An Analytical study of Metal and Synthetic Fiber Reinforcing Regular Concrete

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Abstract: Fibre reinforced concrete (FRC) is the most used structural material in the construction sector. Tensile strength, flexural strength, toughness, and ductility may all be improved in concrete with the use of discrete fiber reinforcement.Fibre reinforced concrete has been used successfully in a wide variety of applications, including but not limited to: tunnel linings, concrete floors, bridge decks, seismic zones, thin and thick repairs, concrete pads and footings, hydraulic structures, precasting, etc. When high performance and durability are essential, FRC is the material of choice.Static and dynamic tensile strengths were increased, and fatigue strength was enhanced; costs were maintained; the material did not rust or corrode; a minimum cover was not required; the aspect ratio was ideal; spraying or putting it required little effort; and the material had a high modulus of elasticity.

Keywords: Fiber Reinforced Concrete (FRC), Alkali Resistant glass fibers

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Introduction

(FRC) was just included to the fib Model Code 2010 [13,14]. You may choose from a huge selection of different fibers. Although steel fibres have been the norm [1,7,8], recent advances in technology have allowed macro-synthetic fibres to significantly increase concrete's hardness [15,16]. Fibres, clinker replacements like fly ash and silica fume, and crystalline admixtures that improve self-healing capabilities all contribute to the durability of cement-based products.

It is common knowledge that adding fibers to concrete decreases the material's workability, which includes its compactability, mobility, and stability. Concrete's mixing, pouring, and compacting might be hampered by the fibres' increased need for water. Because fibers have such a large specific surface area, this occurs. Fibres becoming tangled up while being dispersed might cause an uneven distribution in the concrete matrix. The constructability of the structure and the material's strength and durability will suffer if the FRC used is difficult to put and compress. This highlights the need of doing functional tests on newly manufactured FRC. Workability is affected by factors such as the amount of water, the amount of cement, the qualities of the aggregates, the admixtures, and the kind and number of fibers present.

There have been several investigations on FRC's toughened qualities, but far less focus has been placed on its practical use. In addition, the majority of these investigations have concentrated on steel fibers while just one has looked into macro-synthetic fibers. The slump, Vebe, inverted cone, compacting factor, DIN flow table, and rheometer were only few of the instruments utilized in these studies to determine the key features of the new materials that contribute to their workability. These guidelines were created specifically for the use of plain concrete. The slump test is the gold standard for both PC and FRC, despite its restricted applicability. The slump test is not the best approach to determine if FRC is feasible due to its compactness and ease of placement when subjected to vibration. The Vebe test is preferred over the FRC test under vibration for this reason. Slump testing is more common than the more rigorous Vebe test on construction sites. Contractors should also stay away from the Vebe test since it can only be used with concretes that are low in workability and stiffness. The compacting factor test and the inverted cone test are both useful for evaluating the flowability of concrete, while the DIN flow table is useful for evaluating compaction. In 1933, Graf developed the DIN flow table test for PC, which is now widely used across Germany as a means of determining a material's workability in the field. Finally, rheometers are not often used to determine the rheological properties of concretes, but they are frequently employed to do so for standard and high intensity mortars with fiber addition.

The purpose of this research is to provide fresh insight into the relationship between the raw materials and the final characteristics (such as compressive strength and residual post-cracking behavior under flexure) of FRC blends. Two types of synthetic fibers, one high-stiffness and the other low-stiffness, were combined with either a 0.45% or a 0.50% water-to-cement ratio and a 0%, 0.50%, or 1.00% fibre volume fraction in two distinct base concretes to determine their impacts on the qualities of the fresh concrete.

