Application of Lan Wire Waste as a Reinforcement in Construction of Sustainable Pavement

A

Major Project Report

Submitted in partial fulfilment of the requirements for the award of the degree of

BACHELOR OF TECHNOLOGY

IN

CIVIL ENGINEERING

Under the supervision

of

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to

DEPARTMENT OF CIVIL ENGINEERING

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STUDENT’S DECLARATION

We confirm that the project report titled "**Application of Lan Wire Waste as a Reinforcement in Construction of Sustainable Pavement**," submitted as part of the requirements for the **Bachelor of Technology** degree in **Civil Engineering at Jaypee University of Information Technology, Waknaghat**, is our original creation. This project was carried out under the guidance of **Dr. Amardeep**, and this project has not been submitted elsewhwere for the fulfillment of any other degree or diploma.

We take full accountability for the content of our project report and verify its authenticity.

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CERTIFICATE

This certifies that the project report titled **"Application of Lan Wire Waste as a Reinforcement in Construction of Sustainable Pavement,"** submitted to the **Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat**, for the partial fulfillment of the requirements for the degree of **Bachelor of Technology in Civil Engineering**, is an authentic record of the work carried out by **Jatin Gupta** (201619), **Ankit Ravi** (201628), and **Sidharth Dogra** (201639) from August 2023 to May 2024. The project was conducted under the supervision of **Dr. Amardeep** from the **Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat.**

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ABSTRACT

The integration of Lan Wires (Copper Wires) fibers into concrete represents a groundbreaking and sustainable approach aimed at mitigating environmental pollution and addressing solid waste concerns. This study focuses on the utilization of E-waste (Lan Wires) fibers extracted from the outer casing insulation of electrical wires, with variations in fiber extraction methods, to assess their impact on the strength properties of concrete mixes. These mixes include compression blocks with an aspect ratio of 56.25, with Lan Wires of 4.5cm length and 0.08cm diameter, mesh structures with an aspect ratio of 112.5, having Lan Wires of 9cm length and 0.08cm diameter, and double layers of wires with an aspect ratio of about 28.125 and 56.25, respectively, with a diameter of 0.16cm and lengths of 4.5cm and 9cm. In cylinders, single-layer mesh structures with an aspect ratio of 100 and double layers with an aspect ratio of 300 and a diameter of 0.08cm and 0.16cm were used, respectively, with lengths of 8cm. In beams, single-layer mesh structures with an aspect ratio of 600 and double layers with an aspect ratio of 300 and diameters of 0.08cm and 0.16cm were used, respectively, with lengths of 48cm.

The investigation encompasses an evaluation of both fresh and hardened properties, including slump, fresh density, dry density, compressive strength, flexural strength, split tensile strength, and other key parameters, comparing these properties with those of conventional concrete at various curing stages. The introduction of E-waste (Lan Wires) fibers has shown promising enhancements in the properties of concrete, underscoring its potential as an alternative to conventional concrete while simultaneously curbing the disposal of E-waste (Lan Wires) into natural ecosystems.

In the experimental analysis, the addition of E-waste (Lan Wires) fibers in concrete significantly influenced its characteristics. Notably, the fiber-reinforced concrete exhibited notable improvements in strength properties compared to traditional concrete mixes. The utilization of E-waste (Lan Wires) fibers contributed to a positive trend in properties, augmenting the structural integrity and mechanical performance of the concrete. Moreover, this innovative approach facilitated a reduction in the volume of E-waste (Lan Wires) being deposited into the environment, addressing the challenge of waste accumulation.

The study's findings advocate for the adoption of fiber-reinforced concrete using E-waste (Lan Wires) fibers as a viable and sustainable alternative to conventional concrete. The observed improvements in concrete properties and the reduction in E-waste (Lan Wires) dumping underscore the potential environmental and structural benefits of this novel approach. Embracing this technology not only offers enhanced concrete performance but also contributes significantly to environmental preservation by repurposing E-waste (Lan Wires) into a valuable construction material, thereby advancing the principles of sustainable development and waste reduction.

Keywords: *Lan Wires, E-waste (Lan Wires), Fiber-reinforced concrete, Aspect ratio, Strength, Mesh Structure*

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CHAPTER 1

INTRODUCTION

1.1 GENERAL

The increase in recyclable materials, like Acrylonitrile Butadiene Styrene (ABS), Poly Vinyl Chloride (PVC), and E-waste (Lan Wires), around the world has drawn a lot of interest in the building backgrounds. The increasing utilization of electronic-waste (Lan Wires) materials, which have been linked to environmental risks, is a pressing problem in the context of this development. The goal of this large action is to make a sustainable building material through the incorporation of E-waste (Lan Wires) into concrete. The project aims to address environmental issues while expanding the use of reusable materials in the construction area, resulting in a stronger and eco-friendlier built environment. It accomplishes this by utilizing the creative potential of electronic-waste (Lan Wires) in the manufacturing of concrete.

1.2 INTRODUCTION

In the present era of sustainable development, processing and recycling electronic waste, or "E-waste (Lan Wires)," has become an essential problem. The number of outdated gadgets has increased due to the increasing popularity of electronic devices, highlighting the need for creative, environmentally responsible solutions. Using E-waste (Lan Wires) as a resource for the construction industry, especially in the creation of sustainable pavements, is one such potential direction.

Electrical and electronic equipment that has touched the last stage of its useful life is referred to as electronic-waste (Lan Wires). E-waste (Lan Wires) also includes used electronics that are destined for removal, recycling, rescue, reuse, or resale. The majority of Indian cities, including Bangalore, Delhi, and Mumbai, have unresolved issues with E-waste (Lan Wires) management. More harmful and benign elements can be found in E-waste (Lan Wires). If hazardous materials like mercury, arsenic, cadmium, and lead are not properly managed, they can lead to health issues. On the other hand, dangerous-toxic commodities like gold, platinum, silver, and copper can be used for recycling. In India, the integration of E-waste (Lan Wires) management systems has grown gradually in order to lessen environmental issues and prevent the burning and landfilling of E-waste (Lan Wires). By using E-waste (Lan Wires) plastics and other types of E-waste (Lan Wires), such as printed circuit boards and recovered acrylonitrile butadiene styrene (ABS), E-waste (Lan Wires) concrete can be used as sustainable concrete.

For the purpose to apply the green concrete methodology, E-waste (Lan Wires) fibers are incorporated to the concrete mix, changing the traditional type of construction materials. The findings show that adding E-waste (Lan Wires) fibers to the concrete mix will cause the compressive and flexural strengths to slightly increase. The use of E-waste (Lan Wires) fibers in concrete will lead to a shift in the development of special concrete and improve its strength values. Studies show that adding E-waste (Lan Wires) plastic type fibers to the concrete in varying lengths and mixes will improve the concrete's characteristics more when the size of the waste is smaller than when it is greater.

Concrete that has been reinforced with fibers can be constructed of several kinds of fibers, such as steel, plastic, polypropylene, synthetic, metallic, PET, and glass fibers. After the Lan Wires was removed from the electrical cable and processed into waste fibers with the necessary aspect ratio, these fibers were made available in a variety of lengths.

Standard materials like concrete and asphalt are frequently used in traditional pavement building techniques, and although they are durable, they have a significant environmental impact. But the incorporation of fibers made from E-waste (Lan Wires) offers an enticing chance to transform the infrastructure industry by improving sustainability and simultaneously taking care of the growing E-waste (Lan Wires) problem. The recycling economy's guiding principle—repurposing materials to lessen the load on landfills and the need for new resources—is represented by the idea of using E-waste (Lan Wires) as a fiber in pavement construction. This strategy addresses the threats that E-waste (Lan Wires) poses to the environment and is in accordance with a increasing emphasis on environmentally friendly, sustainable building methods. This introduction lays the foundation for an in-depth investigation of creative use of E-waste (Lan Wires) as a fiber in environmentally friendly pavement construction, emphasizing the advantages it may have for resource optimization, environmental preservation, and the general advancement of infrastructure development toward a more sustainable and greener future.

It is predicted that the development of the global economy and the accessibility of new technology would result in a rise in the generation of E-waste (Lan Wires), since rising GDP will drive up demand for electronics. 20–25 Mt of E-waste (Lan Wires) are created annually worldwide. India, which ranks 177 out of 180 countries and is in the bottom five on the Environmental Performance Index 2018, is the fifth-largest producer of E-waste (Lan Wires) worldwide. In India, major cities like Mumbai, Delhi, and Bangalore are significant contributors to e-waste generation, exacerbating the country's e-waste management challenges. According to recent reports from the International Telecommunications Union and the United Nations Institute for Training and Research (UNITAR), the world produced approximately 62 million tonnes of e-waste in 2022. This staggering amount of e-waste poses serious environmental and health hazards.

With global e-waste increasing at a rate of about 2.6 million tonnes per year, effective management of e-waste has become an urgent necessity. However, only a small fraction, approximately 17%-20%, of electronic-waste are recycled, while the rest is dumped in open landfills, leading to the release of toxic chemicals into the environment. This improper disposal of e-waste not only contaminates soil, air, and water but also poses risks to human health due to exposure to hazardous substances.

Addressing the challenges of e-waste management requires concerted efforts from governments, industries, and communities. Implementing proper recycling and disposal practices, raising awareness about the importance of electronic-waste management, and promoting sustainable consumption and production patterns are essential steps towards mitigating the adverse impacts of e-waste on the environment and public health. Collaboration between stakeholders and the adoption of innovative technologies can play a crucial role in developing effective electronic-waste management ideas to address this pressing global issue.

1.3 SUMMARY

The innovative utilization of E-waste (Lan Wires) as a fiber in sustainable pavement construction holds significant promise for advancing environmental preservation and optimizing resources. By incorporating E-waste (Lan Wires) materials, particularly E-waste (Lan Wires) fibers, into concrete, the construction industry can mitigate environmental impact while enhancing the strength and characteristics of resultant concrete.

CHAPTER 2

LITERATURE REVIEW

2.1 GENERAL

The application of E-waste (Lan Wires) as a reinforcing material in environmentally friendly pavement construction is examined in the literature review. It looks at how recycling electronic waste, or "E-waste (Lan Wires)," is developing and how it might be used to improve pavement sustainability and durability. Examining several research and developments on the integration of E-waste (Lan Wires) plastics, printed circuit boards, and recovered materials like Lan Wires into pavement constructions is the focus of this review. In order to prepare the road for resilient and environmentally friendly pavement building techniques, this investigation attempts to evaluate the feasibility, environmental impact, and performance improvement resulting from incorporating E-waste (Lan Wires) as a reinforcement.

2.2 LITERATURE REVIEW

Masuduzzaman, et al., (2018) conducted an study to assess the potential benefits of using electronic waste as a substitute for lower-value aggregates into concrete. Investigations have revealed comparable strength development tendencies between traditional concrete and E-waste integrated concrete. E-waste presents a promising material suitable for serving as both coarse and fine aggregates in long-lasting concrete structures. With millions of tons of E-waste generated globally annually, incorporating E-waste into concrete can help alleviate the strain on natural resources. Furthermore, the utilization of E-waste contributes to safeguarding the surrounding ecosystem. Since E-waste hasn't been utilized much as a substitute for standard building materials, more research is required to see whether it may be used for concrete and other applications.

Souliman, et al., (2012) explored the feasibility of utilizing Fiber-Reinforced Asphalt Concrete (FRAC) as an eco-conscious paving material for airport applications. Mainly at 100°F (34.8°C), FRAC has a higher dynamic modulus than a control combination. The results of the beam fatigue test additionally demonstrated that the insertion of fibers had significantly improved the situation. A cost analysis of the bid quantities and pricing for FRAC put at the Wyoming airports of Jackson Hole and Sheridan County indicates that the owner can recover the modest upfront additional cost of the polypropylene and aramid fibers by a minimal increase in pavement service life of around one year.

Chau, et al., (2017) investigated the mechanical properties of crushed stone and building waste aggregate, identifying a gap in their comparative analysis within existing tests. Emphasized the need for enhanced testing and detailed analyses to comprehensively understand their differences and characteristics.it is uncommon to use construction waste piles for subgrade treatment; therefore, more research is necessary to determine their bearing capacity and settlement deformation. The lack of applicable specifications for large-scale compression tests and the scarcity of large-scale diameter measurement tools in China today make interior testing unfeasible. The theoretical formula differs significantly from the direct measurement of the composite foundation's compression modulus, which has a significant inaccuracy.

Santana, et al., (2019) conducted research to evaluate the potential utilization of fiber-reinforced recycled aggregate concrete to pavement construction. The example study shown that, regardless of whether they are made of FRC or FRRAC, pavement slabs thicker than 0.22 m need comparable fiber contents to meet the design loads. Furthermore, it was noted that when the slab thickness exceeds 0.20 m, FRRAC's CO2 emissions decrease.

Luhar, et al., (2019) conducted research on recycling cathode ray tube (CRT) glasses by incorporating them into bituminous mix, cement paste, mortar, green concrete, and studying their potential applications have also been evaluated and determined to be suitable for use. Although it has many serious drawbacks, such as the presence of heavy metals and the leachates they produce, which demonstrate that it is harmful to human health and responsible for air, water, and soil contamination, it also has benefits: precious metals, plastics, glasses, and other materials can be recovered and used as a partially substitute for natural coarse or fine aggregates through "urban mining."

Tajjadini, et al., (2023) explored the impact of introducing PP fibers on compaction results, revealing an upward trend in OMC (Optimum Moisture Content). The initial rise in MDD (Maximum Dry Density) attributed to the 0.1% PP was linked to the bridging capacity of PP fibers. This bridging action effectively filled voids, enhancing density even at lower PP concentrations. Nevertheless, MDD dropped as the PP content was raised even further. This decrease was ascribed to the PP fibers reduced density when compared with the RCA material. The UCS greatly enhanced by 61% when the PP content went from 0% to 0.3%. The reason for this improvement can be checked to the reinforcement effect of the PP fibers, which improved the stretching resistance and tensile strength between aggregates. Shear band size increased as a result of friction caused by the fibers. More sand was subsequently deployed as a result, increasing strength. The result was directly related to the PP fibers' bridging action, which effectively prevented tension cracks from developing by withstanding tensile stresses without failing.

Kumar, at al., (2014) carried out a study when it came to using E-plastic waste as construction material, it is recommended that up to 30% of the original volume be replaced. The typical strength of M25 concrete was reached within this range. Another noteworthy discovery is that after failure, concrete kept about 50% of its strength, even at volume replacements of up to 50%. For lightweight components that are not structural, it is suggested to take into account a volume replacement that falls between 40% and 50%. The results of the experiment, however, indicate limitations when it comes to using electronic plastic waste (E-plastic) as a CA when strength is the primary objective.

Kurup, et al., (2017) studied on the impact of silica powder and obtained PVC fibers from electronic waste on the shear strength of concrete. When E-waste fiber and silica powder were added to the concrete, the shear strength of the mixture was somewhat reduced by approximately 21.5% at a maximum addition of 1%. Because silica powder was added, the strength of SFC has been enhanced in comparison to FC. The addition of fibers decreased the brittle failure of the concrete and enhanced its ductility behaviour. Although the shear strength values for FC and SFC are lower, they are still within a suitable range of 6–14 MPa. Concrete reinforced with E-waste) fibers can be utilized for non-structural components.

Devi, et al., (2020) studied that the people in today's world rely heavily on electric and electronic equipment for everyday activities. Technology is advancing at such a pace that newer and better devices are replacing older ones. The former turns into waste, and as a result, the production of electronic waste puts at risk both human health and the environment. Utilizing electronic wastes in the building sector could help save natural resources and reduce waste-related issues.

Shiuli, et al., (2022) employed machine learning methodologies, an investigation was conducted to evaluate the durability and performance of environmentally sustainable concrete incorporating recycled plastic as an aggregate. Findings indicated a decrease in density alongside enhanced workability of the concrete. However, reductions in both tensile and compressive strengths were observed, albeit within acceptable parameters. Given the detrimental impact of plastic aggregates on mechanical strength, the study discourages their utilization for structural applications.

Mehta, et al., (2018) studied that environmentally friendly geopolymer concrete, manufactured using ground-granulated blast furnace slag (GGBS), have focused on its permeability and strength. Findings reveal that employing 85% GGBS results in achieving a peak compressive strength of approximately 69 MPa after a 90-day curing period. Moreover, the microstructural analysis highlighted that the presence of both calcium silica hydrates and sodium alumina sulfate in GGBS-based geopolymer concrete formulations contributed positively to enhancing their strength.

Zhan, et al., (2020) examined how it improves the mechanical properties of cementitious materials, especially in terms of early-stage characteristics like compressive strength, flexural strength, and elastic modulus. Increased nano-metakaolin concentration lowers the water absorption coefficients of cementitious materials and enhances resistance to high temperatures and chloride permeability.

Ullah, et al., (2022) determined that the axial strength of concrete decreases with the incorporation of E-waste (Lan Wires). Thus, reinforcing E-waste (Lan Wires) concrete specimens with CFRP sheets notably enhances their structural performance. The aim of the present study is to examine the axial compressive behavior of E-waste (Lan Wires) concrete compression members reinforced with either one or two CFRP sheets, alongside substituting 20% of natural fine aggregates with E-waste (Lan Wires) aggregates.

Muchhadiya, et al., (2021) studied the most important aspect of sustainable building is the application of E-waste in concrete. According to an analysis of several studies, E-waste can be used to replace less-than-ideal combinations. Because of the decrease in strength, replacing coarse aggregate with more than 15% of its original amount is not very helpful in the construction industry. Compressive strength can be changed by adding E-waste, and it increases as the amount of E-waste increases until it exceeds a certain breaking point, at which point it decreases. We can deduct from this study that it is possible to use E-waste in concrete instead of coarse aggregate. Increased E-waste consumption in concrete lowers environmental issues. Thus, the creation of sustainable or environmentally friendly concrete. As a result, it preserves natural aggregate and resolves a possible disposal issue.

Malik, et al., (2016) explored the impact of incorporating E-plastic into concrete and observed that it does not significantly alter the concrete's compressive strength. However, incorporating 1% of E-plastic at a depth of 5 cm will lead to a reduction in compressive strength by 2.59% compared to the control mixture. Conversely, adding E-plastic at depths of 4 cm and 3 cm will result in an increased compressive strength of 5.9% and 10.6%, respectively, surpassing that of the control mix. Additionally, it has been observed that the presence of E-plastic enhances the tensile strength of concrete. After a curing duration of four weeks, incorporating 1% of E-plastic at a depth of 5 cm yields a 2.3% rise in tensile strength, whereas utilizing 1% of E-plastic at a depth of 4 cm produces a 4.6% increase in force.

Arjun, et al., (2017) conducted a study, it was observed that after a 28-day period, FC exhibited a percentage increase above that of normal concrete in compressive strength by 30.89%, flexural strength by 9.11%, and split tensile strength by 7.11%. Comparing SFC with normal concrete, it was found that there was a 19.6%, 16.0, and 38.49 percent increase in split tensile strength, flexural strength, and compressive strength, respectively. It was discovered that 0.8% of E-waste (Lan Wires) fiber, relative to cement weight, was the optimum percentage.

