A Comparative Study of the Experimental Investigation of different types of fibres used in Concrete

Jaspinder Singh
Assistant Professor in Department of Civil Engineering
Global Group of Institutes, Amritsar

ABSTRACT

Different types of fibres used in concrete have received much attention in civil engineering in recent years, mainly because they improve the low tensile strength and shrinkage cracks of concrete. However, there are still many problems in the research results on different types of Fibers. For example, there is still debate about the performance-enhancing or detrimental effects of different types of fibres in concrete. There is also a dispute about the influence of the size, strength, elastic modulus and other characteristic parameters of each fibre on the properties of the substrate. Research on fibre mixing rules of hybrid fibre reinforced concrete (HFRC) is incomplete. There is controversy regarding the choice of fibres for hybrid yarns as well as the characterization of the hybrid effect. In summary, it is necessary to review, synthesize and compare current research on FRC. Based on the major research achievements on FRC in recent years, this article synthesizes and evaluates existing research in experimental research and theoretical research on different types of fibre materials, aiming to create Reference conditions for researchers in the same field. Finally, combined with research experience in related fields, new perspectives and proposals on FRC's research are proposed for research and application. This research paper is mainly focus on the different fibres (glass, cotton, steel).

KEYWORDS:- GLASS FIBRE, COTTON FIBRE, STEEL FIBRE, TENSILE STRENGTH, COMPRESSIVE STRENGTH,

INTRODUCTION

Concrete is a commonly used building material in civil engineering worldwide. While it is strong in compression, it lacks toughness and strain capacity in tension, leading to cracks under tensile stresses. Adding fibers to concrete enhances its crack resistance and energy absorption. Fiber reinforced concrete provides post-cracking ductility by bridging fibers across cracks, significantly improving concrete toughness. Considering toughness and fracture energy is crucial for ensuring the safety and integrity of structural elements. Concrete is typically reinforced with steel or synthetic fibers like carbon, glass, or aramid. However, due to high costs, energy consumption, and environmental impact, there is a growing interest in environmentally friendly alternatives. Research is focusing on using fast-growing, renewable crops and crop residues as fiber reinforcement in concrete. Natural fibers are cost-effective, widely available, biodegradable, and pose no health risks. They also reduce greenhouse gas emissions and pollutants. Utilizing natural fibers in concrete is a sustainable approach that recycles resources and produces high-performance materials. Coir, derived from the Tamil word "kayiru," is a natural fibre obtained from coconut husks.

FIBRE REINFORCED CONCRETE

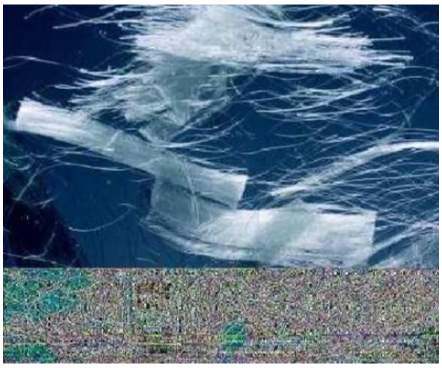
Fiber-reinforced concrete is a composite material made up of mixtures of cement, mortar, or concrete along with discontinuous, discrete, uniformly dispersed suitable fibers. There are various types and properties of fibre-reinforced concrete, each with its own advantages. Continuous meshes, woven fabrics, and long wires or rods are not considered discrete fibers. Fibers are small pieces of reinforcing material with specific properties, which can be circular or flat. The aspect ratio of a fiber, which is the ratio of its length to its diameter, typically ranges from 30 to 150. Fiber-reinforced concrete (FRC) is concrete that contains fibrous material to enhance its structural integrity. It consists of short discrete fibers that are evenly distributed and randomly oriented, including steel fibers, glass fibers, synthetic fibers, and natural fibers. The characteristics of fiber-reinforced concrete vary depending on the type of concrete, fiber materials, geometries, distribution, orientation, and densities. Fiber reinforcement is commonly used in shotcrete and can also be utilized in regular concrete. Fiber-reinforced normal concrete is commonly used for on-ground floors and pavements, but can also be applied to a wide range of construction components (such as beams, columns, foundations, etc.) either alone or in combination with hand-tied rebars. Concrete reinforced with fibers (typically steel, glass, or "plastic" fibers) is more cost-effective than hand-tied rebar, while significantly increasing tensile strength. The shape, dimension, and length of the fiber are crucial factors to consider. For instance, a thin and short fiber, like short hair-shaped glass fiber, is effective only in the initial hours after concrete pouring (reducing cracking during the stiffening phase) and does not enhance concrete tensile strength.