To make the concrete stronger, steel bars are employed. Concrete's tensile strength may be increased with the use of steel rebars, particularly those having a rough, corrugated surface. Both the tensile and bending strengths of the concrete and the steel rebars, as well as their thermal expansion coefficients, need to be improved. Rebar in columns may have a cross-sectional area of 6%, although only 1% is required for slabs and beams (www.wikipedia.com). The concrete's alkaline makeup forms a passivating coating around the bars, protecting them from rust and corrosion. Under basic or neutral conditions, this passivating layer does not develop. The carbonation and chloride absorption of concrete causes the steel reinforcing bars to rust and break. Over-reinforced concrete fails because its tensile capacity is greater than that of the concrete and steel reinforcements, while under-reinforced concrete fails suddenly and unexpectedly because its tensile capacity is less than that of the concrete and steel reinforcements. This calls for the installation of subsurface steel reinforcing. Certain fibers have been used extensively as building materials from prehistoric times. Bricks' durability was improved by substituting straw with horse hair. In 1911, Porter found out that fiber could be used in concrete. Asbestos fiber was first put to use around the turn of the century. As public concern about asbestos increased in the 1950s, so did studies into fibre reinforced concrete. The seminal study on FRC by Romualdi and Batson was published in 1963. Glass, steel, and polypropylene fiber are just some of the modern additions to concrete. Concrete has a number of drawbacks that make it unsuitable for use as a construction material, including low ductility, low fatigue resistance, high brittleness, and poor impact resistance. Forces of explosion are restricted considerably as well. Reinforcement (or pre-stressing steel) is added to a structural part's tensile zone to make up for the material's brittleness. But this doesn't enhance concrete's primary benefit. It's a strategy for combining elements for maximum effect. The use of many reinforcing elements is still necessary to address the primary issue of insufficient tensile strength in relation to the desired high strength. Concrete also lacks the durability to resist repeated blows, wear, and tear. The rising complexity of its use in pre-cast and pre-fabricated construction parts has raised the relevance of concrete production in meeting demand. The difficulties encountered by structural engineers during testing of concrete might be mitigated with the use of fibers and admixtures. Fibres slow the spread of cracks in the matrix by punching at crack tips as they advance. Because of this, the ultimate breaking strain of the composite is much higher than that of an unreinforced matrix. You may utilize granulated blast furnace slag, metakaolin, granulated blast furnace slag, silica fume, and fly ash in this process. However, mixing may become challenging when fibers and mineral admixtures are added, since fibers have a tendency to clump together and the substance becomes less workable. Hybrid fibre reinforced concrete is made by combining two different types of fibres inside the same matrix. These fibers were selected for this endeavor because to their complementing characteristics. If the first fiber is stiff and robust, then the second fiber may be flexible and ductile. The stress at first break, ultimate strength, and toughness after breaking might all be improved by a combination of these features. If the right kind of fiber is utilized, this hybrid fiber reinforced concrete is effective at bridging both tiny and large fissures. By bridging cracks using the fiber's low modulus, the matrix will be strengthened. Although having too much fiber might have the opposite effect, having insufficient packing of fiber and particles can lead to production problems. Because of this, selecting a high-quality fiber is essential..

Behaviour of Fiber in Concrete

Using fibres, you may improve the permeability of hardened concrete and decrease the bleeding of new concrete. When compared to the contribution of the rebars, the concrete fibers provide a negligible contribution to the flexural strength of the concrete. Most significantly, fiber prevents fractures from propagating and ultimately breaking under pressure. Alkali-resistant glass fiber or synthetic fibers are two examples of non-metallic fibers that could provide chemical resistance. Factors such as the fibre's length, diameter, % in the mixture, mixing conditions, orientation, and aspect ratio all have a role in its ability to provide strength. Aspect ratio, or the proportion of fiber length to fiber diameter, is an important parameter to consider when reinforcing anything.

Types of Fiber

Asbestos Fiber

This mineral fiber occurs in nature. Asbestos fibers are very resistant to many common types of corrosion. There is a lack of tensile strength. That's why it became so widespread in the second part of the nineteenth century. Asbestos is composed of six different types of naturally occurring silicates. Initial applications included curing electrical insulation on hot plates in commercial and institutional settings. Asbestos fiber has a high water absorption rate, increasing the quantity of water needed in cement. Asbestos was extensively utilized in building construction prior to the discovery of its carcinogenicity.

Carbon Fiber

Carbon fiber is very malleable and strong under tension. When poly-acronitrile comes into contact with oxygen, it begins to produce fibers. Carbon fibers are produced by thermal pyrolysis, which occurs after oxidation. They have high tensile and elastic strengths. This fiber is used to make airplane rudders.

Aramid Fiber

This was made using synthetic fibers. That, right there, is aromatic polyamide. Aramid fiber is a potential reinforcing material. Amines and carboxylic acid halides react to form these chemicals. Technora, Kevlar, and Nomex are all brand names for this kind of fiber. Due to its remarkable strength-to-weight ratio, Kevlar was first employed as a composite material in airplane construction. These fibers are very robust because the molecular chains that compose them are aligned along the fiber's axis. DuPont was a forerunner in the industry. They served as excellent substitutes for asbestos.

Metallic Fibers

Their production requires a high-pressure deposit onto a polyster film after the metal has been vaporized at a high temperature. Nylon yarn that has been aluminized is often used to make metal thread. Metallic fiber combines the properties of plastic and metal. You can make them out of steel wool too. Two common kinds of metal fibers are carbon steel and stainless steel.