Fazli, et al., (2022) concluded that incorporating WTTF as soil reinforcement enhances the ability of expansive soils to bear more weight while retaining less water. This results in lower volumetric shrinkage strain and reduced permanent deformation when subjected to repeated loads in expansive subgrade conditions. WTTF also demonstrates efficacy in mitigating plastic shrinkage cracking in concrete composites by filling gaps with fibers, thereby halting crack propagation. To further minimize environmental impact, future endeavors in WTTF recycling should focus on improving fiber cleaning efficiency (achieving over 65% fiber purity) through simple mechanical processes, exploring new applications such as floor mats, dampers, recycling bins, automotive components, wheels, gaskets, sports equipment, etc., and identifying novel markets for innovative products crafted entirely from recycled materials.

Saud, et al., (2018), studied that by rewashing awareness of the damaging effects that tire waste desposal has on the environment as well as the possible benefits of using it in construction engineering applications. Introducing green concrete technology, which was better able to employ significant amounts of recovered tire trash and recycled concrete aggregate (from demolition waste).

Guptaa, et al., (2015) studied on exploring effective methods for repurposing e-waste and recycled coarse aggregate. Various methods of e-waste and recycled coarse aggregate were experimented with, and combination 2 emerged as the most effective for subgrade application in pavements. The optimal mixture proves suitable for sub-base preparation in rigid pavements and can also be employed in the construction of low-volume concrete pavements.

Fariaz, et al., (2022) examined the viability of building several layers of flexible pavements utilizing construction and demolition wastes (CDW). After the National Stadium in Brasilia, Brazil, was demolished, aggregates were repurposed and put through a battery of scientific tests. The outcomes were contrasted with the specifications needed for dense asphalt concrete surface courses as well as granular sub-bases and bases.

Vargas, et al., (2018) studied that the concrete including waste e-plastic aggregate often overstate the decrease in compressive strength. The recorded slump test report for all concrete mixes containing e-plastic waste revealed good workability in their fresh form.

Amin, et al., (2022) studied that the global annual production of discarded tires, which amounted to approximately 172.82 million tons between 2011 and 2018. Out of this, an alarming 96.41 million tons constituted discarded tires annually. It is concerning to note that about 63% of these tires were not recycled and ended up in landfills. Waste recycled tire steel (WRTS) fiber was among the several types of waste fibers frequently utilized in producing eco-friendly concrete. Incorporating recycled fibers of different types into concrete enables the creation of environmentally sustainable and structurally robust concrete.

Shariati, et al., (2018) studied that how well rubberized pervious concrete holds up over time, especially because more people are using rubber bits in concrete. It found that concrete with rubber in it tends to have weaker splitting tensile strength, elasticity, and compressive strength, typically ranging from three to thirty MPa. Plus, its permeability falls between 0.025 and 0.61 cm/s.

Annadurai, et al., (2023) studied that for two distinct aspect ratios of AR30 and AR40 of WPCB fibers, mechanical parameters such as compressive strength, tensile strength, and flexural strength were evaluated for WPCB fiber-reinforced concrete in varied amounts (1%, 2%, 3%, 4%, and 5%). Because there were more fibers in the composite, the compressive strength of WPCB fiber-reinforced concrete rose by 32.8% for AR30 and 40.8% for AR40 of WPCB fibers when compared to control concrete. Tensile strength of WPCB-reinforced concrete was 70.1% in AR30 and 80.1% in AR40 when compared to regular concrete. The pattern was almost the same as the compressive strength test findings for flexural and tensile strength, which may have a direct correlation with the higher WPC fiber content of the AR40 concrete mixes.

Bellezze, et al., (2018) examined that Polymer-modified concrete (PMC) was made using recycled polymers as a binder in addition to aggregates and polymeric fibers. The traditional shortcomings of cementitious materials, such as low tensile strength, poor adherence to substrates, and durability-related problems, can be addressed by combining conventional concrete with polymeric resins. PET may be recycled by the glycolysis process, which yields an unsaturated polyester resin that can be utilized as a binder for preparing mortar or concrete.255-217 A few intriguing and encouraging findings were observed, including a marked reduction in water absorption as the PET concentration increased and a corresponding rise in compressive strength as the resin content increased.

Ayob, et al., (2017) studied that one of the creative constructions created to control the amount and quality of urban stormwater for sustainable development was pavement made of pervious concrete. Pervious concrete pavement allows water to percolate through its structure and can support dynamic stresses simultaneously in most cases. On the other hand, as a pavement construction, the traditional pervious concrete pavement was not as strong. Therefore, in order to investigate potential materials to be added to the pervious concrete pavement for improved mechanical, structural, and physical qualities, a great deal of study has been done. This research aims to review the mechanical, durability, and permeability performance of the waste materials utilized in pervious concrete pavement.

Brito, et al., (2019) examined the effectiveness of introducing new materials can often be best showcased through full-scale trials, offering tangible proof of their success. Unlike certain economic sectors, the construction industry typically doesn't readily embrace innovation. Thus, the primary benefit of this approach lies in providing engineers with the opportunity to witness the material within a context they can readily understand.

Dharma, et al., (2019) discussed the best results which were obtained when compressive strength was measured for 28 days using GGBS and up to 15% cement replacement. There was a 12% increase in compressive strength after 10% replacement. 20% replacement was noted in the case of LFS without sacrificing its strength. Following that, SCBA was changed in part up to 50% of the original, and after 28 days of curing, it was found that 15% gave the maximum strength.

Straßenbau, et al., (2020) proposed that if we include both concrete and asphalt pavements, there was no doubt about it because any other alternatives could only be used for testing purposes or a limited amount of precise construction. It was plain that there was no clear winner between asphalt and concrete, even when the technical distinctions are presented. Although concrete pavements serve a variety of purposes, it was acceptable to begin implementing environmental modifications with asphalt due to its abundance. Compared to previous advances, even the financial advantages might materialize quickly if more barriers did not impede progress, as in the case of LEA. Using polymers and recycled plastic in addition to increasing recycling rates can further modify the asphalt's structure and effectively promote environmental protection.

Suryawanshi, et al., (2023) studied that the recycled nylon and polypropylene (PP) waste textile fibers were most frequently used to reinforce concrete. Recycled textile fibers undergo two separate processes—bridging action and pore distribution refinement—that result in a lower great elastic modulus and tensile strength than new fiber. They significantly improve the impact resistance, fracture resistance, and strain capacity of concrete.

Bouras, et al., (2020) studied that the most extensively studied waste materials were discovered to be fly ash and recycled aggregate, with cement and aggregate substitutes being the most widely used uses. The bulk of studies focused on mechanical and durability property testing through experimentation, with only a small number examining the sustainable performance of concrete. Therefore, it is advised that future studies examine the effects of adding waste materials to concrete and mortar mixtures on the economy, the environment, and society.

Bahrami, et al., (2023) observed that substituting CP for cement led to a decrease in compressive strength values. Similarly, the results of splitting tensile strength tests often mirrored the trends observed in compressive strengths. Even with a 10% CP replacement by cement weight, the splitting tensile strength was only 13.8% lower than that of the reference specimen. In comparison to B8-0, the load-carrying capacity decreased between 0.4% and 27.5% as CP replacement increased from 0% to 10%, 20%, and 30%. Conversely, when compared to B10-0 and B12-0, the load-carrying capacity decreased by 2.15% to 39.5% and 5.5% to 39.8%, respectively.

Tataranni, et al., (2023) studied that the fiber had been used in construction for a very long time; its first application dates back to a 4000-year-old clay-earth bridge. Fibers were currently widely used as an important component of asphalt materials, concrete, earth materials, and blocks and bricks. In the long run, it was still worthwhile to research the various applications of fibers in asphalt pavements that have already been looked at. Fibres can act as a stabilizer, preventing or lowering asphalt leaks and raising the binder concentration in the mix design, according to a review of natural and synthetic fibers used in asphalt mixtures. Additionally, fiber was a great reinforcing component that enhances the asphalt mixture's resilience to rutting, water sensitivity, low temperatures, reflective cracking, fatigue life, and freeze-thaw resistance.

Sreeram, et al., (2023) studied that many waste plastic types, such as thermosets and thermoplastics, had demonstrated the potential to be used as modifiers for asphalt mixtures. However, some of these materials' major concerns with practical applications were their high melting temperature and poor stability when stored at high temperatures. When it comes to recycling waste thermoplastics, the mechanical-physical approach was typically used. This procedure entails breaking down waste plastics into tiny particles and then adding them to asphalt mixtures and binders.

Khan, et al., (2023) concluded that waste tire recycling offers an alternative source of steel fibers compared to traditional steel fibers. It was found that waste tire recycled steel fibers (WRTSFs), with aspect ratios falling between 50 and 100, tensile strengths exceeding 1,000 MPa, diameters ranging from 0.2 to 0.5 mm, and lengths ranging from 25 to 50 mm, were the most effective in enhancing the mechanical properties of concrete. Incorporating WRTSFs into concrete presents a promising sustainable solution. However, selecting the appropriate fiber type is crucial to ensure that concrete possesses the necessary mechanical properties for specific applications.

Koutas, et al., (2018) studied that rubber particles were used in place of traditional aggregates in fresh concrete mixes, which increases air content and decreases workability and unit weight. In addition to decreasing workability and raising air content, steel fibers also slightly raise unit weight. With an increase in rubber content, the mechanical characteristics decrease. When added in suitable quantities (up to 40 kg/m3), steel fibers improve the mechanical qualities of regular concrete by up to 30% in terms of compressive strength and slightly raise its modulus of elasticity.

Preziosi, et al., (2020) purposed that the investigation was to provide an overview of recycled materials that are used as fibers in the formulation of concrete and to investigate the scholarly community's perspective on this subject.

Adeyanju, et al., (2019) studied that the amount of waste produced in developed nations during construction and demolition, as well as how the waste was used to create pavement. Reusing this waste was also promoted for its benefits to the environment, the economy, and society. The review's findings showed that the quantity and caliber of CDW are influenced by the original construction material quality, project scale, contract, and construction mode. The bulky nature of CDW makes them unsuitable for incineration or composting. In the end, recycling this waste would result in less raw material being used in building, which would promote conservation.

Oke, et al., (2021) proposed the management of waste tires in contemporary times, with a focus on the characteristics of steel fibers extracted from these tires, their application, and the durability of concrete containing them. Given the substantial volume of waste tires accumulating in landfills globally, the emergence of waste tire steel fiber (WTSF) highlights the importance of extracting valuable materials from these discarded tires. WTSF finds various applications including slope stabilization, bridge decks, tunnel linings, hydraulic structures, and pavements. Fiber length positively influences compressive strength (by more than 10%), flexural strength (by more than 50%), and split-tensile strength (by more than 30%), albeit negatively affecting slump and flow (by more than 80%). However, these drawbacks can be mitigated through careful blending, reduction in coarse aggregates, and the use of short fibers. The integration of WTSF contributes to the sustainability of the construction industry.

Katzer, et al., (2017) studied the in the characteristics of WSFs and ESFs were examined and compared. Tested ESFs turned out to be far more varied than people had previously thought. There is no correlation found between variations in the aspect ratio and other geometric properties and the mechanical properties of ESFs. To obtain distinct correlations, more ESF properties should be examined and tested concurrently (ideally with the aid of multivariate statistics).

Akbar, et al., (2020) proposed that tire recycling to recover steel fibers was not only a cost-effective way to generate energy for cement production, but it is also environmentally and health-friendly. The performance of the fiber is negatively impacted by rubber particles adhered to its surface. Improved recycling protocols and standards are necessary to extract these fibers with optimal qualities. In order to provide a uniform dispersion of fibers, planetary vertical mixers, superplasticizer additions, uniform fiber geometry, and limited content and aspect ratio are found to be promising.

Kiss, et al., (2022) examined the enhancement of concrete performance through the incorporation of dispersed fibers from diverse materials. A range of discontinuous fibers were added to the concrete mix to create dispersed reinforced concrete. Utilizing recycled plastics, such as old soda and water bottles, as additives in concrete offers a sustainable alternative that diverts waste from landfills. Research has investigated the effects of adding plastic materials to both fresh and hardened concrete. This study aims to investigate the utilization of waste polyethylene terephthalate (PET) in concrete.

Li, et al., (2022) investigated the impact of integrating waste materials from solar panels, including glass, aluminum, polymer, and silicon, into concrete pavements to enhance their durability. While some studies have indicated that incorporating glass particles into concrete can bolster its resistance to chloride penetration, the majority of durability assessments have centered on water absorption and acid resistance tests. However, limited research has explored whether concrete compositions containing silicon, polymer, or aluminum exhibit resistance to chloride penetration. Further investigation could focus on the scant studies conducted on the durability of concrete incorporating residual c-Si panels concerning freezing and thawing effects.

Soomro, et al., (2018) proposed that one potential solution to the waste problem associated with construction and demolition is the use of recycled aggregate in concrete. Currently, the majority of recycled aggregate is used in lower-end applications; however, in certain developed economies, because of its certified quality and Confirmite Europeenne (CE) Certificate, it is also used in structural concrete. The normative documents, or standards, control and uphold quality and give producers and consumers alike a guarantee of the recycled aggregate's constant quality. As the two largest consumers of construction aggregate at the moment, China and India have a great deal of potential for recycling and reusing C&D waste; nevertheless, despite this potential, there is a significant difference in the amount of recycling.

Kumar, et al., (2017) studied that the natural coarse aggregate had better physical characteristics than recycled coarse aggregate. The fresh density of the concrete mixes is decreased by 6-8% when recycled aggregate is substituted for natural aggregate. The recycled aggregate concrete had a lower compressive and flexural strength than the natural aggregate concrete. When recycled aggregate is used in place of all-natural aggregate, or between 4.75 and 20 mm, the decrease is noticeably more pronounced. When comparing concrete with recycled aggregate to concrete with natural aggregate, the former's abrasion resistance was noticeably lower. The abrasion resistance of concrete mixes containing only larger size recycled aggregate (10–20 mm) was found to be superior to mixes containing all recycled aggregate (4.75–20 mm).

Singh, et al., (2021) discussed the inclusion of either MSF or RSF fibers in SCC, which led to a decrease in UPV. However, all mixes exhibited UPV values exceeding 3.8 km/s at 7 days, increasing to greater than 4.03 km/s at 90 days, indicating high-quality mixes. There was a reduction of 5.2% and 6% for slump flow in mix M03, and for mix M13, it was 5.2% and 5.3% for J-ring spread, compared to the control mix M0. Conversely, there was an increase in T500 (slump flow) time, i.e., 48% and 30% for mixes M03 and M13, respectively, compared to M0. It was observed that incorporating RSF was advantageous for SCC compared to MSF as it enhanced workability. However, overall workability decreased when compared to SCC without fibers.

Adegoke, et al., (2019) studied that the recycled glass can be used in place of cement and natural aggregates, minimizing the quantity of glass waste that ends up in landfills, discouraging the exploration of natural aggregates, and lowering greenhouse gas emissions. In contrast, there is a perception that employing recycled waste glass for construction will result in higher costs and may not be as efficient as using natural aggregates; however, this perception is changing as a result of more advanced research. This essay examines the standards, sustainable applications, and recycled waste glass as building material.

Jiménez, et al., (2019) proposed a range of case studies showcasing successful applications of recycled aggregates (RAs) in construction, building upon the established technical viability of integrating RAs into concrete production and their diverse potential applications. It delineates the difference between full-scale pilot studies and smaller- or larger-scale laboratory experiments. The case studies highlight the utilization of RA concrete in both non-structural and full-scale structural elements within building construction. Furthermore, in addition to its use in producing non-structural precast elements, RA was employed in constructing rigid pavements for road infrastructure.

Tardieu, et al., (2019) studied about the involvement of the fabrication of composite wires by wire-drawing cylinders at room temperature and consolidating them using spark plasma sintering. These wires consisted of Ag nanowires dispersed within a Cu matrix. Results show that wires with only 1 vol.% Ag exhibit the optimal combination of low electrical resistivity (0.50 μΩ.cm) and high strength (1100 ± 100 MPa at 77 K) compared to samples with 5 and 10 vol.% Ag. Remarkably, these wires outperform Ag-Cu alloy wires containing approximately 20 times more silver. The presence of Ag nanowires at grain boundaries in ultrafine copper grains elongated over several micrometers enables the composite wires to demonstrate tensile strengths at 293 K and 77 K that are more than double those of corresponding pure Cu wires.

2.3 GAP IDENTIFICATION

1. In most of the studies, E-waste (Lan Wires) fibers were utilized without plastic casing which further increase the plastic recycle issue and will be harmful for the environment as well as human health.
2. As per the best knowledge of the authors none of the study was found to utilized Lan Wire Waste in the form of mesh structure (i.e. as reinforcement).

2.4 OBJECTIVE OF THE STUDY

1. To analyse the impact of Lan-Wire in the form of fiber (i.e. with varying aspect ratio) on the mechanical properties of concrete.
2. Examine the impact of Lan-Wire i.e. fully coated or partially coated (in layer system) on strength characteristics of concrete mix.
3. Application of Lan-Wire as a mesh structure in different form (i.e. fully coated, partially coated or fully removed insulation) by keeping a constant aspect ratio.

2.5 SUMMARY

The literature review explores the potential of utilizing electronic waste (E-waste (Lan Wires)) in pavement construction to enhance sustainability and durability. Studies have investigated incorporating E-waste (Lan Wires) materials such as plastics, printed circuit boards, and recovered components like Lan Wires into pavement constructions. Various research efforts have demonstrated promising results regarding the feasibility, environmental impact, and performance improvement achieved by integrating E-waste (Lan Wires) as reinforcement.

However, gaps in existing research include the lack of utilization of E-waste (Lan Wires) fibers with plastic casings and the absence of studies employing E-waste (Lan Wires) fibers in mesh structures. Hence, the objectives of the study include analysing the impact of Lan-wire fibers on concrete mechanical properties and examining various coating configurations of Lan-wire, aiming to contribute to sustainable pavement construction practices.