STEEL FIBRE REINFORCED CONCRETE

Several types of steel fibres are available for reinforcement purposes. The most commonly used type is round steel fibre which is produced by cutting round wire into short lengths. These fibres typically have a diameter ranging from 0.25mm to 0.75mm. Another type of steel fibre with a rectangular cross-section is produced by slitting sheets that are about 0.25mm thick. These fibres are made from mild steel drawn wire and conform to IS:280-1976, with wire diameters varying from 0.3mm to 0.5mm, and have been widely used in India. Additionally, round steel fibres are produced by cutting or chopping wire, while flat sheet fibres with cross-section ranging from 0.15mm to 0.41mm in thickness and 0.25mm to 0.90mm in width are produced by slitting flat sheets. Deformed fibres which are loosely bound with water-soluble glue in form of a bundle, are also available. However, due to the tendency of individual fibres to cluster together, achieving a uniform distribution in matrix can be challenging.

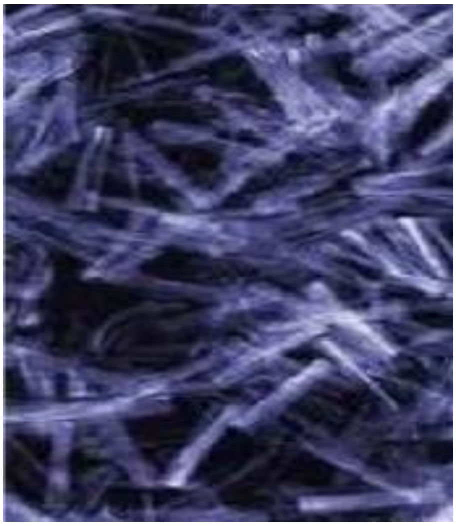
POLYPROPYLENE FIBER REINFORCED CEMENT MORTAR AND CONCRETE

Polypropylene is a widely available and cost-effective polymer known for its chemical resistance. In aggressive chemical environments, the cementitious matrix would deteriorate before the polypropylene fibers. With a high melting point of approximately 165 degrees Celsius, these fibers can withstand short periods of exposure to temperatures up to 100 degrees Celsius without losing their properties. Due to their hydrophobic nature, polypropylene fibers can be easily mixed into concrete without requiring prolonged contact, only needing to be evenly distributed in the mix. Commercially, polypropylene short fibers are commonly used in concrete in small volume fractions ranging from 0.5 to 15.



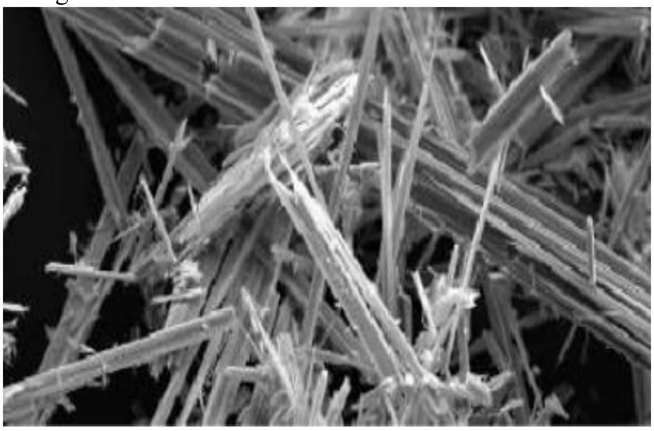
GLASS FIBRE REINFORCED CONCRETE

Glass fiber consists of a collection of 200-400 individual filaments that are lightly bonded together to form a strand. These strands can be cut into different lengths or combined to create cloth mats or tape. When using traditional mixing techniques for regular concrete, it is not feasible to mix more than approximately 2% (by volume) of fibers that are 25mm in length. Glass fiber has primarily been used to reinforce cement or mortar matrices in the production of thin-sheet products. The commonly utilized types of glass fibers include e-glass, which is used in the reinforcement of plastics, and AR glass, which has improved resistance to alkalis found in Portland cement. In some cases, polymers are also added to the mixtures to enhance certain physical properties, such as moisture movement.



