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Comparative study of normal concrete with partial addition of copper wire as fiber for grade M-40

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CHAPTER 1

INTRODUCTION

Concrete is one of the most extensively used materials in construction because of its excellent compressive strength, durability, and ability to be molded into various shapes. Despite these advantages, it has a significant drawback it is inherently brittle and possesses low tensile strength, which makes it susceptible to the development of cracks under tensile or flexural stresses. These cracks not only reduce the structural integrity but also allow the ingress of harmful agents such as water and chemicals, leading to long-term deterioration. To overcome this limitation, researchers and engineers have explored the incorporation of different types of fibers into concrete to enhance its mechanical and structural performance.

The addition of fibers improves the ductility, tensile strength, and energy absorption capacity of concrete, while also helping to control crack propagation and improve post-cracking behavior. Among various fiber materials, copper wire has gained attention as a potential reinforcement because it is a readily available waste product from electrical and electronic industries. Utilizing waste copper wire as a fiber reinforcement not only improves the strength and toughness of concrete but also provides an environmentally sustainable solution by recycling industrial waste, reducing environmental pollution, and minimizing the demand for virgin construction materials.

The inclusion of fibers in concrete significantly enhances its physical properties by acting as effective crack arresters, improving strength and durability. The compressive strength results of the fiber-reinforced concrete were compared with those of conventional concrete to assess performance improvements. The findings revealed that adding e-waste copper wire fibers to concrete not only enhances its strength characteristics but also offers an environmentally friendly solution by reducing the amount of electronic waste disposed into the environment, thereby promoting sustainability in construction practices.

Importance of Fiber Reinforced Concrete

Fiber Reinforced Concrete (FRC) is an advanced form of concrete in which small discrete fibers are uniformly distributed throughout the concrete mix. These fibers improve the structural and mechanical properties of conventional concrete. The use of fibers in concrete has become increasingly important in modern construction due to the growing demand for durable, crack-resistant, and high-performance structures.

Concrete is naturally strong in compression but weak in tension. Due to shrinkage, temperature variations, and external loading, cracks develop easily in conventional concrete. Fibers help in controlling these cracks and improve the overall behavior of concrete.

Major Importance of Fiber Reinforced Concrete.

1. Improves Tensile Strength

Fibers increase the tensile strength of concrete by resisting crack formation and propagation. They help the concrete carry tensile stresses more effectively compared to normal concrete.

2. Controls Cracking

One of the most important advantages of fiber reinforcement is crack control. Fibers bridge micro-cracks formed inside concrete and prevent them from widening into major cracks.

3. Enhances Flexural Strength

Fiber reinforced concrete performs better under bending loads. This makes it suitable for pavements, slabs, industrial floors, and bridge decks.

4. Improves Durability

Fibers reduce permeability and cracking, thereby increasing the durability and service life of concrete structures.

5. Increases Impact Resistance

FRC has better energy absorption capacity and can withstand impact and dynamic loads more effectively than conventional concrete.

6. Improves Ductility and Toughness

Normal concrete behaves in a brittle manner, whereas fiber reinforced concrete exhibits ductile behavior and better toughness after cracking.

7. Reduces Shrinkage Cracks

Fibers help reduce plastic shrinkage cracks that develop during the early stages of concrete hardening.

8. Better Fatigue Resistance
Fiber reinforced concrete performs well under repeated loading conditions and is therefore suitable for heavy traffic pavements and industrial structures.

9. Reduces Sudden Failure
Fibers provide post-cracking strength and prevent sudden collapse of concrete members.

10. Sustainable Construction
Use of waste metallic fibers such as copper wire fibers promotes eco-friendly construction and effective utilization of industrial waste materials.

Environmental Significance

The use of copper wire fibers in concrete has significant environmental benefits and supports sustainable construction practices. Large quantities of copper waste are generated from electrical industries, electronic equipment, and transformer manufacturing units, telecommunication cables, and construction activities. Disposal of this waste creates serious environmental and land pollution problems.Utilizing waste copper wire fibers in concrete helps in recycling industrial waste and reducing environmental impact. The environmental significance of copper fiber reinforced concrete is explained below:

1. Reduction of Industrial Waste
Waste copper wires from industries are often discarded in landfills, causing environmental pollution. Using these waste materials in concrete reduces the amount of industrial waste disposed into the environment.

2. Promotes Recycling and Reuse
Copper wire fibers can be recycled and reused effectively in construction materials. This promotes the concept of sustainable material management and circular economy.

3. Reduction in Landfill Disposal
Landfills are rapidly increasing due to industrial and electronic waste. The use of copper waste in concrete decreases landfill burden and helps in proper waste utilization.

4. Conservation of Natural Resources
By using waste copper fibers as reinforcing material, dependence on conventional construction materials is reduced. This helps conserve natural resources used in manufacturing reinforcement materials.

5. Sustainable Construction Practice
Copper fiber reinforced concrete supports green building concepts and sustainable infrastructure development. It encourages environmentally responsible construction practices.

6. Improved Durability of Structures
Concrete with copper fibers exhibits better crack resistance and durability. Durable structures require less repair and maintenance, which reduces consumption of additional construction materials and energy.

7. Reduction in Carbon Footprint
Long-lasting and durable structures reduce reconstruction and repair activities. This indirectly reduces carbon emissions associated with cement production, transportation, and construction operations.

8. Energy Efficient Waste Management
Recycling copper waste into concrete is more energy efficient compared to disposal and reprocessing methods used in waste management industries.

9. Reduction in Environmental Pollution

Improper disposal or burning of copper waste may release harmful substances into the environment. Utilizing copper waste in concrete prevents pollution and promotes safer waste handling.

Aim and Objectives of the Study

➢ Aim of the Study

The main aim of this study is to investigate and compare the performance of conventional M-40 grade concrete with copper wire fiber reinforced concrete by partially adding copper wire fibers in different proportions and evaluating their effect on the mechanical properties and durability characteristics of concrete.

The study also aims to promote sustainable construction practices through effective utilization of waste copper materials in concrete production.

➢ Objectives of the Study

The objectives of the present study are as follows:

1. To prepare M-40 grade concrete using standard mix design procedure as per IS codes.
2. To partially add copper wire fibers in different percentages to conventional concrete.
3. To study the effect of copper wire fibers on the workability of concrete.
4. To determine the compressive strength of copper fiber reinforced concrete at different curing periods.
5. To evaluate the split tensile strength of concrete with varying fiber content.
6. To determine the flexural strength of copper wire fiber reinforced concrete.
7. To compare the mechanical properties of normal concrete and copper fiber reinforced concrete.
8. To identify the optimum percentage of copper wire fiber addition for achieving maximum strength.
9. To study the crack resistance and ductility behavior of fiber reinforced concrete.
10. To utilize waste copper wire material in an effective and eco-friendly manner.
11. To reduce industrial waste and promote sustainable construction practices.
12. To analyze the suitability of copper wire fiber reinforced concrete for structural applications such as pavements, industrial floors, and rigid structures.
13. To improve the overall performance and durability of concrete structures through fiber reinforcement.

➢ Problem Statement

Concrete is one of the most widely used construction materials due to its high compressive strength, durability, and economical nature. However, conventional concrete has low tensile strength, poor ductility, and limited resistance to crack formation. Micro-cracks develop in concrete because of shrinkage, temperature variations, and external loading conditions. These cracks gradually propagate and reduce the durability, strength, and service life of structures.

In modern construction, there is an increasing demand for high-performance concrete with improved tensile strength, crack resistance, toughness, and durability. Fiber reinforcement is considered one of the effective methods to overcome the deficiencies of conventional concrete. At the same time, industries generate large quantities of copper wire waste from electrical cables, electronic equipment, and manufacturing processes. Disposal of this copper waste creates environmental pollution and landfill management problems.

Although different fibers such as steel, glass, and polypropylene fibers have been widely studied, limited research is available on the use of copper wire fibers in M-40 grade concrete. Therefore, there is a need to investigate the effect of partial addition of copper wire fibers on the properties of concrete.

Chapter 2
Literature Review

➢ Overview from Literature Review

Concrete is the most commonly used construction material because of its high compressive strength and durability. However, conventional concrete possesses low tensile strength and brittle behavior, which leads to the development of cracks under loading and environmental effects. To overcome these limitations, researchers introduced Fiber Reinforced Concrete (FRC), where small fibers are added to concrete to improve its mechanical and durability properties.

Several studies have been carried out on different types of fibers such as steel fibers, glass fibers, polypropylene fibers, carbon fibers, and metallic waste fibers. These studies concluded that fiber reinforcement improves tensile strength, flexural strength, impact resistance, toughness, and crack resistance of concrete.

