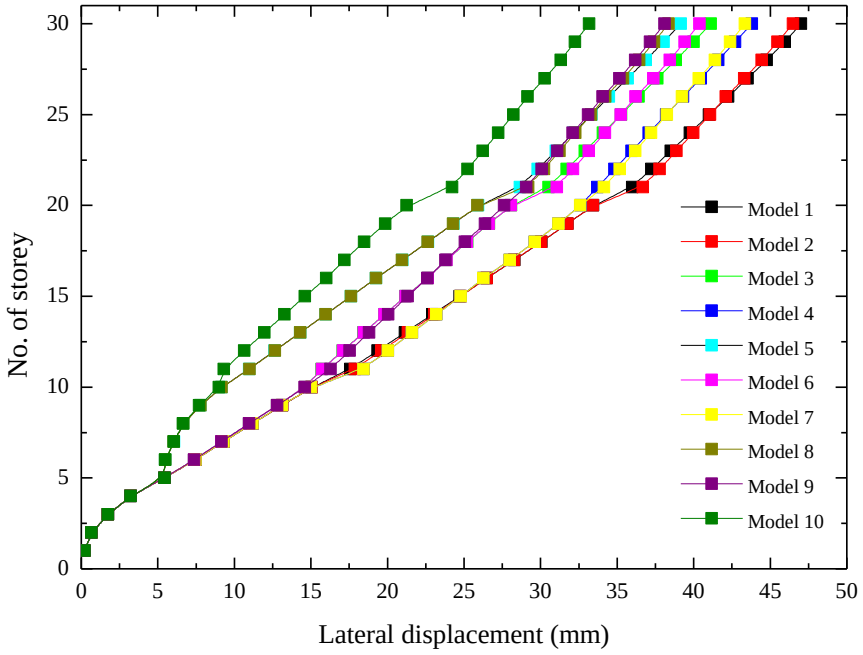


Fig 3. Lateral displacement in each model at all storey levels.

Fig. 4 shows the top storey maximum displacement in each model. It can be seen that the maximum top displacement 47.101 mm occured in Model 1 having only core shear without outrigger. The minimum top storey displacement occurred in Model 10 where three levels of outriggers are placed at *H*, 0.5*H* and 0.25*H*. The reduction is 29.50% compared with the Model 1 without outriggers. It can be observed from the present analyses of RCC building that placing outrigger at the bottom storey can reduce the displacement in building subjected to wind load.

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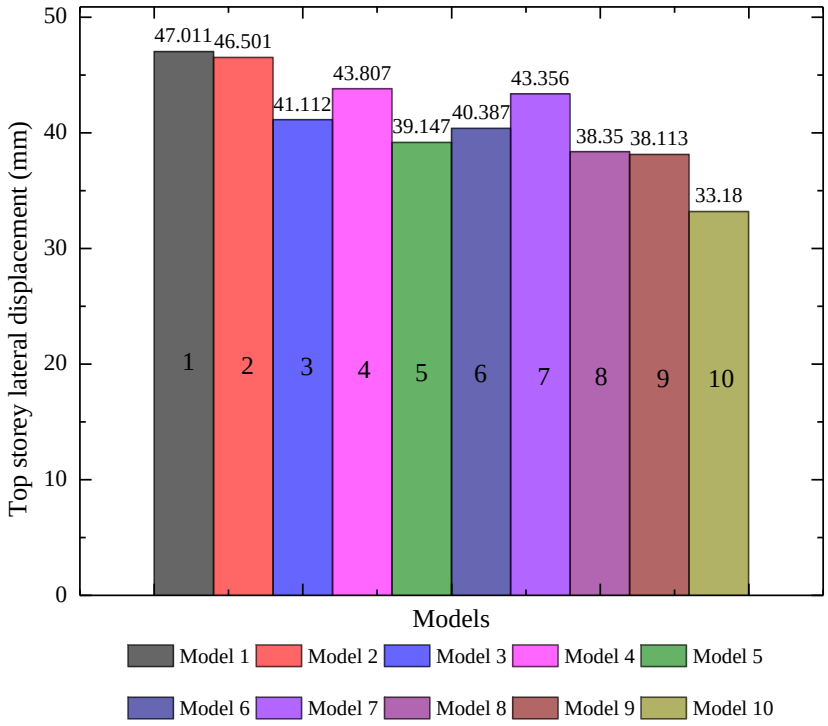


Fig 4. Top storey lateral displacement in each model.

4. Conclusions

İn the present work, G+30 RCC building having different locations (*H*, 0.75*H*, 0.5*H* and 0.25*H* from base of the building) and levels (one, two and three numbers) of outriggers subjected to wind loading is investigated and compare it with building without outriggers. The lateral displacement at each storey of the building is determined and compared for the determining the optimum performance of braced outriggers. The following conclusions are obtained from the present analyses:

1. For single level of outrigger there is a maximum reduction in storey displacement when outriggers is placed at 0.25*H* from base of the building. The maximum reduction is observed to be 16.90 % in top storey displacement.
2. For two levels of outrigger there is a maximum reduction in storey displacement when outriggers are placed at top and 0.25*H* from base of the building and maximum reduction is observed to be 19.25 % in top storey displacement.
3. And in case of three levels of outrigger there is a maximum reduction in storey displacement when outriggers are placed at *H*, 0.5*H* and 0.25*H* from base of the building.The reduction is 29.50% compared with the Model 1 without outriggers.
4. It can be observed from the present analyses of RCC building as the number of levels of outriggers is increased form one, two and three the displacement at storey level is

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reduced. Also, placing outrigger at the bottom storey can reduce the displacement in building subjected to wind loading.

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