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Addition of Steel Fiber's in Concrete – A Review

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Abstract – Composite material composed of fine and coarse aggregate bonded together with water cement that hardens over time is called a concrete. Steel fibres will enhance to crack resistance of the concrete, and they can also be used to replace or supplement structural reinforcement. SF's are added in concrete as they are light weight, economical and enhance strength of concrete or reinforced concrete. The review study years mentioned in this paper were from 1991-2023 of how and what amount of steel fibres are needed to be entertained in concrete. Steel fibres are added in concrete alone or sometimes with another material such as marble powder or rice husk etc. in all of the studies it is concluded that using steel fibres up to 30kg with replacement enhances properties of concrete, good flexural behaviour also increase its toughness.

Keywords – Toughness, Reinforced Concrete, Flexural Behavior, Steel Fibers, Composite

I. Introduction

While structural concrete is the most often used building material, steel fibre offers the lowest cost and strength of all the materials. Yet, it has long been practiced to increase the structurally undesirable characteristics of concrete by mixing steel or carbon fibres directly into the concrete mixture as well as chemical or mineral admixtures in Portland & cement. Since concrete is a brittle material, steel fibers considerably increase concrete's stiffness and energy-absorbing capacity This results in more ductile behavior before ultimate failure, less cracking, and increased durability, among other advantages. For instance, steel fiber is used in concrete construction, rock slope stabilization, repair mortar, shell domes, dam building, composite decking, water reclamation, retrofitting, repair & maintenance of various marine constructions, and fire protection coatings. [1]. According to research on the impact of SFs on RC beam fracture, an SF dose of 30–40 kg/m was required to considerably lower cracking. [2]. Paine et al. [3] came to the conclusion that the ideal SF dose was 1-2% by absolute volume in their investigation of the function played by SFs in RC beams. Ganesan & Sivan&a [4] created an equation linking flexural crack width to SF dosage after conducting tests on SFRC beams with SF dosages of 0.5%, 1%, & 1.5%. To examine the impact of SFAC employing SFs with a dosage of 60 kg/m3 on the performance of SFRC beams under two different conditions: (1) static load and (2)
Temperature. According to Swedish norms, Alavizadeh-Farhang [5] carried out an empirical investigation on load beams caused by heat gradients. Using two distinct SF dosages of 60 kg/m3 and 100 kg/m3, Hartmann [6] conducted experiments employing 12 different SFRC beams made of Mixed mix RC-65/35-BN type SFs. They came to the conclusion that, for SFRC beams utilizing a dosage of 60 kg/m3 SF, the measured ultimate load ratio exceeded the theoretical ultimate load. Gopalratnam et al. [7] looked into how dosage, SF composition (dented or smooth), loading rate, and setup design affected the stiffness of the SFARC beam.

The optimal SF dose for SFARC beams should be between 1.5% and 2.5% by absolute volume, according to a study of the pertinent literature. Because it is exceedingly challenging to evenly disperse the fibers throughout the concrete, doses below 1% SF and doses beyond 2.5% also stop working. When compared to plain concrete of the same class, this causes a considerable drop in compressive strength. Both a comprehensive economic analysis of the usage of SFs in RC beam construction as well as a practical recommendation for the ideal SF dose for SFARC beams are not yet available. Because just one type of concrete was used in all prior trials, the effects of SFs on several classes of concrete have not been discussed [4].

II. LITERATURE VIEW

A. Effects of Steel Fibre Addition on Mechanical Properties of Concrete And RC Beams

C20 and C30 classes of concrete are produced each with addition of Dra mix RC-80/0.60-BN type of steel fibres (SFs) at dosages of 0 kg/m3 , 30 kg/m3 , 60 kg/m3 , and their compressive strengths, split tensile strength, moduli of elasticity and toughness's are measured. Nine reinforced concrete (RC) beams of 300 · 300 · 2000 mm outer dimensions, designed as tension failure and all having the same steel reinforcement, having SFs at dosages of 0 kg/m3, 30 kg/m3, 60 kg/m3 with C20 class concrete, and nine other RC beams of the same peculiarities with C30 class concrete again designed as tension failure and all having the same reinforcement are produced and tested under simple bending. The load versus mid-span deflection relationships of all these RC and steel-fibre-added RC (SFARC) beams under simple bending are recorded. First, the mechanical properties of C20 and C30 classes of concrete with no SFs and with SFs at dosages of 30 kg/m3 and 60 kg/m3 are determined in a comparative way. The flexural behaviours and toughness's of RC and SFARC beams for C20 and C30 classes of concrete are also determined in a comparative way. The experimentally determined (mid-section load)–(SFs dosage) and (toughness)–(SFs dosage) relationships are given to reveal the quantitative effects of concrete class and SFs dosage on these crucial properties. [12]