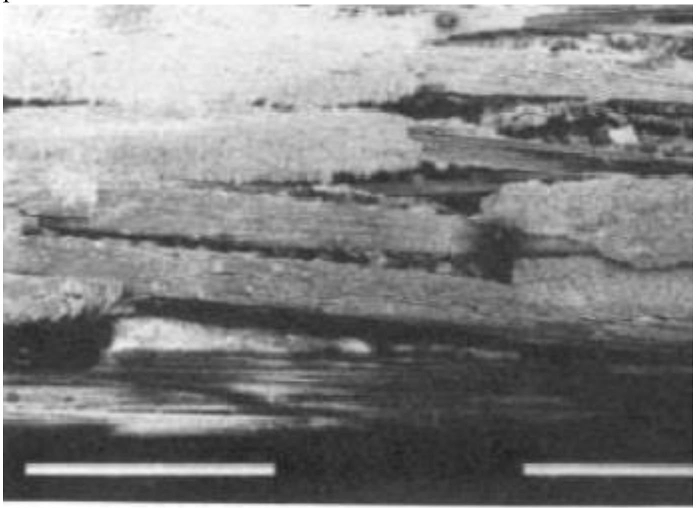
ASBESTOS FIBRE

Asbestos, a naturally occurring mineral fiber that is cost-effective, has been effectively mixed with Portland cement paste to create a popular product known as asbestos cement. The thermal, mechanical, and chemical resistance of asbestos fibers make them ideal for sheet products, pipes, tiles, and corrugated roofing materials. The strength of asbestos cement board is around two to four times greater than that of unreinforced matrix. Nevertheless, due to the fiber's relatively short length of 10mm, it has low impact strength.



CARBON FIBRES

Carbon fibers are a recent and possibly the most remarkable addition to the variety of fibers used in commercial applications. They possess a very high modulus of elasticity and flexural strength, making them expensive. Their strength and stiffness properties have been discovered to surpass even those of steel. However, they are more prone to damage than glass fibers, so they are typically coated with resin for protection.



COTTON FIBRES

Cotton fiber is a specially processed product that is used in the building industry as a lightweight construction material. The accumulation of cotton wastes from various countries has led to serious environmental and health issues. Silica fume, on the other hand, is known for its effectiveness in enhancing the mechanical properties of concrete. By utilizing silica fume as an industrial product, it provides a more environmentally friendly alternative to disposal, thus increasing environmental awareness. Conflow-SP (Super Plasticizer) is used to maintain the workability of concrete affected by mineral admixture. This study presents the findings of an experimental investigation on the split tensile strength of concrete cylinders and the durability of concrete cubes. The addition of cotton fiber ranging from 0.2% to 0.5% and silica fume from 3% to 12% as a replacement for cement has shown improvements in the properties of concrete. The split tensile strength was determined at 7 and 28 days, with minimal loss in weight and compressive strength of cubes against sulphate and chloride attacks observed at 56 days.

TYPES OF MIXES

a) Nominal mixes were traditionally used in concrete specifications, with fixed cement-aggregate ratios ensuring adequate strength. These mixes offer simplicity and typically have a margin of strength above the specified requirements. However, due to ingredient variability, the strength of nominal concrete can vary widely for a given workability.

b) Standard mixes, on the other hand, have fixed cement-aggregate ratios by volume that can result in mixes with varying strengths, leading to under- or over-rich mixes. To address this issue, minimum compressive strength requirements have been included in many specifications. The standard mixes are categorized into grades such as M10, M15, M20, M25, M30, M35, and M40 according to IS456 2000. The letter M denotes the mix, while the number represents the specified 28-day cube strength of the mix in N/mm2. For example, M10, M15, M20, and M25 correspond to mix proportions of (1:3:6), (1:2:4), (1:1.5:3), and (1:1:2) respectively.

c) Designed mixes take a different approach, where the concrete's performance is specified by the designer, but the mix proportions are determined by the concrete producer, with the exception of a minimum cement content requirement. This method allows for a more tailored selection of mix proportions based on the unique characteristics of the materials used, resulting in concrete with the desired properties in a cost-effective manner.

