STRUCTURAL ENGINEERING DIGEST

TECHNICAL MAGAZINE

VOLUME 2, 2024

Department of Structural Engineering,

Sanjivani College of Engineering, Kopargaon 423603

Our Inspiration

Late Shree Shankarrao G. Kolhe Saheb

Founder, Sanjivani Rural Education Society,

Hon’ble Shri Nitin S. Kolhe
Chairman, Sanjivani Group of Institute Kopargaon

Hon’ble Shri Amit N. Kolhe
Managing Trustee, Sanjivani Group of Institute Kopargaon

Dr. M. V. Nagarhalli
Director

We strive to provide our students with an educational journey that transcends the conventional boundaries of textbooks and classroom learning. Our aim is to foster a well-rounded educational experience that encompasses more than just academic knowledge. Although we face numerous challenges, we are firm believers in the power of dedication and effort to achieve extraordinary results. It's our aspiration to make a meaningful impact in your lives by sharing our insights and knowledge. I'm delighted to engage with you via this Technical Magazine, titled "Structural Engineering Digest”.

I am deeply convinced that offering sincere, committed, and systematic services undoubtedly leads to unmatched success. I want to express my sincere congratulations to everyone who has been instrumental in Sanjivani's accomplishments. My appreciation goes to Team Sanjivani for their steadfast dedication and persistent efforts in providing top-notch education to rural communities. Your commitment is invaluable and plays a significant role in enhancing our community's well-being.

Sanjivani is dedicated to creating an encouraging atmosphere that minimizes competition and encourages the pursuit of excellence, while also nurturing close connections among students to foster friendship and enduring relationships. I express my deepest gratitude to the Structural Engineering department for launching the "Structural Engineering Digest" Technical magazine this academic year. I wish them the best in its successful journey ahead. This innovative approach to showcasing the research work of departmental students is set to have a significant impact on society.

Editor-in-Chief

Dr. Atteshamuddin S. Sayyad

Professor and Head

It is with immense pride and a sense of collective achievement that I address you in the second edition of our very own "Structural Engineering Digest." This magazine is testament to the vibrant academic and research environment fostered at Sanjivani College of Engineering, Kopargaon, under the aegis of the Sanjivani Rural Education Society (SRES).

Since our establishment in 1983, we have been at the forefront of delivering exceptional education in the rural heartlands of Maharashtra. Recognizing the burgeoning demand for skilled professionals in the field of structural engineering both in India and globally, we embarked on an ambitious journey by introducing our B. Tech. and M. Tech. programs in Structural Engineering in the academic year 2020-2021. Our journey over the past three years has been nothing short of remarkable. The department has not only made significant strides in academic excellence but has also marked its presence on the national stage by becoming a lifelong member of the Indian Society of Structural Engineers. This affiliation not only honors our past achievements but also lays a robust foundation for our future endeavors.

At Sanjivani, we believe in a holistic approach to education. Our experienced and highly qualified faculty members have been instrumental in driving this vision, ensuring a blend of rigorous academic curriculum, and engaging extracurricular activities. We are equally committed to contributing to the body of knowledge in structural engineering through fundamental and applied research, alongside offering consulting services that bridge the gap between academia and industry.

As we launch "Structural Engineering Digest," we aim to create a platform for sharingknowledge, discussing innovative ideas, and showcasing the exemplary work of our students and faculty. I encourage each one of you to actively participate in this endeavor, making this magazine a rich repository of knowledge and a beacon for aspiring structural engineers.

I extend my heartfelt congratulations to the editorial team and all contributors for their hard work and dedication in bringing this magazine to life. Let us embark on this exciting journey together, aiming to inspire and be inspired.

Associate Editor

Dr. Hrushikesh N. Kedar

Assistant Professor

Welcome to the second edition of "Structural Engineering Digest" by Sanjivani College of Engineering, Kopargaon. As Associate Editor, I'm proud to launch this magazine, whichis dedicated to the ever-evolving field of structural engineering and aimed at spreading knowledge and sparking innovation among our students and faculty. This publication, a symbol of our commitment to engineering excellence, coincides with our educational strides, particularly with our B.Tech. and M.Tech. programs in Structural Engineering. The magazine will showcase a range of research works by students, faculty, and experts, serving as a stage for our community's creative efforts. Our heartfelt thanks go to everyone involved in this premiere edition, and we look forward to what lies ahead. This publication is more than just a knowledge repository; it's a source of inspiration for future engineers. We invite you to embark on this journey of exploration and learning with us.

Editorial Board

Dr. N. S. Naik

Dr. S. M. Gunjal

Dr. B. M. Shinde

Vision of Department

To Achieve National and International Recognition in Structural Engineering Education.

Mission of Department

To maintain a healthy environment which encourages our students and faculty to achieve their best in education and research

To nurture students as problem solvers who develop innovative solutions for engineering problems.

To create technocrats in the structural engineering profession.

To create engineers who possess the knowledge and skills for future challenges and lifelong learning..

Program Educational Objectives (PEOs)

PEO 1: To impart basic and advanced knowledge of structural engineering so thatgraduates are able to analyze and solve industrial problems.

PEO 2: To provide hands-on training to the graduates on the latest equipment andlatest software to make them suitable for industries and consultancies.

PEO 3: To equip the graduates with basic professional skills to work as a team member or leader for the socio-economic growth of the nation.

PEO 4: To motivate the graduates to pursue research, higher education, and entrepreneurship in the structural engineering field.

Program Specific Outcomes (PSOs)

PSO 1: Graduates will be able to provide the best possible solutions for the analysis and design problems using conventional and modern engineering tools for sustainable development related to structural engineering.

PSO 2: Graduates will be able to identify societal and industrial needs through allied courses such as planning and drawing, infrastructural engineering, projectmanagement, materials, mechanics, etc.

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Student Patents

INTELLECTUAL PROPERTY INDIA
PATENTS | DESIGNS | TRADE MARKS
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सत्यमेव जयते

ORIGINAL
क्रम सं/ Serial No. : 181794

पेटेंट कार्यालय, भारत सरकार The Patent Office, Government Of India

डिजाइन के पंजीकरण का प्रमाण पत्र | Certificate of Registration of Design

डिजाइन सं. / Design No.	:	427042-001
तारीख / Date	:	14/08/2024
पारस्परिकता तारीख / Reciprocity Date*	:	
देश / Country	:	

प्रमाणित किया जाता है कि संलग्न प्रति में वर्णित डिजाइन जो *BRICK LAYING CUM LEVELER TOOL* से संबंधित है, का पंजीकरण, श्रेणी 25-99 में 1.Sanjivani College Of Engineering, Kopargaon 2. Dr. Vignesh V 3.Gauri Santosh Repale 4.Prerana Vilas Sangale 5.Shraddha Dattatray Arane 6.Sanket Dnyandeo Asane 7.Tejas Navnath Darunte 8.Sudhir Bhaskarrao Gayake के नाम में उपर्युक्त संख्या और तारीख में कर लिया गया है।

Certified that the design of which a copy is annexed hereto has been registered as of the number and date given above in class 25-99 in respect of the application of such design to *BRICK LAYING CUM LEVELER TOOL* in the name of 1.Sanjivani College Of Engineering, Kopargaon 2. Dr. Vignesh V 3.Gauri Santosh Repale 4.Prerana Vilas Sangale 5.Shraddha Dattatray Arane 6.Sanket Dnyandeo Asane 7.Tejas Navnath Darunte 8.Sudhir Bhaskarrao Gayake.

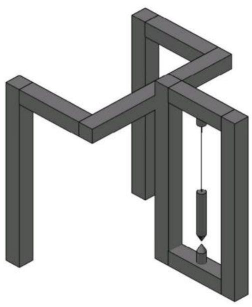
डिजाइन अधिनियम, 2000 तथा डिजाइन नियम, 2001 के अध्यधीन प्रावधानों के अनुसरण में।
In pursuance of and subject to the provisions of the Designs Act, 2000 and the Designs Rules, 2001.

जारी करने की तिथि :
Date of Issue : 03/10/2024

उन्नत की पंडित
महानियंत्रक पेटेंट, डिजाइन और व्यापार चिह्न
Controller General of Patents, Designs and Trade Marks

*पारस्परिकता तारीख (यदि कोई हो) जिसकी अनुमति दी गई है तथा देश का नाम। डिजाइन का स्वत्वाधिकार पंजीकरण की तारीख से दस वर्षों के लिए होगा जिसका विस्तार, अधिनियम एवं नियम के निबंधनों के अधीन, पाँच वर्षों की अतिरिक्त अवधि के लिए किया जा सकेगा। इस प्रमाण पत्र का उपयोग विधिक कार्यवाहियों अथवा विदेश में पंजीकरण प्राप्त करने के लिए नहीं हो सकता है।
The reciprocity date (if any) which has been allowed and the name of the country. Copyright in the design will subsist for ten years from the date of Registration, and may under the terms of the Act and Rules, be extended for a further period of five years. This Certificate is not for use in legal proceedings or for obtaining registration abroad.

DESIGN REGISTRATION

Full name and address of the applicant/s	1. Sanjivani College of Engineering, Kopargaon 2. Dr. Vignesh V 3. Gauri Santosh Repale 4. Prerana Vilas Sangale 5. Shraddha Dattatray Arane 6. Sanket Dnyandeo Asane 7. Tejas Navnath Darunte 8. Sudhir Bhaskarrao Gayake
Nationality of the Applicants	Indian
Name / Title or Description of the article to be protected in less than 15 words	Brick laying cum leveler tool
Description of article, functionality and advantages of the article	**Description:** The Brick Laying Cum Leveler Tool is a versatile, dual-function instrument designed for precise brick placement and accurate leveling. Made from high-quality stainless steel, it features an ergonomic handle for comfortable use and a built-in level for ensuring horizontal accuracy. **Functionality:** It combines the functions of brick laying and leveling into one versatile instrument. It ensures precise placement and alignment of bricks, applies mortar uniformly, and features an integrated level for accurate horizontal leveling. The handle provides a comfortable grip, reducing hand fatigue during extended use. Suitable for various masonry tasks, this tool offers improved control and efficiency, making it ideal for both DIY enthusiasts and professional masons. **Key Features:** ❖ Brick laying and leveling in one tool. ❖ Made from high-quality stainless steel. ❖ Comfortable grip to reduce strain. ❖ Built-in level with easy-to-read vials. ❖ Suitable for various masonry tasks. ❖ Smooth surface for quick cleaning.
Perspective view	

ORIGINAL

क्रम सं/ Serial No. : 191126

INTELLECTUAL PROPERTY INDIA
PATENTS | DESIGNS | TRADE MARKS
GEOGRAPHICAL INDICATIONS

सत्यमेव जयते

पेटेंट कार्यालय, भारत सरकार | The Patent Office, Government Of India

डिजाइन के पंजीकरण का प्रमाण पत्र | Certificate of Registration of Design

डिजाइन सं. / Design No.	:	435465-001
तारीख / Date	:	24/10/2024
पारस्परिकता तारीख / Reciprocity Date*	:	
देश / Country	:	

प्रमाणित किया जाता है कि संलग्न प्रति में वर्णित डिजाइन जो *REBAR BENDER TOOL* से संबंधित है, का पंजीकरण, श्रेणी 08-01 में 1.Harshada Nilesh Wagh 2. Sanskruti Uttam Tambe 3.Mahesh Sakharam Yele 4.Sarthak Devidas Shirsat के नाम में उपर्युक्त संख्या और तारीख में कर लिया गया है।

Certified that the design of which a copy is annexed hereto has been registered as of the number and date given above in class 08-01 in respect of the application of such design to *REBAR BENDER TOOL* in the name of 1.Harshada Nilesh Wagh 2. Sanskruti Uttam Tambe 3.Mahesh Sakharam Yele 4.Sarthak Devidas Shirsat.

डिजाइन अधिनियम, 2000 तथा डिजाइन नियम, 2001 के अध्यधीन प्रावधानों के अनुसरण में।
In pursuance of and subject to the provisions of the Designs Act, 2000 and the Designs Rules, 2001.

जारी करने की तिथि : 30/01/2025
Date of Issue :

महानियंत्रक पेटेंट, डिजाइन और व्यापार चिह्न
Controller General of Patents, Designs and Trade Marks

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The reciprocity date (if any) which has been allowed and the name of the country. Copyright in the design will subsist for ten years from the date of Registration, and may under the terms of the Act and Rules, be extended for a further period of five years. This Certificate is not for use in legal proceedings or for obtaining registration abroad.

DESIGN REGISTRATION

Full name and address of the applicant/s	**1. Jagzap Omkar Ravindra** **2. Wagh Harshada Nilesh** **3. Tambe Sanskruti Uttam**
Nationality of the Applicant/s	Indian
Name / Title or Description of the article to be protected in less than 15 words	MiniPicker for Barrel
Description of article, functionality and advantages of the article	**Description:** This product is made of iron is a practical and reliable tool that simplifies the task of moving water barrels, offering efficiency, durability, and safety in one versatile package.This barrel picker is made of sturdy iron and is designed to withstand heavyuse. Iron has exceptional strength and durability, so even when lifting large objects, the picker will continue to function dependably. The picker's prongs are made to firmly grip the barrel's body or rim, giving users a steady grip for lifting and shifting. **Key Features:** With its easy-to-use design, the barrel picker can be deployed quickly whenever needed, saving time and effort. Suitable for handling various types of barrels, including water barrels, oil drums,etc
Perspective View	

INTELLECTUAL PROPERTY INDIA
PATENTS | DESIGNS | TRADE MARKS
GEOGRAPHICAL INDICATIONS

सत्यमेव जयते

ORIGINAL
क्रम सं/ Serial No. : 181010

पेटेंट कार्यालय, भारत सरकार | The Patent Office, Government Of India

डिजाइन के पंजीकरण का प्रमाण पत्र | Certificate of Registration of Design

डिजाइन सं. / Design No. : 384191-001

तारीख / Date : 18/04/2023

पारस्परिकता तारीख / Reciprocity Date* :

देश / Country :

प्रमाणित किया जाता है कि संलग्न प्रति में वर्णित डिजाइन जो *HYPERHIDROSIS GLOVES* से संबंधित है, का पंजीकरण, श्रेणी 02-06 में 1.Sanjivani College Of Engineering 2. Tejal Vishwas Sonawane 3.Priyanka Ashok Rakshe 4.Bharti Machhindra Shinde के नाम में उपर्युक्त संख्या और तारीख में कर लिया गया है।

Certified that the design of which a copy is annexed hereto has been registered as of the number and date given above in class 02-06 in respect of the application of such design to *HYPERHIDROSIS GLOVES* in the name of 1.Sanjivani College Of Engineering 2. Tejal Vishwas Sonawane 3.Priyanka Ashok Rakshe 4.Bharti Machhindra Shinde.