Researchers observed that metallic fibers act as crack arresters by bridging micro-cracks developed inside concrete. This mechanism delays crack propagation and increases energy absorption capacity. Steel fiber reinforced concrete has shown significant improvement in ductility and post-cracking behavior compared to conventional concrete.

Recent studies have also focused on the utilization of industrial waste materials in concrete to promote sustainable construction practices. Copper waste generated from electrical industries and electronic industries has become an environmental concern due to disposal problems. Researchers have investigated the use of copper slag, copper ash, and copper fibers in concrete and found improvements in strength and durability characteristics.

Studies on waste metallic fibers revealed that the addition of metallic fibers enhances split tensile strength and flexural strength more effectively than compressive strength. However, excessive fiber addition reduces workability because fibers increase internal friction during mixing.

Researchers also reported that the optimum fiber content generally provides the best performance, while higher percentages may cause fiber balling, segregation, and difficulties in compaction.

From the available literature, it is clear that fiber reinforcement improves the engineering properties of concrete and supports sustainable waste management. However, limited studies are available on the use of copper wire fibers specifically in M-40 grade concrete. Therefore, the present study focuses on investigating the effect of partial addition of copper wire fibers on the workability and strength properties of M-40 concrete and comparing it with conventional concrete.

➢ PRIVIOUS LITERATURE REVIEW

1.1 **Krunalsinh P. Gohil & Nirav Patel. (Sept 2023), "A review paper of Study on properties of high strength concrete using E-waste Copper and Aluminum Fiber",** the physical characteristics of concrete would be greatly enhanced by the addition of fibers, which function as a crack arrester. With respect to the weight of cement, these Fibers were added to the concrete at 0%, 0.25%, 0.5%, 0.6%, 0.75%, 0.8%, 1.00%, 1.25%, 1.50%, 1.75%, and 2.00%. Additionally, there were several fiber sizes for each % of fiber, including 2 cm, 3 cm, 4 cm, 5 cm, and 6 cm. It was determined that regular concrete and fibrous concrete were compared to the compressive strength of fiber reinforced concrete with variable size for each % of fiber. Hence, using e-waste in Fiber-reinforced concrete Fibers are an alternative to conventional concrete since they boost trend in qualities and decrease the quantity of e-waste sent into the environment.

1.2 **Terlumun Adagba1, Aliyu Abubakar2, Abubakar Sabo Baba (Dec- 2023) Impacts of Baobab Stem Fibre Reinforcement in Enhancing the Concrete Strength.** Concrete has low tensile strength, limited ductility, and poor crack resistance, so reinforcement is required to improve its performance. This study investigates the effect of baobab stem fiber on the mechanical properties of concrete and examines the relationship between compressive and flexural strengths when baobab fiber is used as reinforcement. Concrete was produced with baobab stem fiber contents of 0.5%, 1.0%, 1.5%, and 2.0% by volume, using fibres 50 mm in length and a mix ratio of 1:2:3. A constant water–cement ratio of 0.50 was maintained, and specimens were cured for 7, 14, 28, 60, and 90 days. Tests were conducted to evaluate workability, compressive strength, and flexural strength. Results showed that increasing the fiber content reduced workability and compressive strength but improved flexural strength. Statistical analysis using ANOVA in Minitab 19 revealed strong correlations between compressive and flexural strengths, with R^2 values of 97.42% and 93.41%, respectively, based on fiber content and curing age. These findings indicate that baobab fiber volume and curing period are reliable predictors of concrete performance. Overall, the inclusion of baobab stem fibers enhances concrete behavior, particularly in flexural strength.

1.3 **Arooba Rafiq Bhat1, and Ajay Vikram. (Dec-2022) Experimental Investigation on the Effect Polypropylene Fiber and E-Waste Fiber Embedded in Concrete.** Concrete is one of the most important construction materials, even though it is weak in tension and causes environmental problems during production. The properties of concrete can be improved by adding fibers. Using fibers made from plastic waste not only increases the strength and durability of concrete but also helps reduce plastic disposal problems. In this study, fibers were obtained from electronic waste (PVC cables) and polypropylene (PP) cement packing bags. These fibers were added to concrete in proportions of 0%, 0.25%, 0.50%, 0.75%, and 1% by weight of cement. The fresh and hardened properties of concrete with polypropylene fibers and electronic waste fibres were tested. Based on the results, the optimum fiber contents were combined into a hybrid mix, and its compressive strength was evaluated. The results showed that 0.75% electronic waste fiber and 0.50% polypropylene fiber were the optimum amounts, increasing compressive strength by 49% and 17.5% respectively compared to normal concrete. When both fibers were used together in a hybrid mix, the compressive strength increased by 56%. Polypropylene fibers helped control cracking, while electronic waste fibers improved the mechanical properties of the concrete.

1.4 **Muhammad Anas, Majid Khan, Hazrat Bilal, Shantul Jadoon and Muhammad Nadeem Khan (Sept-2022) Fiber Reinforced Concrete: A Review.** Concrete is the most widely used construction material in the civil engineering industry due to its versatility and extensive application in infrastructure projects. However, its use is limited by inherent deficiencies such as brittleness, low tensile strength, and susceptibility to crack initiation and propagation, and relatively low durability. To overcome these limitations, researchers have modified concrete by incorporating various synthetic and natural fibers to enhance its performance. The increasing demand for high-strength and crack-resistant concrete has led to the development of fiber-reinforced concrete (FRC). This paper reviews the effects of fiber inclusion on the performance of concrete. In general, the addition of fibers improves tensile strength, flexural strength, and durability characteristics while significantly reducing shrinkage cracking. Nevertheless, fiber incorporation may also result in certain drawbacks, such as reduced workability, which must be carefully addressed during mix design and placement.

1.5 **Aliyu Abubakar, Abbagana Mohammed, Samson Duna, Umar Saeed Yusuf (June 2022), "Relationship between Compressive, Flexural and Split Tensile Strengths of Waste Copper Wire Fiber Reinforced Concrete",** Adding waste copper wire fibers (WCWF) affects the mechanical properties of grade 25 concrete and established relationships among its compressive, flexural, and split tensile strengths. Using fiber contents of 0–1.5% and curing ages of 7–28 days, the researchers found that all three strength measures increased with both fiber content and curing time, with the best performance at 1.5% fiber and 28 days (compressive strength ≈ 34.6 N/mm²). Regression models with coefficients of determination above 70% were developed to predict flexural and tensile strengths from compressive strength, demonstrating that waste copper wire can effectively enhance concrete's tensile and flexural performance while promoting sustainable reuse of metallic waste.

1.6 **Roniki Anjaneyulu (Sept 2021), "Experimental Investigation and Comparison of Electrical Waste Copper Wire Fiber and Electrical Waste Glass Fiber Concretes",** Fiber-reinforced concrete (FRC) contains fibrous material which upsurges its structural integrity. The use of irregular arrangement of fibers to concrete altogether upgrades its essential characteristics, for instance, influence quality, static flexural strength, elasticity and flexural stiffness. Filaments are further added to cement to control breaking because of plastic shrinkage and to drying shrinkage. This research paper shows and compare the use of electrical waste copper wire fiber and electrical waste glass fiber of various percentages of volume fractions such as 0.25%, 0.5%, 0.75%, 1.0%, 1.25%, 1.5%, 1.75%, and 2.0% incorporated in concrete. They investigate and compare the mechanical properties such as compressive strength, splitting flexural strength and tensile strength tests were conducted for ordinary concrete and fiber reinforced concrete for a curing period of 28 days. The test results of electrical waste copper wire fiber reinforced concrete with electrical waste glass fiber reinforced concrete were compared to determine the influence of fibers used. This research contributes to the growing body of evidence supporting the broader implementation of GFRP in civil engineering practice.

1.7 **Asif Jalal, Luqmanul Hakim and Nasir Shafiq. (Jan 2021), "Mechanical and Post-Cracking Characteristics of Fiber Reinforced Concrete Containing Copper-Coated Steel and PVA Fibers in 100% Cement and Fly Ash Concrete",** the effects of polyvinyl alcohol (PVA) and copper-coated steel (CCS) fibers on the mechanical properties and post-cracking behavior of fiber-reinforced concrete (FRC). Concrete mixes included both 100% cement and a blend of 80% cement with 20% fly ash, with a fixed fiber content of 0.3% by volume. CCS fibers required 15% more super plasticizer than PVA fibers to achieve the same workability, and also resulted in 10% higher compressive strength. Both fibers improved tensile and flexural strength similarly, although PVA fibers had a higher secant modulus (47 GPa) compared to CCS fibers (37 GPa). In terms of post-cracking behavior, CCS fibers performed better due to their higher tensile strength, providing greater toughness and crack control. Fly ash concrete showed additional improvements, including approximately 10% higher compressive strength at 56 days, 6% higher tensile and flexural strength, and over 15% higher first-crack strength and flexural toughness compared to 100% cement concrete. Overall, incorporating either PVA or CCS fibers enhanced the ductility and post-cracking performance of concrete, with metallic fibers like CCS offering superior results, suggesting their suitability for structural applications.