Table 1 Materials Used [12]

Materials	Amount (kg)	
Class of Concrete	C20	C30
Mix water	162	170
Portland cement (≈ASTM Type I)	300	385
Filler (saturated surface-dry, SSD)	386	357
Natural s& (SSD)	472	448
Crushed medium aggregate (SSD)	467	455
Crushed coarse aggregate (SSD)	559	530

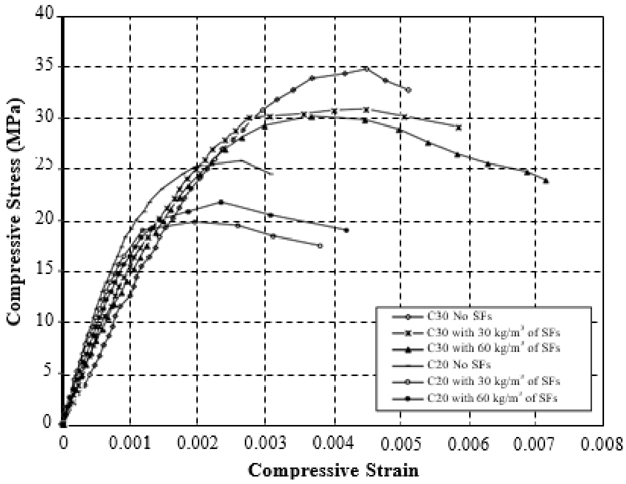

Figure 1 Compressive Stress/Strain Relation [12]

B. Steel Fibre Reinforced Self-Compacting Concrete Incorporating High Volume of Marble Powder

It was observed that it is possible to achieve self-compaction with considerable fibre inclusion. Based on the tests conducted, it can be concluded that the addition of fibres has a slight decreasing effect on the workability of SCC. It is also shown that the main influencing factor on flow ability and workability is the geometry of fibres rather than their percentage. In order to retain high-level workability with fibre reinforcement, the amount of paste in the mix should be increased to provide better dispersion of fibres. Increasing cement content, increasing fine aggregate content or using mineral additions like MP can be alternative solutions to this problem. By increasing fibre content, mode of failure was changed from brittle to ductile failure when subjected to compression and bending. In general, ultrasonic pulse velocities did not seem to be affected by the amount of fibres used in this article. The negligible variation in the ultrasonic pulse velocity test results can be considered as an indication of the uniformity of concrete matrix in all mixes. Another potential benefit in the utilization of MP is the cost saving and preservation of the environment, and this alternative will be investigated through the progress of this experimental program. [13]

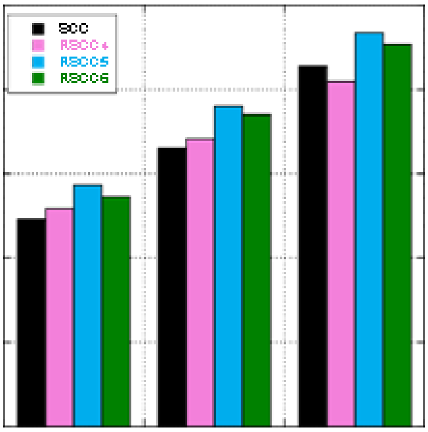

Figure 2 Compressive strength (MPa) with different percentages and length of steel fibers [13]

C. Light weight steel fibre reinforced concrete

Steel fibre reinforced concrete (SFRC) could be a stuff that can decrease brittleness of concrete and can increase the malleability. SFRC is employed extensively to line the tunnels and alternative underground structures, to extend the thickness of pavements, and to repair and strengthen various structures. The study of concrete incorporating different waste fibres has begun to extend in rapid due to economic reasons and positive environmental effects. Among the study reported here, waste steel from steel reinforcement and formworks were mixed with structural light-weight concrete with varied fibre contents, similar results were determined all told the kinds of FRCs studied.

Even small Quantities of Fibres will facilitate In Preventing the Brittle Failure Of light-weight combination Concrete. The influence of steel fibres on the flexural strength of concrete is way bigger than its influence on direct tension or compression. It has additionally been noticed that most gain in strength of concrete is found to depend on the quantity of fibre content. The optimum fibre content to impart most gain in varied strengths varies with style of the quality strengths. With increasing fibre content, mode of failure is modified from brittle to ductile once subjected to compression and bending. The inclusion of steel fibre plays a very vital role in decreasing the brittle failure. From the above study it is also concluded that steel fibres are better than other fibres like glass fibre in improving the mechanical properties. [14]