डिजाइन अधिनियम, 2000 तथा डिजाइन नियम, 2001 के अध्यधीन प्रावधानों के अनुसरण में।
In pursuance of and subject to the provisions of the Designs Act, 2000 and the Designs Rules, 2001.

जारी करने की तिथि :
Date of Issue : 20/09/2024

महानियंत्रक पेटेंट, डिजाइन और व्यापार चिह्न
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The reciprocity date (if any) which has been allowed and the name of the country. Copyright in the design will subsist for ten years from the date of Registration, and may under the terms of the Act and Rules, be extended for a further period of five years. This Certificate is not for use in legal proceedings or for obtaining registration abroad.

DESIGN REGISTRATION

Full name and address of the applicant/s	1. Sanjivani College of Engineering, Kopargaon 2. Tejal Sonawane 3. Priyanka Rakshe 4. Dr. B. M. Shinde
Nationality of the Applicants	Indian
Name / Title or Description of the article to be protected in less than 15 words	Hyperhidrosis gloves
Description of article, functionality and advantages of the article	**Description:** The palm gloves are designed for the person having Palmer Hyperhidrosis problem. **Functionality:** Easy to use For Male or Female, interchangeable for both lefties & righties. The material use for gloves is having features like Quick dry, Comfortable Material, Anti-fouling design, portable, washable and promote airflow. **Key Features:** ❖ Suitable for both male and female users, interchangeable for lefties & righties. ❖ Made from fast-drying material to keep hands dry and comfortable. ❖ Promotes airflow to reduce moisture buildup and enhance comfort. ❖ Designed for everyday wear without discomfort. ❖ Helps in maintaining hygiene and cleanliness.
Perspective view	

INTELLECTUAL PROPERTY INDIA
PATENTS | DESIGNS | TRADE MARKS
GEOGRAPHICAL INDICATIONS

सत्यमेव जयते

ORIGINAL
क्रम सं/ Serial No. : 188750

पेटेंट कार्यालय, भारत सरकार | The Patent Office, Government Of India

डिजाइन के पंजीकरण का प्रमाण पत्र | Certificate of Registration of Design

डिजाइन सं. / Design No.	:	384173-001
तारीख / Date	:	18/04/2023
पारस्परिकता तारीख / Reciprocity Date*	:	
देश / Country	:	

प्रमाणित किया जाता है कि संलग्न प्रति में वर्णित डिजाइन जो *ADJUSTABLE CLOTHING STAND* से संबंधित है, का पंजीकरण, श्रेणी 06-08 में 1.Sanjivani College Of Engineering, Kopargaon 2. Meherkhamb Dharmesh R. 3.Nitin Shankarrao Naik के नाम में उपर्युक्त संख्या और तारीख में कर लिया गया है।

Certified that the design of which a copy is annexed hereto has been registered as of the number and date given above in class 06-08 in respect of the application of such design to *ADJUSTABLE CLOTHING STAND* in the name of 1.Sanjivani College Of Engineering, Kopargaon 2. Meherkhamb Dharmesh R. 3.Nitin Shankarrao Naik.

डिजाइन अधिनियम, 2000 तथा डिजाइन नियम, 2001 के अध्यधीन प्रावधानों के अनुसरण में।
In pursuance of and subject to the provisions of the Designs Act, 2000 and the Designs Rules, 2001.

जारी करने की तिथि : 02/01/2025
Date of Issue :

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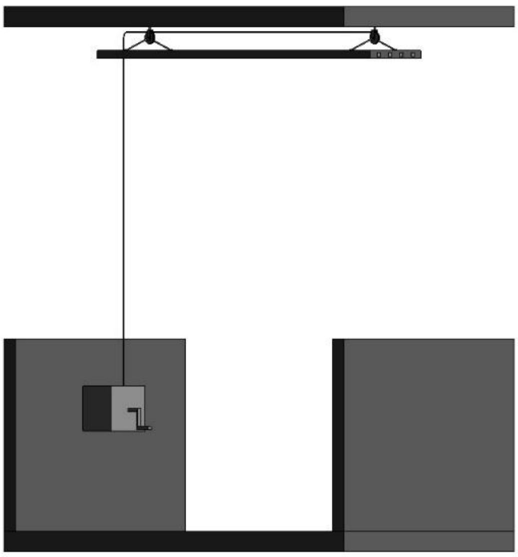
The reciprocity date (if any) which has been allowed and the name of the country. Copyright in the design will subsist for ten years from the date of Registration, and may under the terms of the Act and Rules, be extended for a further period of five years. This Certificate is not for use in legal proceedings or for obtaining registration abroad.

DESIGN REGISTRATION

Full name and address of the applicant/s	1. Sanjivani College of Engineering, Kopargaon 2. Meherkhamb Dharmesh R. 3. Dr. Naik Nitin S.
Nationality of the Applicant/s	Indian
Name / Title or Description of the article to be protected in less than 15 words	Adjustable Clothing Stand
Description of article, functionality and advantages of the article	**Description:** Adjustable clothing stand is modern and easier way for drying the cloths there are conventional clothing stand which available in the market which operate through the rope we can lift the stand on upper side but when the cloth weight exceed it is very hard to any person to lift this rope and consume time **Functionality:** adjustable clothing stand is combination of metal stand, ropes , steel rods and gear box The gear box is fitted to parapet wall with flexible vertically upwards and downward moving cable with the help of the pully's. This pully's is fitted to the celling and the moving cable passed through this pullys tthis rops areb conncetd to gear box which is controlled by horizontal shaft which is present in gear box this gear box can operated by handle & operated manually so stand can move upward and downward **Key Features:** 1) Easiest Way to dry cloth. 2) reduced human effort to operate Conventional stand. 3) easy to handle with the more weight. 4) Require less workmanship. 5) Reduce wastage of time and money 6) can take weight upto 200kg
Perspective view	

ORIGINAL

क्रम सं/ Serial No. : 190179

INTELLECTUAL PROPERTY INDIA

PATENTS | DESIGNS | TRADE MARKS GEOGRAPHICAL INDICATIONS

सत्यमेव जयते

पेटेंट कार्यालय, भारत सरकार | The Patent Office, Government Of India

डिजाइन के पंजीकरण का प्रमाण पत्र | Certificate of Registration of Design

डिजाइन सं. / Design No. : 384183-001

तारीख / Date : 18/04/2023

पारस्परिकता तारीख / Reciprocity Date* :

देश / Country :

प्रमाणित किया जाता है कि संलग्न प्रति में वर्णित डिजाइन जो *PARAPET WALL MORTAR LEVELLER* से संबंधित है, का पंजीकरण, श्रेणी 25-01 में 1.Sanjivani College Of Engineering, Kopargaon 2. Miss. Divya Ravindra Kshirsagar 3.Miss. Snehal Virendra Waghchaure 4.Mr. Sumit Saidas Kolapkar 5.Mr. Atteshamuddin Shamshuddin Sayyad के नाम में उपर्युक्त संख्या और तारीख में कर लिया गया है।

Certified that the design of which a copy is annexed hereto has been registered as of the number and date given above in class 25-01 in respect of the application of such design to *PARAPET WALL MORTAR LEVELLER* in the name of 1.Sanjivani College Of Engineering, Kopargaon 2. Miss. Divya Ravindra Kshirsagar 3.Miss. Snehal Virendra Waghchaure 4.Mr. Sumit Saidas Kolapkar 5.Mr. Atteshamuddin Shamshuddin Sayyad.

डिजाइन अधिनियम, 2000 तथा डिजाइन नियम, 2001 के अध्यधीन प्रावधानों के अनुसरण में।
In pursuance of and subject to the provisions of the Designs Act, 2000 and the Designs Rules, 2001.

जारी करने की तिथि : 17/01/2025
Date of Issue :

उन्नत पंडित

महानियंत्रक पेटेंट, डिजाइन और व्यापार चिह्न
Controller General of Patents, Designs and Trade Marks

*पारस्परिकता तारीख (यदि कोई हो) जिसकी अनुमति दी गई है तथा देश का नाम। डिजाइन का स्वत्वाधिकार पंजीकरण की तारीख से दस वर्षों के लिए होगा जिसका विस्तार, अधिनियम एवं नियम के निबंधनों के अधीन, पाँच वर्षों की अतिरिक्त अवधि के लिए किया जा सकेगा। इस प्रमाण पत्र का उपयोग विधिक कार्यवाहियों अथवा विदेश में पंजीकरण प्राप्त करने के लिए नहीं हो सकता है।
The reciprocity date (if any) which has been allowed and the name of the country. Copyright in the design will subsist for ten years from the date of Registration, and may under the terms of the Act and Rules, be extended for a further period of five years. This Certificate is not for use in legal proceedings or for obtaining registration abroad.

DESIGN REGISTRATION

Full name and address of the applicant/s	1. Sanjivani College of Engineering, Kopargaon 2. Miss. Divya Ravindra Kshirsagar 3. Miss. Snehal Virendra Waghchaure 4. Mr. Sumit Saidas Kolapkar
Nationality of the Applicant/s	Indian
Name / Title or Description of the article to be protected in less than 15 words	Parapet Wall Mortar Leveller
Description of article, functionality and advantages of the article	**Description–**It is the tool used for plaster the wall corner or parapet wall corners precisely and perfectly. It is made of galvanized iron sheet. The idea is about the problem faced by mason or labour while shaping the parapet wall or a wall at its corner to maintain same size. This equipment will help to attain accuracy in work and will reduce the time of the construction. **Key Features–** 1) It is convenient to use. 2) A time saving tool 3) Requires less manpower.
Perspective view	

ORIGINAL

क्रम सं/ Serial No. : 190178

INTELLECTUAL PROPERTY INDIA
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GEOGRAPHICAL INDICATIONS

सत्यमेव जयते

पेटेंट कार्यालय, भारत सरकार | The Patent Office, Government Of India

डिजाइन के पंजीकरण का प्रमाण पत्र | Certificate of Registration of Design

डिजाइन सं. / Design No.	:	384171-001
तारीख / Date	:	18/04/2023
पारस्परिकता तारीख / Reciprocity Date*	:	
देश / Country	:	

प्रमाणित किया जाता है कि संलग्न प्रति में वर्णित डिजाइन जो *POLE CLIMBER APPARATUS* से संबंधित है, का पंजीकरण, श्रेणी 08-99 में 1.Sanjivani College Of Engineering, Kopargaon. 2. Rushikesh Sanjay Kasar 3.Shubham Vijay Jadhav 4.Pravin Ravindra Parhe 5.Sachin Madhavrao Gunjal 6.Atteshamuddin Shamshuddin Sayyad के नाम में उपर्युक्त संख्या और तारीख में कर लिया गया है।

Certified that the design of which a copy is annexed hereto has been registered as of the number and date given above in class 08-99 in respect of the application of such design to *POLE CLIMBER APPARATUS* in the name of 1.Sanjivani College Of Engineering, Kopargaon. 2. Rushikesh Sanjay Kasar 3.Shubham Vijay Jadhav 4.Pravin Ravindra Parhe 5.Sachin Madhavrao Gunjal 6.Atteshamuddin Shamshuddin Sayyad.

डिजाइन अधिनियम, 2000 तथा डिजाइन नियम, 2001 के अध्यधीन प्रावधानों के अनुसरण में।
In pursuance of and subject to the provisions of the Designs Act, 2000 and the Designs Rules, 2001.

जारी करने की तिथि : 17/01/2025
Date of Issue :

महानियंत्रक पेटेंट, डिजाइन और व्यापार चिह्न
Controller General of Patents, Designs and Trade Marks

*पारस्परिकता तारीख (यदि कोई हो) जिसकी अनुमति दी गई है तथा देश का नाम। डिजाइन का स्वत्वाधिकार पंजीकरण की तारीख से दस वर्षों के लिए होगा जिसका विस्तार, अधिनियम एवं नियम के निबंधनों के अधीन, पाँच वर्षों की अतिरिक्त अवधि के लिए किया जा सकेगा। इस प्रमाण पत्र का उपयोग विधिक कार्यवाहियों अथवा विदेश में पंजीकरण प्राप्त करने के लिए नहीं हो सकता है।

The reciprocity date (if any) which has been allowed and the name of the country. Copyright in the design will subsist for ten years from the date of Registration, and may under the terms of the Act and Rules, be extended for a further period of five years. This Certificate is not for use in legal proceedings or for obtaining registration abroad.