Polypropylene, Polyethylene, Nylon Fiber

The ability to withstand both acidic and alkaline conditions is remarkable. One kind of polyolefin is polypropylene. Polypropylene film fibers may easily attach to and integrate with the matrix's fibrils, giving them superior impact resistance. The tensile strength of nylon and polypropylene ranges from 561.0 to 867.0N/mm2. Their ability to absorb energy is greatly enhanced by the dramatic extension (by 15% to 25%) they undergo. This fibre's low modulus is to blame for its subpar strength. They are used as flotation units, fracture inhibitors in gunite, cladding panels, and pile shells. Due to its lower size (thinner sections are created) and better fracture strength, plastic fibre is an ideal steel reinforcing choice for precast components. This translates to reduced material, shipping, and erection costs.

The Properties of Common Fibers .Table 1 shows the typical properties of various Fibers

Table 1: Typical Properties of Fibers (ACI 544.1R)

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Type of Fiber	Tensile Strength (MPa)	Young's Modulus (Gpa)	Ultimate Elongation %	Specific Gravity
Acrylic	210-420	2.1	25-45	1.1
Asbestos	560-980	84-140	0.6	3.2
Carbon	1800-2600	230-380	0.5	1.9
Glass	1050-3850	70	1.5-3.5	2.5
Nylon	770-840	4.2	16-20	1.1
Polyester	735-875	8.4	11-13	1.4
Polyethylene	700	0.14-0.42	10	0.9
Polypropylene	560-770	3.5	25	0.9
Rayon	420-630	7	10-25	1.5
Rock Wool	490-770	70-119	0.6	2.7
Steel	280-2800	203	0.5-3.5	7.8

Literature Review

Joshua Daniel et al. (2017) M30 grade concrete was used to test the strength and flexural capabilities of a geo-polymer concrete (GPC) made from GGBS and reinforced with steel and glass fibers. For this study, we maintained a GPC mixture of 50% Na2Sio3, 50% NaOH, and 25% SF/AL. Because it improved the compressive and split tensile strength of GPC, a blend of 90% steel fibre and 10% glass fibre was chosen as the ideal substitute of hybrid fibres for the tests related to flexural properties. 1200 long beam samples of type A and type A1 with longitudinal and transverse reinforcement were made out of both regular concrete and geo-polymer concrete. This study compares the yield and ultimate load-deflection behaviors of beam specimens and concludes that Type A specimens are superior than Type A1 specimens. The stiffness degradation and displacement ductility of Type A1 specimens is lower and higher, respectively, by 4%. The overall performance of GPC and CC after yield is similar, and the energy dissipation capacity of GPC is 11% greater than that of Type A specimens.

Malgorzata Pajak et al (2016) Compressive and flexural properties of Hybrid Fibre Reinforced Self-Consolidating Concrete (HyFRC SCC) have been investigated, with a focus on the interaction between steel and polypropylene fibres. The required improvements in attributes could not be attained when the volume percentage of fibers in this SCC composite was raised to more than 1.4%.The matrix reinforced with polypropylene fibers at a 7 percent concentration saw the largest decrease in compressive strength.

Aminuddin Jameran et al. (2015) conducted experimental evaluation of steel-propylene hybrid FRC's high-temperature performance. The steel-to-propylene ratio was changed from 0% to 100%, and the test specimens were heated to 27, 200, and 400 degrees Celsius. The concrete's cube strength dropped significantly around 400 degrees Celsius. Compressive strength varied from 1% to 20% over the tested concrete. Prism specimens' flexural strength is diminished when exposed to high temperatures; however, increasing the quantity of propylene fibre in the hybrid combination has only a negligible effect. The split tensile strength of cylindrical specimens increased following fiber addition, however this strength drastically decreased when more propylene fibers were added to the composites at any of the evaluated temperatures.

Khin Soe et al. (2013) Specifically, we look at the mechanical properties of a recently developed category of hybrid fiber-reinforced engineered cementitious composites. The two ECC mixes used in this experiment were ECC_M1 (1.5PVA+0.5SE) and ECC_M2 (1.75PVA+0.58SE). Steel (SE) and polyvinyl alcohol (PVA) fibers were combined to meet effective strength requirements and improve strain hardening capabilities. This new ECC material's workability was enhanced by the addition of a high range super plasticizer. Compressive strength of 50 mm cube specimens made from both ECC mixes was quite similar. Researchers discovered that the lack of coarse aggregate in ECC mixes resulted in somewhat lower Young's modulus values than those of normal concrete. Under flexural stress, ECC_M2 beam specimens also demonstrated better durability and load bearing capabilities. According to the results of the uniaxial strain test, the first fracture and ultimate strain capacity of ECC_M2 were greater than those of ECC_M1.The fracture zones of both ECC matrices were uniformly distributed with fibers, facilitating effective bridging.