CHAPTER 3

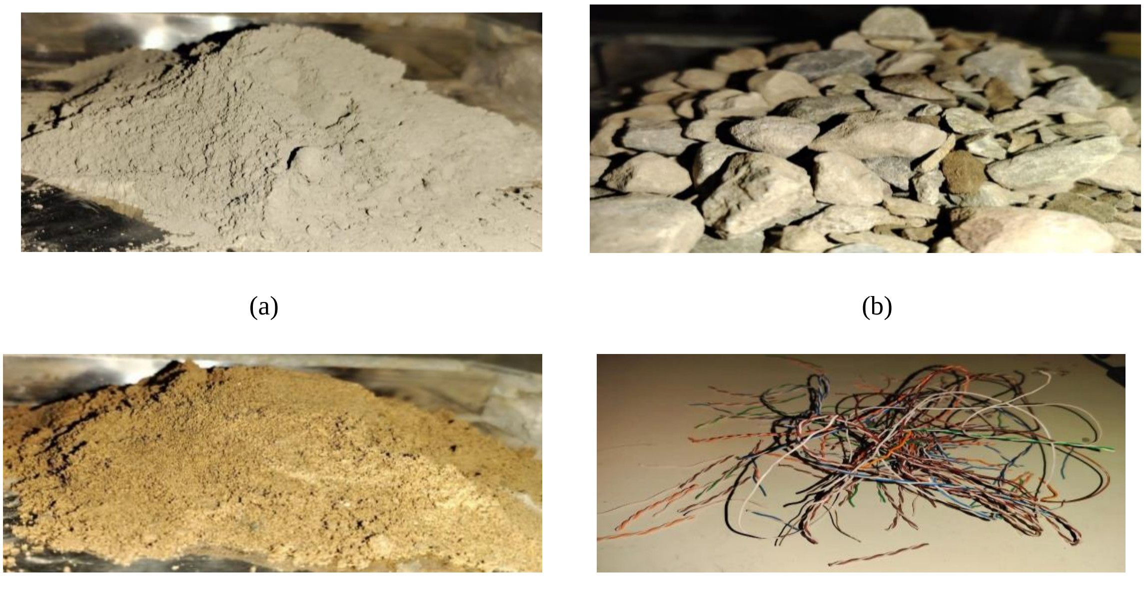
METHODOLOGY OF THE STUDY

3.1 GENERAL

Presently, utilization of different industrial waste materials, especially plastic waste has become a serious issue due to the difficulties in the dumping of these by product which is very difficult. Present study is aiming to utilize this different waste material as the replacement of natural resources i.e., required in construction of rigid pavement with or without E-waste (Lan Wires) reinforcement. Consequently, different materials were procured from different regions of India. A detailed discussion has been made regarding the same in the next section of the present chapter.

3.2 MATERIAL AVAILABILITY

The experiment utilized materials procured from distinct sources. Portland Pozzolana Cement (PPC), Coarse Aggregate, and Fine Aggregate were acquired from a local supplier in Solan, while Lan Wires, crucial for the study, were supplied by JUIT Waknaghat in Himachal Pradesh, as shown in Fig. 3.1.



(a) (b)

(c) (d)

Fig. 3.1 (a) Portland Pozzolana Cement (PPC) (B) Coarse Aggregates (C) Fine Aggregates (D) Lan Wires

3.3 METHODOLOGY OF THE STUDY

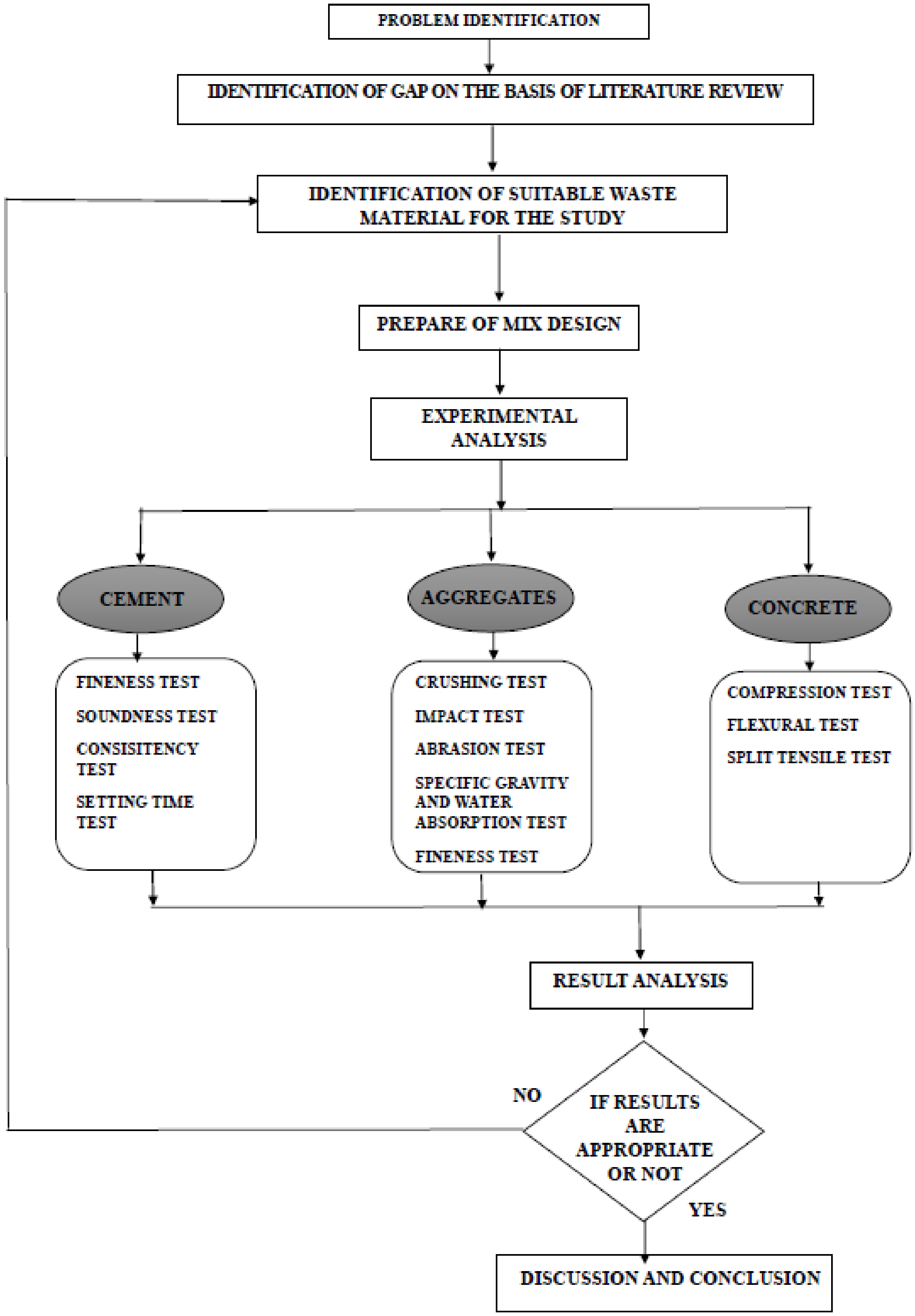


Fig 3.2 Methodology of the Study

3.4 MATERIAL’S CHARACTERISTICS

3.4.1 CEMENT

PPC, or Portland Pozzolana Cement, is a hydraulic cement produced by grinding pozzolanic materials such as fly ash, volcanic ash, calcined clay, or silica fumes with Portland cement clinker. This combination results in cement with improved characteristics in terms of workability, durability, and strength. In India, the IS code for PPC, designated as IS 1489 (Part 1): 1991, outlines the requirements, physical properties, chemical composition, and performance standards for Portland Pozzolana Cement.

i. Fineness Test

The fineness of cement pertains to the size of its particles, which must not exceed 90 microns when sieved according to IS requirements. Specifically, IS 4031 Part-I should be adhered to for conducting the test, while sample collection should follow IS 3535 guidelines. The apparatus comprises a pressure gauge, a valve, pipework, and a spray nozzle. The Fineness Test Sieve consists of a single-piece brass frame and stainless-steel No. 325 wire cloth.

ii. Settling Time Test

As per IS 12269, the initial setting time must be a minimum of 30 minutes, while the final setting time should not exceed 600 minutes. The apparatus required includes Vicat’s apparatus, a balance, a measuring cylinder, a stopwatch, a glass plate, an enamel tray, and a trowel.

iii. Consistency Test

The consistency test is a commonly used laboratory method to ascertain the amount of water necessary to achieve a standard consistency in cement paste. This test aids in determining the water content required for various cement applications. As per IS 4031-4(1988), the normal consistency of cement is approximately 31%, as indicated in Table 3.3. The apparatus required for this test includes a Vicat apparatus, a balance, a trowel, and a stopwatch.

3.4.2 AGGREGATES

i. Coarse Aggregates

A necessary component in concrete and construction material are coarse aggregates. These are granular materials having particle sizes greater than 4.75 millimetres (mm) and usually vary in diameter from 9.5 mm to 37.5 mm. They are typically crushed stone, gravel, or a combination of both. The IS code IS 383:2016 defines the quality criteria for coarse and fine aggregates utilized in concrete. This code delineates the necessary attributes, encompassing grading, strength, durability, and various properties that aggregates must possess to meet the standards required for construction applications.

ii. Fine Aggregates

Compared to coarse aggregates, fine aggregates are smaller-sized granular materials used in construction. These materials usually range in size from 0.075 millimetres (mm) to 4.75 mm and are composed of sand, crushed stone dust, or natural silica sand particles. The IS code for fine aggregates used in concrete is IS 383:2016. This code sets out the specifications and quality requirements for fine aggregates, encompassing parameters such as grading, strength, durability, and other essential properties necessary for construction purposes.

3.4.2.1 TEST ON COARSE AGGREGATES

i. Crushing Test

The aggregate crushing value serves as a numerical indicator of an aggregate's strength, assessing its ability to withstand crushing under a gradually applied compressive load. This value is crucial in road and pavement construction. The Indian Standard Code, IS code 2386 Part 4, outlines the procedure for conducting the aggregate crushing value test. As indicated in Table 3.4, the crushing value of coarse aggregates is approximately 26.6%. The necessary apparatus for this test includes a tamping rod, a balance, sieves, a cylindrical measure, and a steel measure.

ii. Impact Test

The impact test assesses a material's resilience to sudden loads and measures the energy absorbed during fracture, which can indicate its brittleness or ductility. The impact value is calculated using the ratio of aggregates sieved through 10 mm and 2.36 mm. Conducting the aggregate impact value test follows the guidelines of the Indian Standard Code, IS code 2386 Part 4. As outlined in Table 3.5, the impact test value for coarse aggregates is approximately 16.93%. The necessary apparatus for this test includes a cylindrical measure, a tamping rod, an impact testing machine, and sieves with apertures of 12.5 mm, 10 mm, and 2.36 mm.

iii. Abrasion Test

The abrasion test assesses the hardness of aggregates, with the Los Angeles abrasion test aimed at determining the percentage of wear endured by the aggregate and steel balls used as the abrasive charge as they rub against each other. Conducting the aggregate abrasion value test adheres to the Indian Standard Code, IS code 2386 Part 4. As depicted in Table 3.6, the abrasion test value for coarse aggregates is approximately 29.14%. The necessary apparatus for this test includes a Los Angeles Machine, a drying oven, a tray, and a balance.

iv. Specific Gravity and Water Absorption

Specific gravity serves as an indirect indicator of aggregate porosity and is also indicative of strength, with stronger materials typically exhibiting higher specific gravity values. The specific gravity test was conducted in accordance with the guidelines outlined in IS code 2386: Part 3. The specific gravity and water absorption values for coarse aggregates are detailed in Table 3.7, approximately 2.71 and 0.326%, respectively. The necessary apparatus for this test includes a balance, a box wire bucket, and a drying oven.

3.4.2.2 TEST ON FINE AGGREGATES

i. *Particle Size Distribution*

Sieve analysis serves to assess the gradation of aggregate. The IS code governing sieve analysis and the determination of fineness modulus for fine aggregates is IS 2386 (Part 1):2015. This standard delineates the procedure for conducting sieve analysis of fine aggregates, which entails passing them through a series of sieves of varying sizes and computing the fineness modulus based on the cumulative percentages retained on each sieve.

3.4.3 TESTS ON CONCRETE

i. Compression Test

Compression testing is utilized to assess fundamental factors such as strain, stress, and deformation to predict how a material will respond to compressive forces. Through compression testing, various properties including compressive strength, yield strength, ultimate strength, elastic limit, and elastic modulus can be determined. The IS code governing compression testing of concrete is IS code 516:1959. This standard offers detailed instructions for conducting compression tests on concrete cubes, cylinders, and other concrete specimens to evaluate their compressive strength. It provides a standardized procedure, specifies the required apparatus, and outlines necessary precautions for conducting these tests.

Fig.3.3 Compression Testing Machine

ii. Split Tensile Test

The split tensile test serves as an indirect method for assessing the tensile strength of concrete. In this test, a standard cylindrical specimen is positioned horizontally, and radial force is applied to its surface, inducing vertical cracking along its diameter. The IS code governing the split tensile test of concrete is IS 5816:1999. This code outlines the procedure for determining the split tensile strength of concrete specimens. It specifies the necessary apparatus, testing procedure, and calculations to be undertaken to determine the split tensile strength of concrete.

Fig 3.4 Split Tensile Testing Machine

iii. Flexural Test

A transverse beam test, commonly referred to as flexural testing, evaluates the bending properties of a material. In this test, a sample is placed between two supports, with a load applied at a third point. Alternatively, a 4-Point Bending Test can be conducted, where two points are used for loading. The IS code governing flexural testing of concrete is IS 516:1959. These standard details the procedure for testing the flexural strength of concrete specimens. It specifies the required testing apparatus, the testing procedure, and the calculations necessary to determine the flexural strength of concrete beams.

Fig 3.5 Flexural Testing Machine

3.5 SUMMARY

This chapter summarizes the methodology of the study, material availability and different test performed on Cement, Aggregates, Concrete. Materials were procured from various Indian sources. Portland Pozzolana Cement (PPC), coarse and fine aggregates were obtained locally, while Lan Wires were sourced from JUIT Waknaghat. Cement properties were evaluated through fineness, settling time, and consistency tests. Aggregate tests included crushing, impact, abrasion, specific gravity, and water absorption tests. Concrete tests encompassed compression, split tensile, and flexural tests, following respective IS codes. Overall, the research explores the feasibility of incorporating waste materials into construction, emphasizing sustainability and resource optimization.

CHAPTER 4

RESULT ANALYSIS AND DISCUSSION

4.1 GENERAL

In this chapter, different methods were discussed to incorporate E-waste (Lan Wires) into concrete. Thereafter, a comparison will be made between all the modified mixes w.r.t NC to specify the impact of different mix design. The objective of this assessment is to identify the unique characteristics of E-waste (Lan Wires), particularly Lan Wires, in order to assess its suitability for utilization in construction purposes.

4.2 MIX DESIGN OF M40 GRADE CONCRETE

M40 grade concrete mix design involves selecting precise proportions of cement, aggregates, water, and admixtures to achieve a compressive strength of 40 MPa. It demands careful consideration of material properties, water-cement ratio, and workability requirements, ensuring durability and performance in structural applications.

4.2.1 STANDARD AND SPECIFICATIONS

For M40 grade concrete mix design, several Indian standards and codes are typically referenced. Here are some of the relevant codes commonly used:

1. IS 10262:2019 - This code provides guidelines for concrete mix proportioning. It details the method for mix design for ordinary and standard concrete, including higher grade concretes like M40, specifying the principles and procedures to be adopted for the selection of ingredients, their proportions, and the determination of the water content and workability.

2. IS 456:2000 - This code covers general requirements for the design and construction of concrete structures. It includes information on mix design, materials, testing, and various aspects of concrete construction.

3. IS 383:2016 - This standard specifies the grading requirements for coarse and fine aggregates used in concrete, ensuring the quality of aggregates for construction purposes.

4. IRC SP 62:2014 - This code, published by the Indian Roads Congress (IRC), provides guidelines for concrete mix design for road and pavement construction. It might not directly

relate to M40 concrete mix design but can be referred to for specific road-related construction requirements.

These codes offer specifications and guidelines for material selection, mix proportioning, testing methods, and quality control procedures essential for designing M40 grade concrete.

4.2.2 MATERIALS USED

The materials employed for the construction include PPC (Portland Pozzolana Cement) as the primary binding agent, fine aggregates characterized by particle sizes smaller than 4.75mm, categorized under Zone II specifications, and coarse aggregates with particle sizes less than 20mm. Additionally, the inclusion of E-waste (Lan Wires), particularly Lan Wires, serves as a distinctive component within the construction composition. The prescribed mix ratio aligns the proportions of cement, fine aggregate, and coarse aggregate at 1:1.34:2.6, respectively.

4.2.3 MIX DESIGN CALCULATION

i. *Selection of Water-Cement Ratio*

The water-cement ratio in concrete dictates the balance between workability and strength. It determines the amount of water needed per unit of cement, crucial for hydration and durability. Optimal ratios ensure adequate workability for placement and finishing while enhancing concrete strength and minimizing porosity. Careful selection considers factors like desired strength, environmental exposure, and aggregate properties to achieve a durable and resilient concrete mix, vital for sustainable construction practices. As per IRC 44: 2014, the water cement ratio for different grades of concrete as shown in Table 4.1. Attaining the target strength of 48.25 N/mm² requires a free water-to-cement ratio of 0.36 for PPC grade. This ratio falls below the maximum limit of 0.50, specifically 0.36 < 0.40, rendering it acceptable.

Table 4.1 Water-cement ratio for different grades of concrete (IRC 44: 2017)

Minimum Grade of Concrete	Maximum Water-cement ratio
M20	0.55
M25	0.5
M30	0.45
M35	0.4
M40	0.4

ii. *Selection of Water Content*

Water content selection in concrete, crucial for hydration and workability, must balance ease of placement with strength and durability. It's determined by factors like cement type, aggregate characteristics, and desired concrete properties. Precise control ensures optimal performance, longevity, and resilience in construction applications.

As per the IRC 44:2017, the maximum water content for a concrete mix having an aggregate of size 20 mm was 186 kg (for a slump of 25 to 50 mm). Water Content as shown in Table 4.2.

Table 4.2 Water content (IRC 44:2017)

Nominal maximum size of aggregates (mm)	Maximum water content (Kg)
10	208
20	186
40	165

We were targeting a 75 mm slump, so we had to increase the water content. To get a 25mm rise in slump, we had to increase the water content by 3%, and so on.

Water content estimate: 186 + (3/100) x 186 = 180 kg

iii. *Compressive Strength-Based Mix Proportioning for Design*

Target Compressive strength is calculated by Equation (1) or Equation (2):

$$f'_{ck} = f_{ck} + 1.65S_c \qquad \text{Equation (1)}$$

$$f'_{Ck} = f_{Ck} - Xf'_{Ck} \qquad \text{Equation (2)}$$

Where,

S_C = Standard deviation,

f_{ck}= Compressive Strength,

f_{ck} = *Target Compressive Strength,*

X = 6.5 as per IRC 44: 2014 as shown in Table 4.3

Table 4.3 Value of X (IRC:44-2017)

S. No.	Grade of Concrete	Value of X (in mm)
1	M30	5.0
2	M35	6.5
3	M40	
4	M45	
5	M50	
6	M55	
7	M60	
8	M65 or above	8.0

the higher number to be used is 48.25 N/mm². Since it exceeds 46.5 N/mm², 48.25 N/mm² becomes the target strength.

iv. *Air Content Approximation*

Air content approximation in concrete involves estimating the volume of air voids within the mixture. It's typically determined using methods like the pressure meter test or the volumetric method. Accurate air content estimation ensures proper freeze-thaw resistance, workability, and durability of the concrete, crucial for construction quality and longevity.

For aggregate with a nominal maximum size of 19 mm, the approximate quantity of entrapped air to be expected in normal (non-air entrained) concrete is 1.0%. As per IRC 44: 2017, Air Content Approximation as shown in Table 4.4

Table 4.4 Air Content Approximation

Max Size of Aggregate, mm	Entrapped Air
9.5	1.5
19	1.0
26.5	0.9
31.5	0.8

v. Cement Content Calculation

Cement content in concrete denotes the quantity of cementitious material per unit volume or weight of the mix. It's a pivotal factor in mix design, directly impacting strength and durability. Determined by factors like water-cement ratio and desired properties, precise calculation ensures optimal concrete performance in construction applications.