DESIGN REGISTRATION

Full name and address of the applicant/s	1. Sanjivani College of Engineering, Kopargaon. 2. Mr. Rushikesh Sanjay Kasar 3. Mr. Shubham Vijay Jadhav 4. Mr. Pravin Ravindra Parhe 5. Dr. Sachin Madhavrao Gunjal
Nationality of the Applicant/s	Indian
Name / Title or Description of the article to be protected in less than 15 words	**Pole Climber Apparatus**
Description of article, functionality and advantages of the article	**Description-** Pole Climber is a handy tool to climb on rectangular electrical poles easily. Using this equipment time and efforts are save. **Functionality–** 1) This Equipment is a made from MS square pipe in letter F Shape . 2) The two chapels(or Sandal) is provided on top of the equipment fixed with the screw. 3) The equipment attached on the pole due to the weight of person it is fixed.The person standing on equipment walked in vertical direction along the pole. **Advantages-** 1) Use in the climbing on electricity pole at time any problem happens in the electricity wires. 2) By using this Equipment without any support stands and do the work properly.
Perspective view	

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सत्यमेव जयते

ORIGINAL

क्रम सं/ Serial No. : 192313

पेटेंट कार्यालय, भारत सरकार | The Patent Office, Government Of India

डिजाइन के पंजीकरण का प्रमाण पत्र | Certificate of Registration of Design

डिजाइन सं. / Design No.	:	384175-001
तारीख / Date	:	18/04/2023
पारस्परिकता तारीख / Reciprocity Date*	:	
देश / Country	:	

प्रमाणित किया जाता है कि संलग्न प्रति में वर्णित डिजाइन जो *BAR BENDING & STIRRUP MAKING INSTRUMENTS* से संबंधित है, का पंजीकरण, श्रेणी 25-01 में 1.Sanjivani College Of Engineering, Kopargaon 2. Sanghavi Bhushan Santosh 3.Gite Akshay Bhausaheb 4.Gunjal Sachin Madhvrao के नाम में उपर्युक्त संख्या और तारीख में कर लिया गया है।

Certified that the design of which a copy is annexed hereto has been registered as of the number and date given above in class 25-01 in respect of the application of such design to *BAR BENDING & STIRRUP MAKING INSTRUMENTS* in the name of 1.Sanjivani College Of Engineering, Kopargaon 2. Sanghavi Bhushan Santosh 3.Gite Akshay Bhausaheb 4.Gunjal Sachin Madhvrao.

डिजाइन अधिनियम, 2000 तथा डिजाइन नियम, 2001 के अध्यधीन प्रावधानों के अनुसरण में।
In pursuance of and subject to the provisions of the Designs Act, 2000 and the Designs Rules, 2001.

जारी करने की तिथि : 13/02/2025
Date of Issue :

महानियंत्रक पेटेंट, डिजाइन और व्यापार चिह्न
Controller General of Patents, Designs and Trade Marks

*पारस्परिकता तारीख (यदि कोई हो) जिसकी अनुमति दी गई है तथा देश का नाम। डिजाइन का स्वत्वाधिकार पंजीकरण की तारीख से दस वर्षों के लिए होगा जिसका विस्तार, अधिनियम एवं नियम के निबंधनों के अधीन, पाँच वर्षों की अतिरिक्त अवधि के लिए किया जा सकेगा। इस प्रमाण पत्र का उपयोग विधिक कार्यवाहियों अथवा विदेश में पंजीकरण प्राप्त करने के लिए नहीं हो सकता है।
The reciprocity date (if any) which has been allowed and the name of the country. Copyright in the design will subsist for ten years from the date of Registration, and may under the terms of the Act and Rules, be extended for a further period of five years. This Certificate is not for use in legal proceedings or for obtaining registration abroad.

DESIGN REGISTRATION

Full name and address of the applicant/s	1. 1.Sanjivani College of Engineering, Kopargaon. 2. Mr. Sanghavi Bhushan Santosh 3. Mr. Gite Akshay Bhausaheb 4. Mr. Gunjal Sachin Madhvrao
Nationality of the Applicant/s	Indian
Name / Title or Description of the article to be protected in less than 15 words	Bar Bending & Stirrup Making Instruments
Description of article, functionality and advantages of the article	**Description**– The stirrup making apparatus is used for making stirrups and ties of different dimensions. **Functionality**– This apparatus consist of two bolts which are placed in the middle hollow slot for easy movement. These two bolts are fixed to hollow slot by using nuts. Along with these two bolts at the end of hollow slot, two studs are fixed. These studs are fixed to take stresses at time of bending action. A bar having a diameter of up to 12mm will bend easily using bar bending apparatus. For accurate measurement of size of stirrups or ties the scale is fixed on longer side. The angle is fixed at top along full length. The angle take stresses and holds the bar in correct position at time of bending operation. The arrangement is made for fixing the apparatus for firm base by using screws. **Key features–** 1. Most important feature of this apparatus is the different sizes of stirrups or ties that produce easily. 2. The square and rectangular shaped stirrups are made easily. 3. This apparatus is portable and lightweight. 4. This apparatus is economical.
Perspective view	

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सत्यमेव जयते

ORIGINAL

क्रम सं/ Serial No. : 189471

पेटेंट कार्यालय, भारत सरकार | The Patent Office, Government Of India

डिजाइन के पंजीकरण का प्रमाण पत्र | Certificate of Registration of Design

डिजाइन सं. / Design No. : 434637-001

तारीख / Date : 17/10/2024

पारस्परिकता तारीख / Reciprocity Date* :

देश / Country :

प्रमाणित किया जाता है कि संलग्न प्रति में वर्णित डिजाइन जो *MULTI-TOOL PLIER* से संबंधित है, का पंजीकरण, श्रेणी 08-05 में 1.Akash Namdeo Gholap 2. Sachin Madhavrao Gunjal 3.Suyog Gorakshnath Patare 4.Rohit Shyam Vairal 5.Ashish Ambadas Meherkhamb 6.Pratiksha Ashok Tupke 7.Kaveri Ramrao Sanvatsarkar के नाम में उपर्युक्त संख्या और तारीख में कर लिया गया है।

Certified that the design of which a copy is annexed hereto has been registered as of the number and date given above in class 08-05 in respect of the application of such design to *MULTI-TOOL PLIER* in the name of 1.Akash Namdeo Gholap 2. Sachin Madhavrao Gunjal 3.Suyog Gorakshnath Patare 4.Rohit Shyam Vairal 5.Ashish Ambadas Meherkhamb 6.Pratiksha Ashok Tupke 7.Kaveri Ramrao Sanvatsarkar.

डिजाइन अधिनियम, 2000 तथा डिजाइन नियम, 2001 के अध्यधीन प्रावधानों के अनुसरण में।
In pursuance of and subject to the provisions of the Designs Act, 2000 and the Designs Rules, 2001.

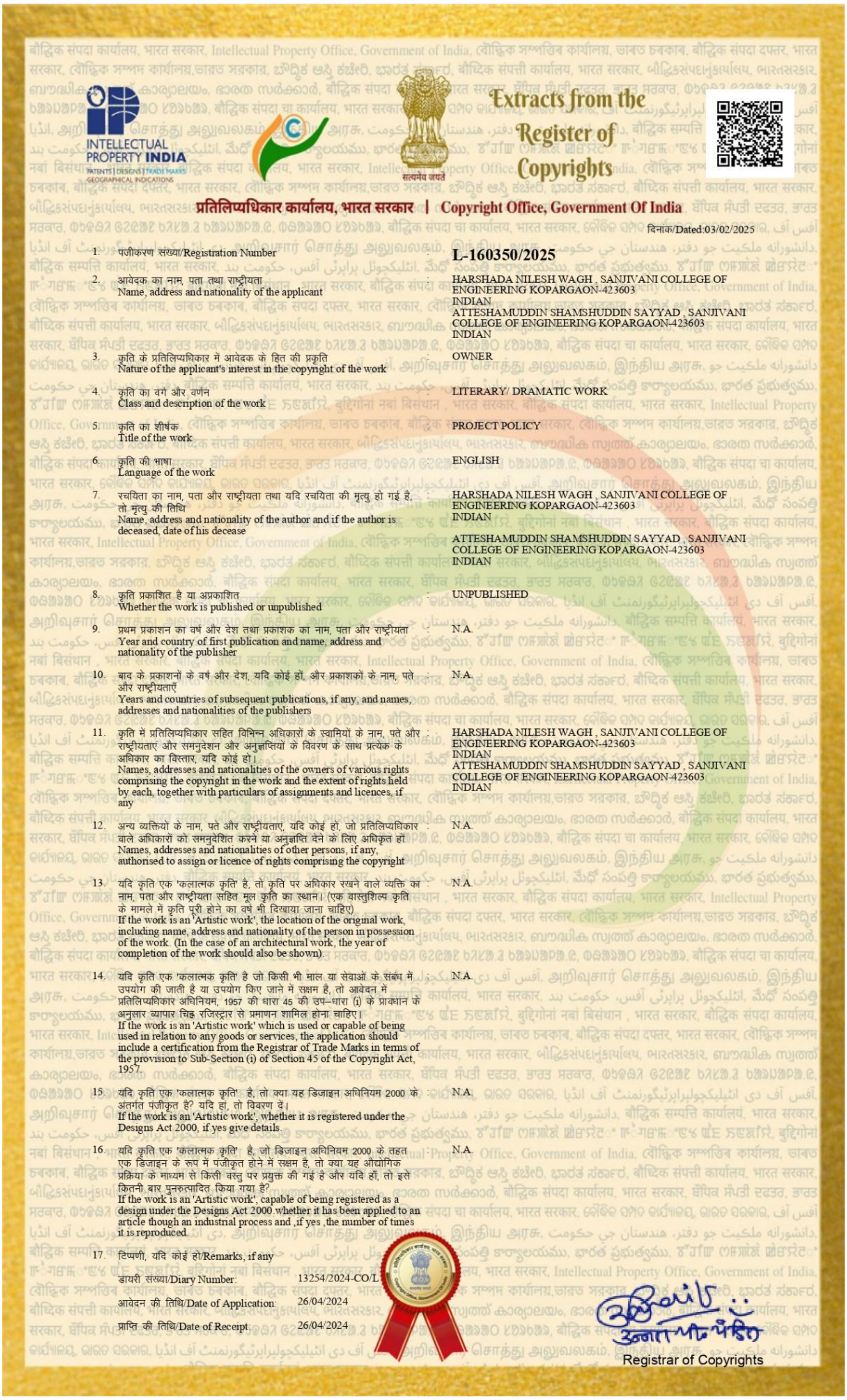
जारी करने की तिथि : 09/01/2025
Date of Issue :

उन्नत पं. पंडित

महानियंत्रक पेटेंट, डिजाइन और व्यापार चिह्न
Controller General of Patents, Designs and Trade Marks

*पारस्परिकता तारीख (यदि कोई हो) जिसकी अनुमति दी गई है तथा देश का नाम। डिजाइन का स्वत्वाधिकार पंजीकरण की तारीख से दस वर्षों के लिए होगा जिसका विस्तार, अधिनियम एवं नियम के निबंधनों के अधीन, पाँच वर्षों की अतिरिक्त अवधि के लिए किया जा सकेगा। इस प्रमाण पत्र का उपयोग विधिक कार्यवाहियों अथवा विदेश में पंजीकरण प्राप्त करने के लिए नहीं हो सकता है।
The reciprocity date (if any) which has been allowed and the name of the country. Copyright in the design will subsist for ten years from the date of Registration, and may under the terms of the Act and Rules, be extended for a further period of five years. This Certificate is not for use in legal proceedings or for obtaining registration abroad.

We are proud to congratulate **Prof. Ms. Harshada N. Wagh** for receiving copyright for her work on the topic "**Project Policy.**"



INTELLECTUAL PROPERTY INDIA
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सत्यमेव जयते

Extracts from the Register of Copyrights

प्रतिलिप्यधिकार कार्यालय, भारत सरकार | Copyright Office, Government Of India

दिनांक/Dated:03/02/2025

1.	पंजीकरण संख्या/Registration Number	:	**L-160350/2025**
2.	आवेदक का नाम, पता तथा राष्ट्रीयता Name, address and nationality of the applicant	:	HARSHADA NILESH WAGH , SANJIVANI COLLEGE OF ENGINEERING KOPARGAON-423603 INDIAN ATTESHAMUDDIN SHAMSHUDDIN SAYYAD , SANJIVANI COLLEGE OF ENGINEERING KOPARGAON-423603 INDIAN
3.	कृति के प्रतिलिप्यधिकार में आवेदक के हित की प्रकृति Nature of the applicant's interest in the copyright of the work	:	OWNER
4.	कृति का वर्ग और वर्णन Class and description of the work	:	LITERARY/ DRAMATIC WORK
5.	कृति का शीर्षक Title of the work	:	PROJECT POLICY
6.	कृति की भाषा Language of the work	:	ENGLISH
7.	रचयिता का नाम, पता और राष्ट्रीयता तथा यदि रचयिता की मृत्यु हो गई है, तो मृत्यु की तिथि Name, address and nationality of the author and if the author is deceased, date of his decease	:	HARSHADA NILESH WAGH , SANJIVANI COLLEGE OF ENGINEERING KOPARGAON-423603 INDIAN ATTESHAMUDDIN SHAMSHUDDIN SAYYAD , SANJIVANI COLLEGE OF ENGINEERING KOPARGAON-423603 INDIAN
8.	कृति प्रकाशित है या अप्रकाशित Whether the work is published or unpublished	:	UNPUBLISHED
9.	प्रथम प्रकाशन का वर्ष और देश तथा प्रकाशक का नाम, पता और राष्ट्रीयता Year and country of first publication and name, address and nationality of the publisher	:	N.A.
10.	बाद के प्रकाशनों के वर्ष और देश, यदि कोई हों, और प्रकाशकों के नाम, पते और राष्ट्रीयताएँ Years and countries of subsequent publications, if any, and names, addresses and nationalities of the publishers	:	N.A.
11.	कृति में प्रतिलिप्यधिकार सहित विभिन्न अधिकारों के स्वामियों के नाम, पते और राष्ट्रीयताएं और समनुदेशन और अनुज्ञप्तियों के विवरण के साथ प्रत्येक के अधिकार का विस्तार, यदि कोई हो। Names, addresses and nationalities of the owners of various rights comprising the copyright in the work and the extent of rights held by each, together with particulars of assignments and licences, if any	:	HARSHADA NILESH WAGH , SANJIVANI COLLEGE OF ENGINEERING KOPARGAON-423603 INDIAN ATTESHAMUDDIN SHAMSHUDDIN SAYYAD , SANJIVANI COLLEGE OF ENGINEERING KOPARGAON-423603 INDIAN
12.	अन्य व्यक्तियों के नाम, पते और राष्ट्रीयताएं, यदि कोई हों, जो प्रतिलिप्यधिकार वाले अधिकारों को समनुदेशित करने या अनुज्ञप्ति देने के लिए अधिकृत हों Names, addresses and nationalities of other persons, if any, authorised to assign or licence of rights comprising the copyright	:	N.A.
13.	यदि कृति एक 'कलात्मक कृति' है, तो कृति पर अधिकार रखने वाले व्यक्ति का नाम, पता और राष्ट्रीयता सहित मूल कृति का स्थान। (एक वास्तुशिल्प कृति के मामले में कृति पूरी होने का वर्ष भी दिखाया जाना चाहिए) If the work is an 'Artistic work', the location of the original work, including name, address and nationality of the person in possession of the work. (In the case of an architectural work, the year of completion of the work should also be shown).	:	N.A.
14.	यदि कृति एक 'कलात्मक कृति' है जो किसी भी माल या सेवाओं के संबंध में उपयोग की जाती है या उपयोग किए जाने में सक्षम है, तो आवेदन में प्रतिलिप्यधिकार अधिनियम, 1957 की धारा 45 की उप–धारा (i) के प्रावधान के अनुसार व्यापार चिह्न रजिस्ट्रार से प्रमाणन शामिल होना चाहिए। If the work is an 'Artistic work' which is used or capable of being used in relation to any goods or services, the application should include a certification from the Registrar of Trade Marks in terms of the provision to Sub-Section (i) of Section 45 of the Copyright Act, 1957.	:	N.A.
15.	यदि कृति एक 'कलात्मक कृति' है, तो क्या यह डिजाइन अधिनियम 2000 के अंतर्गत पंजीकृत है? यदि हां, तो विवरण दें। If the work is an 'Artistic work', whether it is registered under the Designs Act 2000, if yes give details.	:	N.A.
16.	यदि कृति एक 'कलात्मक कृति' है, जो डिजाइन अधिनियम 2000 के तहत एक डिजाइन के रूप में पंजीकृत होने में सक्षम है, तो क्या यह औद्योगिक प्रक्रिया के माध्यम से किसी वस्तु पर प्रयुक्त की गई है और यदि हाँ, तो इसे कितनी बार पुनरुत्पादित किया गया है? If the work is an 'Artistic work', capable of being registered as a design under the Designs Act 2000.whether it has been applied to an article though an industrial process and ,if yes ,the number of times it is reproduced.	:	N.A.
17.	टिप्पणी, यदि कोई हो/Remarks, if any		