D. The recent progress of recycled steel fibre reinforced concrete

Environmental issues such as exhaustion of natural resources and generation of enormous amounts of waste and their dumping are currently steering the modern civilization to sustainable construction. Steel fibre reinforced concrete has been in application for many decades because of its capability in arresting crack and introducing ductility to structural concrete. Concerning about natural resources and adverse environmental impact of CO_2 emission during the production of industrial steel fibres at a larger scale, significant research efforts have been made towards sustainable, resource conservative and recycled alternatives to replace these high-cost commercially available steel fibres with recycled steel fibres (RSFs). Recycled steel fibre reinforced cement mixtures behaves differently in fresh and hardened states compared to plain and industrial steel fibre reinforced cement mixtures. This review provides a brief overview of the recycled steel fibres from different sources, their characteristics, and application in the production of various cement-based composites. Effect of RSFs on the different properties of concrete in fresh state including workability, porosity, bulk density, and volumetric stability has been addressed. Detail discussion on the mechanical properties of various cementitious systems has been included, comprising compressive and flexural strength, tensile splitting strength, toughness, resistance to impacts and durability of RSFRC. This study aims to critically examine the currently reported literature and to identify research gaps for those who intend to further study of behaviour of recycled steel fibre reinforced cementitious systems for various applications. [15]

Figure 3 SF added to Concrete

E. Shear Strength of Sand-Lightweight Concrete Deep Beams with Steel Fibres

Six deep beams without transversal reinforcement made of sand-lightweight concrete and six deep beams made of sand-lightweight concrete with 1.0% of steel fibres were tested and compared with conventional concrete deep beams with and without fibres. The shear-span to deep beam height ratio (a/h) was 0.5, 0.8, and 1.0. The cross section heights were 400, 600, and 700 mm (15.7, 23.6, and 27.6 in.). The deep beams were tested to failure under a four-point bending test, using a hydraulic actuator with 500 kN (674 kip) capacity load cell. After testing, it was concluded that the shear-strength values were smaller in larger span deep beams. The presence of steel fibres increased the maximum strength and contributed quantify to the strength to diagonal cracking. The maximum shear load in steel fibre deep beams increased by approximately 16%. The size effect was more significant in sand-lightweight concrete deep beams. Besides, it was proposed a coefficient to validate the cracking strut-and-tie model (CSTM) to evaluate the applicability in deep beams of sand-lightweight concrete with and without steel fibres and the experimental maximum shear predictions are compared according to some codes for sand-lightweight concrete deep beams and by codes and some codes and researchers for sand lightweight concrete deep beams with steel fibres. [16]

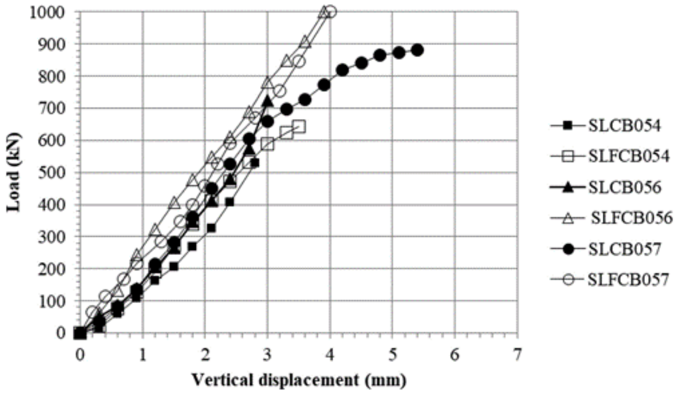

Figure 4 Load versus vertical displacement curves of deep beams with shear-span to overall height ratio of a/h = 0.5 [16]

F. Orientation of steel fibres in concrete attracted by magnetized rebar and its effects on bond behaviour

This study investigates the orientation of steel fibres in concrete attracted by magnetized rebar and its effects on bond behaviour between concrete and rebar. The authors propose a new method to improve the bonding between rebar and concrete by attracting steel fibres closely around the magnetized rebar during the casting of fresh concrete. The study clarifies the effects of fibre types, magnetic strength, and aggregate on the orientation of fibres. The study finds that steel fibres can be gathered and oriented radially around the magnetized rebar. The bond behaviour improved by oriented fibres is more significant than that by non-oriented fibres. The positive effects of steel fibres on bond behaviour mainly come from the mechanical interlocking between the rebar ribs and steel fibres near the rebar. The study performs a pull-out test to investigate the effects of oriented fibres on bond behaviour between rebar and concrete. The study finds that the oriented fibres show more positive effects on bond strength for the case with big size fibres while the non-oriented fibres increase the bond strength more significantly for the case with small size fibres. The study concludes that the new method provides a feasible way to improve the bonding between rebar and concrete without much weakening of fluidity in fresh concrete by adding a few steel fibres. The study uses transparent silicone oil to simulate the fresh concrete for the visual observation of steel fibres orientation by magnetized rebar. [17]