Water content: 180 kg/m3

Water–cement ratio: 0.4

180 / 0.4 = 450 kg/m3 is the cement content.

vi. *Calculations for Mixes*

a) Absolute concrete volume equals one air volume, or 1-0.01 = 0.99 m3.

b) Cement volume (mass/specific gravity) x (1/1000) = (450/3.03) x (1/1000) = 0.148 m^}

c) The volume of water is equal to the mass of water divided by the specific gravity of water, or (180/1) x (1/1000) = 0.180 m3.

d) The total volume is equal to {a - (b+c)} = 0.99 - (0.148+0.180) = 0.66 m3.

e) Masses of coarse aggregate and fine aggregate are respectively equal to (c) x 0.648 x Specific gravity of coarse aggregate x 1000 = 0.66 x 0.648 x 2.71 x 1000 = 1166 kg/m3 and (f) x 0.352 x Specific gravity of fine aggregate x 1000 = 0.66 x 0.352 x 2.61 x 1000 = 603 kg/m^3

vii. Mix Proportions

Cement = 450 kg/m^3

Water = 180 kg/m^3

Fine Aggregate = 603 kg/m^3

Coarse Aggregate = 1166 kg/m^3

Water-cement ratio = 0.4

Table 4.5 showing the mix design adopted for different categories whereas, Table 4.6 showing the abbreviation used for different mix design categories.

We had utilized the fibers as a replacement of coarse aggregates, the fibers were taken by weight of cement as 1% and 2%

Table 4.5 Quantities of Aggregates and Cement

Sr. No.	MIX ID	Cement (kg/m^3)	Fine Aggregates (kg/m^3)	Coarse Aggregates (kg/m^3)
1	NC	450	603	1166
2	FCF	450	603	1154.34
3	PCF	450	603	1154.34
4	FCMS	450	603	1154.34
5	WCMS	450	603	1154.34
6	DFCF	450	603	1142.68
7	DWCF	450	603	1142.68
8	DFCMS	450	603	1142.68
9	DWCMS	450	603	1142.68

Table 4.6 Full form of MIX ID's

S.No.	MIX ID	Full Form
1	NC	Normal Concrete
2	FCF	Fully Coated Fiber
3	PCF	Partially Coated Fiber
4	FCMS	Fully Coated Mesh Structure
5	WCMS	Without Coated Mesh Structure
6	DFCF	Doubly Fully Coated Fiber
7	DWCF	Doubly Without Coated Fiber
8	DFCMS	Doubly Fully Coated Mesh Structure
9	DWCMS	Doubly Without Coated Mesh Structure

4.3 EXPERIMENTAL INVESTIGATION

The experimental investigation of concrete involves testing various mixtures and additives to optimize strength, durability, and sustainability. Factors such as aggregate type, water-cement ratio, and curing methods are analysed to enhance concrete performance. Testing methods include compression tests, slump tests, and durability assessments. Results inform industry standards and contribute to advancements in concrete technology for more resilient and efficient infrastructure.

4.3.1 PHYSICAL PROPERTIES OF CEMENT AND AGGREGATES

Cement, a binder in concrete, exhibits key physical properties vital for construction. Its fineness influences setting time and strength development, with finer particles accelerating reactions. Specific gravity indicates density, impacting mix proportions and durability. Meanwhile, aggregates, comprising coarse and fine particles, contribute to concrete's mechanical properties. Aggregate size distribution affects workability and strength, while shape influences concrete cohesion and segregation. Ultimately, understanding these physical properties ensures proper material selection and proportioning, essential for durable and structurally sound concrete construction.

4.3.1.1 RESULTS OF TEST PERFORMED ON CEMENT

The cement test results revealed different findings which were made in the present studies as shown in Table 4.7 to 4.9. Key findings include compressive strength, setting time, and consistency. These results inform concrete mix designs, ensuring durability and performance in various applications.

i. *Fineness Test*

A minimum 3 samples were tested to find out the fineness of the cement which was formed to be varying from 5.58% to 7.2%. Average value of fineness of cement was 6.47% as shown in Table 4.7.

Table 4.7 Fineness Value of Cement

Sr. No.	**Samples**	**W1 (Weight of cement sample in g)**	**W2 (Weight of cement retained on 90 µm sieve in g)**	**Fineness of cement (W2/W1)×100**
1	S1	100	5.58	5.58%
2	S2	100	6.63	6.63%
3	S3	100	7.2	7.2%
	Avg. Fineness Value		6.47%	

ii. *Settling Time Test*

A sample was tested to find out the setting time of the cement which was found to be about the initial setting time of cement was 36 min and the final setting time of cement was 248 min as shown in Table 4.8.

Table 4.8 Setting Time of Cement

Sr. No.	Consistency Test	Weight of cement (g)	Water to be added in cement (ml)	Initial Setting Time of Cement (min)	Final setting Time of Cement (min)
1	31	400	102	36	248

iii. Consistency Test

A minimum 3 samples were tested to find out the Normal Consistency of the cement which was found to be about the average consistency value was 31% as shown in Table 4.9.

Table 4.9 Normal Consistency of Cement

Sr. No.	Samples	Weight of cement (g)	% of water to be added in cement sample	Weight of water to be added in sample (ml)	Penetration value (%)
1	S1	400	27	108	30
2	S2	400	30	120	32
3	S3	400	33	132	31
	Avg. Consistency of cement		31%		

4.3.1.2 RESULTS OF TEST PERFORMED ON COARSE AGGREGATES

The test results on coarse aggregates for the concrete project indicate satisfactory performance. Aggregate crushing strength surpasses minimum requirements, promising durability and load-bearing capacity. Absorption and moisture content fall within acceptable limits, preventing excessive water ingress and maintaining consistency in concrete mixtures. Aggregate shape and texture are conducive to optimal concrete cohesion and workability.

i. Crushing Test

A minimum 3 samples were tested to find out the Crushing Test of Coarse Aggregates which was found to be about the average Crushing Value was 27.5% as shown in Table 4.10.

Table 4.10 Crushing Test

Sr. No.	Total weight of aggregates W1 (g)	Weight of aggregates passing 2.36mm (g) (W2)	Weight of aggregates retained on 2.36mm W3(g)	Aggregate Crushing value (%) [W2×100]/[W1]
1	2700	692	2008	26.6%
2	2700	729	1971	27%
3	2700	782	1918	28.9%
Avg. Crushing Value			27.5%	

ii. Impact Test

A minimum 3 samples were tested to find out the Impact Test of Coarse Aggregates which was found to be about the average Impact Value was 16.96% as shown in Table 4.11.

Table 4.11 Impact Test

Sr. No.	Weight of dry sample taken (g)	Weight of aggregates passing 2.36mm sieve (g)	Aggregate impact value (%)
1	400	70.6	17.46
2	400	64.86	16.18
3	400	60.54	17.23
Avg. Impact Test		16.96%	

iii. Abrasion Test

A minimum 3samples were tested to find out the Abrasion Test of Coarse Aggregates which was found to be about the average Abrasion Value was 30% as shown in Table 4.12.

Table 4.12 Abrasion Test

Sr. No.	Weight of Aggregates (W1) (g)	Weight of Aggregate retain on 1.70mm sieve (W2) in g	% Abrasion Value {(W1-W2)/W1} ×100
1	5000	3543	29.14%
2	5000	3267	34.66%
3	5000	3689	26.22%
Avg. Abrasion Value		30%	

iv. Specific Gravity and Water Absorption

A sample was tested to find out the Specific Gravity and Water Absorption of Coarse Aggregates as shown in Table 4.13.

Table 4.13 Specific Gravity and Water Absorption of coarse aggregates

Weight of saturated aggregates in water with bucket (W1)	1664 g
Weight of Bucket suspended in water (W2)	690 g
Weight of saturated dry aggregates in air (W3)	1540 g
Weight of aggregates (W4)	1535 g

4.3.1.3 RESULTS OF TEST PERFORMED ON FINE AGGREGATES

The test results on fine aggregates for the concrete project indicate optimal characteristics. Aggregate grading meets specifications, ensuring proper particle distribution. Aggregate fineness modulus falls within the desired range, indicating suitable particle sizes for cohesive concrete mixtures. Specific gravity and absorption values adhere to standards, indicating good quality aggregates. Overall, the test results affirm the suitability of the fine aggregates for the intended concrete application, meeting quality and performance requirements.

i. Fineness Modulus of Fine Aggregates

Table 4.14 shows the fineness modulus value of fine aggregates about 45.23% and Fig. 4.1 shows the graphical Particle Size Distribution of Fine Aggregates

Table 4.14 Fineness modulus of fine aggregates

Sr. No.	**IS Sieve (mm)**	**Weight Retained on Sieve (W)**	**% Weight retaines A=(W/1000) ×100**	**Cumulative Retained %age (B)**	**Passing %age (100-B)**
1	10	0	0	0	100
2	4.75	65	6.5	6.5	93.5
3	2.36	110	11	17.5	82.5
4	1.18	140	14	31.5	68.5
5	0.6	96	9.6	41.1	58.9
6	0.3	263	26.3	67.4	32.6
7	0.15	246	24.6	92	8.0
8	0.075	39	3.9	95.9	4.1
9	Pan	41	4.1	99.9	0.01
	Total	1000		452.3	

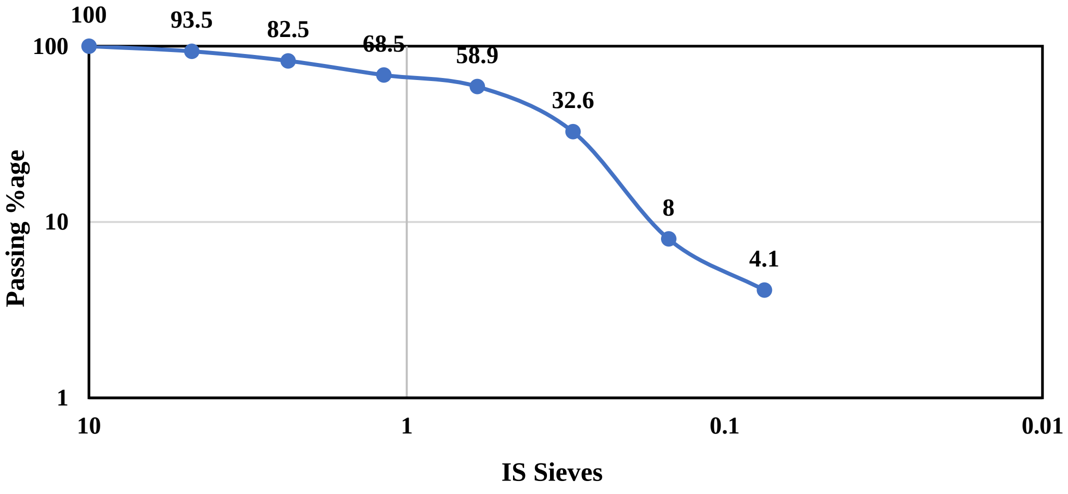


Fig 4.1 Particle Size Distribution

4.3.2 COMPRESSIVE STRENGTH OF CONCRETE

The Compressive Test was conducted using a Compression Testing Machine (CTM) on concrete blocks formulated with the M40-Grade concrete mix. This particular set of blocks represented the standard or "Normal Concrete" without the incorporation of any fibers, serving as the benchmark against which other concrete mixes were evaluated and compared for their strength characteristics.

Table 4.15 in the experimental findings provides a comprehensive overview of the compressive strength exhibited by normal concrete at varying curing intervals: 7, 14, and 28 days. Notably, at the conclusion of the 28-day curing period, the compressive strength recorded for normal concrete stood at 43.55 MPa. This acts as a fundamental benchmark for evaluating and contrasting the strength improvements brought about by different fiber-reinforced concrete formulations in subsequent tests and analyses.

Table 4.15 Compressive Strength of a Normal Concrete

Sr. No.	MIX ID	Days	Weight (Kg)	Strength (MPa)
1	NC	7	7.74	25.65
2	NC	14	7.9	31.9
3	NC	28	7.96	43.55

In Fig. 4.2, the 28-day compressive strength of normal concrete is visually depicted at 43.55 MPa, aligning with the acceptability criteria outlined in IRC:44-2017. This strength level qualifies it for use in the construction of rural roads, indicating its suitability for such applications.

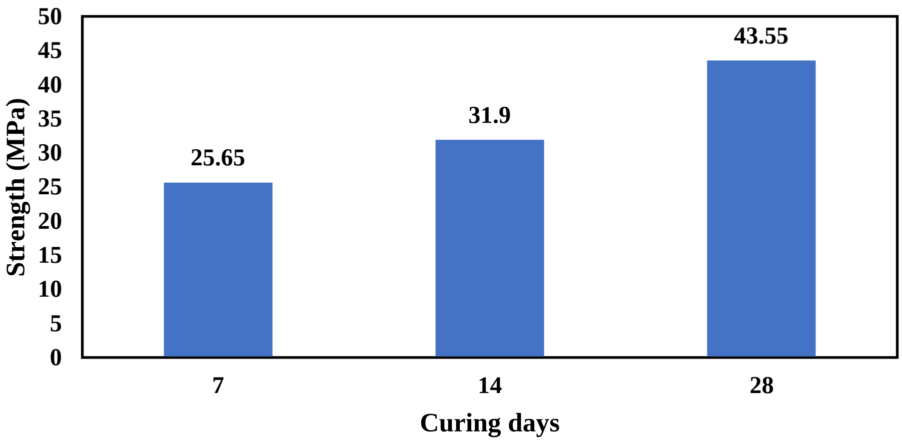


Fig 4.2 Mean Compressive Strength of Normal Concrete

Fig.s 4.3(a) and 4.2(b) present pictorial representations before and after testing, respectively of the Normal Concrete blocks. These images offer visual insights into the concrete blocks both pre- and post-testing, showcasing their structural integrity and any potential changes or damages incurred during the testing process.

(a) (b)

Fig 4.3 (a) Cubes before application of load **(b)** Cubes after application of load

The concrete blocks were prepared by integrating E-waste (Lan Wires), specifically Lan Wires, as a reinforcing element in the concrete mix, possessing an aspect ratio of 56.25. This E-waste (Lan Wires) material was incorporated at a proportion of 1% relative to the weight of the cement. In this specific instance, Lan Wires were employed as fibers within the concrete, maintaining their full insulation casing.

Following the casting and subsequent testing, cubes featuring the mix ID "FCF," representing a 1% fiber content of Lan Wires with the complete insulation casing, were examined. Table 4.16 encapsulates the conclusive results obtained from this specific configuration. At the 28-day curing mark, the concrete blocks exhibited a notable strength achievement of 43.55 MPa. This outcome signifies the robustness and improved compressive strength imparted to the concrete due to the inclusion of Lan Wires as fibers with their insulation casing fully intact.

Table 4.16 Compressive Strength of FCF

Sr. No.	**MIX ID**	**Days**	**Weight (Kg)**	**Strength (MPa)**
1	FCF	7	7.74	26.19
2	FCF	14	7.82	32.3
3	FCF	28	7.96	43.62

Fig 4.4 depicts the 28-day compressive strength achieved by the concrete mix denoted as FCF. This strength assessment, measuring at 43.62 MPa, meets the acceptability standards specified in IRC:44-2017. Meeting these criteria signifies that the concrete composition with FCF designation fulfills the necessary strength requirements outlined for construction materials in the IRC:44-2017 guidelines which is higher than the optimum compressive strength of normal concrete.

Such a level of compressive strength renders the FCF concrete mix suitable and capable of being used in the construction of rural roads. The attained strength level surpasses the minimum threshold necessary for ensuring the durability and structural integrity of road surfaces in rural areas. Therefore, based on its strength characteristics meeting the outlined standards, the FCF concrete blend can be considered a viable and reliable option for use in the construction and development of road infrastructure in rural regions.

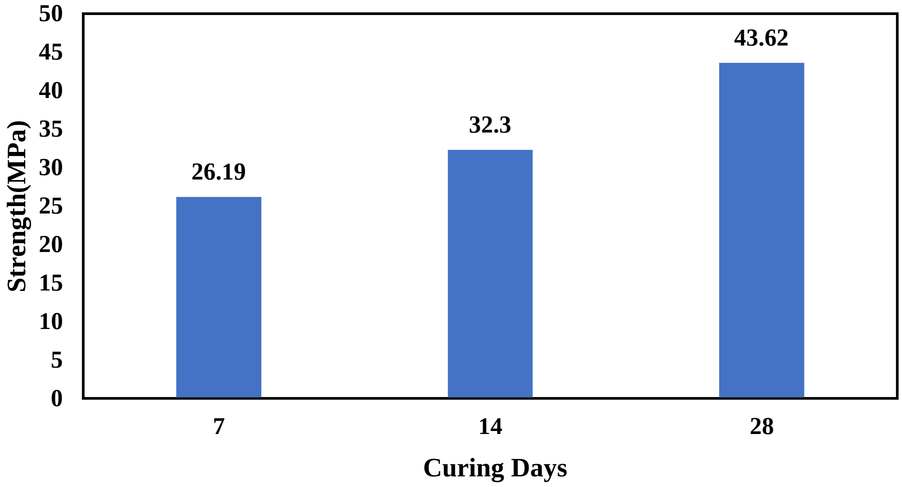


Fig 4.4 Mean Compressive Strength of FCF

Fig 4.5 illustrates the visual representation of Lan Wires embedded within cubes, arranged in three distinct layers. The depiction showcases the Lan Wires placement within the concrete cubes, highlighting the arrangement of the wire in three separate layers. Specifically, the first layer of Lan Wires spans roughly 2.5 cm, followed by the second layer, which extends approximately 7.5 cm, and finally, the third layer measures around 12 cm in length from the bottom level of cube.

Additionally, the Lan Wires utilized in this arrangement measures approximately 4.5 cm in length and features a diameter of 0.08 cm. These images provide a visual insight into how the Lan Wires were strategically positioned and integrated into the concrete cubes across various layers, demonstrating the configuration and distribution of the wires within the concrete specimens.

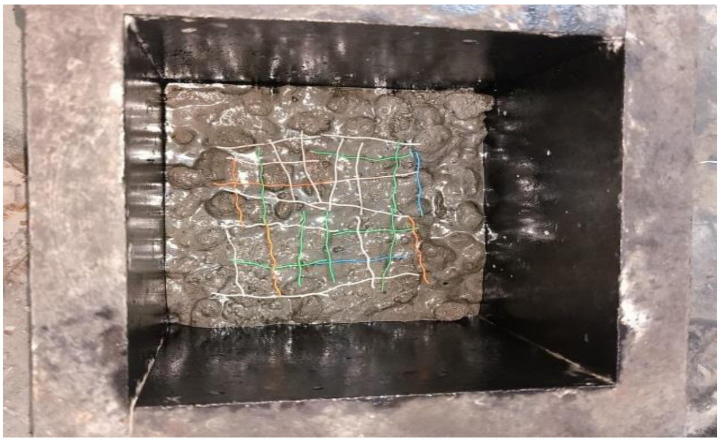


Fig 4.5 Placement of fibers in Concrete Mix

The experimental setup involved incorporating E-waste (Lan Wires), particularly Lan Wires, as a reinforcement in the concrete mixture. These Lan Wires, with an aspect ratio of 56.25, were added to the concrete mix at a 1% ratio concerning the weight of the cement. In the MIX ID - PCF scenario, the Lan Wires were introduced into the concrete as fibers after partially removing their insulation casing.