डायरी संख्या/Diary Number: 13254/2024-CO/L

आवेदन की तिथि/Date of Application: 26/04/2024

प्राप्ति की तिथि/Date of Receipt: 26/04/2024

Registrar of Copyrights

Student Articles

Use of recycled plastic waste as a coarse aggregate for the development of sustainable concrete

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Abstract. In recent years, there has been growing interest in using plastic waste as a partial replacement for conventional aggregates in concrete production. This approach has the potential to address both the environmental issue of plastic waste and reduce the consumption of natural resources in construction materials. An attempt has been made to reduce the plastic waste and conserve the environment by using plastic waste as a construction material. In this study coarse aggregate in concrete is been replaced with the High-Density Polyethylene (HDPE) plastic waste coarse aggregate. Studies shows that plastic can be used in the construction industry due to some its beneficial properties like inert behaviour, durability etc. This study is carried out to determine the compressive strength, split tensile strength, workability and mass density of the recycled plastic concrete. In this study, total 36 cubes and 12 cylinders were prepared by using stone aggregate and 5%, 10% and 20% replacement of stone by recycled plastic aggregate at w/c ratio 0.45. Compressive strength was performed after 7, 14 and 28 days of curing whereas split tensile test were performed after 28 days age of curing. It has been found that reduction in compressive strength at 20 % replacement of recycled plastic aggregate. Split tensile strength also shows decrement with increase in the plastic waste coarse aggregate.

Keywords: high density polyethylene, plastic waste, coarse aggregate, sustainable concrete, compressive strength

1 Introduction

The use of plastic plays vital role in our day-to-day life, permeating every facet of our lives. Plastics find their utility in an incredibly vast array of sectors encompassing the entire spectrum of manufacturing. The production of plastic and the generation of plastic waste is increasing day by day worldwide creating an sustainable environmental issue [1]. More specifically, the preponderance of plastic waste emanates from the realm of packaging and containers, further exacerbating the magnitude of the issue. The escalating concern regarding the expanse of land necessitated for accommodating landfills has become an increasingly pressing matter of apprehension and disquietude, evoking universal perturbation and unease amongst nations far and wide. Every year, approximately 6500 million tons of plastic and rubber waste is generated globally with a growth of 4.6% per year, facing the challenge of disposal. As a waste management method 9% globally generated plastic waste is recycled and 12% is burned [2,3]. Remaining 80% plastic wastes are either disposed by landfill method or in aquatic system. The incineration of plastic waste in open environment causes air pollution by releasing the toxic gases like Dioxins, Furans, Mercury and Polychlorinated Biphenyls in the atmosphere. Further, burning of Poly Vinyl Chloride (PVC) liberates toxic and hazardous halogens and pollutes air [4]. About 20% of the total plastic waste is of Polyethylene Terephthalate (PET) type, and 29% comprises items with Polyethylene (PE) foundation [5]. Using plastic waste in the construction industry is an environmental solution to reduce the landfill and incineration proportion [6]. In recent years use of plastic waste in concrete becoming the research area for the many researchers. Characteristics like light in weight, corrosion resistance, high impact resistance capacity of plastic waste is proved to be one of the economic and environmentally friendly alternatives for the replacement of natural fine and coarse aggregates in concrete. This leads to the decrement into the concrete unit weight and hence can be considered as a lightweight concrete [7]. Main advantage of lightweight concrete is thermal insulation and cost reductions [8]. Due to reduction in self-weight of the structure, impact of earthquake forces reduces significantly [9]. Many studies shows decreases in workability with increase in the replacement level of plastic waste [10–12]. Most studies shows reduction in compressive strength, splitting tensile strength and flexural strength with increase in the replacement level of the plastic waste [12–14]. Plastics are classified as Polyethylene Terephthalate (PET), High-Density Polyethylene (HDPE), Low-Density Polyethylene (LDPE), Poly Vinyl Chloride (PVC), Polypropylene (PP), Polystyrene (PS) and other resins [15].

The current research examines the utilization of plastic waste as a substitute for sand in concrete. In this investigation, the workability test is conducted on fresh concrete, while the compressive strength and split tensile strength are determined on hardened concrete. The replacement of stone by recycled plastic aggregate at 5%, 10%, and 20% is carried out with a water-to-cement ratio of 0.45. The compressive strength is measured after 7, 14, and 28 days of curing, while the split tensile test is determined after 28 days of curing.

2 Material and Mix Design

2.1 Materials used

In this study a concrete mix is prepared using locally available Portland Pozzolanic Cement (PPC) of 43-grade confirming to IS:1489 part-I. Table 1 shows the physical and mechanical properties of the cement. River sand free of organic matter is used. Fine aggregate with fineness modulus of 2.80 and specific gravity 2.42 is used in the current study. As a coarse aggregate naturally available crushed stone having specific gravity 2.48 is used. Table 2 shows the physical properties of the natural coarse and fine aggregate.

TABLE I. PHYSICAL AND MECHANICAL PROPERTIES OF CEMENT

	Property	**Result Obtained**	**Requirement as per IS specifications**
Physical	Standard consistency (%)	33.75	30
	Initial setting time (min.)	72	Minimum 30
	Final setting time (min.)	300	Maximum 600
	Soundness (mm)	5.5	Maximum 10
	Fineness of cement (dry sieving %)	4 %	Maximum 10
Mechanical	Compressive strength (MPa)	26.3	22.4

TABLE II. PROPERTIES OF NATURAL COARSE AND FINE AGGREGATE

Property	**Coarse Aggregate**	**Fine Aggregate**
Fineness modulus (%)	4.64	2.80
Specific gravity	2.48	2.42
Aggregate crushing value (%)	21.875	-
Aggregate impact strength (%)	11.30	-

Table 3 shows classification of plastic types and their uses [16,17]. Many scholars investigate the utilization of various kinds of recycled plastic in concrete, whether it is in the form of aggregate or fibers. This article presents a fresh analysis of the limited number of current studies on the application of high-density polyethylene (HDPE) plastic waste as coarse aggregate in concrete, and its impact on the concrete's physical and mechanical properties, which ultimately determine its overall performance.

2.2 Mix design

The replacement ratios considered to determine the effect of HDPE by weight are as follows- 5%, 10% and 20%. Mix design were carried out with different quantities of HDPE. Mix design of M25 grade concrete has been carried out to determine the various properties of the concrete as per IS:10262 (2019) revised. For control mix and with water-cement ratio 0.45 the quantities of cement, aggregates (Fine and Coarse) and water required were determined as 433 kg, 860.75 kg, 1063.76 kg and 197 kg respectively. No chemical admixture was used in the entire mix design process. Three percentages of HDPE were used in the mixes (HDPE5, HDPE10 and HDPE20) along with one control mix without HDPE. Table 4 shows the concrete composition mixtures for 1 m^3 concrete.

TABLE III. CLASSIFICATION OF PLASTIC TYPES AND THEIR USES

Sr. No.	Abbreviation	Scientific Name	Description	Uses
1	PET	Polyethylene Terephthalate	Tough Plastic	Water bottles
2	HDPE	High-Density Polyethylene	White or coloured common plastic	Carry bags, food container etc.
3	LDPE	Low-Density Polyethylene	Soft, flexible plastic	Carry bags
4	PVC	Poly Vinyl Chloride	Hard, rigid plastic	Pipes, cables etc.
5	PP	Polypropylene	Hard, flexible plastic	Medicine bottles etc
6	PS	Polystyrene	Rigid, brittle plastic	Ice-cream containers, cups etc.
7	O	Others	-	Thermoset plastic, nylon etc.

TABLE IV. CONCRETE MIX COMPOSITION

Mix	HDPE0	HDPE5	HDPE10	HDPE20
Cement (kg)	433	433	433	433
Fine aggregate (kg)	860.75	860.75	860.75	860.75
Coarse aggregate (kg)	1063.76	1010.572	957.384	851.008
HDPE (kg)	0	53.188	106.376	212.752
Water (kg)	197	197	197	197
Total weight (kg)	2554.51	2554.51	2554.51	2554.51

2.3 Casting and Curing of Specimens

All ingredients of the concrete are prepared and mixed thoroughly in dry condition in a non-absorbent pan. The mixture is added with the tap water and specimens were compacted using a table vibrator. After casting the samples were cured at an ambient room temperature of 27 ^{o}C ± 1 ^{o}C and at 90% relative humidity for the first 24 hrs. of casting. After that specimens were demoulded and immersed in a normal water in the curing tank until testing of a particular day. Sample preparation and curing of test specimens are as shown in “Fig. 1”.

Fig. 1. Sample preparation and curing of test specimens

3. RESULTS AND DISCUSSIONS

3.1 Fresh properties of concrete

Workability- The control mix without HDPE shows high degree of workability with a slump value of 88 mm. With increase in the HDPE content the workability reduces considerably. with increase in HDPE percentage. For a replacement ratio of 5% of HDPE slump reduces by an amount 7%. At 10% of HDPE, it reduces by an amount 13% and at 20% replacement workability reduces by an amount 45%. The addition of HDPE causes reduction in workability of concrete as shown in "Fig. 2".

Mass density- HDPE as a lightweight aggregate usually have lower unit weight. The weight density of concrete decreases thereby producing the lightweight concrete. The control mix without HDPE has mass density of 2345.62 kg/m^3 and results shows that concrete with 5%, 10% and 20% HDPE decreases the mass density to 2310.15 kg/m^3, 2289.0 kg/m^3 and 2118.20 kg/m^3 respectively. Figure 2 shows mass density of concrete with different proportions of HDPE. "Fig. 3" shows reduction in mass density of concrete with percentage replacement of HDPE.

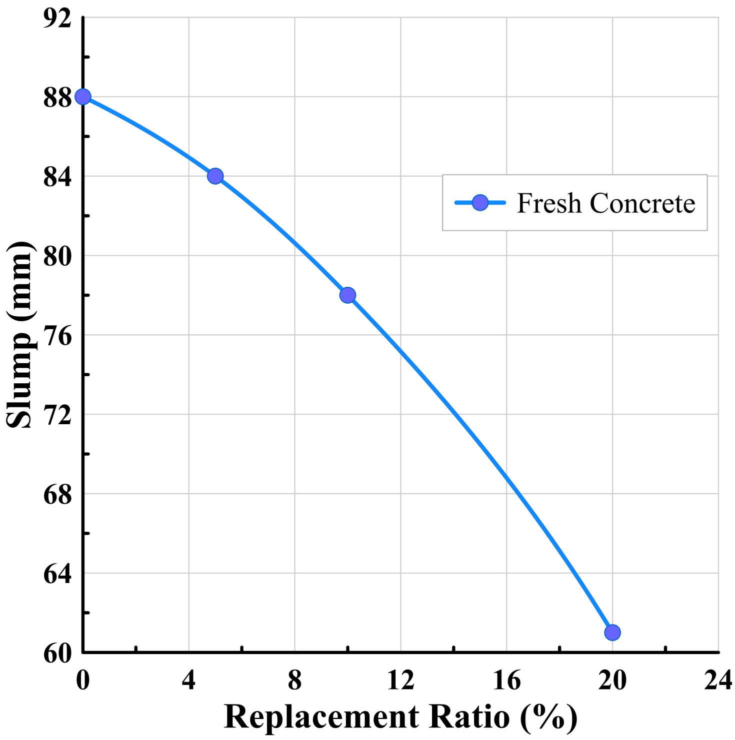

Fig. 2. Effect of addition of HDPE on slump value

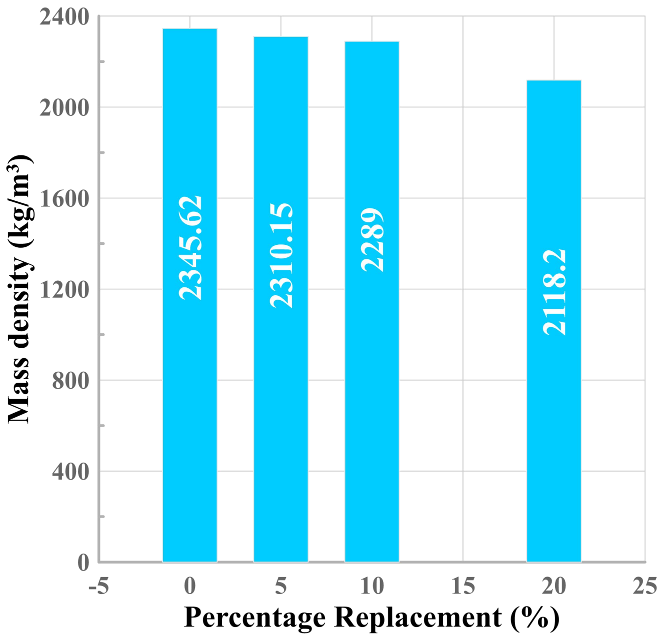

Fig. 3. Effect of addition of HDPE on mass density

3.2 Hardened properties of concrete

3.2.1 Compressive strength

Results shows that with increase in HDPE content compressive strength of the mixtures decreases at each curing age. The compressive strength of different concrete mixes for curing age of 7, 14 and 28 days are shown in "Fig. 4". It has been found that with increase in the HDPE content in place of coarse aggregates the compressive strength decreases considerably. The compressive strength values of the control specimen without HDPE were 22.07,24.60 and 26.33 MPa at 7, 14 and 28 days respectively. Compressive strength decreased slightly at 5% and 10% replacement ratios whereas at 20% it decreases significantly at 28 days. For the same proportional mix, the strength increased from 7 to 28 days curing age. This decrease in the strength is mainly due to decrease of the mass density of the concrete matrix. Along with this strength decreases due the improper bonding strength of the plastic waste and cement paste.