EXPERIMENTAL INVESTIGATION

Fiber reinforced concrete specimens were produced using steel fibers with dosages of 0, 40, 75, and 110 kg/m3. Four test series of samples were created, with the basic concrete mixture consisting of fine-grained concrete. The material tests conducted included determining compressive strength, splitting tensile strength, and bending tensile strength. the average strength values obtained from the tests, along with the corresponding coefficient of variation. Additional information regarding the fibers' properties, shape, tests, and test specimens can be found. It displays the basic mechanical properties of fiber reinforced concrete, including dosage, density, coefficient of variation, compressive strength, splitting tensile strength, and bending tensile strength. The values for each parameter are provided, along with their respective coefficient of variation.Based on the three-point bending test, the load displacement diagrams were analyzed. From the data presented it is evident that there is an increase in fracture energy with higher fiber dosing. Specifically, the fracture energy for an 8 mm displacement increased by 60% when the fiber dosage was increased from 40 kg/m3 to 75 kg/m3.

When dosing at 110 kg/m3, the fracture energy increased by 49% compared to dosing at 75 kg/m3. The ratio of fracture energies for displacements of 8 mm and 5 mm was similar for all dosages. The research conducted by involved experimental testing of reinforced concrete beams with dimensions of 150 x 150 x 700 mm. Two reinforcement bars with a diameter of 10 mm were used at the lower bottom, and the concrete cover was 20 mm. A total of 8 RC beams were tested, with two beams for each fiber dosage. The test results showed that the maximum load achieved in the test increased with the amount of fiber. For the dosage of 40 kg/m3, there was a 24% increase compared to plain concrete. A more significant increase of 65% and 80% was observed for dosages of 75 kg/m3 and 110 kg/m3, respectively. The functional dependence of the maximum load on the amount of fiber and a regression linear function demonstrated a good agreement of 97%. The maximum load, denoted as Pmax, represents the load at which the sample was broken. It can be observed that with increasing amount of fiber, the maximum load Pmax increases. In the case of lower dosing, i.e. 40 kg/m3, there was increase of 24 % compared to plain concrete. A more significant increase up to 65 %, respectively 80 % can be observed in case of dosing of 75 and 110 kg/m3.

The Experimental Program was developed to analyze the impact of cotton fibers and silica fume as mineral admixture, along with super plasticizer, on the strength and durability of concrete. This study aims to provide insights into the effects of these materials on concrete properties. In this experimental study, a combination of cotton fiber and silica fume was added individually to 25 different mixes. Standard cylinders (150mmX300mm) were used for testing split tensile strength, while cubes (150X150X150mm) were utilized for conducting Sulphate attack and Chloride attack tests. The binder ratio of 0.50 was employed, with concrete cylinders cast for split tensile strength and cubes cast for durability assessment. The split tensile strength of cylinders was evaluated after 7 and 28 days of normal water curing at room temperature. Cube specimens for durability were cured for 28 days, then removed for drying for 24 hours before their weight was measured. For the sulphate attack test, a 5% dilute Na_2SO_4 solution was used, while a 5% dilute NaCl solution was employed for the chloride attack test. The cubes were submerged in both solutions for a period of 28 days. After this duration, the specimens were removed from the solutions, and the minimum loss of weight and compressive strength due to sulphate and chloride attacks was determined.