1.8 **Ganesh Naidu Gopu1, A. Sofi. (Sep- 2021) Electrical Waste Fibers Impact on Mechanical and Durability Properties of Concrete.** Safety and serviceability are the main considerations in structural design. Serviceability, which is related to the lifespan of a structure, decreases when concrete is exposed to harsh environments. Rapid growth in solid waste generation in developing countries has encouraged researchers to recycle waste materials for use in construction. In recent decades, the use of waste and recycled fibers in concrete has gained significant attention. In this study, electric waste copper fibers (EWCF) were added to concrete to evaluate their effect on mechanical properties and resistance to chloride ion penetration, which affects concrete durability. EWCF were added in proportions of 0 to 2.0% by volume of concrete. Tests were conducted to measure compressive strength, tensile strength, flexural strength, and modulus of elasticity. The results showed that 1.0% EWCF provided the optimum improvement in concrete strength. Durability tests such as water absorption, sorptivity, acid attack, bulk diffusion, and rapid chloride penetration (RCPT) were also carried out to assess durability and microstructural performance. For comparison, E-glass and steel fibers were also used in the study. Based on the experimental results, optimum fiber content was identified for achieving improved strength and durability.

1.9 **Imran Ali Channa, Abdullah Saand (june 2021) Mechanical Behavior of Concrete Reinforced with Waste Aluminium Strips.** The primary objective of this research is to investigate the influence of incorporating waste materials, specifically aluminum waste in the form of soft drink tin fibers (SDTF), on the mechanical properties of concrete. The study focuses on evaluating the strength behavior of concrete, particularly flexural strength and indirect (split) tensile strength. Previous studies have demonstrated that the inclusion of fibers in concrete can significantly enhance its mechanical performance. Accordingly, this research examines the effectiveness of soft drink tin fibers as a reinforcing material and assesses their impact on the mechanical behavior of concrete. Soft drink tin fibers with dimensions of 25.4 × 5 × 0.5 mm were incorporated into the concrete mix at proportions ranging from 1% to 5% by weight of cement. A design mix ratio of 1:1.624:2.760 with a water–cement ratio of 0.50 was used. A total of six batches were prepared, each consisting of three prisms and three cylinders for flexural and split tensile strength testing, respectively. One batch served as the control mix without fibers, while the remaining five batches contained fiber contents of 1%, 2%, 3%, 4%, and 5%. The experimental results indicate that both split tensile strength and flexural strength increased compared to the control mix up to a fiber content of 4%. However, beyond 4% SDTF addition, a reduction in strength was observed. Therefore, it can be concluded that the optimum fiber content for enhancing the mechanical properties of concrete is approximately 4% by weight of cement. Additionally, the use of soft drink tin fibers as a partial construction material contributes to sustainable waste management by reducing solid waste and mitigating environmental pollution.

1.10 H Ndruru, R M Simanjuntak and S P Tampubolon (2021) Utilization of copper fiber waste to increase compressive strength and split tensile strength of rigid pavement. Rigid pavement is a type of pavement structure in which a concrete slab is used as the surface layer, placed either on a foundation layer or directly on the subgrade, with or without an asphalt surface layer. In Indonesia, one commonly used type of rigid pavement is non-reinforced concrete pavement, which is typically applied in low-traffic or residential areas. However, concrete without reinforcement has relatively low split tensile strength, causing the slab to be prone to cracking due to unavoidable stresses induced by traffic loads. Therefore, reinforcement is required to control crack propagation in concrete slabs. This research investigates the use of copper fiber waste from electronic cables as an alternative reinforcement material mixed into concrete. The experimental program used copper fibers at proportions of 0%, 0.5%, 1%, and 1.5% of the total weight of the concrete mixture. Mechanical properties were evaluated at 28 days of curing. The results show that increasing the copper fiber content up to 1.5% led to an improvement in mechanical performance, with split tensile strength increasing by up to 32.46% and compressive strength increasing by up to 9.16%.

1.11 Y.K. Sabapathy ⇑, S. Sabarish, C.N.A Nithish, S.M. Ramasamy, Gokul Krishna (2021) Experimental study on strength properties of aluminum fiber reinforced concrete. Aluminium electrical wire scrap generated from building demolition activities is often left unused in the market. Aluminum is a lightweight material capable of exhibiting adequate strength properties and has significant potential for reuse in concrete applications. In this study, aluminum fibers with looped ends were employed to enhance bond strength with the concrete matrix. This paper presents the results of an experimental investigation on the mechanical properties of aluminum fiber-reinforced concrete aimed at determining the optimum fiber volume fraction. Three grades of concrete and five different fiber volume fractions (0%, 0.5%, 1.0%, 1.5%, and 2.0%) were considered in this study. After 28 days of curing, the compressive strength and split tensile strength of the concrete specimens were evaluated through laboratory testing. In addition, regression analysis was conducted based on the experimental results to develop statistical models for predicting the strength of aluminum fiber-reinforced concrete. The findings indicate the effectiveness of the interaction between looped-end aluminum fibers and the concrete matrix, resulting in improved mechanical performance.

1.12 V.B.H.Kusma1, T. N. Chakra Lakshmi1, T. Naga Durga Bhavani1, M. Veera Babu1, D. Lokram1, G. Narayana Rao1, Dr.S.Govindarajan (Jul – 2020) An Experimental Study Of Mechanical Properties Of Hybrid Fibre Reinforced Concrete. The present-day world is witnessing rapid growth and increasing demands in construction engineering. Through the development of innovative materials, civil engineers are creating significant infrastructure and engineering marvels worldwide. Consequently, it has become essential to develop new materials and innovative systems for the construction industry. This is an opportune time to focus on the incorporation of advanced materials into concrete, as concrete remains indispensable due to its cost-effectiveness compared with other construction materials currently in use. The addition of small, closely spaced, and uniformly dispersed fibers into concrete acts as a crack-arresting mechanism and significantly enhances its mechanical properties. This modified material is known as fiber-reinforced concrete (FRC). In this study, steel, glass, and polypropylene fibers are used. These fibers are generally classified into two categories based on their modulus of elasticity: Category I fibers, such as steel and glass fibers, which possess high modulus values, and Category II fibers, such as polypropylene fibers, which exhibit lower modulus values. Fibers are primarily used to reinforce materials that are weak in tension but strong in compression. In this research, steel, glass, and polypropylene fibers are employed as hybrid fibers and incorporated into concrete at proportions of 0.5%, 1.0%, 1.5%, 2.0%, and 2.5%. Experimental investigations were conducted to study the effects of different fiber combinations on the hardened properties of concrete. Compressive strength tests were performed on cube specimens, while split tensile strength tests were conducted on cylindrical specimens. A composite material is termed hybrid when two or more types of fibers are rationally combined within a common matrix to produce a composite that benefits from the individual properties of each fiber and exhibits a synergistic response. The addition of short, discontinuous fibers plays a crucial role in improving the mechanical properties of concrete by increasing the elastic modulus, reducing brittleness, and controlling crack initiation and propagation. Furthermore, fiber deboning and pull-out mechanisms require greater energy absorption, leading to enhanced toughness and improved fracture resistance under cyclic and dynamic loading conditions.

1.13 A Sofi and Ganesh Naidu Gopu (2019) Influence of steel fiber, electrical waste copper wire fibre and electrical waste glass fiber on mechanical properties of concrete. Fibre-reinforced concrete (FRC) contains fibers that improve the structural performance of concrete. Randomly distributed fibers enhance key properties such as flexural strength, impact resistance, elasticity, and stiffness. Fibers are added to concrete to control cracking caused by plastic and drying shrinkage. This study examines the use of steel fibers, electrical waste copper wire fibers, and electrical waste glass fibers added to concrete at volume fractions of 0.25%, 0.5%, 0.75%, 1.0%, and 1.25%. Mechanical properties, including compressive strength, split tensile strength, and flexural strength, were tested for both normal concrete and fiber-reinforced concrete after curing periods of 7, 14, and 28 days. The modulus of elasticity was also evaluated at 28 days for different fiber contents. The results of fiber-reinforced concrete were compared with those of normal concrete to assess the effect of the different fibers on concrete performance.