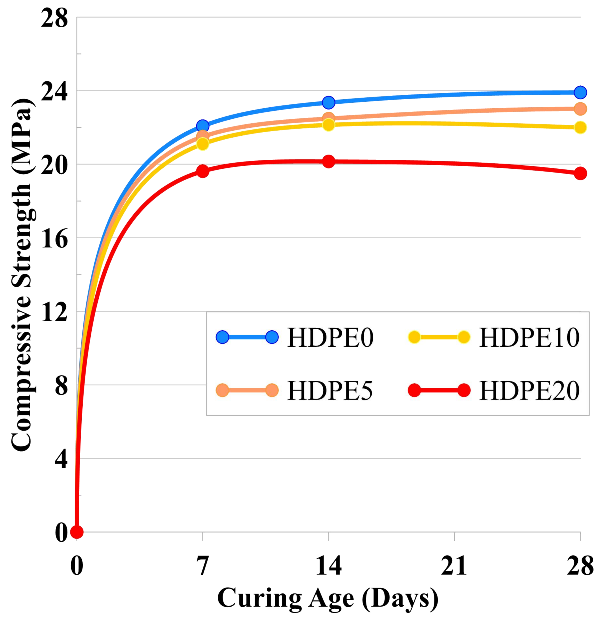

Fig. 4. Variation of compressive strength of HDPE based concrete

3.2.2 Split tensile strength -

Is an indirect method to check the tensile strength of the concrete. The splitting tensile is determined at 28 days of curing. The results obtained are presented in “Fig. 5”. The behaviour of concrete is similar to the compressive strength and hence split tensile strength decreases with increase in the HDPE content. The control mix without HDPE has split tensile strength of 2.99 MPa and with increase in the HDPE replacement ratio (5%, 10% and 20%) it drops to 2.74, 2.46 and 1.89 MPa respectively. The decrement in the split tensile strength is attributed to shape and size of the aggregate.

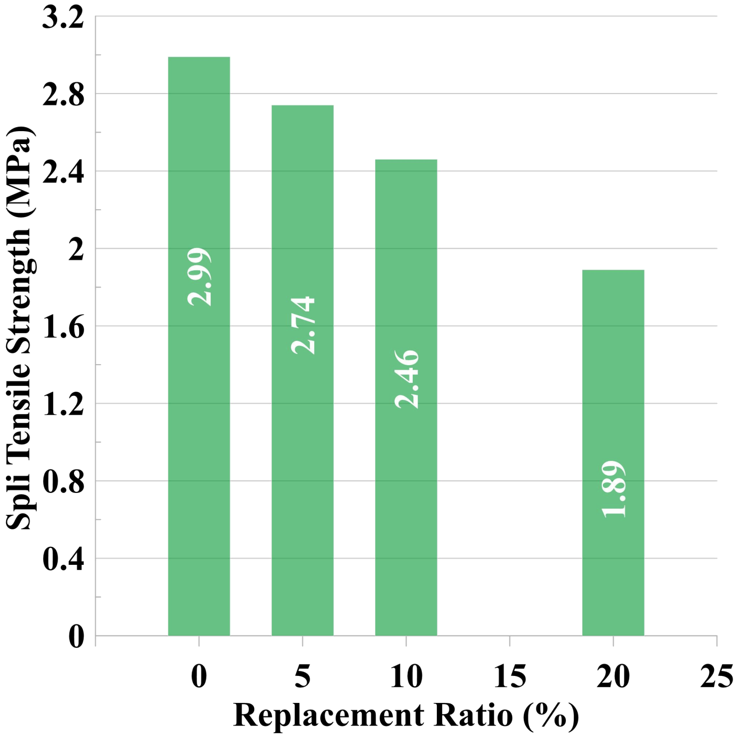

Fig. 5. Variation of split tensile strength with replacement ratio

4. CONCLUSIONS

- Concrete with HDPE has lower workability as compared with natural aggregates. It is due to plastic waste having irregular and non-uniform shapes.
- With increase in the replacement ratio of HDPE mass density decreases considerably.

  Compressive strength and split tensile strength of concrete with HDPE decreases with increase in the HDPE replacement ratio. It is due weak bonding effect between plastic surface and concrete matrix which leads to early failure of the concrete specimens.

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Optimizing Industrial Waste in Road Construction: A Response Surface Methodology Approach

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Abstract

With the increasing need to integrate sustainable practices in construction to mitigate environmental impacts, this study explores the use of industrial waste materials, specifically fly ash, glass fiber, and ground granulated blast furnace slag (GGBS), as stabilizing binders for the base and subbase layers of flexible pavements. By employing Design Expert 13 software and Response Surface Methodology (RSM), optimal mixture designs were determined. According to the analysis, a mix containing 88% fly ash, 3% glass fiber, and 9% GGBS meets the necessary specifications for a subbase layer, while a blend of 83% fly ash, 5% glass fiber, and 12% GGBS is adequate for the base layer. This investigation incorporated Modified Compaction tests, Unconfined Compressive Strength (UCS) tests, California Bearing Ratio (CBR) tests, and an ANOVA framework to ensure a robust statistical approach. The study's outcomes not only reveal the mechanical prowess of these industrial by-products when stabilized for pavement layers but also contribute to the discourse on sustainable road construction, offering an environmentally friendly solution by repurposing industrial waste.

Keywords: Sustainable Pavement Construction, Fly Ash Stabilization, Response Surface Methodology, Flexible Pavement

1. Introduction

In the realm of civil engineering and construction, the burgeoning need for sustainable and eco-friendly practices has become increasingly paramount. As global environmental concerns intensify, the construction sector faces mounting pressure to reduce its ecological footprint. One promising avenue for achieving this goal lies in the utilization of industrial waste materials in road construction. Not only does this approach aid in mitigating the adverse environmental impacts associated with the disposal of industrial by-products, but it also presents a resource-efficient alternative to conventional construction materials [1–3]. The incorporation of industrial waste such as fly ash, glass fiber, and ground granulated blast furnace slag (GGBS) in road construction not only aligns with the principles of sustainable development but also offers enhanced material properties and cost-effectiveness. This paradigm shift towards embracing industrial waste in road infrastructure signifies a critical step in advancing sustainable construction practices while addressing the urgent need for environmental stewardship.

Many researchers done the study on stabilization of soil with different binders like lime [4, 5] , GGBS [6–8], Gypsum [9], fly ash [10], etc. There is a need to use bulk utilization of coal ash (Fly ash, Bottom ash, and Pond ash) for different engineering applications. In recent decades, extensive research has been conducted to explore the potential of using industrial waste and by-products in road construction, with a focus on improving the mechanical properties of pavement layers and promoting sustainable practices. Kumar et al. [11] demonstrated that higher lime content in ground granulated blast furnace slag (GBFS) and lime mixtures enhances the California Bearing Ratio (CBR) values, yielding subbase and base layers with CBR ranging from 37 to 151. Similarly, Reddy and Gourav [12] observed that the

Unconfined Compressive Strength (UCS) of a mixture comprising lime-fly ash and gypsum increased with the lime content and curing temperature, reporting a UCS of 10 MPa in a subbase mixture with 2% gypsum and 12% lime.

2. Materials and Method

In this research, the fly ash sample was sourced from a thermal power plant located in Surat, Gujarat, India. Grain size analysis revealed that over half of the fly ash particles were smaller than 75 microns, falling into the clay and silt categories. Physical properties of the fly ash included a specific gravity of 2.23 and a bulk density of 805 kg/m3. The stabilizers used, namely glass fiber and GGBS, were obtained locally in Nashik area. An X-ray fluorescence test revealed the composition of the binders, indicating that glass fiber contained approximately 19.2% CaO, while GGBS had about 34.21% CaO (Table 1). Based on its low CaO content (roughly 0.87%), the fly ash was categorized as Class F according to the ASTM C618 standards .

Table 1 Chemical Composition of raw materials used in this study

Material	**SiO_2**	**Al_2O_3**	**Fe_2O_3**	**CaO**	**MgO**	**SO_3**	**Loss on ignition**
Fly Ash	52.30%	33.05%	5.23%	0.87%	1.53%	1.0%	1.0%
Glass Fiber	54.30%	14.52%	-	19.21%	4.5%	-	-
GGBS	35.24%	12.22%	0.53%	34.21%	8.0%	1.5%	-

3. Results and Discussion

3.1 Response Surface Methodology

Table 2 and Table 3 presents input data from an experimental study exploring the impact of varying percentages of Fly Ash and Glass Fibre on the Unconfined Compressive Strength (UCS) of a mixture measured at two different curing periods (7 days and 28 days). All the UCS samples were cast at their corresponding Maximum dry density (MDD) and Optimum Moisture content (OMC). The experiment employs a factorial design, where Fly Ash and Glass Fibre are the primary factors varied across different runs. Each run is identified by a standard number and includes readings for UCS at both 7 and 28 days. The Table 1 also includes a range (Low-High) for each component and adjusted values with positive and negative alpha levels.

Table 2 Input Parameters provided in Design Expert 13 software

Name	Units	Low	High	-Alpha	+Alpha
Fly Ash	%	75	100	66.4776	108.522
Glass Fibre	%	1	5	-0.363586	6.36359
GGBS	%	3	18	-2.11345	23.1134

Table 3 Experimental Data on the Effect of Fly Ash and Glass Fibre Percentage on the Unconfined Compressive Strength (UCS) of a Composite Material

Std	Run	Factor 1 A: Fly ash (%)	Factor 2 A: Glass fiber (%)	Factor 3 A: GGBS (%)	Response 1 UCS (7 Days) MPa	Response 2 UCS (28 Days) MPa
17	1	100	0	0	0.1	0.18
12	2	97	0	3	0.19	0.31
20	3	96	1	3	0.62	0.98
10	4	90	1	9	1.21	1.63
7	5	81	1	18	2.21	3.05
3	6	95	2	3	1.1	1.4
18	7	89	2	9	1.72	2.52
13	8	83	2	15	2.44	3.21
1	9	88	0	12	0.6	0.84
4	10	82	0	18	0.75	0.98
19	11	94	3	3	1.46	1.96
2	12	88	3	9	2.34	3.1
9	13	85	3	12	2.62	3.54
5	14	99	1	0	0.17	0.29
8	15	97	3	0	0.54	0.93
15	16	95	5	0	0.95	1.45
14	17	90	4	6	2.3	2.91
16	18	84	4	12	3.14	4.43
6	19	89	5	6	3.6	4.5
11	20	83	5	12	4.67	6.76

3.2 ANOVA for 7 Days Unconfined Compressive Test Results

Table 4 shows the results of an analysis of variance (ANOVA) for a study investigating the effects of different components namely Fly Ash, Glass Fibre, and Ground Granulated Blast-furnace Slag (GGBS) on a particular response, possibly related to the properties of a composite material. The analysis includes various interaction terms, such as AB (Fly Ash and Glass Fibre interaction), AC, BC, and a three-way interaction ABC, along with quadratic effects like A^2 and A^2B. The model is statistically significant, as indicated by a very low p-value (< 0.0001) and a high F-value (53.63). This implies that at least one of the factors or interactions significantly affects the response variable. Among the factors, both Fly Ash (A) and Glass Fibre (B) show significant effects, with p-values of 0.0005 and < 0.0001, respectively. However, GGBS (C) does not seem to have a significant impact on its own, as its sum of squares is zero. The interaction terms AB, AC, BC, ABC, and the quadratic term A^2B do not show statistical significance, given their high p-values, suggesting these interactions and quadratic effects do not significantly influence the response.

The residual sum of squares is relatively low (0.9253), indicating a good fit of the model. The total corrected sum of squares is 29.87. The standard deviation of the model is 0.2777. The coefficient of variation (C.V.%) is 8.97%, suggesting a moderate level of variability relative to the mean of the response (1.64). The R^2 value is very high (0.9690), indicating that 96.90% of the variability in the response is explained by the model. The adjusted R^2, which accounts for the number of predictors in the model, is also high (0.9510), suggesting a good fit. The predicted R^2 (0.8288) is somewhat lower, indicating that the model might be slightly less effective at predicting new observations. The Adequate Precision ratio of 24.9227, being greater than 4, suggests an adequate signal-to-noise ratio for this model.