Table 4.17 presents the conclusive findings derived from the concrete cubes reinforced with Lan Wires, wherein the insulation casing was partially removed. Upon completing the 28-day curing period, these concrete specimens exhibited a notable compressive strength of 43.92 MPa.

Table 4.17 Compressive Strength of PCF

Sr. No.	MIX ID	Days	Weight (Kg)	Strength (MPa)
1	PCF	7	7.74	26.35
2	PCF	14	7.92	32.95
3	PCF	28	8	43.92

Fig 4.6 shows, the 28-day compressive strength of PCF stands at 43.92 MPa, meeting the acceptability criteria outlined in IRC:44-2017 which is higher than the optimum compressive strength of normal concrete. This strength level makes it suitable for utilization in the construction of rural roads.

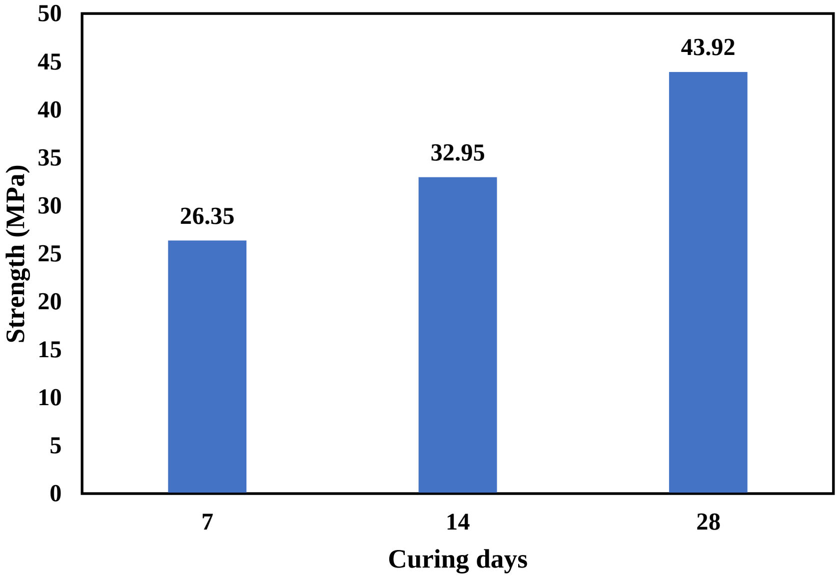


Fig 4.6 Mean Compressive Strength of PCF

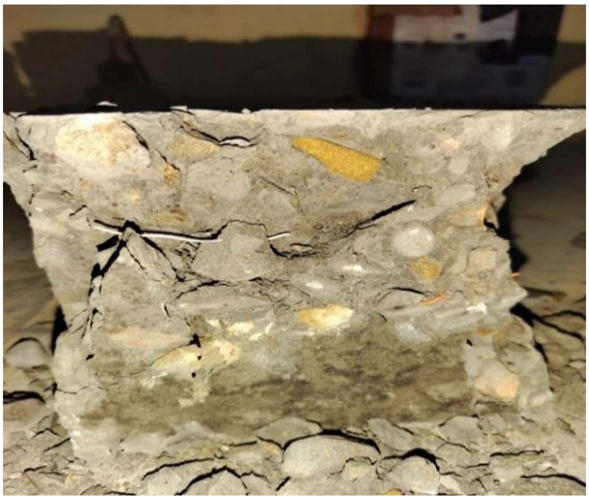


Fig 4.7 Placement of fiber after failure of cube

Fig 4.7 shows the pictorial image of Lan Wires incorporated in cubes after testing in which the Lan Wires were visible.

Fibers were configured to form mesh structures. The incorporation ratio was 1% relative to the weight of the cement. The concrete mix included these configured fibers, resulting in fiber-reinforced concrete. Lan Wires were used as the fiber material. The Lan Wires were fully insulated with casing. Cubes with the MIX ID – FCMS, containing Lan Wires with fully insulation casing, were subjected to testing. Table 4.18 presents the final results of these tests. The achieved strength for these cubes was 44.25 MPa at 28 days.

The Lan Wires were incorporated into the concrete in a mesh structure. The mesh structure likely provides additional strength and reinforcement to the concrete. The length of the Lan Wires used was 9cm. The diameter of the Lan Wires was 0.08cm. The aspect ratio of the Lan Wires was specified as approximately 112.5.

Table 4.18 Compressive Strength of FCMS

Sr. No.	MIX ID	Days	Weight (Kg)	Strength (MPa)
1	FCMS	7	8.1	26.37
2	FCMS	14	7.9	33.1
3	FCMS	28	8.05	44.25

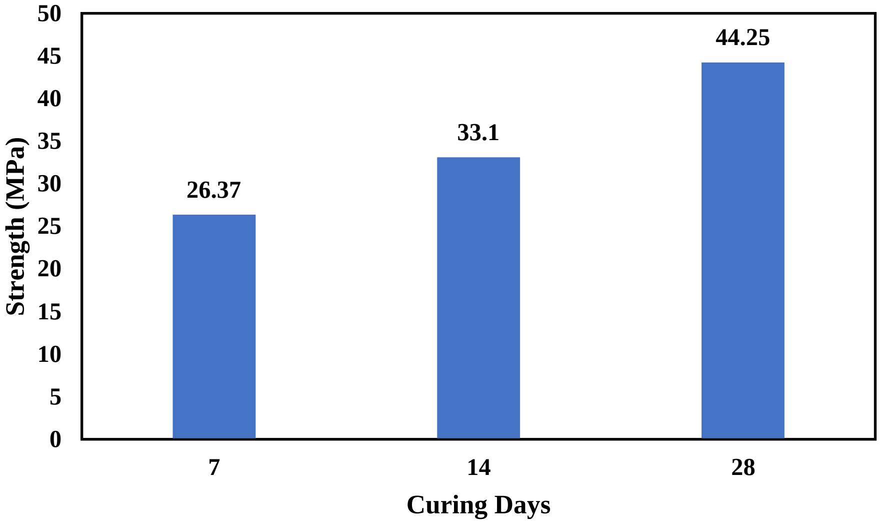


Fig 4.8 Mean Compressive Strength of FCMS

Fig 4.8 shows, the 28-day compressive strength of FCMS stands at 44.25 MPa, meeting the acceptability criteria outlined in IRC:44-2017 which is higher than the optimum compressive strength of normal concrete.

Fibers designed to create mesh structures were added to the concrete mix at a ratio of 1% relative to the cement's weight, featuring an aspect ratio of 112.5. This integration aimed to produce fiber-reinforced concrete. Lan Wires were used as fibers, forming a mesh structure within the concrete after the partial removal of the insulation casing. Subsequent testing focused on cubes labelled MIX ID – WCMS, involving the complete removal of the insulation casing from the Lan Wires. The conclusive findings presented in Table 4.19 revealed an impressive strength result of 44.86 MPa at the 28-day of curing. A visual representation of the Lan Wires mesh structure within the concrete mix, achieved through the full removal of insulation casing, is depicted in Fig 4.9. This image provides a graphical insight into the intricate arrangement of the Lan Wires mesh, showcasing the effectiveness of this innovative approach to reinforce the concrete.

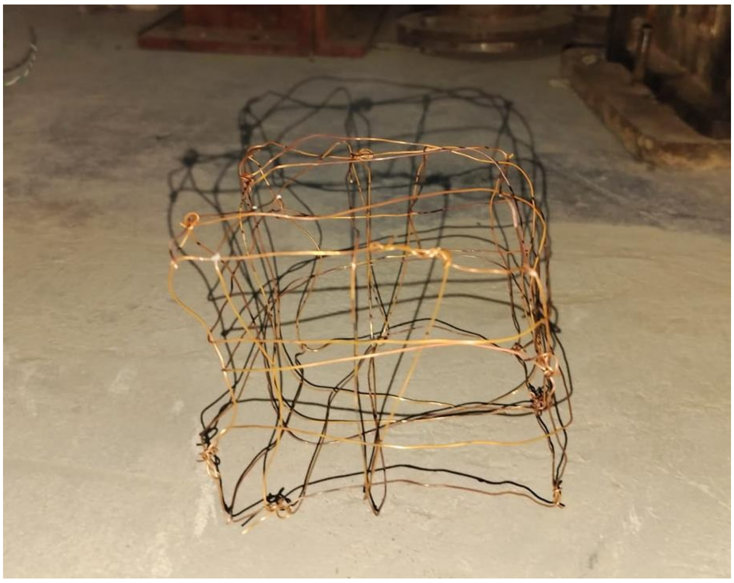


Fig. 4.9 Mesh Structure of Lan Wires (after fully removal of insulation casing of fiber)

Table 4.19 Compressive Strength of WCMS

Sr. No.	MIX ID	Days	Weight (Kg)	Strength (MPa)
1	WCMS	7	7.94	26.68
2	WCMS	14	7.78	33.165
3	WCMS	28	8.06	44.86

Fig 4.10 shows, the 28-day compressive strength of WCMS stands at 44.86 MPa, meeting the acceptability criteria outlined in IRC:44-2017 which is higher than the optimum compressive strength of normal concrete.

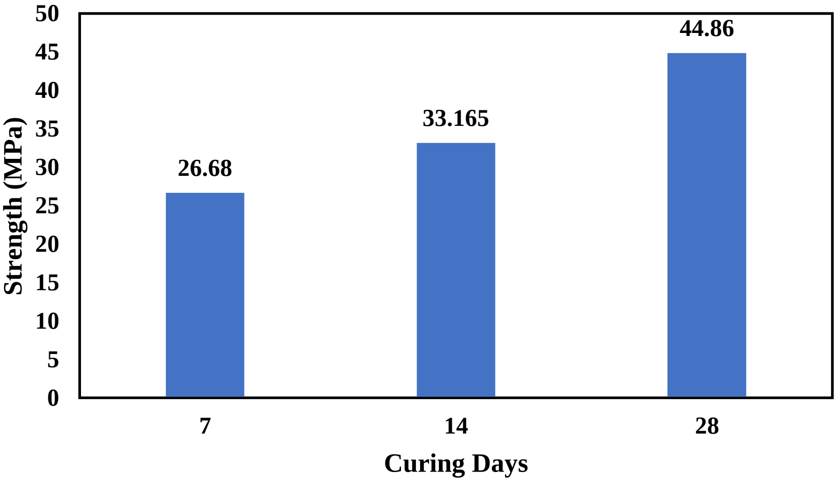


Fig. 4.10 Mean Compressive Strength of WCMS

Fig. 4.11 Placement of double layered of fiber in Concrete Mix

The application of the doubled layer copper wire followed the same procedure as the single layer application but with a varied number of layers. This resulted in a distinct aspect ratio compared to the prior application.

The concrete blocks were prepared by integrating E-waste (Lan Wires), specifically Lan Wires, as a reinforcing element in the concrete mix, possessing an aspect ratio of 28.125. This E-waste (Lan Wires) material was incorporated at a proportion of 2% relative to the weight of the cement. In this specific instance, Lan Wires were employed as fibers within the concrete, maintaining their full insulation casing, in which the diameter of copper wire is 0.016 cm and length is about 4.5 cm.

Following the casting and subsequent testing, cubes featuring the mix ID "DFCF," representing a 2% fiber content of Lan Wires with the complete insulation casing by doubling the layers of copper wire, were examined. Table 4.20 encapsulates the conclusive results obtained from this specific configuration. At the 28-day curing mark, the concrete blocks exhibited a notable strength achievement of 46.67 MPa. This outcome signifies the robustness and improved compressive strength imparted to the concrete due to the inclusion of Lan Wires as fibers with their insulation casing fully intact.

Table 4.20 Compressive Strength of DFCF

Sr. No.	MIX ID	Days	Weight (Kg)	Strength (MPa)
1	DFCF	7	7.98	27.8
2	DFCF	14	8.06	35.8
3	DFCF	28	7.75	46.67

Fig 4.12 depicts the 28-day compressive strength achieved by the concrete mix denoted as DFCF. This strength assessment, measuring at 46.67 MPa, meets the acceptability standards specified in IRC:44-2017. Meeting these criteria signifies that the concrete composition with DFCF designation fulfils the necessary strength requirements outlined for construction materials in the IRC:44-2017 guidelines which is higher than the optimum compressive strength of normal concrete.

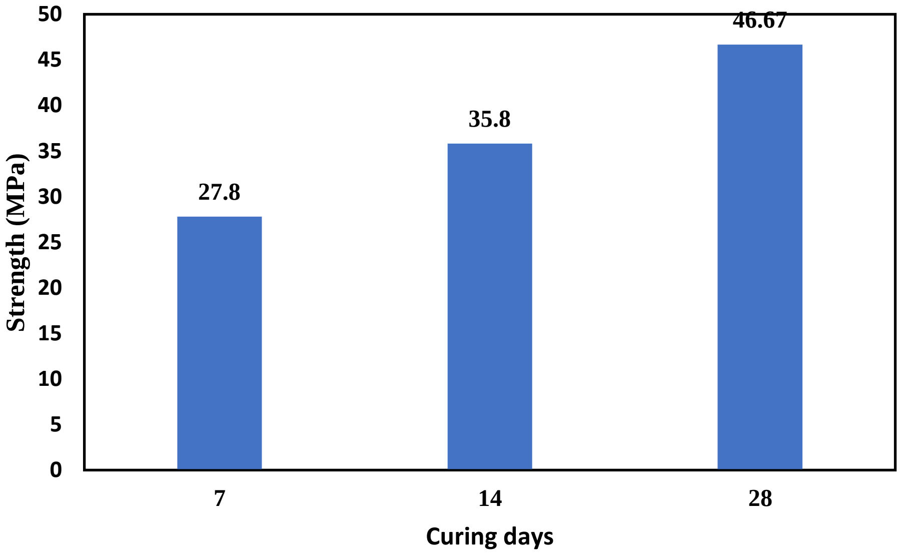


Fig. 4.12 Mean Compressive Strength of DFCF

Such a level of compressive strength renders the DFCF concrete mix suitable and capable of being used in the construction of rural roads. The attained strength level surpasses the minimum threshold necessary for ensuring the durability and structural integrity of road surfaces in rural areas. Therefore, based on its strength characteristics meeting the outlined standards, the DFCF concrete blend can be considered a viable and reliable option for use in the construction and development of road infrastructure in rural regions.

The experimental setup involved incorporating E-waste (Lan Wires), particularly Lan Wires, as a reinforcement in the concrete mixture. These Lan Wires, with an aspect ratio of 28.125, were added to the concrete mix at a 2% ratio concerning the weight of the cement. In the MIX ID - DWCF scenario, the Lan Wires were introduced into the concrete as fibers after partially removing their insulation casing. Table 4.21 presents the conclusive findings derived from the concrete cubes reinforced with Lan Wires, wherein the insulation casing was partially removed. Upon completing the 28-day curing period, these concrete specimens exhibited a notable compressive strength of 46.93 MPa.

Table 4.21 Compressive Strength of DWCF

Sr. No.	MIX ID	Days	Weight (Kg)	Strength (MPa)
1	DWCF	7	7.98	28
2	DWCF	14	8.06	36.2
3	DWCF	28	7.75	46.93

Fig 4.13 shows, the 28-day compressive strength of DWCF stands at 46.93 MPa, meeting the acceptability criteria outlined in IRC:44-2017 which is higher than the optimum compressive strength of normal concrete. This strength level makes it suitable for utilization in the construction of rural roads.

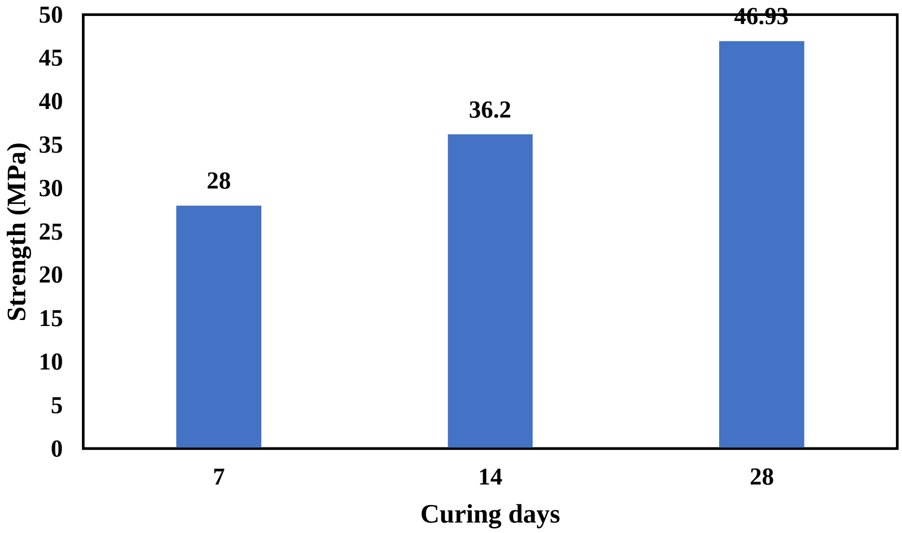


Fig 4.13 Mean Compressive Strength of DWCF

Fibers designed to create mesh structures were added to the concrete mix at a ratio of 2% relative to the cement's weight, featuring an aspect ratio of 56.25. This integration aimed to produce fiber-reinforced concrete. Copper wires was used as fibers, forming a mesh structure within the concrete after the partial removal of the insulation casing. Subsequent testing focused on cubes labelled MIX ID – DWCF, involving the complete removal of the insulation casing from the Lan Wires. The conclusive findings presented in Table 4.8 revealed an impressive strength result of 46.93 MPa at the 28-day of curing. A visual representation of the Lan Wires mesh structure within the concrete mix, achieved through the full removal of insulation casing, is depicted in Fig 4.13. This image provides a graphical insight into the intricate arrangement of the Lan Wires mesh, showcasing the effectiveness of this innovative approach to reinforce the concrete.

In the doubled layer mesh structure, we kept the dimensions consistent with the previous setup. However, we adjusted the diameter to 0.16cm, resulting in a unique aspect ratio for this iteration. Despite maintaining overall dimensions, the change in diameter brought about a notable variation in the structure's geometric proportions. This adjustment likely influences factors such as strength, flexibility, and conductivity compared to the previous setup. It's essential to assess how this modification impacts the performance and suitability of the mesh structure for its intended application, ensuring optimal functionality and efficiency in its use.