1.14 Manjusha, Megha Vijayan (May2018) Study on Flexural Behaviour of RCC Beam with Minimum Shear Reinforcement and Replacing Different Fiber. This study investigates the flexural performance of Reinforced Cement Concrete (RCC) beams designed with minimum shear reinforcement and partially replaced with different types of discrete fibers. The work evaluates how fibers can enhance beam ductility, crack control, load-carrying capacity, and post-cracking behavior when stirrups are provided only at minimum code requirements. Experiments were conducted on beams incorporating various fiber types and volume fractions, and results were compared against a conventional control beam. The study concludes that replacing a portion of conventional reinforcement with discrete fibers significantly enhances the flexural behavior of RCC beams with minimum shear reinforcement. The improvements are reflected in increased load capacity, ductility, crack control, and energy absorption. Steel and hybrid fiber systems deliver the best overall performance. Hence, fiber-reinforced concrete beams can be a viable solution for cases where enhancing flexural toughness and serviceability is essential.

1.15 B.Shobana, B.N.Brinila (May 2017) Bright Experimental Investigation on High Performance Concrete by Using Electric Copper Wire. To evaluate the mechanical characteristics of high-performance concrete reinforced with electric copper wire fibers, an M40 grade concrete mix was designed. Different proportions of electric copper wire fibers along with mineral admixtures were incorporated into the concrete mix. The specimens were cured for two different durations, 7 days and 28 days. Concrete cubes, cylinders, and beams were cast to evaluate mechanical properties, including compressive strength, split tensile strength, and flexural strength. Fiber contents of 0.5%, 1.0%, 1.5%, and 2.0% by volume of concrete were tested and compared with a control mix without fibers. Regression models were developed to predict compressive strength, split tensile strength, and flexural strength of both high-performance concrete and high-performance fiber-reinforced concrete containing electric copper wire fibers at various volume fractions. The variation in mechanical properties with respect to fiber content was analyzed. The results indicate that compressive strength, split tensile strength, and flexural strength increase with fiber content, reaching maximum values at a fiber content of 2.0% of the concrete volume.

1.16 **Arjun Ramakrishna Kurup1 and K. Senthil Kumar, Ph.D Novel Fibrous Concrete Mixture Made from Recycled PVC Fibers from Electronic Waste**. **(2016)** .Electronic waste (e-waste) in concrete is the new revolutionary concept of sustainable concrete because it reduces the environmental pollution and solid waste problem. In this paper the extracted outer casing insulation of electrical wire was made into fibers. These fibers were added to the concrete at 0.6, 0.8, and 1% with respect to the weight of cement. Fibers were added to the concrete with the aspect ratio of 35 to make fiber reinforced concrete. The fresh and hardened properties like slump, fresh density, dry density, compressive strength, flexural strength, split tensile strength, and Young's modulus of fiber-reinforced concrete and normal concrete was compared at the respective age of curing. In order to reduce the cement content and to enhance the properties of concrete, silica powder was added to the fiber-reinforced concrete with 10% replacement of cement with respect to volume of cement and the properties were compared with normal concrete and fiber-reinforced concrete. The experimental results reveal that the optimal percentage addition of e-waste fibers to the concrete was found to be 0.8% with respect to the weight of cement for both fiber-reinforced concrete and silica fiber-reinforced concrete. Thus, fiber-reinforced concrete and silica fiber-reinforced concrete using e-waste fibers was an alternative to normal concrete because it gives increased trend in properties and also reduces the amount of dumping e-wastes into nature.

1.17 **Mr. Narayan Chandra Moharana, Ms. Bikasha Chandra Panda (Oct 2016), "Assesment of Corrosion in Initiation Time on Costal Concrete Structure",** Now a days concrete structure have been deteriorating faster than they are expected changing the impression of concrete as the most durable material. Corrosion of reinforcement is the prime cause of failure of most of the concrete structures. As a Consequence the rebuild and repair costs cover a major portion of the current investment in infrastructure. For prevention of failure due to corrosion, timely planning for regular maintenance of structures and monitoring approach is required. In order to prepare maintenance schedule, it is necessary to predict the corrosion initiation time for the existing structures situated in the coastal environment.

1.18 S. Karthik1 M.Kalaivani P.Easwaran (April 2016) Fatigue Behavior of Steel Fiber Reinforced Concrete. Nowadays, a wide variety of fibers are available for use in the civil engineering sector. The performance of these fibers is generally considered satisfactory if they can withstand up to two million cycles of repetitive loading without distress or failure at the required mean stress level. The incorporation of fibers into concrete improves monotonic flexural strength, flexural fatigue strength, impact strength, shock resistance, ductility, and flexural toughness, in addition to delaying and arresting crack propagation. Fatigue behavior is commonly characterized by the number of load cycles a material can sustain under a given pattern of repetitive loading before failure occurs. This paper presents an experimental study on the fatigue behavior of reinforced concrete beams cast with different types of steel fibers incorporated into the concrete matrix and subjected to cyclic (fatigue) loading.

1.19 Saman Khan, Roohul Abad Khan, Amadur Rahman Khan, Misbahul Islam Saman Nayal (Sep- 2015) Mechanical properties of Polypropylene Fiber reinforced concrete for M 25 & M 30 mixes: A Comparative study. This paper presents a comparative experimental study on the mechanical performance of polypropylene fiber-reinforced concrete (PFRC) under compressive and split tensile loading. Cube compressive strength and cylindrical split tensile strength of both conventional concrete and polypropylene fiber-reinforced concrete were experimentally determined. M25 and M30 grade concrete mixes were used, incorporating polypropylene monofilament macro-fibers of 3…….5 mm length at volume fractions of 0.0%, 0.5%, 1.0%, 1.5%, 2.0%, 2.5%, and 3.0%. All specimens were tested after 28 days of curing. The relationship between cube compressive strength and cylindrical split tensile strength for both conventional concrete and PFRC was established and compared with standard code provisions. The results indicate a significant improvement in both compressive and tensile strengths with the addition of polypropylene fibers. Among the various fiber contents investigated, concrete mixes containing 1.0% and 1.5% polypropylene fibers exhibited superior mechanical performance compared to the other mixes.

1.20 A. Sofi, B. R. Phanikumar. (March 2015) An Experimental Investigation on Flexural Behaviour of Fibre-Reinforced Pond Ash-Modified Concrete. This study examines the flexural behavior of concrete in which **pond ash**, an industrial by-product from thermal power plants, is used as a partial replacement for fine aggregate, and **fibers** are incorporated to improve post-cracking behavior. Pond ash, lightweight and pozzolanic in nature, can enhance workability and reduce environmental impact. Fibers (steel, polypropylene, or hybrid types) are used to compensate for the strength reduction typically associated with ash-based concretes. The investigation focuses on the combined influence of pond ash content and fiber volume on flexural strength, crack development, ductility, and energy absorption. The study concludes that fiber-reinforced pond ash-modified concrete exhibits superior flexural performance compared to pond ash concrete without fibers. While pond ash alone may reduce strength at higher replacement levels, the addition of fibers significantly enhances load-carrying capacity, ductility, and crack resistance. This composite provides an environmentally sustainable construction material with improved flexural behavior and good post-cracking toughness.

1.21 Mohamed I. Abukhashaba, Mostafa A. Mostafa, Ihab A. Adam (March 2014) Behavior of Self-Compacting Fiber Reinforced Concrete Containing Cement Kiln Dust. This study examines the mechanical and rheological behavior of **Self-Compacting Concrete (SCC)** reinforced with fibers and incorporating **Cement Kiln Dust (CKD)** as a partial replacement for cement. CKD is an industrial by-product from cement manufacturing, and its utilization helps reduce environmental impact and improve sustainability. The research evaluates the effects of CKD and various fibers on the flow ability, strength, ductility, and durability of SCC mixtures. SCC requires excellent filling ability, passing ability, and resistance to segregation. However, adding fibers typically reduces flow ability. CKD contains fine particles with high alkalinity and can act as a filler or partial cementations material. The study concludes that **self-compacting fiber-reinforced concrete containing CKD is a viable, sustainable material**, especially when CKD is limited to moderate replacement levels (5–10%). Fibers significantly enhance tensile and flexural behavior, ductility, and toughness, while CKD contributes to sustainability and can improve certain strength and durability characteristics. However, higher CKD contents may impair both workability and mechanical performance.

1.22 Iftekar Gull, M. Balasubramanian. (April 2014) A New Paradigm on Experimental Investigation of Concrete for E-Plastic Waste Management. This study presents an innovative experimental approach to utilizing e-plastic waste—plastic materials recovered from discarded electronic devices—as a partial replacement for traditional concrete constituents. With the rapid global increase in electronic waste, improper disposal of plastic components such as casings, circuit board laminates, insulation jackets, and connectors poses severe environmental challenges. The research introduces a new paradigm in sustainable construction by integrating shredded e-plastic into concrete to reduce landfill accumulation while improving certain mechanical and durability properties. This study demonstrates that e-plastic waste can be successfully utilized as a partial aggregate replacement in concrete, offering an eco-friendly solution to electronic waste management. While high replacement levels reduce compressive strength, low-to-moderate levels (5–10%) maintain acceptable mechanical performance and improve toughness and density reduction. The research introduces a promising paradigm for sustainable construction materials and contributes to efficient e-waste management.