Table 4 ANOVA for UCS at 7 Days: Significance of Fly Ash and Glass Fibre with Model Validation Metrics

Source	Sum of Squares	df	Mean Square	F-value	p-value
Model	28.95	7	4.14	53.63	< 0.0001
A-Fly Ash	1.76	1	1.76	22.79	0.0005
B-Glass Fibre	7.97	1	7.97	103.37	< 0.0001
AB	0.0316	1	0.0316	0.4104	0.5338
AC	0.2501	1	0.2501	3.24	0.0969
BC	0.0109	1	0.0109	0.1409	0.7139
ABC	0.1482	1	0.1482	1.92	0.1909
A^2B	0.0535	1	0.0535	0.6938	0.4211
Residual	0.9253	12	0.0771	C.V. %	16.97
Cor Total	29.87	19	-	R^2	0.9690
Std. Dev.	0.2777	Mean	1.64	Adjusted R^2	0.9510
Predicted R^2	0.8288	-	-	Adeq Precision	24.92

Table 5 provides the regression coefficients, standard errors, 95% confidence intervals, and Variance Inflation Factors (VIFs) for each term in a statistical model assessing the impact of Fly Ash (A), Glass Fibre (B), their interactions (AB, AC, BC, ABC), and a quadratic interaction term (A^2B) on a response variable. Notably, both Fly Ash and Glass Fibre show significant effects, with Fly Ash negatively influencing the response, while Glass Fibre shows a positive effect. The high VIFs for some interaction terms suggest potential multicollinearity issues in the model.

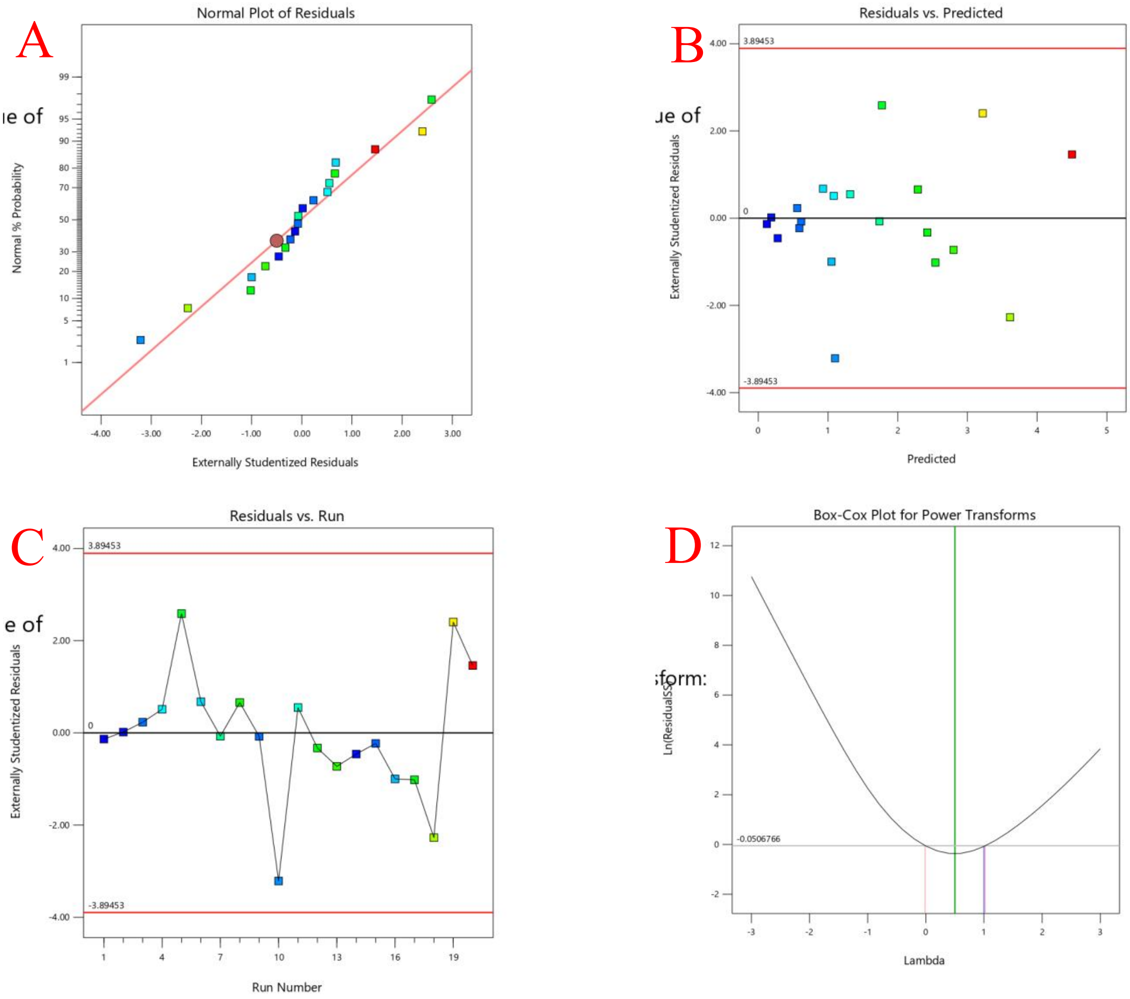
Table 5 Regression Coefficients and Diagnostics: Impact of Fly Ash and Glass Fibre on the response, with confidence intervals and multicollinearity assessment

	Coefficient Estimate	df	Standard Error	95% CI Low	95% CI High	VIF
Intercept	2.50	1	0.1222	2.23	2.76	
A-Fly Ash	-1.65	1	0.3462	-2.41	-0.8985	6.90
B-Glass Fibre	1.19	1	0.1170	0.9347	1.44	2.56
AB	-0.4815	1	0.7516	-2.12	1.16	42.22
AC	0.6111	1	0.3394	-0.1283	1.35	5.73
BC	0.1549	1	0.4126	-0.7441	1.05	34.58
ABC	1.23	1	0.8898	-0.7052	3.17	79.06
A^2B	1.14	1	1.37	-1.85	4.14	85.46

The equation for predicting the Unconfined Compressive Strength (UCS) at 7 days, based on the coefficients provided, is:

$$\text{UCS (7 Days)}=2.50-1.65\times A+1.19\times B-0.4815\times AB+0.6111\times AC+0.1549\times BC+1.23\times ABC+1.14\times A^2B \quad \ldots\ldots\ldots\ldots.(1)$$

This equation (1) represents a predictive model for the 7-day Unconfined Compressive Strength (UCS) of a material, incorporating factors like the percentages of Fly Ash (A), Glass Fibre (B), and Ground Granulated Blast-furnace Slag (GGBS) (C), as well as their interactions. The coefficients indicate the magnitude and direction of each factor's impact on UCS. Notably, both Fly Ash and Glass Fibre show significant individual effects, while their combined interactions and quadratic terms are also factored into the model. The collection of diagrams provides a comprehensive analysis of a 7-day UCS study (Figure 1). A 3D surface plot reveals the interaction between Fly Ash and Glass Fibre percentages on UCS, indicating that both materials' proportions significantly affect compressive strength (Figure 1-F). A cube plot further elucidates these effects by showing predicted UCS values at various material levels (Figure 1-E).



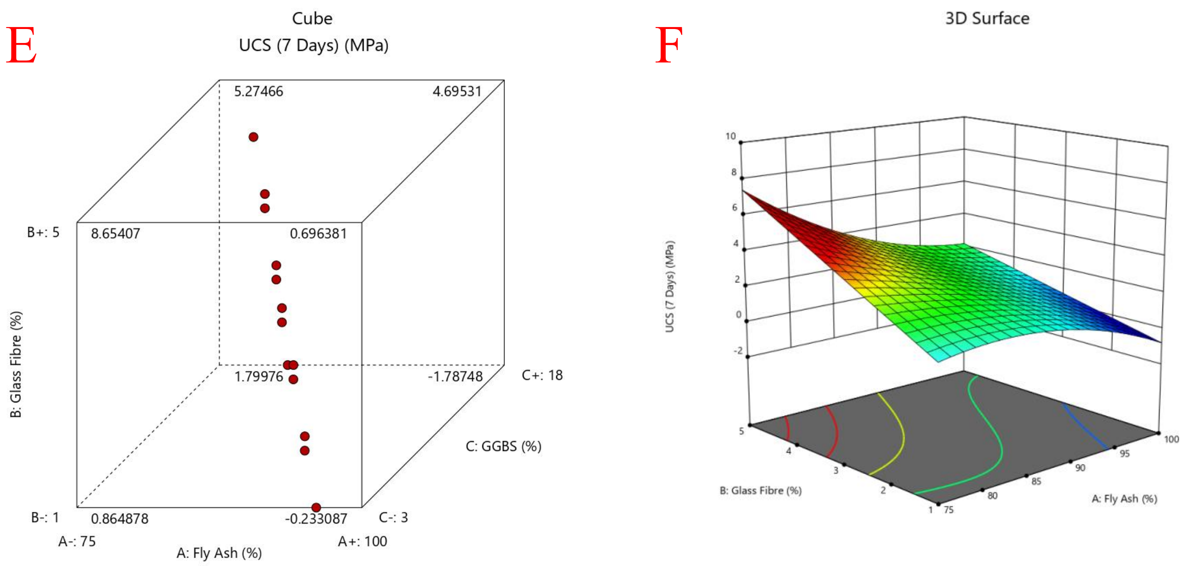


Figure 1 The set includes a 3D surface plot for UCS impact analysis, a predictive cube plot, model diagnostic plots, and a Box-Cox plot confirming the adequacy of the current model for 7-day UCS outcomes

4. Conclusion

In summary, this research provides significant insights into sustainable construction practices while addressing key challenges in pavement engineering. The main conclusions are:

1. The study demonstrates the effective application of industrial waste such as fly ash, glass fiber, and GGBS in enhancing the sustainability of pavement base and subbase layers.
2. Utilization of Response Surface Methodology enabled the identification of optimal mixture proportions, ensuring that the compositions for both subbase and base layers meet required strength criteria.
3. Through the application of Response Surface Methodology and ANOVA analysis, the research identifies optimal mix proportions for pavement layers. A mix containing 88% fly ash, 3% glass fiber, and 9% GGBS is found suitable for the subbase layer, while 83% fly ash, 5% glass fiber, and 12% GGBS meet the criteria for the base layer, thus ensuring both structural integrity and durability.
4. It also highlights the necessity for further exploration into the use of glass fiber as a binder and the implementation of RSM and ANOVA techniques in pavement mix optimization.
5. Overall, the study significantly contributes to the field of sustainable road construction by demonstrating the effective use of industrial by-products, thereby fostering more environmentally conscious construction practices.

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Static analysis of FGM beam using hyperbolic beam theory

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Abstract
Hyperbolic beam theory is applied in this paper for the static analysis of functionally graded beam under uniform load. The theory is developed using the principle of virtual work. A hyperbolic beam theory was used in this paper to compare the static response of functionally graded beams under uniform load. This hyperbolic beam theory satisfies the traction free conditions on the top and bottom surfaces of the beam. Navier's solution is used to solve the governing equations considering simple ends of the FG beam. Solutions available in the literature are taken for comparison purpose and found that the present findings are matching with the present beam theory.
Keywords: Static Analysis, FGM, Hyperbolic Beam Theory.

1. Introduction

Functionally graded material (FGM) refers to a type of material that exhibits a gradation in its composition, microstructure, or properties over its volume. Stress concentration, often a concern in materials with abrupt changes in properties, is mitigated in FGM due to their gradual transitions. This property is particularly valuable in applications where mechanical stresses vary, as FGMs can distribute these stresses more evenly throughout the material. FGMs find applications in aerospace, civil engineering, nuclear reactors, and other areas where materials with specific and tailored properties are crucial. Static analysis provides information about the distribution of deformations and stresses within the FG beam. This knowledge is crucial for ensuring that the material does not experience localized failures or excessive deformations. Classical beam theory (CBT), attributed to Bernoulli [1]and Euler [2], is the most basic beam theory in literature for analyzing isotropic and anisotropic beams. However, it falls short when applied to thick beams made of composite materials like FGM, due to the neglect of transverse shear deformation. For the examination of thick beams composed of composite materials, it is inaccurate. Timoshenko [3] introduced the first-order shear deformation theory to address this, but it has drawbacks such as constant shear strain through the thickness and the necessity of a shear correction factor. Overcoming these limitations, higher-order shear deformation theories have been developed, providing more accurate results by properly accounting for shear deformation. Reddy [4] presented a higher-order shear deformation theory for analyzing laminated composite plates. The theory relaxes the assumption of straightness of normal to the mid-surface often made in classical plate theories. Sayyad [5] this analysis examines the bending, buckling, and vibration characteristics of FGM nanobeams. Various higher order shear deformation theories have been developed by various researchers for the analysis of isotropic and anisotropic beams, such as those by Soldatos [6].

In the present paper, normal stress and shear stress of simply supported FGM beam is calculated using hyperbolic beam theory. This hyperbolic shape function accounts for the realistic behaviour of transverse shear stress at top and bottom of rectangular cross section of the FG beam. Power Law is used for FGM gradation through the thickness of beam. Governing equations are obtained by using principal of virtual work. Navier's solution approach is used for solving the governing equations. Numerical results for normal stress and shear stress of FG beam are compared with available results in the literature.

2. FGM Beam under Consideration

For the mathematical formulation, FGM beam of length L and cross section $b \times d$, as shown in Fig. 1 is considered with simply supported end condition. Downward z direction is considered as positive. The beam is composed of a FGM consisting of Al/Al_2O_3, wherein the material properties vary in the thickness direction.

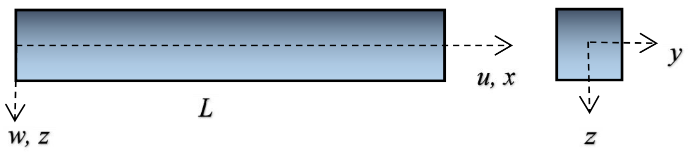


Fig. 1. FGM beam under consideration

This variation in material properties of the FGM beam follows power law gradation as given in equation (1).

$$E(z) = E_m + (E_c - E_m)\left(0.5 + \frac{z}{h}\right)^p \tag{1}$$

where E is the Modulus of Elasticity, E_m and E_c are the elastic properties metallic and ceramic material respectively, and p is the power law coefficient which ranges from zero to infinity. z/h is the thickness ordinate. Zero value of power law coefficient represents a beam fully made of ceramic material and power law coefficient equal to infinity represents a beam of fully metallic material.