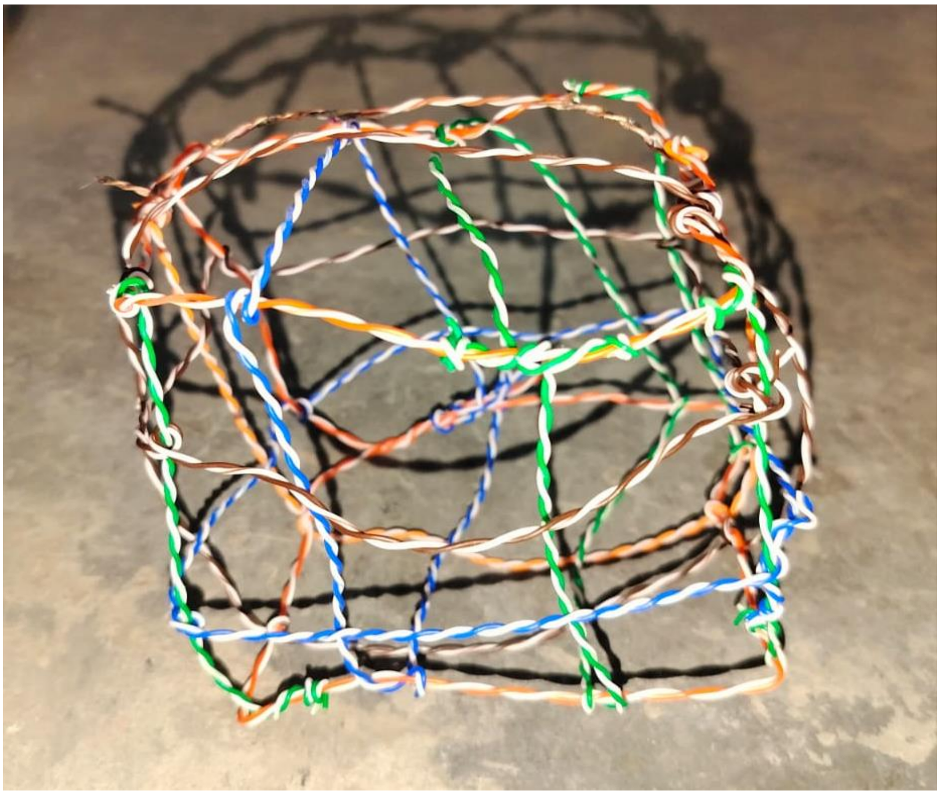


Fig. 4.14 Mesh Structure of DFCMS

Table 4.22 Compressive Strength of DFCMS

Sr. No.	MIX ID	Days	Weight (Kg)	Strength (MPa)
1	DFCMS	7	8.23	28.3
2	DFCMS	14	7.86	36.7
3	DFCMS	28	7.94	48.97

Table 4.22 shows, the 28-day compressive strength of DFCMS stands at 49.42 MPa, meeting the acceptability criteria outlined in IRC:44-2017 which is higher than the optimum compressive strength of normal concrete.

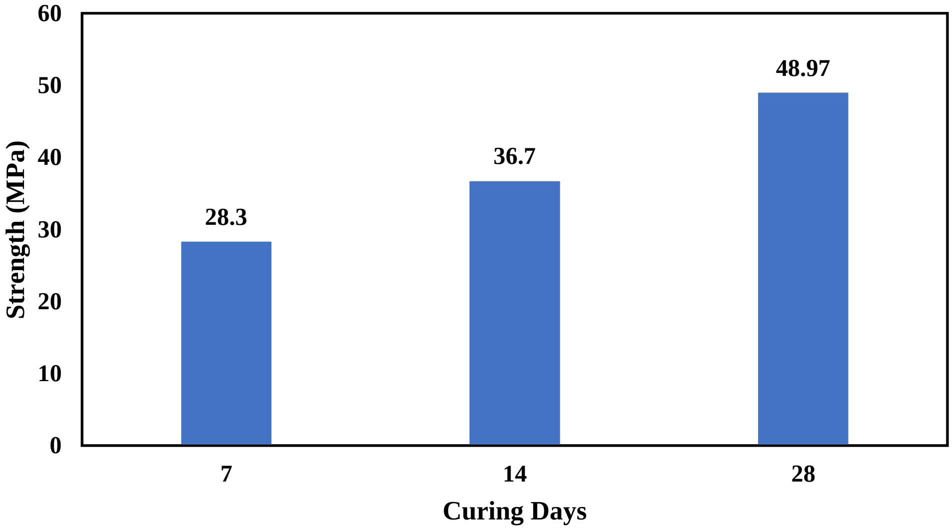


Fig. 4.15 Mean Compressive Strength of DFCMS

Fibers designed to create mesh structures were added to the concrete mix at a ratio of 2% relative to the cement's weight, featuring an aspect ratio of 56.25. This integration aimed to produce fiber-reinforced concrete. Lan Wires were used as fibers, forming a mesh structure within the concrete after the fully insulation casing. Subsequent testing focused on cubes labelled MIX ID – DFCMS, involving the complete removal of the insulation casing from the Lan Wires. The conclusive findings presented in Table 4.23 revealed an impressive strength result of 48.97 MPa at the 28-day of curing. A visual representation of the Lan Wires mesh structure within the concrete mix, achieved through the full removal of insulation casing, is depicted in Fig 4.15. This image provides a graphical insight into the intricate arrangement of the Lan Wires mesh, showcasing the effectiveness of this innovative approach to reinforce the concrete.

Table 4.23 Compressive Strength of DWCMS

Sr. No.	MIX ID	Days	Weight (Kg)	Strength (MPa)
1	DWCMS	7	7.62	28.9
2	DWCMS	14	7.89	37.2
3	DWCMS	28	7.87	49.42

Table 4.21 shows, the 28-day compressive strength of DWCMS stands at 49.42 MPa, meeting the acceptability criteria outlined in IRC:44-2017 which is higher than the optimum compressive strength of normal concrete.

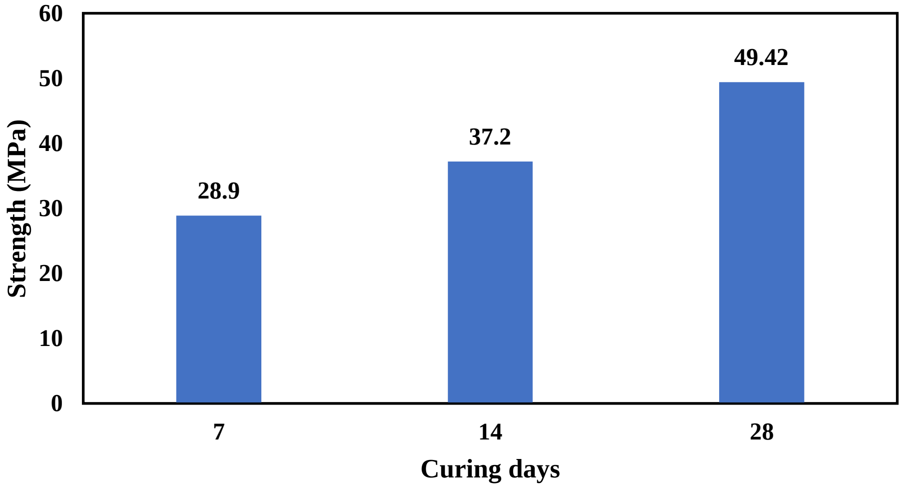


Fig. 4.16 Mean Compressive Strength of DWCMS

Fibers designed to create mesh structures were added to the concrete mix at a ratio of 2% relative to the cement's weight, featuring an aspect ratio of 56.25. This integration aimed to produce fiber-reinforced concrete. Lan Wires were used as fibers, forming a mesh structure within the concrete after the partial removal of the insulation casing. Subsequent testing focused on cubes labelled MIX ID – DWCMS, involving the complete removal of the insulation casing from the Lan Wires. The conclusive findings presented in Table 4.16 revealed an impressive strength result of 49.42 MPa at the 28-day of curing.

Additionally, the compressive strength values at 28 days demonstrated increases of 30.82% and 38.49% with respect to standard concrete. (Kumar, et al., (2016)). While adding the fibers with insulation, the concrete's ductility was increased and reduced its susceptibility to brittle failure. (Kurup, et al., (2017)). The addition of various materials, such as resin, e-plastic, and steel slag, impacted the properties of concrete differently. Optimal ratios were observed for strength and durability, with some materials enhancing certain properties while others caused reductions. E-waste, when appropriately managed, showed potential for improving concrete performance in specific applications. (Devi, et al., (2020)).

4.3.3 SPLIT TENSILE TESTING RESULTS

In concrete cylinder, the Split Tensile Test is performed under CTM. According to IS 5816: 1999, the strength of the specimen is calculated by Equation 3:

$$f_{Ct} = \frac{2P}{\pi l d} \qquad \textit{Equation (3).}$$

Where, f_{ct} is the splitting tensile strength of tensile, P is the maximum load applied on the specimen, *d* is the diameter of the specimen, *l* is the length of the specimen.

We had casted normal concrete specimens of cylinder of 150mm of height and 100 mm of diameter.

(a) **(b)**

Fig. 4.17 (a) Cylinder during casting **(b)** Cylinder During Application of load

Fig. 4.17 shows the pictorial image of casting of cylinder and the cylinder during the application of load. Table 4.24 shows, the 28-day split tensile strength of NC stands at 4.07 MPa, meeting the acceptability criteria outlined in IRC:44-2017. Fig 4.18 shows, the 28-day split tensile strength of NC stands at 4.07 MPa, meeting the acceptability criteria outlined in IRC:44-2017.

Table 4.24 Split Tensile Strength of NC

Sr. No.	Mix ID	Days	Weight (Kg)	Strength (MPa)
1	NC	7	4.65	1.94
2	NC	14	5.03	3.4
3	NC	28	5.33	4.07

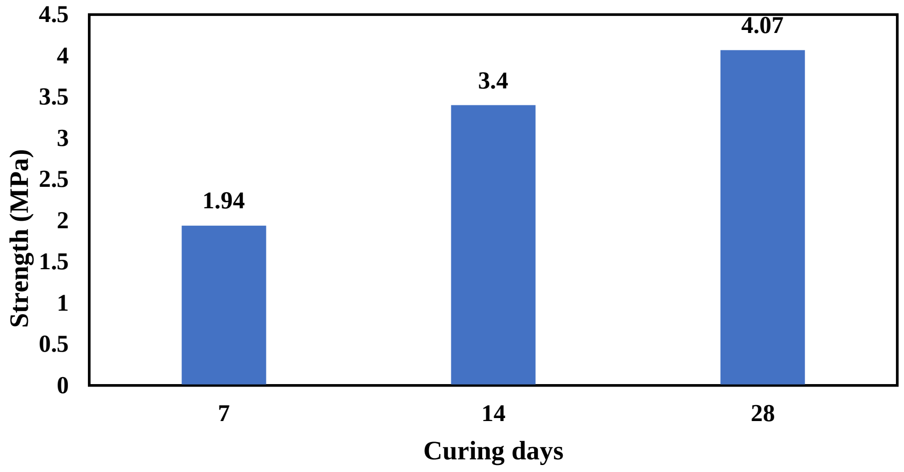


Fig. 4.18 Mean Result of Split Tensile Strength of NC

Table 4.25 shows, the 28-day split tensile strength of FCMS stands at 4.2 MPa, meeting the acceptability criteria outlined in IRC:44-2017 which is higher than the optimum split tensile strength of normal concrete. This strength level makes it suitable for utilization in the construction of rural roads.

Table 4.25 Split Tensile Strength of FCMS

Sr. No.	Mix ID	Days	Weight (Kg)	Strength (MPa)
1	7	FCMS	4.67	2.06
2	14	FCMS	5.021	3.48
3	28	FCMS	5.43	4.2

Fig. 4.19 Cracks produced after testing

Fig. 4.19 shows the pictorial image of cracks produced in cylinder after the testing is completed.The integration of Lan Wires, single in layers within concrete, resulted in a notable enhancement in flexural strength, equivalent to a split tensile strength of approximately 4.2 MPa at the 28-day curing mark. This substantial improvement, achieved with E-waste (Lan Wires) comprising 1% of the mix and an aspect ratio of 100, underscores the efficacy of Lan Wires in reinforcing concrete. Maintaining the full insulation casing, each fiber's copper wire measured 0.08 cm in diameter and approximately 8 cm in length. These findings highlight the potential of Lan Wires reinforcement for enhancing the durability and structural integrity of construction materials. Fig. 4.20 shows the graphical representation of Split Tensile Strength of Cylinder at 28 days of curing about 4.2 MPa.

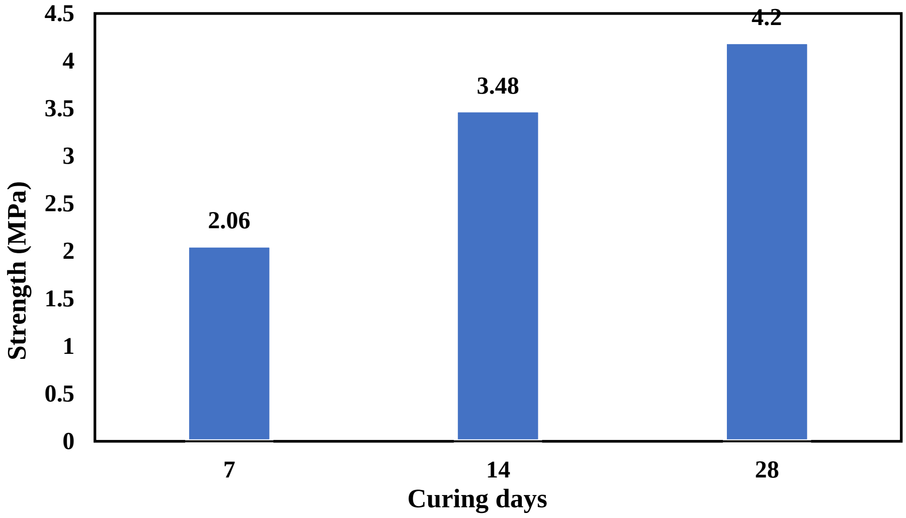


Fig. 4.20 Mean Result of Split Tensile Strength of FCMS

Table 4.26 shows, the 28-day split tensile strength of WCMS stands at 4.36 MPa, meeting the acceptability criteria outlined in IRC:44-2017 which is higher than the optimum split tensile strength of normal concrete. This strength level makes it suitable for utilization in the construction of rural roads.

Table 4.26 Split Tensile Strength of WCMS

Sr. No.	**Mix ID**	**Days**	**Weight (Kg)**	**Strength (MPa)**
1	WCMS	7	5.2	2.29
2	WCMS	14	4.86	3.72
3	WCMS	28	4.93	4.36

The integration of Lan Wires, single in layers within concrete, resulted in a notable enhancement in flexural strength, equivalent to a split tensile strength of approximately 4.36 MPa at the 28-day curing mark. This substantial improvement, achieved with E-waste (Lan Wires) comprising 1% of the mix and an aspect ratio of 100, underscores the efficacy of Lan Wires in reinforcing concrete. Maintaining the fully removal of insulation casing, each fiber's copper wire measured 0.08 cm in diameter and approximately 8 cm in length. These findings highlight the potential of Lan Wires reinforcement for enhancing the durability and structural integrity of construction materials. Fig. 4.21 shows the graphical representation of Split Tensile Strength of Cylinder at 28 days of curing about 4.36 Mpa.

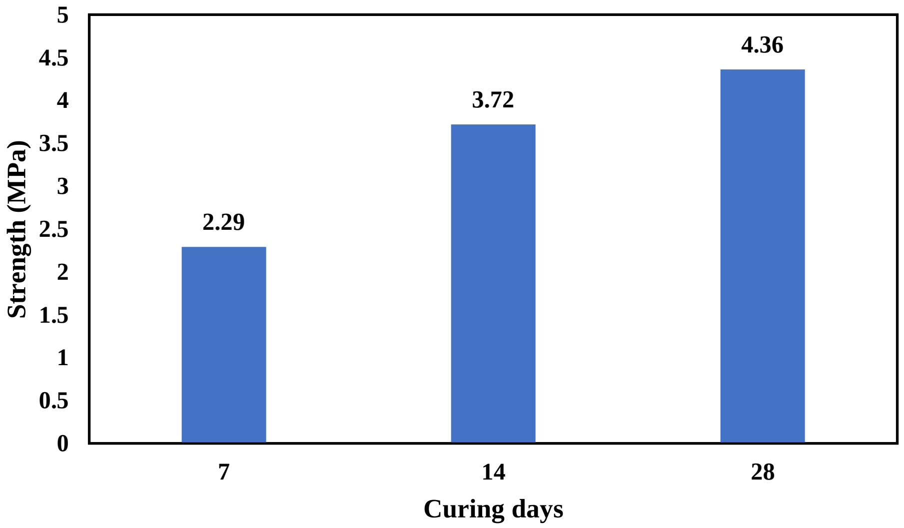


Fig. 4.21 Mean Result of Split Tensile Strength of WCMS

Table 4.27 shows, the 28-day split tensile strength of DFCMS stands at 4.43 MPa, meeting the acceptability criteria outlined in IRC:44-2017 which is higher than the optimum split tensile strength of normal concrete. This strength level makes it suitable for utilization in the construction of rural roads.

Table 4.27 Split Tensile Strength of DFCMS

Sr. No.	Mix ID	Days	Weight (Kg)	Strength (MPa)
1	DFCMS	7	4.84	2.35
2	DFCMS	14	5.23	3.81
3	DFCMS	28	5.16	4.43

The integration of Lan Wires, doubled in layers within concrete, resulted in a notable enhancement in flexural strength, equivalent to a split tensile strength of approximately 4.43 MPa at the 28-day curing mark. This substantial improvement, achieved with E-waste (Lan Wires) comprising 2% of the mix and an aspect ratio of 50, underscores the efficacy of Lan Wires in reinforcing concrete. Maintaining the full insulation casing, each fiber's copper wire measured 0.16 cm in diameter and approximately 8 cm in length. These findings highlight the potential of Lan Wires reinforcement for enhancing the durability and structural integrity of construction materials. Fig. 4.22 shows the graphical representation of Split Tensile Strength of Cylinder at 28 days of curing about 4.43 MPa.

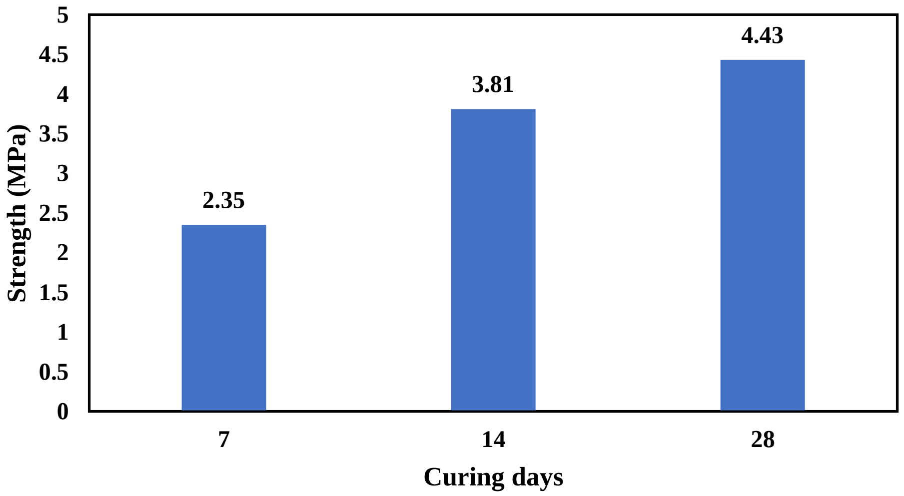


Fig. 4.22 Mean Result of Split Tensile Strength of DFCMS

Table 4.28 shows, the 28-day split tensile strength of DWCMS stands at 4.58 MPa, meeting the acceptability criteria outlined in IRC:44-2017 which is higher than the optimum split tensile strength of normal concrete. This strength level makes it suitable for utilization in the construction of rural roads.