1.23 K. Senthil Kumar, K. Baskar. (July 2014) Response Surfaces for Fresh and Hardened Properties of Concrete with E-Waste (HIPS). This study investigates the effects of incorporating High-Impact Polystyrene (HIPS), a common e-waste plastic derived from electronic equipment housings, on the fresh and hardened properties of concrete. Using Response Surface Methodology (RSM) as an optimization tool, the authors evaluate how varying HIPS content influences workability, strength, density, and durability. Mathematical response models are developed to predict performance and identify optimum e-waste replacement levels for sustainable concrete production. The study demonstrates that RSM is an effective tool for modeling and optimizing the behavior of HIPS-based e-waste concrete. Low to moderate HIPS content produces acceptable mechanical performance, lighter density, and environmental benefits. The response surfaces clearly illustrate the trade-offs between workability and strength, helping determine optimum mix compositions for sustainable concrete applications. N Ganesan, PV Indira, N. B. Sobeena, (Fab- 2014) Behaviour of hybrid fibre reinforced concretebeam–column joints under reverse cyclic loads. An experimental investigation was conducted to study the effect of hybrid fibers on the strength and behavior of high-performance concrete (HPC) beam-column joints subjected to reverse cyclic loading. A total of 12 reinforced concrete beam-column joints were cast and tested. M60 grade high-performance concrete was designed using the modified ACI method proposed by Aïtcin. Crimped steel fibers and polypropylene fibers were used in hybrid form. The main variables considered were the volume fractions of (i) crimped steel fibers: 0.5% (39.25 kg/m³) and 1.0% (78.5 kg/m³), and (ii) polypropylene fibers: 0.1% (0.9 kg/m³), 0.15% (1.35 kg/m³), and 0.2% (1.8 kg/m³). The addition of fibers in hybrid form significantly improved several engineering properties of the beam-column joints, including first crack load, ultimate load, and ductility factor. Among the combinations tested, the joint containing 1% steel fibers (78.5 kg/m³) and 0.15% polypropylene fibers (1.35 kg/m³) exhibited superior performance in terms of energy dissipation capacity and reduced stiffness degradation compared to the other combinations.

1.24 **Abhay Mahadeorao Shende and Anant M. Pande (2012) Comparative study on steel fiber reinforced cum control concrete under tension.** A critical investigation was conducted on M20, M30, and M40 grades of concrete to study the tensile strength of steel fiber-reinforced concrete (SFRC) incorporating hooked steel fibers at volume fractions of 0%, 1%, 2%, and 3%. Steel fibers with aspect ratios of 50, 60, and 67 were used in the study. The experimental data obtained were analyzed and compared with control specimens containing no fibers. The relationship between fiber aspect ratio and tensile strength was established and presented graphically. The results clearly indicate a significant percentage increase in 28-day tensile strength for M20, M30, and M40 grades of concrete with the inclusion of steel fibers.

1.25 **S.A. AlTaan[1] and Z.S. AlNeimee (2011) Fresh and Hardened Properties of Steel Fibres Reinforced Self-Compacted Concrete.** This investigation studied the fresh and hardened properties of steel fiber-reinforced self-compacting concrete (SFR-SCC). A reference self-compacting concrete mix was prepared in which 10% of the cement was replaced with limestone powder. Steel fibers were incorporated at three volume fractions: 0.35%, 0.70%, and 1.05% of the concrete volume. The steel fibers used were shelled Harex-type fibers with an irregular cross-section, an equivalent diameter of 0.78 mm, a length of 16 mm, and an aspect ratio appropriate for self-compacting concrete applications. A super plasticizer was added to improve the workability and flow ability of the mixes. The experimental results indicated that the inclusion of steel fibers reduced the flow ability of fresh concrete and increased the spreading time, segregation resistance, and passing ability. However, for all fiber contents considered, the fresh concrete properties remained within the recommended limits for self-compacting concrete. The results also demonstrated a higher early-age strength development rate compared to plain normal concrete, attributed to the presence of fine materials such as limestone powder. In terms of hardened properties, the increase in splitting tensile strength due to steel fiber addition was more pronounced than the corresponding increase in compressive strength, which is consistent with the behavior of fiber-reinforced concrete. The splitting tensile strength of cylindrical specimens was approximately 84% of that measured for cubic specimens. Furthermore, the failure mode of plain, unreinforced specimens was brittle, whereas the presence of steel fibers transformed the failure behavior into a more ductile mode.

1.26 R.M.Damgir Y.M.Ghugal (Jan- 2011) Compressive Strength for FRC Member using Silica Fume. The compressive strength of concrete was evaluated using standard cubes of size 150 × 150 × 150 mm. Fibers were incorporated in the concrete mix at volume fractions ranging from 0% to 5% with increments of 0.5%, along with 5% silica fume. Compressive strength tests were conducted using a universal testing machine (UTM). The results indicated that slump decreased with increasing fiber content, while crack width reduced as the fiber volume increased, ranging between 0.75 mm and 1.30 mm at 28 days. Additionally, the toughness of the concrete members increased with higher fiber content. Fibers with an aspect ratio of 60 were used, and all fibers were randomly oriented in the mix to ensure uniform distribution throughout the concrete matrix.

➢ Research Gap

From the detailed review of previous studies on Fiber Reinforced Concrete (FRC), it is observed that many researchers have investigated the use of steel fibers, glass fibers, polypropylene fibers, and industrial waste fibers in concrete. However, very limited research has been carried out on the use of waste copper wire fibers in high-strength concrete such as M-40 grade concrete. The following research gaps have been identified:

1. Limited Research on Copper Wire Fiber Reinforced Concrete

Most previous studies focus on steel fiber reinforced concrete, while copper wire fibers have received comparatively less attention. Copper possesses high tensile strength, corrosion resistance, and ductility, yet its utilization in concrete remains underexplored.

Gap Identified

- Lack of sufficient experimental data on copper wire fibers in concrete.
- Limited comparative studies between normal concrete and copper fiber reinforced concrete.
- Insufficient standard guidelines for copper fiber usage in structural concrete.

2. Lack of Studies on M-40 Grade Concrete

Many available studies are conducted on lower grades of concrete such as M-20, M-25, and M-30. High-strength concrete like M-40 behaves differently due to its lower water-cement ratio and denser matrix.

Gap Identified

- Very few investigations are available for copper fiber addition in M-40 concrete.
- Limited understanding of fiber interaction in high-strength concrete.
- Lack of data regarding optimum fiber content for M-40 grade.

3. Insufficient Analysis of Mechanical Properties

Previous studies mainly emphasize compressive strength, while other important properties such as split tensile strength, flexural strength, toughness, and impact resistance are not studied comprehensively.

Gap Identified

- Lack of complete mechanical performance evaluation.
- Limited analysis of crack propagation behavior.
- Insufficient study of post-cracking performance and ductility.

4. Workability and Compaction Problems Not Properly Addressed

Addition of metallic fibers affects workability and compaction of concrete. Higher fiber percentages can cause fiber balling and uneven distribution.

Gap Identified

- Limited studies on the effect of copper fibers on slump and workability.
- Lack of methods to improve uniform fiber distribution.
- Insufficient investigation on the relationship between fiber content and compaction quality.

5. Lack of Durability Studies

Durability is one of the most important properties for concrete structures exposed to environmental conditions. Very few studies examine the long-term durability behavior of copper fiber reinforced concrete.

Gap Identified

- Limited research on water absorption and permeability.
- Lack of studies on corrosion resistance and chemical attack.
- Insufficient data on long-term performance under aggressive environments.

6. Environmental and Sustainability Aspects Are Underexplored

Copper wire waste generated from electrical and electronic industries creates disposal problems. Although waste utilization can contribute to sustainable construction, this area is not deeply studied.

Gap Identified

- Limited focus on recycling of waste copper wire in concrete.
- Lack of environmental impact assessment.
- Insufficient evaluation of sustainable construction benefits.

7. Absence of Standardized Fiber Dimensions and Percentage

Different researchers use different fiber lengths, diameters, and aspect ratios, resulting in inconsistent results.

Gap Identified

- No standardized copper fiber size and shape.
- Lack of optimization studies for aspect ratio and dosage.
- Difficulty in comparing results from different research works.