Hybrid Fiber Reinforced Concrete

When two different kinds of fibers are combined in the same matrix, we get hybrid fiber reinforced concrete. The fibers were chosen because of the complementary qualities they have. That instance, if the first fiber is rigid and strong, we may go with a second fiber that is both pliable and ductile. We may be able to improve the stress at first break, the strength at the end of the material, and the toughness after cracking by combining these attributes. This Hybrid fibre reinforced concrete is particularly successful in bridging both micro- and macro-cracks, provided that the appropriate fibre is used in the bridging process. Because of the fiber's low modulus, it may be used to bridge fractures, making the matrix stronger. However, there is a possibility that too much fiber is harmful since it leads to production flaws because of improper packing of fiber and particles. Because of this, picking the fiber requires careful consideration.

Steel Metal Fibers

The primary plant produces "Dramix steel fibres" in Bakaert, Belgium. When it comes to strength, safety, and affordability, nothing beats the steel reinforcement supplied by steel fibers. Low carbon steel fibers with hooks at both ends were used in this research. These fibers are either highly reflective or galvanized, and they are very strong and flexible. The aspect ratios (L/d) of 80 and 55 are used to cast the test specimens. Figure 1(a) and Table 3 both depict the steel fibers that were used in this investigation.Table 2 details the steel fiber parameters used in this study.

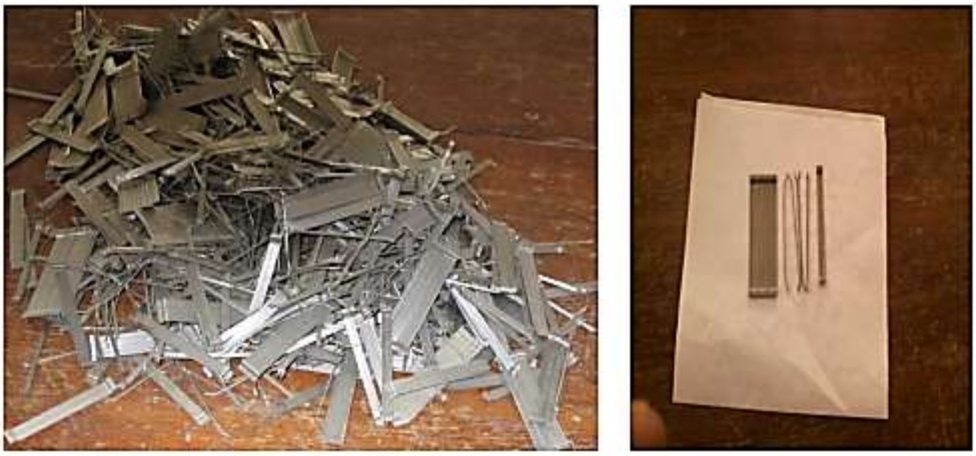

Figure 1(a) Steel fiber of aspect ratio 80

Energy absorption capacity values

Table 2 shows the results of split tensile stress tests performed on cylindrical specimens to evaluate the energy-absorbing potential. Calculations of load-deformation curves are performed on control concrete, single FRC, and Hybrid FRC. Diametric split tension is used to assess absorption capacity, which is then utilized to provide a hardness grade. Toughness estimations were obtained up to a distortion of 0.4 mm for each of the four groups and are shown in Table 1 below.

Table 2 Energy absorption capacity under split tension

Mixture Group	Mix Series	Fiber volume fraction % Vf		Energy absorption capacity(up to 0.4mm deformation) in kN-mm
		Steel	Polyester	
Control Concrete	CC	--	--	3.566
Steel fiber reinforced concrete	MS0.3	0.30	--	98.605
	MS0.5	0.50	--	122.755
	MS0.75	0.75	--	129.565
Polyester fiber reinforced concrete	MP0.5	--	0.50	78.901
	MP1.0	--	1.00	89.851
	MP2.0	--	2.00	103.376
Hybrid fiber reinforced concrete	HF1	0.50	1.00	145.638
	HF2	0.50	0.50	135.612
	HF3	0.50	2.00	131.789
	HF4	0.75	1.00	159.078

Conclusion

The experiments show that adding steel fibers to normal concrete significantly improves its quality. When used for reinforcement, polyester fibers also reduce the material's ability to withstand impacts. This steel-polyester hybrid fibre reinforced concrete may be used in a variety of applications, including concrete pavement, industrial slabs, overlays, the precast concrete industry, and structural rehabilitation projects. It was also discovered that the qualities of the hybrid material were either similar to or superior to those of regular concrete.