G. Effect of Incorporation of Rice Husk Ash Instead of Cement on the Performance of Steel Fibres Reinforced Concrete

The article discusses the potential use of rice husk ash (RHA) as a substitute for cement in concrete production. Cement is an expensive material and its increasing demand necessitates the use of alternative materials to control construction costs. Agricultural waste such as RHA can be used instead of cement, producing efficient concrete with improved properties. Various studies have been conducted to examine the use of RHA in concrete, with some showing a reduction in compressive strength while others show an increase. Steel fibres can be incorporated in the mix to increase tensile strength and change brittle behaviour to a more ductile response. Nine mixes were designed and tested with varying doses of RHA and the presence or absence of steel fibres. The results show that up to 10% of cement can be replaced with RHA mixed with steel fibres with almost equal compressive strength, but replacing more than 15% of cement with RHA produces concrete with low performance in terms of strength and durability. The yearly worldwide formation of paddy is 0.579 billion tons, and RHA produced during the husk removal cycle is a significant environmental problem that harms the land and the surrounding area where it is unloaded. The use of RHA in concrete production can help mitigate this problem. The main focus of the study mentioned in the text is to examine the influence of different doses of Rice Husk Ash (RHA) on the performance of concrete in the presence and absence of steel fibres. A total of nine mixes have been designed, and tests with 5, 10, 15, and 20% percentages of RHA replacing the concrete have been targeted. The key findings of the study suggest that about 10% of cement may be replaced with Rice Husk Ash mixed in with steel fibres with almost equal compressive strength. However, replacing more than 15% of cement with RHA may produce concrete with low performance in terms of strength and durability. Overall, the study indicates that RHA has potential as a substitute for cement in concrete, but the appropriate dosage must be carefully determined. [18]

H. Machine learning-based prediction for compressive and flexural strengths of steel fibre-reinforced concrete

The article discusses the development of machine learning algorithms for predicting the compressive and flexural strengths of steel fibre-reinforced concrete (SFRC). The use of SFRC is becoming more popular due to its superior performance compared to normal concrete. However, predicting the strength of SFRC is more complex due to its many variables. The study collected compressive and flexural strength data from SFRC and created a database to develop 11 machine learning algorithms. K-fold validation was used to prevent overfitting, and boosting and tree-based models had the best performance. Water-to-cement ratio and silica fume content were found to be the most influential factors in compressive strength prediction, while silica fume and fibre volume fraction strongly influenced flexural strength. The article concludes that machine learning techniques can provide a solution for predicting the strength of SFRC and highlights the importance of data pre-processing and feature selection in building reliable models. [19]

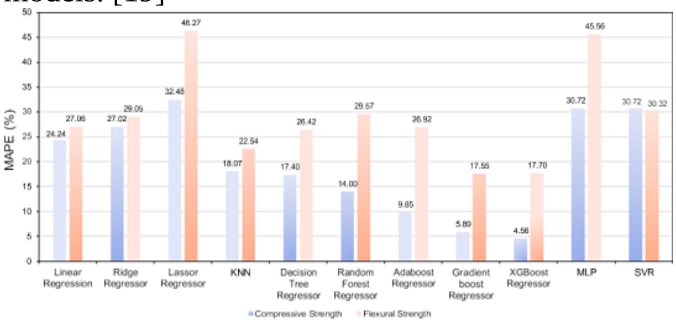

Figure 5: MAPE comparison of prediction models [19]

İ. Inductive method for assessing the amount and orientation of steel fibres in concrete

This paper discusses a non-destructive method to measure the amount and orientation of steel fibres in cubic concrete specimens using an inductive coil sensor. Various destructive and non-destructive methods have been used to determine the fibre content and orientation in fibre-reinforced concrete. However, the presented method provides a systematic control method for SFRC that not only determines the amount of fibres present in concrete but also their orientation. Several prototypes based on inductive methods were created, analysed, and compared for their suitability in measuring the amount and orientation of steel fibres. The method proves to be economic and reliable, making it an important tool to guarantee the quality control of SFRC. The paper also provides information about regulations related to fibre-reinforced concrete and the disadvantages of conventional testing techniques for measuring fibre content. Magnetic methods, including the inductive method presented in this paper, provide a feasible and non-destructive method for quantifying the presence of steel fibres and their possible orientation, which have a decisive influence on the subsequent behaviour of the structure. The paper highlights the importance of non-destructive control systems for SFRC, which can be easily calibrated on smaller samples and avoid uncertainties that tend to exist between small-scale elements and large-scale ones. [20]

III. CONCLUSION

Adding different amounts of steel fibres in the concrete gave different results such as SFs to a dosage of 60 kg/ m3 cause's only small improvements in toughness, so after experimental results and past articles it is concluded clearly that SFs dosage of 30 kg/m3 is better in both compression and flexure strength. Comparatively more studies show a hybrid mix in concrete means Sf's are added with other substance such as marble powder to enhance properties of concrete.

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