CONCLUSION

- The article presents an experimental investigation into the shear resistance of reinforced concrete beams that lack shear reinforcement. Small beam specimens were used in the study, which were reinforced with steel reinforcing bars and short, straight fibers at dosages of 40, 75, and 110 kg/m3. These specimens were subjected to a three-point bending test. In all cases, the inclusion of fibers led to a significant increase in load capacity compared to plain concrete. The study also involved determining the fundamental mechanical properties, which were then utilized in numerical modelling of three-point bending tests on fiber-reinforced concrete beams with longitudinal reinforcement but without shear reinforcement. To conduct numerical simulations on these specimens, appropriate input parameters are required. The authors explored two concepts of the fiber-reinforced concrete model to approximate the suitable input parameters.
- The study conducted aimed to investigate the impact of adding cotton fiber and silica fume on the strength and durability of concrete. The results showed that the addition of only 0.4% cotton fiber increased the maximum split tensile strength by 6.80%. Furthermore, the split tensile strength was 9.27% higher than normal concrete at 7 and 28 days. On the other hand, the addition of only 9% silica fume increased the split tensile strength by 15.20% and 16.81% higher than normal concrete at 7 and 28 days, respectively. When both cotton fiber (0.3%) and silica fume (6%) were combined, the maximum split tensile strength increased by 11.60% and 14.78% compared to normal concrete at 7 and 28 days.
- In terms of durability, the addition of only 0.4% cotton fiber resulted in a minimum loss in weight of 2.10% and a decrease in compressive strength of 3.14% when subjected to the Sulphate attack test at 56 days. Similarly, the addition of only 9% silica fume resulted in a minimum loss in weight of 2.22% and a decrease in compressive strength of 3.64% under the same test conditions. When both cotton fiber (0.3%) and silica fume (6%) were combined, the minimum loss in weight was 2.05% and the decrease in compressive strength was 2.82% when subjected to the Sulphate attack test at 56 days. Furthermore, the addition of only 0.4% cotton fiber resulted in a minimum loss in weight of 1.16% and a decrease in compressive strength of 2.68% when subjected to the Chloride attack test at 56 days. Similarly, the addition of only 9% silica fume resulted in a minimum loss in weight of 0.98% and a decrease in compressive strength of 2.43% under the same test conditions.When both cotton fiber (0.3%) and silica fume (9%) were combined, the minimum loss in weight was 1.21% and the decrease in compressive strength was 2.11% when subjected to the Chloride attack test at 56 days. Overall, the study demonstrated that the addition of cotton fiber and silica fume can significantly enhance the strength and durability of concrete.
- 1. Various synthetic fibers have been utilized to enhance the tensile properties of concrete due to their inherent weaknesses. Despite the potential benefits of these fibers, concerns regarding their

sustainability and cost remain significant. However, recent attention has shifted towards the incorporation of natural fibers in cement composites.

- Cotton fibers, being one of the most abundant natural fibers globally, have numerous applications in the textile industry. Yet, a substantial amount of cotton is wasted annually. Therefore, repurposing waste cotton fibers could offer both economic and sustainable advantages.
- This study investigates the use of waste cotton fibers as a natural reinforcement in Portland cement concrete. Since cotton has a high moisture absorption rate, additional water was required during the mixing process. The optimal excess water level was determined prior to mixing to ensure the best results. Considering the water absorbency, lightweight nature, and hydrophobic surface of raw cotton, the mix design and mixing procedure were fine-tuned to enhance mix consistency and strength. The findings indicate an improvement in tensile strength and ductility of the concrete when cotton fibers are added.
- Concrete specimens containing cotton exhibited a less brittle failure mode compared to the control samples. Microscopic analysis revealed the formation of calcium hydroxide on the surface of cotton fibers, leading to a stronger bond. Overall, the promising outcomes of this research suggest that utilizing cellulose fibers from waste cotton could pave the way for more sustainable and cost-effective applications in reinforcing traditional concrete structures.
- The research conducted in this study titled "Effect on Strength of Concrete Incorporating Cotton Fiber and Silica Fume" (IJSRD/Vol. 2/Issue 06/2014/027) reveals some interesting findings. Firstly, the addition of 0.4% cotton fiber resulted in an 8% increase in maximum compressive strength compared to normal concrete. Additionally, the flexural strength of the concrete incorporating cotton fiber and silica fume was found to be 10.4% higher than that of normal concrete at 28 days.
- Furthermore, the inclusion of silica fume in the concrete mixture led to a significant improvement in strength. The compressive strength increased by 9% and the flexural strength by 19.5% compared to normal concrete at 28 days.
- It is worth noting that the use of both cotton fiber and silica fume had a marginal effect on the maximum compressive strength at 7 days compared to the strength at 28 days.
- However, when a combination of 0.2% cotton fiber and 9% silica fume was used, there was a 13% increase in maximum compressive strength at 28 days. Similarly, a combination of 0.4% cotton fiber and 6% silica fume resulted in a 15.41% increase in maximum flexural strength at 28 days.
- While the combination of cotton fiber and silica fume did decrease the workability of the concrete, the use of a super plasticizer was able to compensate for this and maintain the desired workability.
- In conclusion, the addition of cotton fiber and silica fume to concrete mixtures can significantly enhance the compressive and flexural strength of the resulting concrete. These findings have important implications for the construction industry and can contribute to the development of stronger and more durable concrete structures.