Table 4.28 Split Tensile Strength of DWCMS

Sr. No.	Mix ID	Days	Weight (Kg)	Strength (MPa)
1	DWCMS	7	4.71	2.38
2	DWCMS	14	4.82	3.86
3	DWCMS	28	5	4.58

The integration of Lan Wires, doubled in layers within concrete, resulted in a notable enhancement in flexural strength, equivalent to a split tensile strength of approximately 4.58 MPa at the 28-day curing mark. This substantial improvement, achieved with E-waste (Lan Wires) comprising 2% of the mix and an aspect ratio of 50, underscores the efficacy of Lan Wires in reinforcing concrete. Maintaining the fully removal of insulation casing, each fiber's copper wire measured 0.16 cm in diameter and approximately 48 cm in length. These findings highlight the potential of Lan Wires reinforcement for enhancing the durability and structural integrity of construction materials. Fig. 4.23 shows the graphical representation of Split Tensile Strength of Cylinder at 28 days of curing about 4.58 MPa.

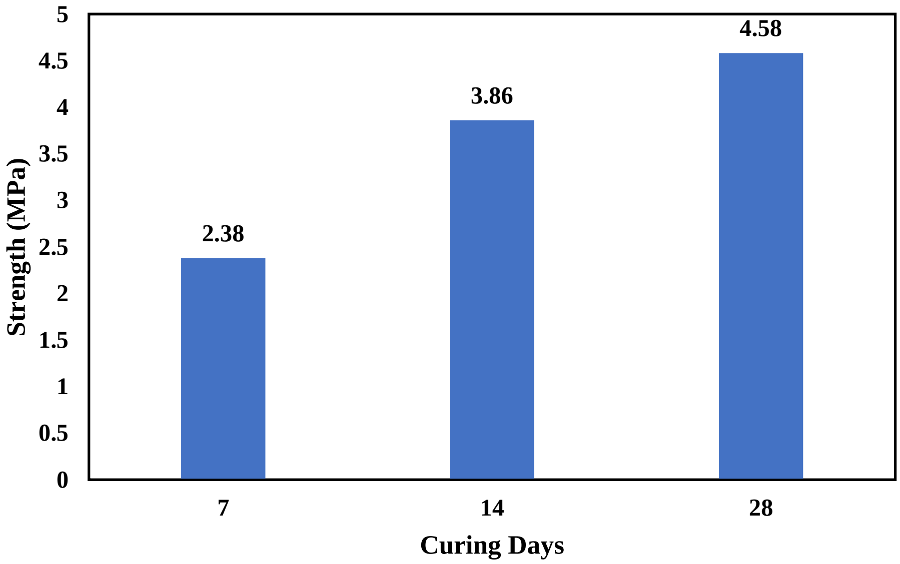


Fig. 4.23 Mean Split Tensile Strength of DWCMS

On comparing with the previous study, we had concluded that we had also achieve same strength. The split tensile strength values exhibited increases of 7.1% and 18.5% relative to standard concrete at 28 days. (Kumar, et al., (2016)).

4.3.4 RESULTS OF FLEXURAL STRENGTH TEST PERFORMED ON CONCRETE BEAM

In concrete beam, the Flexural Test is performed under Flexural strength testing machine. According to IS 516: 1959, the strength of the specimen is calculated by this formula, when the measured distance (a) was greater than 13.3 cm then the flexural strength is calculated by Equation 4 and when the distance was in-between 11cm and 13.3cm then the flexural strength is calculated by Equation 5.

$$\text{Flexural Strength} = [(P\times L)/(B\times D^2)] \qquad \text{Equation (4)}$$

$$\text{Flexural Strength} = [(3P\times a)/(B\times D^2)] \qquad \text{Equation (5)}$$

Where, P is the maximum load sustained by the specimen, B is the width of specimen, L is the length of specimen, D is the depth of specimen, a is the distance between the crack generated on the tensile side of the specimen. The dimension of the beam is 500cm×100cm×100cm.

The image presented in Fig. 4.24 displays a visual representation of a beam structure after the application of a load. The image serves to depict the impact of the load on the beam, highlighting the resultant crack pattern that has developed due to the applied stress or force. Fig 4.25 shows the graphical image of average Flexural strength of NC about 4.4 MPa at 28 days. Table 4.29 shows the flexural strength of NC achieved 4.4 MPa at 28 day of curing.

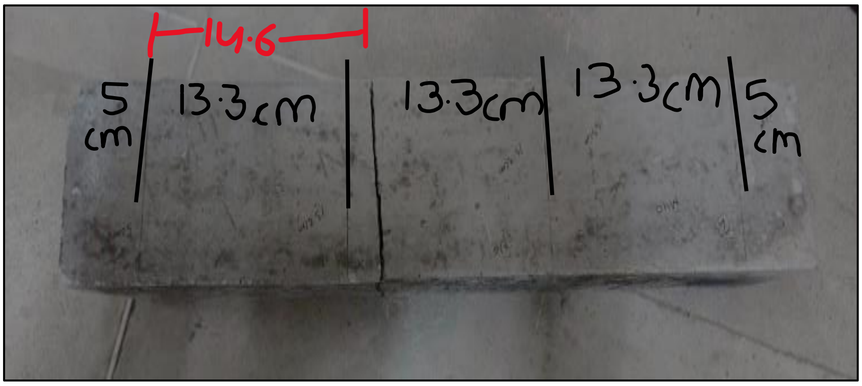


Fig 4.24 Beam after application of load

Table 4.29 Flexural Strength of NC

Sr. No.	**MIX ID**	**Days**	**Average Length of Cracks (cm)**	**Weight (Kg)**	**Strength**
1	NC	7	13.7	10.44	2.65
2	NC	14	14	10.57	3.35
3	NC	28	13.6	10.85	4.4

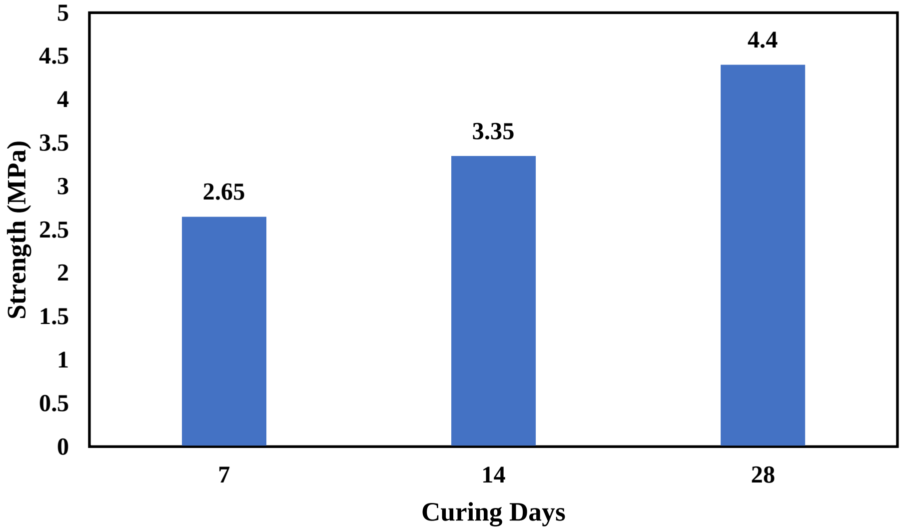


Fig 4.25 Mean Flexural Strength of NC

We had utlized the fibers of optical wires as mesh structure in beam as a reinforcement. With a dimension of 480 mm X 80mm X 80mm. The integration of Lan Wires, doubled in layers within concrete, yielded significant flexural strength improvements. With E-waste (Lan Wires) comprising 2% of the mix, the aspect ratio of 600 facilitated enhanced reinforcement. Maintaining the full insulation casing, each fiber's copper wire measured 0.08 cm in diameter and approximately 48 cm in length. The resultant mix, labeled "FCMS," exhibited impressive flexural strength of 4.65 MPa at the 28-day curing mark. This underscores the efficacy of Lan Wires in bolstering concrete's mechanical properties, promising durability and structural integrity for construction applications.

Table 4.30 shows the flexural strength of FCMS achieved 4.65 MPa at 28 day of curing and fig 4.26 shows the graphical image of average Flexural strength of FCMS about 4.65 MPa at 28 days.

Table 4.30 Flexural Strength of FCMS

Sr. No.	MIX ID	Days	Average Length of Cracks (cm)	Weight (Kg)	Strength
1	FCMS	7	10.88	13	2.73
2	FCMS	14	11	13.2	3.74
3	FCMS	28	11.2	12.6	4.65

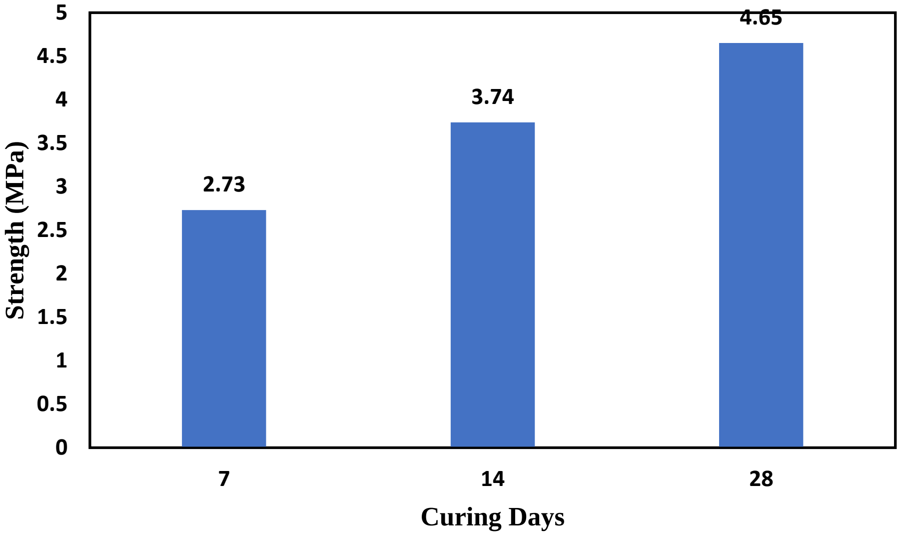


Fig 4.26 Mean Flexural Strength of FCMS

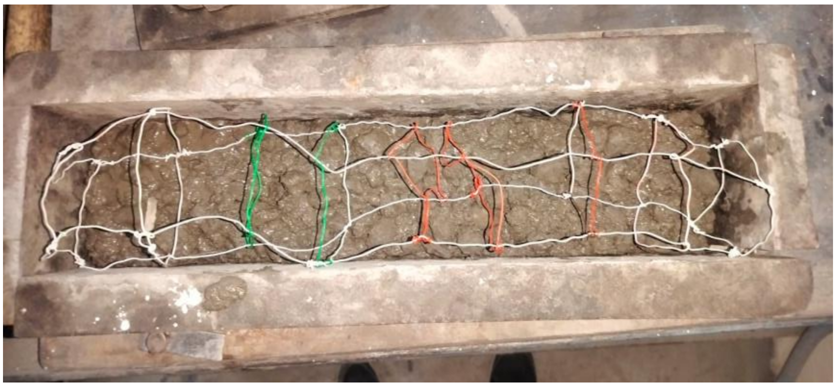


Fig. 4.27 Placement of mesh structure during casting

Fig. 4.27 shows the pictorial image of Mesh Structure placed in the concrete mix.

The integration of Lan Wires, single in layers within concrete, yielded significant flexural strength improvements. With E-waste (Lan Wires) comprising 1% of the mix, the aspect ratio of 600 facilitated enhanced reinforcement. Maintaining the fully removal of insulation casing, each fiber's copper wire measured 0.08 cm in diameter and approximately 48 cm in length. The resultant mix, labeled "WCMS," exhibited impressive flexural strength of 4.85 MPa at the 28-

day curing mark. This underscores the efficacy of Lan Wires in bolstering concrete's mechanical properties, promising durability and structural integrity for construction applications.

Table 4.31 shows the flexural strength of WCMS achieved 4.85 MPa at 28 day of curing and fig 4.28 shows the graphical image of average Flexural strength of WCMS about 4.85 MPa at 28 days.

Table 4.31 Flexural Strength of WCMS

Sr. No.	MIX ID	Days	Average Length of Cracks (cm)	Weight (Kg)	Strength
1	WCMS	7	10.2	13	2.81
2	WCMS	14	10.7	13.2	3.9
3	WCMS	28	10.35	12.6	4.85

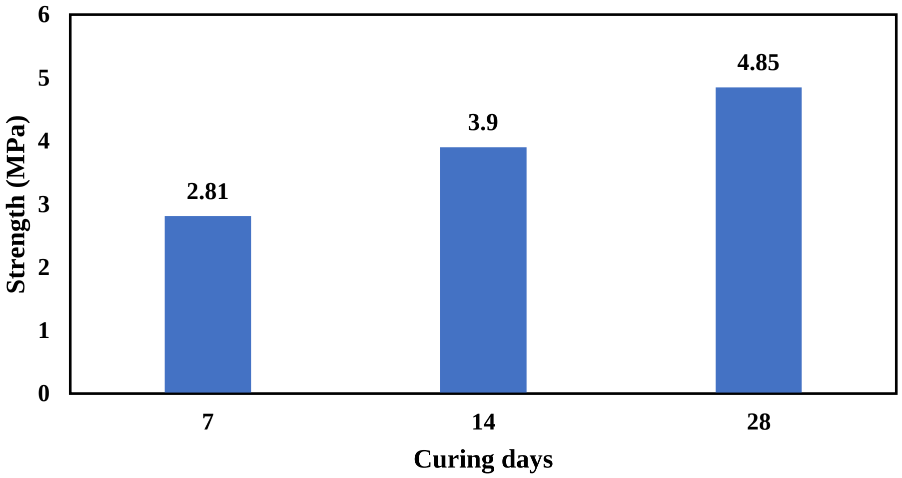


Fig 4.28 Mean Flexural Strength of WCMS

We had utlized the fibers of optical wires as mesh structure in beam as a reinforcement. With a dimension of 480 mm X 80mm X 80mm. The integration of Lan Wires, doubled in layers within concrete, yielded significant flexural strength improvements. With E-waste (Lan Wires) comprising 2% of the mix, the aspect ratio of 300 facilitated enhanced reinforcement. Maintaining the full of insulation casing, each fiber's copper wire measured 0.16 cm in diameter and approximately 48 cm in length. The resultant mix, labeled "DFCMS," exhibited impressive flexural strength of 4.9 MPa at the 28-day curing mark. This underscores the efficacy of Lan Wires in bolstering concrete's mechanical properties, promising durability and structural integrity for construction applications.

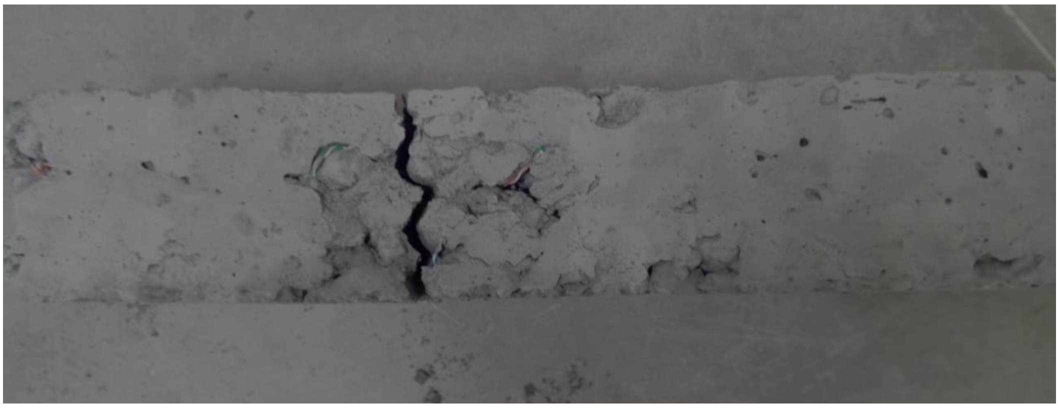


Fig. 4.29 Cracks in DFCMS beam

Fig. 4.29 shows the pictorial image of cracks generated after the testing performed and we had noticed that the bond between the mesh structure and concrete was excellent.

The flexural strength of DFCMS was achieved aroun4.9 MPa at 28 day of curing as shown in Table 4.32 and fig 4.30. While fig. 4.31 shows the pictorial image of DWCMS sample was placed in 4-point bending testing machine.

Table 4.32 Flexural Strength of DFCMS

Sr. No.	**MIX ID**	**Days**	**Average Length of Cracks (cm)**	**Weight (Kg)**	**Strength**
1	DFCMS	7	11.2	14.2	2.97
2	DFCMS	14	11.6	14.24	3.93
3	DFCMS	28	10.8	12.92	4.9

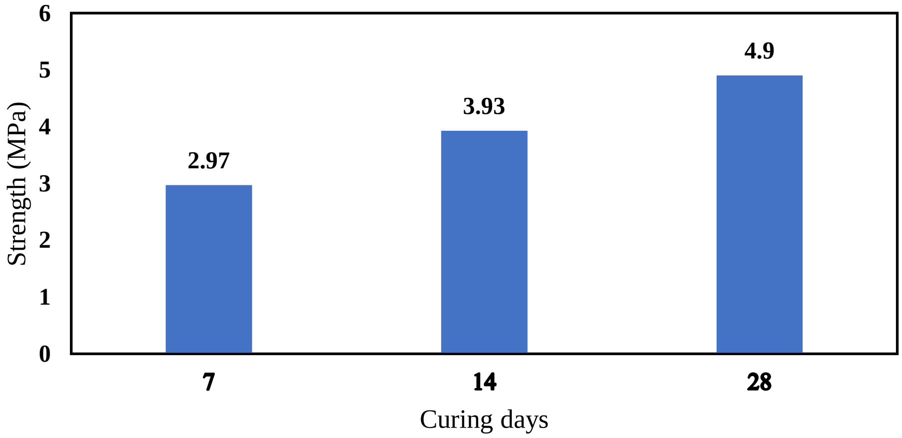


Fig 4.30 Mean Flexural Strength of DFCMS

Fig. 4.31 DWCMS during testing

We had utlized the fibers of optical wires as mesh structure in beam as a reinforcement. With a dimension of 480 mm X 80mm X 80mm. The integration of Lan Wires, double in layers within concrete, yielded significant flexural strength improvements. With E-waste (Lan Wires) comprising 2% of the mix, the aspect ratio of 300 facilitated enhanced reinforcement. Maintaining the full of insulation casing, each fiber's copper wire measured 0.16 cm in diameter and approximately 48 cm in length. The resultant mix, labeled "DWCMS," exhibited impressive flexural strength of 5.1 MPa at the 28-day curing mark. This underscores the efficacy of Lan Wires in bolstering concrete's mechanical properties, promising durability and structural integrity for construction applications. Table 4.33 shows the flexural strength of DWCMS achieved 5.1 at 28 day of curing & Fig 4.32 shows the graphical image of average Flexural strength of DWCMS about 5.1 MPa at 28 days.