3. **Kinematics of the Present Theory**

The displacement field of the present theory is stated in equation (2). The traction-free boundary conditions on the top and bottom surfaces of the FGM beam are obtained using the parabolic shape function in the present beam theory.

$$\Delta_x(x,z) = \Delta_{x0}(x) - z\frac{\partial \Delta_{z0}}{\partial x} + \left(z\,cosh\frac{\xi}{2} - \frac{h}{\xi}sinh\frac{\xi z}{h}\right)\theta_x$$
$$\Delta_z(x) = \Delta_{z0}(x) \tag{2}$$

where, Δ_x and Δ_z are the axial and transverse displacements along x and z axis respectively; θ is the rotation. Parabolic shape function accounts for the impacts of transverse shear deformation, in the axial displacement. The nonzero strains as stated in equation (3) are obtained from the theory of elasticity.

$$\varepsilon = \frac{\partial \Delta_x}{\partial x} - z\frac{\partial^2 \Delta_y}{\partial x^2} + \left(z\,cosh\frac{\xi}{2} - \frac{h}{\xi}sinh\frac{\xi z}{h}\right)\frac{\partial \theta}{\partial x}$$
$$\gamma = \left(cosh\frac{\xi}{2} - cosh\frac{\xi z}{h}\right)\theta \tag{3}$$

Stresses in FGM beam are calculated from Hooke's law as given in equation (4).

$$\sigma = E(z)\varepsilon$$
$$\tau = \frac{E(z)}{2(1+\mu)}\gamma \tag{4}$$

Differential equations are developed using the principle of work done as stated in equation (5).

$$\int_0^L \int_{-h/2}^{h/2} (\sigma\delta\varepsilon + \tau\delta\gamma)dzdx - \int_0^L q(x)\delta\Delta_z dx = 0 \tag{5}$$

where $q(x)$ is the transverse load acting on FGM beam. The differential equations are obtained by part wise integrating Eq. (5) and collecting the differential coefficient terms of unknowns, and equating them with zero. Equation (6) states the governing equations of the present theory.

$$A\frac{\partial^2\Delta_{x0}}{\partial x^2}-B\frac{\partial^3\Delta_{z0}}{\partial x^3}+C\frac{\partial^2\theta}{\partial x^2}=0$$
$$B\frac{\partial^3\Delta_{x0}}{\partial x^3}-D\frac{\partial^4\Delta_{z0}}{\partial x^4}+F\frac{\partial^3\theta}{\partial x^3}=-q(x) \quad (6)$$
$$C\frac{\partial^2\Delta_{x0}}{\partial x^2}-F\frac{\partial^3\Delta_{z0}}{\partial x^3}+H\frac{\partial^2\theta}{\partial x^2}-J\theta=0$$

Where

$$(A,B,C,D,F,H,J)=b\int_{-h/2}^{h/2}E(z)\left[1,z,f(z),z^2,zf(z),f^2(z),\left(f^{'}(z)\right)^2\right]dz \quad (7)$$

Transverse deflection and axial deflection in simply supported FG nanobeam are calculated using the Navier solution scheme that satisfies the simply supported end conditions exactly i.e. $N_x=\Delta_z=M_x^b=M_x^s=0$. The unknown degree of freedom of the present theory and the transverse load are assumed in the single Fourier series.

$$\Delta_{x0}=\sum_{m=1}^{\infty}\Delta_{xm}\cos rx,$$
$$\Delta_{z0}=\sum_{m=1}^{\infty}\Delta_{zm}\sin rx,$$
$$\theta_m=\sum_{m=1}^{\infty}\theta_m\cos rx, \quad (8)$$
$$q(x)=\sum_{m=1}^{\infty}\frac{4q_0}{m\pi}\sin rx$$

Where $r=\frac{m\pi}{L}$, $(\Delta_{xm},\Delta_{zm},\theta_m)$ are unknown coefficients, q_0 is the maximum intensity of uniform loading. Eq. (8) substituted into Eq. (6) to give solutions for the static problem stated in Eq. (9).

$$\begin{bmatrix}-Ar^4 & Br^3 & -Cr^2\\ Br^3 & -Dr^4 & Fr^3\\ -Cr^2 & Fr^3 & -(Hr^2+J)\end{bmatrix}\begin{Bmatrix}\Delta_{xm}\\ \Delta_{zm}\\ \theta_m\end{Bmatrix}=\begin{Bmatrix}0\\ -\frac{4q_0}{m\pi}\\ 0\end{Bmatrix} \quad (9)$$

4. Results and Discussions

In this present section, static problem of FGM beam is discussed. The FGM beam made up of Al/Al_2O_3 metal/ceramic material is considered for generating the results. Properties of metal/ceramic are presented in equation (10).

$$Ec=380\,GPa, Em=70\,GPa, \mu_c=\mu_m=0.3 \quad (10)$$

All results are generated in following non-dimensional form for the simplicity.

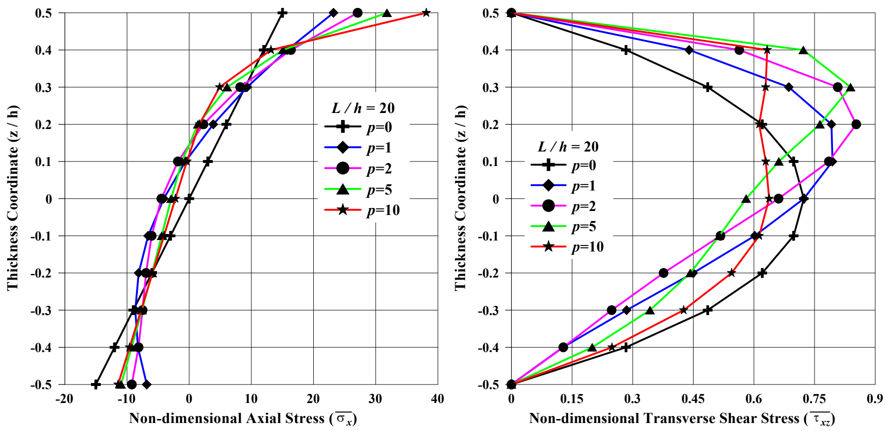
$$\overline{\sigma_x}=\frac{\sigma_x h}{q_{0L}}\quad ,\overline{\tau_{xz}}=\frac{\tau_{xz}h}{q_{0L}} \quad (11)$$

Table 1. A comparison of the non-dimensional displacements and stress of the FG beams subjected to uniform loads with various power law exponent values

p	Theory	*L/h* = 5				*L/h* = 20			
		$\overline{\Delta}_x$	$\overline{\Delta}_z$	$\overline{\sigma}_x$	$\overline{\tau}_{xz}$	$\overline{\Delta}_x$	$\overline{\Delta}_z$	$\overline{\sigma}_x$	$\overline{\tau}_{xz}$
0	Present	0.9390	3.1653	3.8008	0.7171	0.2305	2.8962	15.0132	0.7234
	Reddy [4]	0.9397	3.1654	3.8019	0.7330	0.2306	2.8962	15.0129	0.7437
	CBT [1,2]	0.9211	2.8783	3.7500	-	0.2303	2.8783	15.0000	-
1	Present	2.3025	6.2953	5.8816	0.7171	0.5685	5.8049	23.2057	0.7234
	Reddy [4]	2.3036	6.2594	5.8836	0.7330	0.5686	5.5685	23.2051	0.7432
	CBT [1,2]	2.2722	5.7746	5.7959	-	0.5680	5.7746	23.1834	-
2	Present	3.1113	8.0663	6.8797	0.6544	0.7691	7.4491	27.0994	0.6610
	Reddy [4]	3.1127	8.0677	6.8824	0.6704	0.7691	7.4421	27.0989	0.6812
	CBT [1,2]	3.0740	7.4003	6.7676	-	0.7685	7.4003	27.0704	-
5	Present	3.7074	9.8212	8.1057	0.5737	0.9133	8.8178	31.8132	0.5806
	Reddy [4]	3.7097	9.8281	8.1104	0.5904	0.9134	8.8182	31.8127	0.6013
	CBT [1,2]	3.6496	8.7508	7.9428	-	0.9124	8.7508	31.7711	-
10	Present	3.8831	10.934	9.7076	0.6300	0.9536	9.6902	38.1391	0.6377
	Reddy [4]	3.8859	10.938	9.7119	0.6465	0.9536	9.6905	38.1382	0.6586
	CBT [1,2]	3.8097	9.6072	9.5228	-	0.9524	9.6072	38.0913	-

5. Discussions

The numerical results for axial stress $(\overline{\sigma_x})$ and transverse shear stress $(\overline{\tau_{xz}})$ in FGM beam subjected to uniform load are presented in Table 1 for L/h=5 and 20 and various values of power law coefficient $(p = 0, 1, 2, 5, 10)$. All results are presented in non-dimensional form. The present results are compared with previously published results. It can be seen from Table 1 all results are in a good accord previously published theories. This shows the accuracy of the present theory. Figs.(3-4) shows axial stress and transverse shear stress distribution through the thickness for various values power law coefficient (p) for the simply supported FGM beam.



(a) *(b)*

Fig.3 Variation of (a) non-dimensional axial stresses (b)non-dimensional transverse shear stresses through the thickness

6. Conclusions

This study highlights the use of hyperbolic shape function to predict the axial and transverse shear stress in FGM beam subjected to uniform load. The non-dimensional axial stress increases with the increase in power law coefficient. Due to inclusion of hyperbolic shape functions in the displacement field, non-dimensional transverse shear stress across the thickness of the beam satisfies the traction free conditions at the top and bottom surfaces of the beam. It is concluded that the present theory is in good accord with previous research results.

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Faculty Articles

Variation in water absorption and density of polyethylene terephthalate (PET) modified concrete

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Abstract: This study investigates the impact of replacing conventional coarse aggregates (CA) with polyethylene terephthalate (PET) bottle caps in concrete, focusing on density and water absorption. Concrete mixes were designed by incorporating Full (F-PA), Half (H-PA), and Quarter (Q-PA) PET aggregates at varying replacement levels. Results indicated that PET incorporation reduced density, with F-PA showing the lowest value (2326.52 kg/m³) after 56 days, a 1.48% reduction compared to the control mix, while maintaining strength. Water absorption increased with larger PET aggregates due to higher void content, whereas Q-PA exhibited values nearly identical to the control mix, improving density and reducing permeability. These findings highlight the potential of PET-modified concrete as a sustainable, lightweight alternative without compromising structural performance.

Keywors: *PET waste, density, water absorption, aggregate replacement.*

1. Introduction

The increasing demand for sustainable construction materials has led to extensive research on incorporating waste plastics into concrete. Among various plastic wastes, polyethylene terephthalate (PET) has gained significant attention due to its availability and potential to enhance mechanical properties when used as fibers or aggregates. Studies have shown that PET fibers derived from waste bottles can improve concrete's durability and mechanical strength when optimized for specific parameters (Mouna et al., 2024). Similarly, PET aggregates, both uniform and non-uniform in size, have been investigated for their influence on the mechanical and microstructural properties of concrete, highlighting their feasibility as a sustainable alternative to natural aggregates (Wattanavichien & Iwanami, 2024). Innovative applications of PET waste have also extended to bottle caps, which can be used as aggregate replacements in concrete. Research indicates that incorporating PET bottle cap waste can contribute to sustainable construction while maintaining desirable structural properties (Gayake & Desai, 2024). Furthermore, multi-criteria decision-making (MCDM) tools have been employed to assess the sustainability of concrete produced using PET bottle cap aggregates, ensuring an optimal balance between environmental and mechanical performance (Gayake & Desai, 2024). In addition to PET, waste microplastics have been explored as reinforcement in mine waste backfills, demonstrating their potential in geotechnical applications (Yaya et al., 2025). Beyond PET-based materials, other plastic waste, such as ground recycled acrylonitrile butadiene styrene (GRABS), has been incorporated into cementitious mortar. Studies have shown that factors like particle size and replacement ratios significantly impact the mechanical performance of such composites (Olsen et al., 2025). Further research on impact strength has highlighted the effectiveness of PET waste additives in improving concrete's toughness and resilience (Gayake et al., 2025). These advancements emphasize the growing importance of integrating waste plastics into construction materials, contributing to environmental sustainability while enhancing material performance. Despite significant research on PET-modified concrete, there is limited literature available on the variation in density and water absorption properties of such materials. This study aims to address this gap by investigating the effects of PET incorporation on the density and water absorption characteristics of concrete, providing valuable insights into its performance and potential applications in sustainable construction.

2. Raw materials and Mix design

Portland Pozzolana Cement (PPC) of 43 grade was used with 20mm quarry stones as coarse aggregates (CCA) and natural river sand as fine aggregate (FA). Materials were cleaned, and specific gravity and water absorption were tested per IS 2386 (Part IV) – 1963 and IS 1489 (Part I) – 1991. Four mix types replaced CCA with PET aggregates (PETA) at 3%, 5%, and 8%, using a volumetric design approach due to specific gravity differences. Full, half, and quarter cap PET aggregates were compared with M25 concrete. The mix design followed IS 10262:2009 with a 0.50 water-cement ratio and a target strength of 25 MPa, maintaining a proportion of 1:2.09:2.83:0.5 for cement (383.2 kg/m³), fine aggregate (800.94 kg/m³), coarse aggregate (1087.7 kg/m³), and water. PET bottle caps, collected from restaurants and hotels, were cleaned, air-dried, and cut into different shapes (28mm diameter) without pre-heating or shredding, modifying only the surface configuration.

3. Result and discussions

Standard 150mm concrete cubes were used to evaluate the density and water absorption characteristics of PET-modified concrete. The specimens were prepared following standard procedures, including proper mould preparation, casting, demoulding, and full immersion curing for 28 days. The influence of PET aggregates on concrete properties was assessed through density measurements and water absorption tests, ensuring consistency and reliability in the results.

3.1 Variation in density of PET modified concrete

The weight of content refers to the volume a material occupies, which can be determined from its density. In concrete, density affects dead load and structural performance, typically decreasing strength as it reduces. However, replacing coarse aggregates (CA) with PET bottle caps lowered density while maintaining strength. Experimental results as cited in **Figure 1** showed that PET incorporation reduced density, with Full PET Aggregates (F-PA) having the lowest value of 2326.52 kg/m³ after 56 days. This is due to F-PA's larger surface area, which reduces CA volume. Density increased as PET aggregate size decreased, with Half (H-PA) and Quarter (Q-PA) PET showing nearly identical values. The overall density reduction was 1.48% compared to the control mix, yet strength remained unaffected. This highlights PET-modified concrete's potential for lightweight applications without compromising strength, making it a viable sustainable alternative.