FUTURE SCOPE

In future research, the authors will focus on the issue of identifying the appropriate input parameters for non-linear numerical analysis.

REFERENCES

- Algin, H.M. and Turgut, P.2008, "Cotton and Lime stone powder wastes as brick material, construction and building materials", 22(8): 1074-1080.
- T. Alomatri, I. M. Low, "Synthesis and characterization Properties in Cotton FiberReinforced Geo-polymer composites", Journal of Asian Ceramic Societies, Vol.1, PP-30-34. (March 2013)
- Lewis, R. C. Hasbi, S. A., Use of Silica Fume Concrete: Selective case studies, Indian Concrete Journal, (Oct.2001)
- Nabil, M. and Al-Akharas. (2005), "Investigation of the effect of metakaolin (MK) replacement of cement on the durability of concrete to sulphate attack".
- Yogendra V, Langan BW, Haque M and Ward MA Silica on High Strength Concrete, ACI Material Journal, No.2, 84(1987)124-129.
- Ramasamy, V.; Biswas,s. “Mechanical properties and durability of rise husk ash concrete” International Journal of Applied Engineering Research December 1, 2008.
- Ghugal, Y. M., (2003), Effect of Steel Fiber on Various Strength of Concrete, Indian Concrete Institute of Journal,4(3),pp.23-29.
- Bhanja S. and Sengupta B. (2005), "Influence of Silica Fume on Tensile Strength of Concrete" Cement and Concrete Research,35,pp.743-747.