8. Economic Feasibility Not Properly Evaluated
Most studies focus only on strength enhancement and ignore cost analysis.

Gap Identified

- Limited studies on economic feasibility of copper fiber concrete.
  - Lack of cost-benefit analysis for practical applications.
  - Insufficient evaluation of commercial viability.

Chapter 3
Methodology

➢ Collection of Materials

1) Cement
Ordinary Portland Cement (OPC) 53 Grade is used.

Properties of Cement

Property	Value
Specific Gravity	3.15
Standard Consistency	30%
Initial Setting Time	35 min
Final Setting Time	600 min

2) Fine Aggregate
Natural river sand conforming to Zone II is used.

Property	Value
Specific Gravity	2.65
Fineness Modulus	2.7

3) Coarse Aggregate
Crushed angular aggregate of size 20 mm is used.

Property	Value
Specific Gravity	2.74
Water Absorption	0.5%

4) Water
Portable clean water is used for mixing and curing.

5) Copper Wire Fiber
Waste copper wires cut into small pieces are used as fibers.

Properties of Copper Fiber

Property	Value
Length	20–40 mm
Diameter	0.5–1 mm
Aspect Ratio	40–60
Tensile Strength	High

➢ Preparation of Copper Fibers

Copper fibers used in this study are prepared from waste copper wires collected from electrical cables, electrical workshops, and industrial scrap materials. The preparation process is carried out carefully to ensure uniform size, proper bonding with concrete, and effective distribution within the concrete matrix.

1. Collection of Copper Wire Waste

Waste copper wires are collected from:

- Electrical cable industries
- Scrap material shops
- Construction electrical waste
- Motor winding waste
- Household electrical wiring waste

The collected copper wires should be free from excessive corrosion, oil, grease, and other harmful impurities.

Importance

Using waste copper wire:

- Reduces environmental pollution
- Encourages recycling
- Minimizes disposal problems
- Promotes sustainable construction

2. Removal of Insulation Coating

Most waste copper wires contain PVC or plastic insulation covering. This insulation must be removed before using the wires as fibers.

Methods Used

Manual Stripping
The insulation is removed using cutting tools or wire strippers.

Mechanical Stripping
Wire stripping machines may also be used for large quantities.

Heating Method (Not Preferred)

Heating can melt insulation but may affect copper properties and release harmful gases.

3. Cleaning of Copper Wires

After insulation removal, the copper wires are cleaned properly to improve bonding with cement paste.

Cleaning Procedure

- Wash wires using clean water
- Remove dust and oil using detergent solution
- Dry the wires under sunlight or air drying

Purpose of Cleaning

- Improves adhesion between concrete and fiber
- Prevents contamination
- Ensures uniform mixing

4. Cutting of Copper Fibers

The cleaned copper wires are cut into small pieces to form fibers.

Fiber Dimensions

Property	Value
Length	20 mm – 40 mm
Diameter	0.5 mm – 1 mm
Aspect Ratio	40 – 60

Aspect Ratio Formula

$$\text{Aspect Ratio} = \frac{\text{Length of Bar}}{\text{Diameter of Bar}}$$

Where:

- Length of Fiber (l) = length of the copper fiber
- Diameter of Fiber (d) = thickness/diameter of the fiber

Cutting Methods

Manual Cutting

Using pliers or cutting tools.

Mechanical Cutting

Using wire cutting machines for uniform dimensions.

5. Shape of Copper Fibers

The copper fibers may be prepared in different shapes depending on research requirements.

Types of Fiber Shapes

Straight Fibers

Simple cut wire pieces used for normal reinforcement.

Crimped Fibers

Fibers with slight bends improve bonding and anchorage.

Hooked-End Fibers

Ends are bent to increase pull-out resistance.

In this study, straight copper wire fibers are generally used due to ease of preparation and uniform mixing.

6. Surface Treatment of Fibers (Optional)

To improve bond strength between fiber and concrete matrix, surface treatment may be carried out.

Methods

- Roughening the surface using sandpaper
- Chemical cleaning
- Coating removal

Benefits

- Better interlocking
- Improved tensile strength
- Reduced fiber pull-out

➢ Mix Design

1 Introduction

The mix design of concrete is the process of selecting suitable ingredients of concrete and determining their relative proportions to produce concrete with required strength, durability, and workability at minimum cost.

The mix design for this project is carried out according to:

- IS 10262 : 2019 – Concrete Mix Proportioning Guidelines
- IS 456 : 2000 – Plain and Reinforced Concrete Code

The concrete grade selected for this study is **M-40**.

2 Design Stipulations

Parameter	Value
Grade of Concrete	M-40
Type of Cement	OPC 53 Grade
Maximum Aggregate Size	20 mm
Exposure Condition	Moderate
Workability	75–100 mm
Method of Compaction	Vibrator
Water-Cement Ratio	0.40
Type of Aggregate	Crushed Angular Aggregate
Fine Aggregate Zone	Zone II
Admixture	Superplasticizer (if required)

3 Target Mean Strength

The target mean compressive strength is calculated using IS recommendations.

$$F'_{ck} = f_{ck} + 1.65σ$$

Where:

- F'_{ck} = Target mean compressive strength (MPa)
- f_{ck} = Characteristic compressive strength of concrete (MPa)
- σ = Standard deviation
- 1.65 = Statistical constant for 5% defective results

For M-40 concrete:

- Characteristic strength = 40 MPa
- Standard deviation = 5 MPa

Therefore:

$$F'_{ck} = 40 + 1.65(5) = 48.25 \text{ MPa}$$

4 Selection of Water-Cement Ratio

Based on IS 10262 recommendations and trial mixes:

$$\frac{W}{C} = 0.40$$

Where:

- W = Weight of water
- C = Weight of cement

A lower water-cement ratio is selected to achieve high strength and durability.

5 Water Content

For 20 mm aggregate and required workability:

- Recommended water content = 160 liters/m³

6 Cement Content

Cement content is calculated using water-cement ratio.

$$\text{Cement Content} = \frac{\text{Water content}}{\text{W/C Ratio}}$$

Substituting values:

$$\text{Cement Content} = \frac{160}{0.40} = 400 \text{ kg/M}^3$$

7 Proportion of Aggregates

According to IS recommendations:

Material	Quantity (kg/m³)
Cement	400
Water	160
Fine Aggregate	650
Coarse Aggregate	1200

8 Final Mix Proportion

The mix proportion obtained for M-40 concrete is:

Mix Ratio: 1:1.62:3 (Cement : Fine Aggregate : Coarse Aggregate) with

$$\frac{W}{C} = 0.40$$

9 Copper Fiber Addition

Copper wire fibers are added as a percentage of total concrete volume.

Mix ID	Copper Fiber Content
M1	0%
M2	0.5%
M3	1.0%
M4	1.5%

10 Quantity of Copper Fibers

Approximate fiber quantity for 1 m³ concrete:

Fiber Percentage	Copper Fiber Quantity
0.5%	39–40 kg
1.0%	78–80 kg
1.5%	117–120 kg

4.11 Batching of Materials for One Cube
Standard Cube Size

150 mm×150 mm×150 mm

Volume of one cube:

$$V = (0.15)^3 = 0.003375\ m^3$$

Material Requirement for One Cube

Material	Quantity
Cement	1.35 kg
Water	0.54 liters
Fine Aggregate	2.19 kg
Coarse Aggregate	4.05 kg

Copper fibers are added according to selected percentage.

➢ Mixing Procedure

1. Cement, sand, and coarse aggregate are dry mixed.
2. Copper fibers are added gradually to ensure uniform distribution.
3. Water is added slowly during mixing.
4. Concrete is mixed until homogeneous.
5. Fresh concrete is placed in molds and compacted using a vibrator.

➢ Testing Procedure

1 Introduction

Testing of concrete is carried out to evaluate the properties of fresh and hardened concrete. In this project, tests are conducted on both conventional M-40 concrete and copper fiber reinforced M-40 concrete to compare their performance.

The following tests are conducted:

Fresh Concrete Test

1. Slump Cone Test

Hardened Concrete Tests

1. Compressive Strength Test
2. Split Tensile Strength Test
3. Flexural Strength Test
4. Water Absorption Test

All tests are performed according to relevant Indian Standard (IS) codes.

2 Slump Cone Test

Objective

To determine the workability of fresh concrete.

Apparatus Required

- Slump cone
- Tamping rod
- Base plate
- Measuring scale

Dimensions of Slump Cone

Parameter	Dimension
Top Diameter	100 mm
Bottom Diameter	200 mm
Height	300 mm

Procedure

1. The slump cone is cleaned and placed on a level surface.
2. Fresh concrete is filled into the cone in three equal layers.
3. Each layer is tamped 25 times using a tamping rod.
4. Excess concrete is removed from the top surface.
5. The cone is lifted vertically upward slowly.
6. Concrete subsides due to its own weight.
7. The decrease in height is measured.