References

1. Joshua Daniel, A, Sivakamasundari, S & Abhilash, D 2017, Comparative Study on the Behaviour of Geopolymer Concrete with Hybrid Fibers under Static Cyclic Loading Procedia Engineering, vol. 173, pp. 417-423.
2. Malgorzata Pajak 2016, 'Investigation On Flexural Properties of Hybrid Fiber Reinforced Self-Compacting Concrete', Procedia Engineering, vol. 161, pp. 121-126
3. Aminuddin Jamerana, Izni Ibrahim, S, Siti Hamizah Yazana, S & Siti Nor Rahim, AA 2015, 'Mechanical properties of steel-polypropylene fiber reinforced concrete under elevated temperature', Procedia Engineering, vol. 125, pp. 818-824
4. Jodilson Amorim Carnerio, Paulo Roberto Lopes Lima, Monica Bastista Leite & Romildo Dias Toledo Filho 2014, 'Compressive stress-strain behaviour of steel fiber

reinforced recycled aggregate concrete, Cement and Concrete Composites, vol. 46, pp. 65-72.

5. Khin Soe, T, Zhang, YX & Zhang, LC 2013, ‘Material properties of new hybrid fiber reinforced engineered cementitious composites’, Construction Building Materials, vol. 43, pp. 399 -407
6. Ahmet Raif Boga, Murat Öztürk & Ilker Bekir Topçu, 2013, ‘Using ANN and ANFIS to predict the mechanical and chloride permeability properties of concrete containing GGBFS and CNI’, Composites, vol. 45, pp. 688-696.
7. Bingol, AF, Tortum, A & Gül, R 2013, ‘Neural networks analysis of compressive strength of lightweight concrete after high temperatures’, Materials and Design, vol. 52, pp. 258-264
8. Rajarajeshwari, V, Radha, K & Aravind, N 2013, ‘Mechanical properties of hybrid fiber reinforced concrete for pavements’, Int. J. Res. Eng. Technol. pp. 244-247
9. Shaikh, FUA 2013, ‘Review of mechanical properties of short fiber reinforced geopolymer composites’, Construction Building Materials, vol. 43, pp. 37-49
10. Nia, AA, Hedayatian, M, Nili, M & Sabet, VA 2012, ‘An experimental and numerical study on how steel and polypropylene fibers affect the impact resistance of fiber-reinforced concrete’, Int. J. Impact Eng., vol. 31, no. 46, pp. 62-73.
11. Patel, PA, Desai, AK, Desai, JA, Bayasi, Z & Zeng, J 2012, ‘Evaluation of engineering properties for polypropylene fiber reinforced concrete’, Int. J. Adv. Eng. Technol, vol. 3, no. 1, pp. 42-45
12. Pu Wang, Zhen Huang, Jing Jiang & Yongjun Wu 2012, ‘Performances of Hybrid Fiber Reinforced Concrete with Steel Fibers and Polypropylene Fibers’, Civil Engineering and Urban Planning, ASCE , pp. 458-461
13. Xu, Z, Hao, H & Li, HN 2012, ‘Dynamic tensile behaviour of fiber reinforced concrete with spiral fibers’, Materials and Design, vol. 42, pp. 72-88.
14. Meda, A, Minelli, F & Plizzari, GA 2012, ‘Flexural behaviour of RC beams in fiberreinforced concrete’, Composites. Part B, vol. 43, pp. 2930-2937.
15. Atici, U 2011, ‘Prediction of the strength of mineral admixture concrete using multivariable regression analysis and an artificial neural network’, Expert Systems with Applications, vol. 38, pp. 9609-9618
16. Eethar Thanon Dawooda & Mahyuddin Ramli 2011, ‘Contribution of Hybrid Fibers on The Hybrid Fibers on the Properties of High Strength Concrete Having High workability’, Procedia Engineering, vol. 14, pp. 814-820
17. Nicolas Ali Libre, Mohammad Shekarchi, Mehrdad Mahoutian & Parviz Soroushian, 2011, ‘Mechanical properties of hybrid fiber reinforced lightweight aggregate concrete made with natural pumice ’, Construction and Building Materials , vol. 25, pp. 2458-2464
18. Rafat Siddique, Paratibha Aggarwal & Yogesh Aggarwal 2011, ‘Prediction of compressive strength of self-compacting concrete containing bottom ash using artificial neural networks’, Advances in Engineering Software, vol. 42, pp. 780-786