3.2 Variation in water absorption of PET modified concrete

Water content significantly impacts concrete's fresh and hardened properties, influencing durability and service life. This study assessed water absorption in PET-modified concrete by weighing cube specimens before and after curing. Results observed in **Figure 2** showed that larger PET aggregates, like Full PET Aggregates (F-PA), had the highest absorption 2.629% more than the control due to increased voids. In contrast, Half (H-PA) and Quarter (Q-PA) PET aggregates exhibited lower absorption, with Q-PA nearly matching the control, indicating improved density and reduced permeability. Smaller PET aggregates enhanced both density and mechanical properties, making them beneficial for durable concrete.

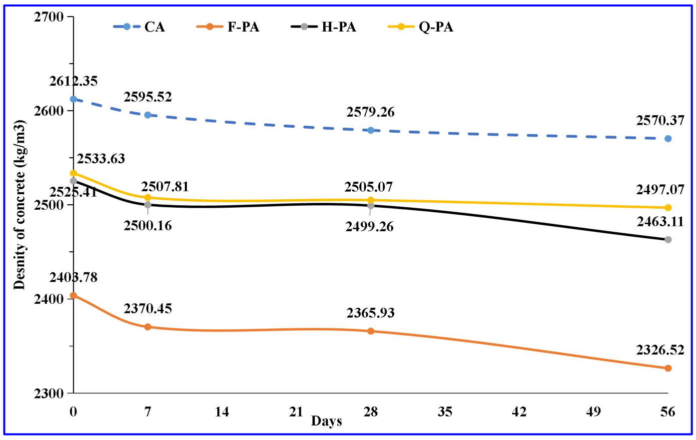

Figure 1 Variation in density of PET modified concrete

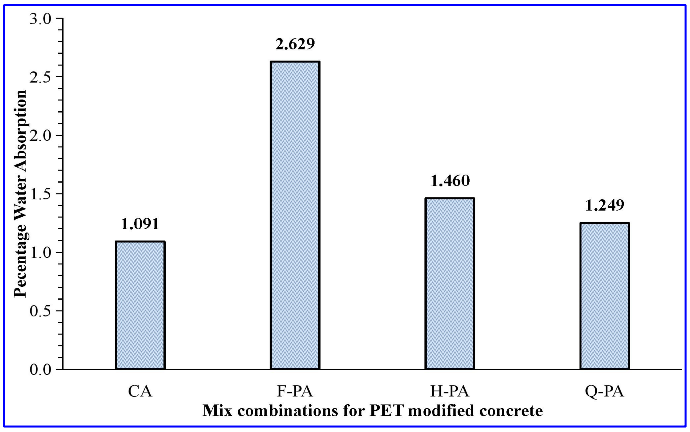

Figure 2 Variation in water absorption of PET modified concrete

4. Conclusions

This study evaluated the effects of replacing conventional coarse aggregates (CA) with PET bottle caps in concrete, focusing on density and water absorption. The findings highlight the feasibility of using PET-modified concrete as a lightweight and sustainable alternative without compromising strength. The following conclusions are drawn from the study;

1. **Density reduction with strength retention:** Incorporating PET aggregates reduced concrete density by 1.48% compared to the control mix, with Full PET Aggregates (F-PA) exhibiting the lowest density (2326.52 kg/m³ after 56 days). Despite the reduction, the strength remained unaffected, making it suitable for lightweight applications.
2. **Influence of pet aggregate size on water absorption:** Larger PET aggregates, such as F-PA, increased water absorption by 2.629% due to higher void content. However, smaller aggregates, particularly Quarter PET Aggregates (Q-PA), demonstrated absorption levels nearly identical to the control mix, indicating better density and lower permeability.
3. **Optimized pet aggregate size for performance:** Smaller PET aggregates improved mechanical properties and durability by reducing voids in the concrete matrix. Q-PA emerged as the most effective modification, offering a balance between lightweight characteristics, reduced permeability, and retained strength.

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Study of Moment Resisting Frame Used for a Tall Building

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Abstract

With the rising population, the demand for space in urban areas has increased significantly. Due to the limited availability of land in developed cities, vertical expansion has become the most viable solution for accommodating the growing need for residential and commercial spaces. This has led to the development and adoption of various framing techniques to enhance the structural stability and performance of tall buildings. The selection of an appropriate framing system is influenced by both architectural and structural requirements, ensuring optimal load resistance and serviceability. This study examines different moment-resisting framing techniques for high-rise structures, as per IS 16700:2017, focusing on their performance under different loading conditions. The study employs linear static analysis, nonlinear static analysis (pushover analysis), and linear dynamic analysis to compare the effectiveness of these framing systems. By evaluating the analytically designed sections, this research aims to provide insights into the strength, deformation behavior, and lateral load resistance of different moment-resisting frame (MRF) techniques. The findings contribute to the optimization of structural design strategies for improving the resilience and efficiency of tall buildings in urban environments.

Keywords: High-rise buildings, Moment-resisting frames,Vertical expansion,Linear static analysis

Introduction

With rising population, the requirement of tall building is on peak in cities. Many approaches for modeling of tall building are made for fulfilling the required structural demand. Many of such modeling approaches are given in IS 16700 [1]. With change in modeling technique the behavior of building changes [2,3]. This change in behavior of building is studied in this paper using nonlinear static, linear static and linear dynamic analysis. During the process of performance evaluation of the building following steps were taken. Initially the sections were designed analytically using gravity and lateral load combinations. The designed cross-sections were later used for capacity evaluation of the different framing techniques [4,5,6].

Cracked RC section properties

Unfactored loads are considered to ensure compliance with all serviceability criteria, including deflection limits, vibration control, and crack width restrictions, as per standard design guidelines. On the other hand, factored loads are applied to account for safety margins in structural design, ensuring that the building can withstand extreme loading conditions without failure.

However, for performance evaluation of the building using pushover analysis, the structural elements are not considered as cracked sections. This approach allows for assessing the full capacity and ultimate strength of the structure, including its ability to resist progressive lateral load application until failure. The analysis helps in understanding the elastic and inelastic behavior, failure mechanisms, and potential weak zones in the structure, which is crucial for optimizing the design for seismic and lateral load resistance [7].

Table 1 - Cracked RC section properties

Structural element	Unfactored loads		Factored load	
	area	I	Area	I
Slab	1 A_g	0.35 I_g	1 A_g	0.25 I_g
Beams	1 A_g	0.70 I_g	1 A_g	0.35 I_g
Columns	1 A_g	0.90 I_g	1 A_g	0.7 I_g
Shear walls	1 A_g	0..90 I_g	1 A_g	0.7 I_g

Moment frame system- this frame consists of analytically designed lateral load resisting frames consisting of column and beams. The assumed data for this frame is given in table below.

a) Columns are assumed rectangular as the have equal moment if inertia in assumed two direction
b) The minimum grade of concrete to be used for tall building is M30 as per IS16700:2017

Table 2 Assumed data for RCMRF framing-

DATA	VALUE
Grade of steel	Fe 415
Grade of concrete	M30
Live load	3KN
Floor finishing load	1.5 KN
Response reduction factor	5
No of story's	21
No of bays along x direction	6
Span along x direction	4
No of bays along x direction	6
Span along x direction	4
Floor to floor height	3m
Column size	700*700mm
Beam size	300*400mm
Depth of slab	150mm

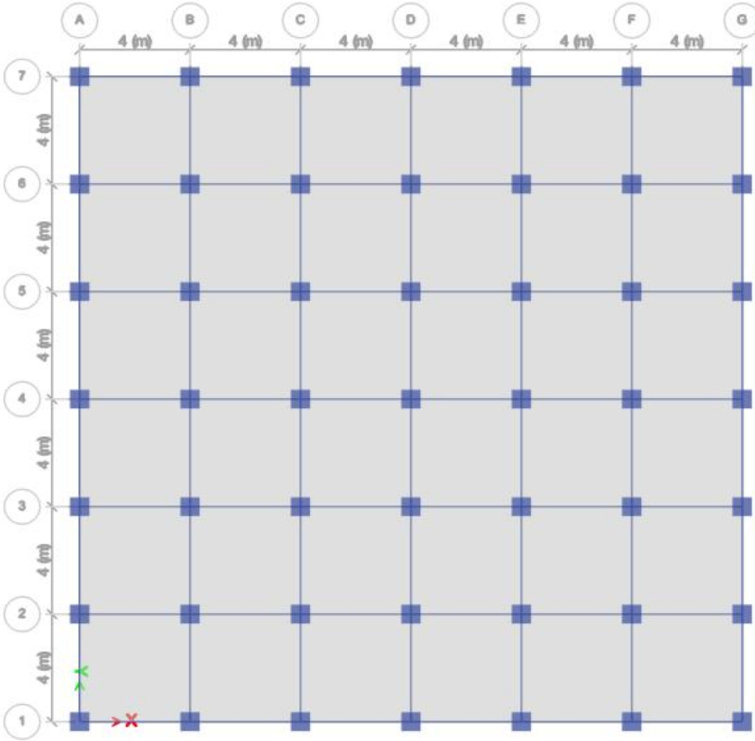

Fig 1 RC MRF Building

Results and discussions-

1. Stiffness – 115.6678 kN/mm: The stiffness of the moment-resisting frame is given as 115.6678 kN/mm. Stiffness is a measure of a structure's resistance to deformation under applied forces. In this case, the high stiffness value indicates that the moment-resisting frame is relatively rigid and resistant to lateral movements (such as those caused by wind or seismic forces). A higher stiffness generally means that the structure is designed to limit deflections and deformations, which is important for ensuring the overall stability and performance of the building. In seismic design, a sufficiently stiff frame helps in preventing excessive structural movement that could lead to damage or failure. This stiffness value suggests that the frame is likely well-designed to withstand applied forces without excessive deformation.

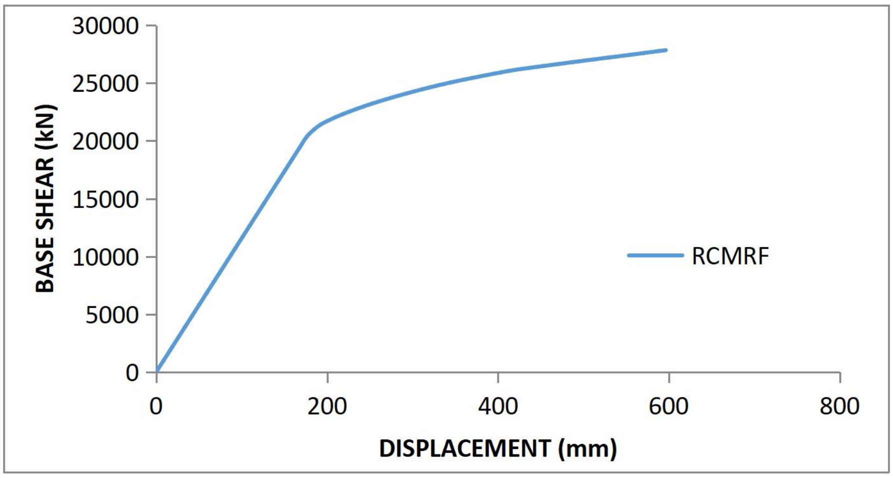

Fig 1 Push over curve of RC MRF building

2. Maximum Story Displacement – 191.617 mm: The maximum story displacement of 191.617 mm refers to the lateral movement of the top floor relative to the base or foundation of the building. This is the horizontal distance the structure shifts due to lateral forces such as wind or earthquake loading. While displacement is a necessary response of a building to lateral forces, it is critical to ensure that it remains within acceptable limits. Excessive displacement can lead to non-structural damage (e.g., partition walls, windows) or even affect the safety and comfort of the occupants. The value of 191.617 mm needs to be evaluated against the design limits stipulated by building codes. In general, larger displacements are acceptable for more flexible structures, but in high-rise buildings, limiting displacement is crucial to maintain functionality and occupant safety.
3. Maximum Story Drift – 0.0050: Story drift is the relative horizontal displacement between two consecutive floors. The maximum story drift of 0.0050 (which is 0.5% of the building's floor height) indicates the amount of horizontal shift between two adjacent floors due to lateral loads. Story drift is a key factor in evaluating the building's seismic performance. Most modern building codes (e.g., the International Building Code or IBC) prescribe limits for story drift to ensure that the building does not suffer structural or non-structural damage. A story drift of 0.0050 (or 0.5%) is generally within acceptable limits for most building types, indicating that the building is performing well under lateral loading conditions. Excessive drift could cause structural damage or discomfort for the building's occupants, but the given value suggests that the drift is within a tolerable range, balancing structural performance and occupant safety.

Conclusion:

The analysis revealed that all considered framing systems were structurally safe, with adequate strength and serviceability criteria. However, the effectiveness of framing technique varied based on stiffness, load distribution, and deformation characteristics. Moment-resisting frames (MRF) are widely used due to their flexibility, ease of construction, and ability to resist lateral forces. The results indicate that optimizing beam and column sizes, material selection, and connection detailing plays a crucial role in improving the overall structural efficiency. The study also emphasizes the importance of nonlinear and dynamic analysis in evaluating the behavior of tall buildings, particularly in seismic-prone and high-wind regions. Overall, this study reinforces the importance of selecting the appropriate framing technique in high-rise construction and highlights the need for further research on hybrid structural systems, advanced damping mechanisms, and sustainable materials to enhance the stability, safety, and performance of tall buildings.

Based on the results:

The high stiffness of the moment-resisting frame (115.6678 kN/mm) indicates that the structure has good resistance to lateral forces, which is vital for maintaining stability.

The maximum story displacement of 191.617 mm reflects the extent of lateral movement the building undergoes under lateral forces. Depending on the building's height and the design codes, this displacement is within the allowable range, but careful consideration of non-structural elements is needed.

The maximum story drift of 0.0050 indicates that the building's floors are shifting within acceptable limits, ensuring that the structure remains stable while avoiding excessive movement that could lead to damage or safety issues.

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