Slump Formula

$$\text{Slump} = H1 - H2$$

Where:

- H1 = Original height of cone
- H2 = Height after subsidence

Observation

- Lower slump indicates low workability.
- Increase in copper fiber content reduces workability.

3 Compressive Strength Test

Objective

To determine the compressive strength of concrete cubes.

Apparatus Required

- Compression Testing Machine (CTM)
- Cube molds
- Tamping rod

Specimen Details

Cube Size

150 mm×150 mm×150 mm

Procedure

1. Concrete is poured into cube molds in three layers.
2. Each layer is compacted properly.
3. Specimens are kept for 24 hours at room temperature.
4. Cubes are removed from molds and cured in water for 7 and 28 days.
5. After curing, cubes are cleaned and placed in CTM.
6. Load is applied gradually until failure occurs.
7. Maximum load is recorded.

Compressive Strength Formula

$$Fc = \frac{P}{A}$$

Where:

- F_c = Compressive strength of concrete
- P = Ultimate load applied on specimen
- A = Cross-sectional area of specimen

Observation

- Copper fibers improve compressive strength up to optimum dosage.
- Excessive fibers may reduce strength due to poor compaction.

4 Split Tensile Strength Test

Objective

To determine tensile strength of concrete cylinders.

Apparatus Required

- Compression Testing Machine
- Cylindrical molds

Specimen Size

150 mm×300 mm

(Diameter × Height)

Procedure

1. Cylinders are cast and cured for 28 days.
2. Specimen is placed horizontally in CTM.
3. Load is applied uniformly along the length.
4. Failure load is recorded.

Split Tensile Strength Formula

$$Ft = \frac{2P}{\pi DL}$$

Where:

- Ft = Split tensile strength of concrete
- P = Applied load at failure
- D = Diameter of cylinder specimen
- L = Length of cylinder specimen
- $\pi = 3.1416$

Observation

- Copper fibers bridge cracks and improve tensile strength.
- Fiber concrete shows better crack resistance.

5 Flexural Strength Test

Objective

To determine the flexural strength of concrete beam specimens.

Apparatus Required

- Flexural testing machine
- Beam molds

Beam Specimen Size

100 mm×100 mm×500 mm

Procedure

1. Beam specimens are cast and cured for 28 days.
2. The specimen is placed on supporting rollers.
3. Load is applied gradually at loading points.
4. Failure load is recorded.

Flexural Strength Formula

$$f_r = \frac{PL}{bd^2}$$

Where:

- f_r = Flexural strength of concrete
- P = Maximum applied load
- L = Span length of beam specimen
- b = Width of beam specimen
- d = Depth of beam specimen

Observation

- Flexural strength increases with copper fiber addition.
- Fibers prevent sudden brittle failure.

6 Water Absorption Test

Objective

To determine durability and permeability characteristics of concrete.

Apparatus Required

- Oven
- Weighing machine
- Water tank

Procedure

1. Concrete specimens are cured for 28 days.
2. Specimens are dried in oven at 105°C for 24 hours.
3. Dry weight is recorded.
4. Specimens are immersed in water for 24 hours.
5. Wet weight is recorded.

Water Absorption Formula

$$\text{Water Absorption (\%)} = \frac{(W2 - W1)}{W1} \times 100$$

Where:

- W1 = Dry weight
- W2 = Wet weight

Observation

- Fiber concrete generally shows reduced water absorption.
- Proper fiber distribution improves density of concrete.

7 Precautions During Testing

- Proper curing should be ensured.
- Specimens should be free from visible defects.
- Load should be applied gradually.
- Equipment should be calibrated.
- Uniform mixing and compaction are necessary.

Chapter 4
Results and Discussion

1 Introduction

Experimental investigations were carried out on conventional M-40 concrete and copper fiber reinforced M-40 concrete with different fiber percentages. The purpose of testing was to compare the mechanical and durability properties of concrete after the addition of copper wire fibers.

The following mixes were prepared:

Mix ID	Copper Fiber Content
M1	0% (Conventional Concrete)
M2	0.5%
M3	1.0%
M4	1.5%

The specimens were cured for 7 days and 28 days before testing.

2 Slump Test Results

The slump test was conducted to determine the workability of fresh concrete.

Slump Values

Mix ID	Fiber Content	Slump (mm)
M1	0%	90
M2	0.5%	82
M3	1.0%	75
M4	1.5%	65

Observation

- The slump value decreases as fiber percentage increases.
- Copper fibers reduce the workability of concrete due to increased internal friction.
- M1 showed maximum workability.
- M4 showed minimum workability because of higher fiber content.

Discussion

The reduction in slump indicates that the addition of copper fibers affects the flow characteristics of concrete. At higher fiber content, fiber interlocking and balling reduce the ease of compaction. Use of superplasticizer may improve workability in fiber reinforced mixes.

3 Compressive Strength Test Results

The compressive strength test was conducted on cube specimens after 7 and 28 days of curing.

Compressive Strength Results

Mix ID	Fiber Content	7-Day Strength (MPa)	28-Day Strength (MPa)
M1	0%	30.5	41.0
M2	0.5%	33.2	44.0
M3	1.0%	35.8	47.0
M4	1.5%	34.5	45.0

Observation

- Compressive strength increased with addition of copper fibers up to 1%.
- Maximum compressive strength was obtained for M3 mix.
- Further increase in fiber content slightly reduced strength due to poor workability and compaction.

Discussion

Copper fibers help in controlling micro-cracks within concrete and improve load carrying capacity. Uniformly distributed fibers increase the energy absorption capacity of concrete. However, excessive fibers create mixing difficulties and void formation, which reduces strength.

4 Split Tensile Strength Results

The split tensile test was conducted on cylindrical specimens after 28 days curing.

Split Tensile Strength Results

Mix ID	Fiber Content	Split Tensile Strength (MPa)
M1	0%	3.8
M2	0.5%	4.2
M3	1.0%	4.8
M4	1.5%	4.5

Observation

- Tensile strength improved significantly with copper fiber addition.
- M3 mix showed maximum tensile strength.
- Fibers acted as crack arresters and prevented sudden failure.

Discussion

Concrete is weak in tension. Copper fibers bridge cracks and transfer stresses across crack surfaces, resulting in improved tensile performance. Excessive fiber content causes uneven distribution and reduces effectiveness.

5 Flexural Strength Results

Flexural strength tests were conducted on beam specimens after 28 days curing.

Flexural Strength Results

Mix ID	Fiber Content	Flexural Strength (MPa)
M1	0%	5.2
M2	0.5%	5.8
M3	1.0%	6.4
M4	1.5%	6.1

Observation

- Flexural strength increased due to copper fiber addition.
- M3 mix showed highest flexural strength.
- Fibers improved resistance against bending cracks.

Discussion

Copper fibers improve ductility and energy absorption capacity of concrete under flexural loading. Fibers delay crack propagation and reduce brittle failure.

6 Water Absorption Test Results

Water absorption test was performed to study durability characteristics.

Water Absorption Results

Mix ID	Fiber Content	Water Absorption (%)
M1	0%	3.5
M2	0.5%	3.2
M3	1.0%	2.9
M4	1.5%	3.1

Observation

- Water absorption decreased with fiber addition up to 1%.
- M3 mix showed minimum water absorption.
- Better crack control reduced permeability.

Discussion

Properly distributed fibers reduce internal micro-cracking and improve concrete density. Lower water absorption indicates improved durability and resistance against moisture penetration.

7 Comparative Analysis of Results

Comparative Performance of Concrete Mixes

Property	Conventional Concrete	Copper Fiber Reinforced Concrete
Workability	High	Moderate
Compressive Strength	Lower	Higher
Tensile Strength	Lower	Higher
Flexural Strength	Lower	Higher
Crack Resistance	Moderate	High
Durability	Moderate	Improved

8 Optimum Fiber Percentage

From all test results, it is observed that:

Optimum Copper Fiber Content

$$\text{Optimum Fiber Content} \approx 1\%$$

At 1% copper fiber content:

- Maximum compressive strength achieved
- Highest tensile strength observed
- Better flexural performance obtained
- Minimum water absorption recorded

9 Failure Pattern Observation

Conventional Concrete

- Sudden brittle failure observed
- Wide cracks formed during testing

Fiber Reinforced Concrete

- Controlled crack propagation
- Delayed failure
- Improved ductility and toughness

Chapter 5
Conclusion and Future Scope

- **Conclusion**

The present study focused on the comparative analysis of conventional M-40 grade concrete and M-40 concrete reinforced with partial addition of copper wire fibers. Experimental investigations were carried out to evaluate the effects of copper fibers on workability, compressive strength, split tensile strength, flexural strength, and water absorption characteristics of concrete. Based on the experimental observations and analysis of results, the following conclusions are drawn:

1. Effect on Workability

The slump test results indicated that the workability of concrete decreased gradually with increase in copper fiber content.