- Dinakar P, Babu K G and Manu Santhanam (2008), " Durability properties of high volume fly ash selfcompacting concretes", Cement & concrete composites, Vol.30, pp. 880-886.
- Mohammad Iqbal Khana and rafat Siddiquieb, "Utilization of silica fume in concrete" Review of durability properties" Resources, Conservation and recycling, 2011, 57, 30-35.
- Shannag, M. J., Hussein A. Shaia (2003), "Sulphate resistance of high performance concrete, cement and concrete composites, 25, 363-369.
- Wee, T.H., Suryavanshi A.K., Wong S.F., "Rahman A.K.(2000), Sulphate resistance of concrete containing mineral admixtures", ACI material Journal, 97, 536-549.
- Khadilkar, S.A., and Kulkarni V.R., "Engineered fly ash based blended cement for durable concrete: A review, Indian concrete journal", April 2003, 1009-1021
- Reda, R. M., Mahmoud, H. S. E., Ahmad, S. S. E. & Sallam, H. E. M. Mechanical properties of sustainable concrete comprising various wastes. Sci. Rep. 13, 13234. https://doi.org/10.1038/s41598-023-40392-2 (2023).
- Nematzadeh, M., Karimi, A. & Gholampour, A. Pre- and post-heating behavior of concrete-filled steel tube stub columns containing steel fiber and tire rubber. Structures 27, 2346–2364 (2020).
- Alshaikh, I. M. H., Abadel, A. A. & Alrubaidi, M. Precast RC structures' progressive collapse resistance: Current knowledge and future requirements. Structures 37, 338–352 (2022).
- Hossain, F. M. Z., Shahjalal, M., Islam, K., Tiznobaik, M. & Alam, M. S. Mechanical properties of recycled aggregate concrete containing crumb rubber and polypropylene fiber. Constr. Build. Mater. 225, 983–996 (2019).
- Chakradhara Rao, M., Bhattacharyya, S. K. & Barai, S. V. Behaviour of recycled aggregate concrete under drop weight impact load. Constr. Build. Mater. 25(1), 69–80 (2011).
- Liu, L., Cai, G., Zhang, J., Liu, X. & Liu, K. Evaluation of engineering properties and environmental effect of recycled waste tire-sand/soil in geotechnical engineering: A compressive review. Renew. Sustain. Energy Rev. 126, 109831 (2020).
- Ngo, T. T., Pham, T. M., Hao, H., Chen, W. & Ha, N. S. Proposed new dry and hybrid concrete joints with GFRP bolts and GFRP reinforcement under cyclic loading: Testing and analysis. J. Build. Eng. 49, 104033 (2022).
- Ha, N. S. et al. Effect of grounded blast furnace slag and rice husk ash on performance of ultra-high-performance concrete (UHPC) subjected to impact loading. Constr. Build. Mater. 329, 127213 (2022).
- Sukontasukkul, P., Jamnam, S., Sappakittipakorn, M. & Banthia, N. Preliminary study on bullet resistance of double-layer concrete panel made of rubberized and steel fiber reinforced concrete. Mater. Struct. Constr. 47, 117–127 (2014).
- BS: EN: 934-3:2009:+A1:2012. Admixtures for concrete, mortar and grout Part 3: Admixtures for masonry mortar: Definitions, requirements, conformity and marking and labelling. BSI Stand. Publ. (2012).
- BS EN 12390-3:2019. BS EN 12390-3:2019: Testing Hardened Concrete Compressive Strength of Test Specimens. (British Standard Institution, 2019).
- British Standard. Testing hardened concrete: Part 6: Tensile splitting strength of test specimens. BS EN 12390-62009 (2009).
- British Standards. BS EN 12390-5: Flexural Strength of Test Specimens. (British Standard Institutes, 2009).
- ACI Committee 544. ACI 544.2R-89. Measurement of properties of fiber reinforced concrete (reapproved 1999). Am. Concr. Inst. (1984).
- Charkhtab Moghaddam, S., Madandoust, R., Jamshidi, M. & Nikbin, I. M. Mechanical properties of fly ash-based geopolymer concrete with crumb rubber and steel fiber under ambient and sulfuric acid conditions. Constr. Build. Mater. 281, 122571 (2021).
- Ali, B. & Qureshi, L. A. Influence of glass fibers on mechanical and durability performance of concrete with recycled aggregates. Constr. Build. Mater. 228, 116783 (2019).
- Teng, S., Afroughsabet, V. & Ostertag, C. P. Flexural behavior and durability properties of high performance hybrid-fiber-reinforced concrete. Constr. Build. Mater. 182, 504–515 (2018).
- ASTM C1018-97. Standard Test Method for Flexural Toughness and First-Crack Strength of Fiber-Reinforced Concrete (Using Beam With Third-Point Loading). (American Society for Testing and Materials, 1998).
- Fu, C., Ye, H., Wang, K., Zhu, K. & He, C. Evolution of mechanical properties of steel fiber-reinforced rubberized concrete (FR-RC). Composites B 160, 158–166 (2019).