Table 4.33 Flexural Strength of DWCMS

Sr. No.	MIX ID	Days	Average Length of Cracks (cm)	Weight (Kg)	Strength
1	DWCMS	7	11.3	13.5	3.1
2	DWCMS	14	10.64	14.8	4.2
3	DWCMS	28	12.4	12.9	5.1

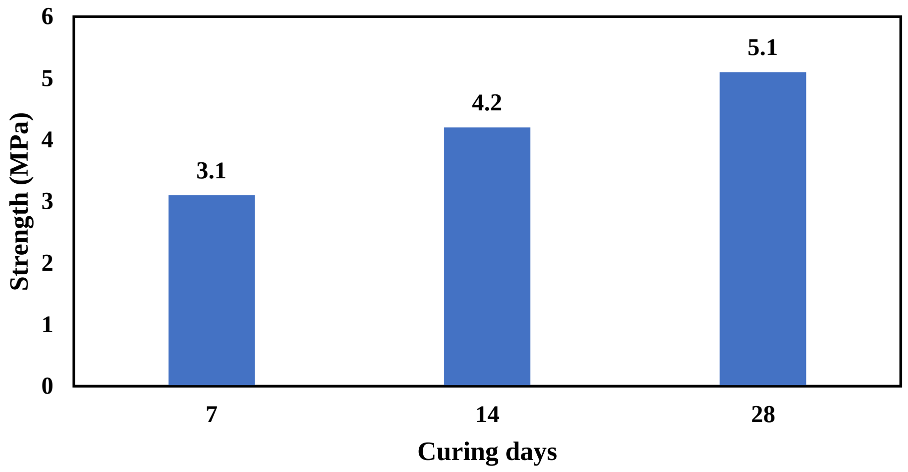


Fig 4.32 Mean Flexural Strength of DWCMS

The flexural strength values at 28 days showed increases of 16% as compared to standard concrete. (Kumar, et al., (2016)).

4.3.5 TENSILE STRENGTH OF REINFORCING FIBER

The tensile test conducted on the copper wire of Lan Wires using a Universal Testing Machine (UTM) provided valuable insights into the wire's mechanical properties and behavior under load. The specimen, with a length of approximately 60 cm and a diameter of 0.16 cm, was carefully prepared and placed onto the UTM for testing.

As the tensile load was applied gradually to the specimen, the UTM recorded the corresponding deformation and applied force. It was observed that as the load increased, the copper wire began to undergo elongation. This elongation was measured and found to be approximately 6.7 cm from its original length before the wire reached its failure point.

The UTM allowed for precise control and monitoring of the testing process, ensuring accurate data collection. By analysing the load-deformation curve generated during the test, valuable information about the wire's tensile strength, modulus of elasticity, and ductility could be obtained.

The significant elongation of the wire before failure indicates its ability to undergo plastic deformation under tensile stress. This ductile behavior is characteristic of many metallic materials and is desirable in applications where the material may be subjected to high loads or impact forces.

Overall, the tensile test conducted on the copper wire provided essential data for understanding its mechanical behavior and suitability for use as reinforcement in Lan Wires applications. The results of the test can inform design decisions and help ensure the reliability and performance of products incorporating this material. Table 4.34 shows the elongation of wire & Table 4.34 shows the details of elongation of wire before its application on UTM. Percentage elongation is calculated by Equation (6).

Table 4.34 Tensile Strength of Lan Wire Fiber

Sample	Load (kN)	Length before elongation (cm)	Length after elongation (cm)
S1	14	60	66.7

Fig. 4.33 Copper wire under UTM

Elongation of lan wire:

Initial gauge length of specimen (I_L)=660mm

Final length (I_F)=726.7mm

Elongation of the specimen (Δ) = 66.7mm

Percentage elongation=Change in length/Original length

$$= \frac{I_{F-I_L}}{I_L} \times 100 \qquad \text{Equation (6)}$$

=726.7-660/660 ×100

=10.10%

From above results it conclude that percentage elongation of lan wire was 10.10% which satisfy the criteria mentioned in IS1786 for road construction work.

4.4 DISCUSSION

The results from the experimental investigation provide a comprehensive understanding of the suitability and performance of materials used in concrete production, specifically focusing on cement and aggregates. Starting with cement, various crucial parameters such as fineness, setting time, and consistency were evaluated to ensure optimal mix designs.

The fineness test revealed an average fineness value of 6.47%, meeting industry standards and indicating satisfactory particle size distribution. This parameter is crucial as it influences the rate of hydration and, consequently, the strength development of concrete. Additionally, setting time tests demonstrated reasonable initial and final setting times of 36 minutes and 248 minutes, respectively. These values ensure adequate workability and curing time, facilitating proper placement and finishing of concrete.

Consistency tests further corroborated the suitability of the cement by providing an average penetration value of 31%. This value indicates the appropriate water-cement ratio for achieving desired concrete properties, such as workability and strength development. Moving on to coarse aggregates, a series of tests including crushing, impact, and abrasion tests were conducted to assess their performance. The results showcased satisfactory performance, with an aggregate crushing value of 26.6% and an impact value averaging at 16.93%. These values indicate robust load-bearing capacity and resistance to wear and tear, essential for durable concrete structures.

Specific gravity and water absorption tests confirmed the quality of coarse aggregates, ensuring proper mix consistency and durability. These tests are crucial as they provide insights into the aggregates' density and ability to resist moisture ingress, both of which are vital for achieving durable concrete mixes. Fine aggregates also exhibited optimal characteristics, with a fineness modulus indicating suitable particle sizes for cohesive concrete mixtures. Particle size distribution showed proper grading, essential for achieving desired concrete properties such as workability and strength.

Moving on to the experimental findings related to fiber-reinforced concrete mixes, the focus was on evaluating compressive, split tensile, and flexural strengths. These tests were conducted on various concrete mixes with different percentages of Lan Wires and varying degrees of insulation casing removal. On comparing with the previous study, we conluded that we had also achieve same strength. The flexural strength values at 7 days showed increases of 9.11% and 16% compared to standard concrete, while the split tensile strength values exhibited increases of 7.1% and 18.5% relative to standard concrete at 28 days. Additionally, the compressive strength values at 28 days demonstrated increases of 30.82% and 38.49% with respect to standard concrete.

The results revealed a clear correlation between fiber content, casing removal, and the strength characteristics of the concrete mixes. Increasing fiber content generally led to higher strength in compression, tension, and flexion. Notably, partial or complete removal of insulation casing enhanced the bonding between fibers and the concrete matrix, further improving strength.

Mesh structure reinforcement emerged as a promising technique for concrete reinforcement, significantly enhancing both tensile and flexural strength. Overall, the findings suggest that incorporating Lan Wires in concrete mixes can substantially enhance their mechanical properties, making them suitable for various construction applications, particularly in rural road infrastructure where durability and strength are crucial.

4.5 SUMMARY

The experiment evaluated the compressive, split tensile, and flexural strengths of concrete mixes, including normal concrete (NC) and fiber-reinforced mix incorporating Lan Wires. Results showed improved strengths compared to NC, with mix like FCMS, WCMS, DFCMS, and DWCMS exceeding standards for rural road construction. Lan Wires, with varying configurations and insulation conditions, contributed to enhanced strength. The split tensile test demonstrated strengths ranging from 4.2 to 4.58 MPa for fiber-reinforced mixes, surpassing NC. Flexural tests indicated strengths up to 5.1 MPa for fiber-reinforced mix, highlighting the influence of Lan Wire aspect ratios and casing conditions. Additionally, the tensile test on Lan Wire showcased its ductile behavior under load. Overall, incorporating Lan Wires in concrete mixes enhances mechanical properties, offering durable alternatives for infrastructure development, particularly in rural road construction, where strength and durability are essential.

CHAPTER 5

CONCLUSION

5.1 GENERAL

Concrete that contained E-waste (Lan Wires) more specifically, Lan Wires—showed positive outcomes in terms of increased compressive strength, indicating that it could find use in construction particularly in the context of rural highways. With the use of E-waste (Lan Wires) materials, sustainable construction techniques may become even more advantageous with more study and improvement.

5.2 CONCLUSION

Different finding and observations were concluded on the basis of experimental analysis in Chapter 4. The experiment investigated the compressive strength of various concrete mixes, comparing a standard normal concrete (NC) mix with several fiber-reinforced concrete mix. The baseline NC mix showed a 28-day compressive strength of 43.55 MPa, which meets the required standards for rural road construction as per IRC:44-2017 guidelines.

The study incorporated Lan Wires into the concrete mixes, with variations in aspect ratios and insulation casing conditions. The fiber-reinforced mixes displayed an overall enhancement in compressive strength compared to the standard NC mix. Here are the detailed results for each mix ID:

- On the basis of the findings, it was observed that the incorporation of fully coated fiber (FCF) in concrete mix responsible for the increase in compressive strength value about 0.1% after 28 days curing time period.
- Similarly, an increase of 0.8% in the compressive strength value was observed for the concrete mix having partial coated fiber (PCF) after 28 days of curing periodin comparison to the normal mix.
- While, the compressive strength of concrete mix having FCMS was found about 44.25 MPa after 28 days of curing period which is 1.6% higher than the normal mix.

- On the other hand, an increase of 3% in strength value was observed in case of concrete mix having mesh structure without any coating and which may be due to the better bonding between lan wire and concrete mix.
- Interestingly, the mix titled as DFCF was showing an increase of 7.16% in compressive strength value in comparison to the normal mix.
- Likewise, DWCF was also showing the increment of 7.76% which is again due to the better bonding between fiber and concrete mix.
- It is to note that the concrete mix having doubly mesh structure i.e. DFCMS and DWCMS were also reported the increase in the strength value i.e. 12.44% and13.47% respectively.

The mesh structures formed by Lan Wires significantly contribute to the enhanced strength, with variations in aspect ratios and insulation casing conditions affecting performance. Among the various mixes, DWCMS exhibited the highest compressive strength improvement (49.42 MPa, a 13.47% enhancement). This suggests a strong binding factor between the copper wire and the concrete mix, resulting in superior performance. However, DFCMS (48.97 MPa, a 12.44% enhancement) also showed substantial improvement, and its compressive strength is close to that of DWCMS. Given the negligible difference in strength between DFCMS and DWCMS of about 1.08%, DFCMS can be considered an efficient alternative for applications where slightly lower compressive strength is acceptable but other factors (such as cost or material availability) might favor its use. All the modified concrete mixes were showing strength value more than the required strength value i.e. 40 MPa as per IRC 44: 2017. Therefore, the same methodology may be adopted in the construction of National Highways (NHs).

The study focused on evaluating the compressive, split tensile, and flexural strengths of various concrete mixes, particularly comparing normal concrete (NC) with different fiber-reinforced concrete blends incorporating Lan Wires. The inclusion of Lan Wires, varying in aspect ratios and insulation casing conditions, aimed to enhance the mechanical properties of the concrete mixes, making them suitable for infrastructure developments, particularly rural road construction.

The Split Tensile Test was conducted on concrete cylinders with dimensions (diameter: 100mm, height: 150mm) according to IS 5816:1999 standards. This test evaluates the tensile strength of concrete, which is crucial for understanding how the material will perform under indirect tension forces, the split tensile strength of NC was about 4.07 MPa. The results of all other MIX IDs were compared as follows:

- Based on the findings, it was concluded that introducing FCMS into the concrete mix improved split tensile strength by more than 3% due to the bonding between the fibers and the concrete mix.
- Similarly, the split tensile strength of WCMS improved by approximately 7%.
- The incorporation of a double mesh structure in the concrete mix enhanced the split tensile strength of DFCMS and DWCMS by approximately 8.53% and 12.53%, respectively, compared to the normal mix.

The significant improvements in split tensile strength with the use of single and double layers of Lan Wires indicate that these fiber-reinforced mixes not only meet but exceed the standards set by IRC:44-2017. This suggests that these mixes are highly suitable for rural road construction where enhanced tensile strength is required.

Flexural strength tests, conducted according to IS 516:1959 standards, involved evaluating concrete beams with dimensions of 500mm × 100mm × 100mm. This test measures the ability of concrete to resist deformation under bending and is essential for understanding the load-bearing capacity of concrete structures under flexural stresses. The flexural strength of NC was about 4.4 MPa. The results of all other MIX IDs were compared:

- On the basis of finding, it was observed that with the incorporation of singly layered mesh structure FCMS and WCMS in concrete mix, there was an increment in the flexural strength of 5% and 10 % respectively.
- On the other hand, in case of double layered mesh structure DFCMS and DWCMS showed an enhancement in flexural strength of about 11% and 15% respectively.

The improvements in flexural strength demonstrate the effectiveness of Lan Wires as reinforcement, particularly with double layers of fibers. The aspect ratios and insulation casing conditions of the Lan Wires play a critical role in enhancing the concrete's flexural properties, thereby improving its durability and structural integrity under flexural loads.

The study concludes that fiber-reinforced concrete mixes, especially those incorporating double fibers and mesh structures, significantly enhance the mechanical properties of concrete. These mixes not only meet but exceed the standards required for rural road construction as per IRC:44-

2017. The integration of Lan Wires, whether as single or double layers, improves compressive, split tensile, and flexural strengths, offering durable and structurally sound alternatives for infrastructure development.

The tensile test conducted on the copper wire of Lan Wires using a Universal Testing Machine (UTM) provided crucial insights into the wire's mechanical behavior. The specimen, carefully prepared and tested, exhibited significant elongation of approximately 6.7 cm before reaching its failure point under a load of 14 kN. The test revealed the wire's ability to undergo plastic deformation, indicating its ductile behavior under tensile stress. This characteristic is desirable, particularly in applications where materials may be subjected to high loads or impact forces.

Overall, the results suggest that incorporating Lan Wires in concrete mixes can substantially enhance their mechanical properties, making them suitable for various construction applications, particularly in rural road infrastructure where durability and strength are crucial for sustainable development.

5.3 FUTURE SCOPE

- To enhance the mechanical property of concrete such as strength, durability etc., by utilizing other additives such as silica fume, metakaolin etc.
- To amplify the strength of concrete, the percentage of fiber used w.r.t the weight of cement can be further increased.
- Similar methodology may be adopted by utilizing other additives like slag, plastic aggregates as the replacement of cement or coarse, fine aggregates.

5.4 SUMMARY

Concrete incorporating E-waste, specifically Lan Wires, exhibited higher compressive strength, suggesting its potential in construction, especially for rural highways. The utilization of E-waste materials opens avenues for sustainable construction practices, promising enhanced durability and environmental benefits. Further research and improvements in incorporating E-waste in concrete could lead to more advantageous sustainable construction techniques. This highlights the significance of exploring innovative solutions like repurposing E-waste to address construction challenges and promote environmental sustainability in infrastructure development, particularly in rural areas.

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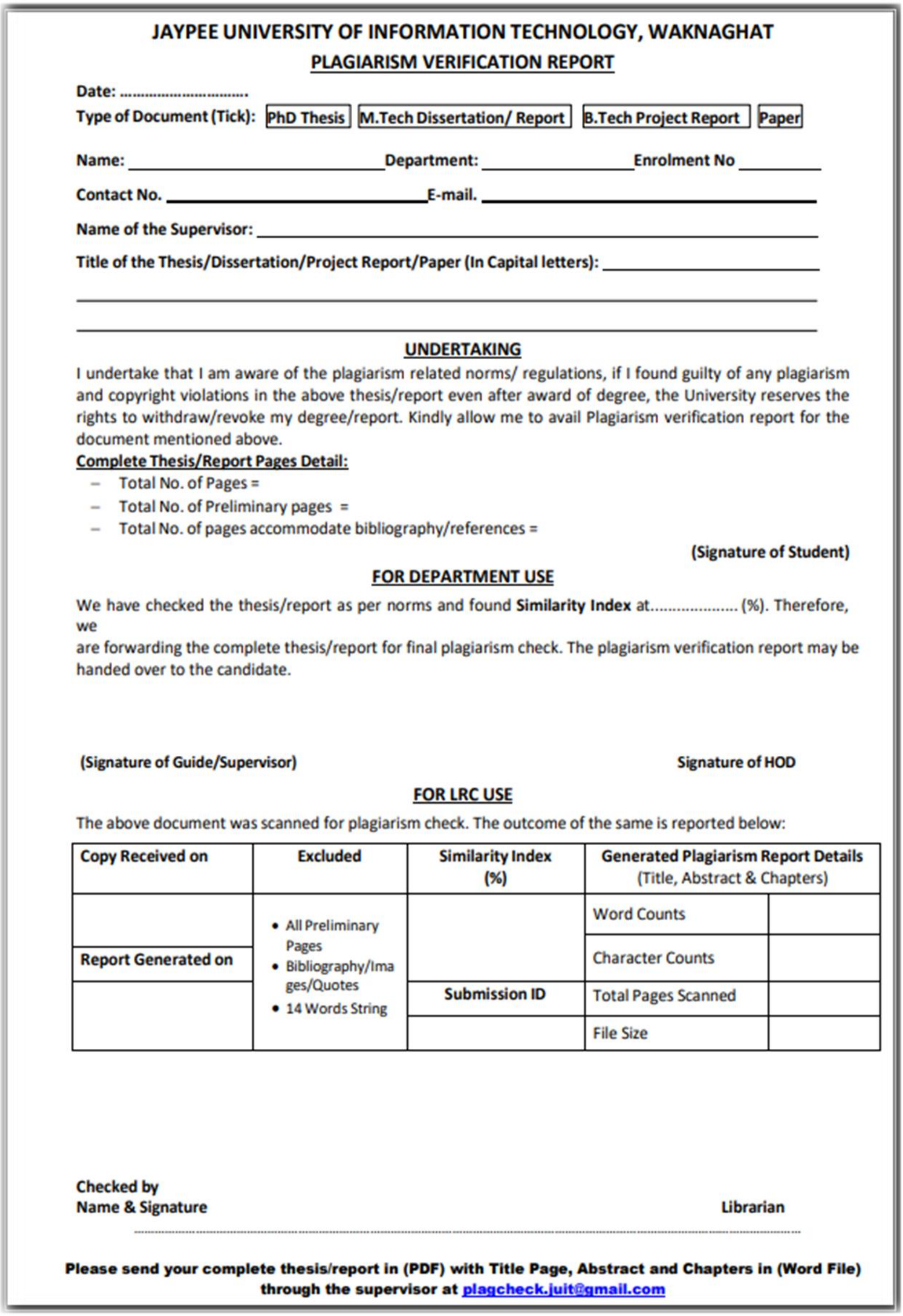

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