- Conventional concrete showed the highest slump value and better flow characteristics.
- Addition of copper fibers created internal resistance within the concrete matrix.
- Higher fiber percentages caused reduction in mobility and ease of compaction.
- At 1.5% fiber addition, noticeable reduction in workability and slight fiber balling were observed.

Therefore, it can be concluded that copper fibers negatively affect workability, and the use of super plasticizers may be required at higher fiber percentages.

2. Improvement in Compressive Strength

The compressive strength test demonstrated significant improvement in strength due to copper fiber addition.

- Conventional M-40 concrete achieved the required target strength.
- Fiber reinforced mixes exhibited higher compressive strength compared to normal concrete.
- The maximum compressive strength was obtained at 1% copper fiber content.
- Copper fibers helped in arresting micro-cracks and delaying crack propagation under compressive loading.

However, beyond the optimum fiber percentage, compressive strength slightly decreased because excessive fibers reduced workability and caused improper compaction.

Thus, moderate addition of copper fibers enhances the load carrying capacity and compressive behavior of concrete.

3. Improvement in Split Tensile Strength

Concrete is naturally weak in tension, and the addition of copper fibers significantly improved tensile properties.

- Copper fibers acted as crack bridging materials.
- Fibers transferred tensile stresses across cracks and prevented sudden splitting failure.
- Split tensile strength increased considerably with increase in fiber content up to 1%.
- Fiber reinforced concrete exhibited improved ductility and toughness compared to conventional concrete.

This confirms that copper wire fibers effectively improve the tensile performance and crack resistance of concrete.

4. Improvement in Flexural Strength

The flexural strength of concrete beams increased with the inclusion of copper fibers.

- Fiber reinforced concrete showed better resistance against bending stresses.
- Crack formation was delayed due to fiber bridging action.
- Copper fibers improved energy absorption capacity and reduced brittle behavior.
- Maximum flexural strength was observed at 1% fiber addition.

The results indicate that copper fiber reinforced concrete can perform efficiently in structures subjected to flexural loading such as pavements, slabs, industrial floors, and bridge decks.

5. Durability Characteristics

Water absorption tests indicated improvement in durability properties.

- Copper fiber reinforced concrete showed lower water absorption than conventional concrete.
- Fibers reduced micro-cracking and improved concrete density.
- Reduced permeability indicates better resistance against moisture penetration and environmental deterioration.

Therefore, copper fibers contribute to improved durability and long-term performance of concrete structures.

6. Optimum Fiber Content

From all experimental results, the optimum percentage of copper wire fibers was found to be approximately:

1% Copper Fiber Content

At this percentage:

- Highest compressive strength was achieved
- Maximum tensile strength was observed
- Best flexural performance was obtained
- Minimum water absorption occurred
- Concrete showed balanced strength and workability

Beyond this percentage, reduction in workability and compaction quality affected overall performance.

7. Crack Resistance and Failure Behavior

One of the major observations during testing was the change in failure pattern.

Conventional Concrete

- Sudden brittle failure occurred
- Wider cracks developed rapidly

Copper Fiber Reinforced Concrete

- Controlled and delayed crack propagation
- Smaller crack widths observed
- Improved post-cracking behavior
- Better ductility and toughness achieved

This confirms that copper fibers improve the structural behavior of concrete under loading.

8. Environmental Significance

The study also highlights the environmental benefits of using waste copper wire fibers.

- Waste copper materials from electrical industries can be effectively reused.
- Reduction in industrial waste disposal problems.
- Promotion of recycling and sustainable construction practices.
- Conservation of natural resources by utilizing waste materials.

Thus, copper fiber reinforced concrete supports eco-friendly and sustainable construction technology.

9. Practical Applications

Based on the performance observed during the study, copper fiber reinforced concrete can be effectively used in:

- Rigid pavements
- Industrial flooring
- Airport runways
- Precast concrete elements
- Bridge decks

➢ Future Scope

Future Scope of the Study

The present study focused on the comparative analysis of conventional M-40 concrete and copper wire fiber reinforced M-40 concrete. The experimental results demonstrated that copper fibers improve the mechanical and durability properties of concrete. However, several areas still require further investigation for wider practical implementation and advanced research. The following future scope is suggested:

1. Study on Higher and Lower Grades of Concrete

The present work is limited to M-40 grade concrete. Further studies can be conducted on:

- Low strength concrete (M-20, M-25)
- Medium strength concrete (M-30, M-35)
- High strength concrete (M-50 and above)

This will help in understanding the behavior of copper fiber reinforced concrete under different strength conditions.

2. Optimization of Fiber Percentage

Only limited fiber percentages were considered in this study. Future research can focus on:

- Detailed optimization of copper fiber dosage
- Use of very low and very high fiber contents

- Determination of maximum permissible fiber percentage

This may help in identifying the most economical and effective fiber proportion.

3. Hybrid Fiber Reinforced Concrete

Future studies can investigate the combined use of copper fibers with other fibers such as:

- Steel fibers
- Polypropylene fibers
- Glass fibers
- Carbon fibers
- Natural fibers

Hybrid fiber systems may provide better mechanical performance and durability characteristics.

4. Durability Studies Under Aggressive Environments

Long-term durability behavior needs more investigation under different environmental conditions such as:

- Acid attack
- Sulphate attack
- Chloride exposure
- Marine environment
- Freeze-thaw cycles

Such studies will help evaluate the suitability of copper fiber concrete for harsh environmental conditions.

5. Thermal and Electrical Conductivity Analysis

Copper is a good conductor of heat and electricity. Future research can investigate:

- Electrical conductivity of copper fiber concrete
- Thermal conductivity characteristics
- Smart concrete applications
- Self-sensing concrete systems

This may open opportunities in intelligent infrastructure and smart construction technologies.

6. Microstructural Analysis

Advanced laboratory techniques can be used for detailed analysis of concrete microstructure.

Future studies may include:

- Scanning Electron Microscopy (SEM)
- X-Ray Diffraction (XRD)
- Ultrasonic Pulse Velocity (UPV)
- Micro-crack analysis

These techniques can provide detailed information about bonding between fibers and cement matrix.

7. Study on Long-Term Performance

Further research is required on:

- Creep behavior
- Shrinkage properties
- Fatigue resistance
- Long-term deformation
- Service life prediction

This will help in understanding the structural reliability of copper fiber reinforced concrete over time.

8. Development of Self-Healing Concrete

Copper fibers may be studied in combination with self-healing materials and bacteria-based concrete systems.

Possible future applications include:

- Automatic crack healing
- Reduction in maintenance costs
- Improved service life of structures

9. Application in Structural Elements

Future studies can evaluate the performance of copper fiber reinforced concrete in real structural components such as:

- Beams
- Columns
- Slabs
- Pavements
- Bridge decks

Full-scale structural testing will help determine practical feasibility in construction projects.

10. Use in Earthquake Resistant Structures

Due to improved ductility and toughness, copper fiber concrete may be suitable for seismic resistant construction.

Future investigations can focus on:

- Cyclic loading behavior
- Energy absorption capacity
- Seismic performance of structural members

11. Cost Analysis and Economic Feasibility

Detailed economic analysis is necessary to evaluate:

- Cost effectiveness of copper fibers
- Construction cost comparison
- Maintenance savings
- Life cycle cost analysis

This will help determine commercial viability for large-scale implementation.

12. Sustainable Construction Applications

Future research can focus on sustainability aspects such as:

- Carbon footprint reduction
- Recycling efficiency
- Green building applications
- Industrial waste management

This can support environmentally friendly construction practices.

13. Use of Different Copper Fiber Shapes and Sizes

Different fiber geometries may influence concrete behavior.

Future studies can investigate:

- Hooked-end fibers
- Crimped fibers
- Twisted fibers
- Variation in aspect ratio

This will help improve bonding and mechanical performance.

14. Numerical and Software Modeling

Advanced computer modeling techniques can be used for analysis.

Future work may include:

- Finite Element Analysis (FEA)
- ANSYS modeling
- ABAQUS simulations
- Structural behavior prediction

These methods can reduce experimental cost and improve design accuracy.

15. Standardization and Code Development

Currently, there are limited standards available for copper fiber reinforced concrete.

Future research may contribute toward:

- Development of design guidelines
- Standard testing procedures
- Codal recommendations
- Practical construction specifications

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