- Carneiro, J. A., Lima, P. R. L., Leite, M. B. & Toledo Filho, R. D. Compressive stress-strain behavior of steel fiber reinforced-recycled aggregate concrete. Cem. Concr. Compos. https://doi.org/10.1016/j.cemconcomp.2013.11.006 (2014).
- Mo, K. H., Yap, S. P., Alengaram, U. J., Jumaat, M. Z. & Bu, C. H. Impact resistance of hybrid fibre-reinforced oil palm shell concrete. Constr. Build. Mater. https://doi.org/10.1016/j.conbuildmat.2013.10.016 (2014).
- Naraganti, S. R., Pannem, R. M. R. & Putta, J. Impact resistance of hybrid fibre reinforced concrete containing sisal fibres. Ain Shams Eng. J. https://doi.org/10.1016/j.asej.2018.12.004 (2019).
- T. Alomatri, I. M. Low, Synthesis and characterization Properties in Cotton FiberReinforced Geo-polymer composites, Journal of Asian Ceramic Societies, Vol.1, PP-30-34. (March 2013)
- Lewis, R. C. Hasbi, S. A., Use of Silica Fume Concrete: Selective case studies, Indian Concrete Journal, (Oct.2001)
- Aitcin, P.C. and Laplante, P. (1990), Long-term Compressive Strength of Silica Fume Concrete, Journal of Materials in Civil Engineering, Vol.2, No.3, pp 164-170.
- Yogendra V, Langan BW, Haque M and Ward MA Silica on High Strength Concrete, ACI Material Journal, No.2, 84(1987)124-129.
- H.Katkhuda, B, Hanayanch N. Shatarat, Influence of Silica Fume on High Strength Light Weight Concrete, World Academy of Science, Engineering and Technology,58,2009, pp781 to 788.
- Ghugal, Y. M., (2003), Effect of Steel Fiber on Various Strength of Concrete, Indian Concrete Institute of Journal,4(3),pp.23-29.
- Bhanja S. and Sengupta B. (2005), "Influence of Silica Fume on tensile Strength on Tensile Strength of Concrete" Cement and Concrete Research,35,pp.743-747.
- Feldman, R. F., Cheng-yi, H. (1985), "properties of portland cement silica fume pastes. II mechanical properties" cement and concrete research, Vol.15 No.6, pp.943.
- Mohammad Iqbal Khana and rafat Siddiquieb, "Utilization of silica fume in concrete" Review of durability properties. Resources, Conservation and recycling, 2011, 57, 30-35.
- ACI Committee 544 report, (1988), "Design of steel fiber reinforced concrete" ACI Structural Jurnal85, pp 563-580.
- Bhikshma V. Nittukar K. Venkatesham Y. (2009), "Investigation on mechanical properties of high strength silica fume concrete" Asian journal of civil engineering (building & housing) 10(3), pp.335-346.
- Palanisamay T and meenambal T, (2008), "Effect of GGBS and silica fume on mechanical Properties of concrete composites", Indian concrete institute journal, 9(1), pp.07-12.
- Anoopsingh chandel, tanmay shah, tarak shah, Dixit varde a comparative strength study of coir fibre reinforced concrete (CFRC) over plain cement concrete (PCC) e- ISSN:2278- 1684 P-ISSN:2320-334X volume B,ISSUE 2 ver (Mar-Apr-2016)PP 101-103.
- N.Santhoshkumar,P.Bavatharini, M.Gokulapriya, M.Janani;C.Jeeva. Experimental study on concrete using coconut shell and coir fibre By partial replacement method ISSN 2347-3258,volume 6,ISSUE 4(2019) 1-3.
- Neeraj Agarwal; Research on coir fibre reinforced cement concrete e-ISSN:2395- 0056,P-ISSN:2395-0072 volume:5 ISSUE:03 Mar-2018.
- Jagmohanmeena,Dr.Bharatnagar,An experimental study on M-25 grade of a concrete with partial replacement of cement with coconut fibre.ISSN:2454-4116, volume-6, ISSUE-12, December 2020 pages 104-107.
- Baltesanjykuma ,Prof.S.N.Daule use of plastic fibre in the concrete volume 4 ISSUE 11- Nov 2017.
- Hadj Mostafa Sdda, Merdaci Slimane study of concrete reinforced by plastic fibre based on local materials ISSN:1663-4144, volume - 42,pp 100-108.
- Ravikumar.G and Manjunath.M Investigation on waste plastic fibre reinforced concrete using manufactured sand as a fine aggregate.eISSN:2395-0056, P-ISSN:2395-0072 volume.02 ISSUE:04,July-2015.
- A.Ananthi ,A.Jay Tamil Eniyan ,S.Venkatesh utilization of waste plastic as a fibre in a concrete volume 3-ISSUE 1.
- Prasad Karunkaran.R, Jegudha.K.J, Experimental study on behaviour of steel fibre reinforced concrete ISSN 2017.