Effect of Waste Steel Binding Wires on Strength of Concrete

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Abstract: Today many different types of materials are used determining the most economical and suitable material as fibre that can provide in such fortification chemically and mechanically. This research is emphasised on the study of waste industrial steel binding wires to reinforce the concrete. This study analyse the various types of percentage of steel wires mixed with reinforced cement concrete which improve the strength of concrete in comparison with designed concrete. This research is set to be carried out the crushing strength of concrete and the optimum range of steel binding wires to fortify and enhance concrete compressive strength. The percentage of steel binding wires are used as 0%, 1%, 1.5% and 2% content by weight and tested in 7, 14 and 28 days. The results validate the previous research that the optimum range of steel fibre percentage lies between 0.5 % -1% by weight. The research also proves that the workability of concrete decreases as the percentage of steel wires increases.

Keywords: Environment, Fiber reinforced concrete, Waste steel wire, Slump test.

1. Introduction

The concrete is one of the base elements in construction work in Civil Engineering. It is defined as a blend of mixture of sand, cement, and aggregate that produces different quality and grade of concrete with respect to the mixture quality used. It's characterized by brittle failure, the almost complete loss of stacking limit also called loading capacity due to tensile and compression strength to overcome this issue, long studies were made on using fiber to enhance the strength and reinforce the concrete for intended usages. The use of small amount of short randomly distributed fibers (like steel, glass, engineered synthetic and natural fibers) in concrete can be drilled among others that cure and fixes issues of concrete, for example low growth resistance, high shrinkage, cracking, low durability, etc. The idea of using fibres to strengthen concretes weak in tension is over 4500 years old. Portland cement concrete began to be used widely as a construction material attempts were made to use fibres for overcoming cracks. Engineers had to beat the key deficiencies of concrete, which were the low tensile strength and the high brittleness. The employment of continuous steel reinforcing bars within the tensile zone of concrete un-doubtfully helped to beat the matter of low tensile strength of concrete. However, the concept of using discontinuous fibres within the concrete was always a challenge. Since early 1960's there has been associate enhanced interest in fibre reinforced concrete (F.R.C.).This era is that the turning point for the event of F.R.C. However, additional new applications were known a good vary of fibres was introduced which includes: steel fibres, glass fibres, carbon fibres, natural organic fibres, polypropylene fibres etc. Steel Fiber Reinforced Concrete (S.F.R.C.) has the ability of excellent tensile strength, flexural strength, shock resistance, fatigue resistance, ductility and crack arrest.

The M.C. Nataraja et al. (1999) have proposed a condition to evaluate the impact of fiber on compressive quality of cement regarding fiber fortifying or reinforcement parameter. Similarly, Song P.S. et al. (2004), have stamped weakness with low elasticity and strain limits of high-quality cement can be overcome by expansion of steel strands. They made an exploratory examination were steel fibers included at the volume of 0.5%, 1.0%, 1.5% and 2.0%. The observation indicates that compressive strength of fiber concrete reached a maximum at 1.5% volume fraction, being 15.3% improvement over the H.S.C. The split tensile and Flexural Strength improved 98.3% and 126.6% at 2.0% volume fraction.

Targum Gehlot (2017), found that the strength of the steel fibre reinforced concrete depends largely on the quantity of fibres added to it. The increase in the volume of fibres, increase approximately linearly.[1] Use of higher percentage of fibre is likely to cause segregation and hardness of concrete and mortar and also the workability of concrete is greatly reduced. The 7 and 28 days compressive strength of the concrete increases linearly with the increase in amount of steel added to it, but to a maximum of 1% steel fibre inclusion. After that the compressive strength decreases. So the optimum percentage of steel fibre inclusion is 1% by volume of the concrete mix".

Ashish Shukla (2020) performed experiment with M20 grade concrete with marble dust in 0%, 5%, 10%, 15% and 20% in proportion along with ratios of steel wires were used and tested for 7 and 28 days on mechanical parameters. The marble dust was partially replaced with cement, which makes it clear that marble dust can be used to reduce cement consumption. 15 percent ratio, the test results start to decrease. It is concluded that the use of marble waste dust is a very good way to reduce the consumption of cement and also the waste steel fiber from the industry is mixed with concrete so that the environment is also balanced, the soil does not deteriorate. And the construction sector also gets a new component

In addition, Maryam et al. (2020) conducted an experiment based on the use of wastes electrical connections wires and galvanized binding wires in mix proportion. The water cement ratio was (0.39), and 2% by weight of cement of superplasticizer was used to obtain a plain mortar with good workability. The fiber ratio used in this study were 0%, 0.5%, 0.75%, 1.0%, 1.5%, 2. 0% for mono CE and GB fibers and for the combination of both fibers. The combinations of the two types of fiber used are (C.E.: G.B.) in (50%:50%), (30%: 70%) and (70%: 30%). Twenty six mixes for mono and hybrid fibers were used, all mix symbols are identified in Table 4". It is found in the experiment that the (C.E.) fibers are the most effective in increasing the compressive strength value in all volume addition of fibers. Moreover, it is generally noticed that as the fiber percentages increases, the compressive strength increases till a ratio of 1.5%. On the other hand, the G.B. fibers mixes exhibit a slight improvement in compressive strength with a percentage range between 2% to 9%. The optimum percentage of (G.B.) fibers is 1%. As for mixes with hybrid fibers, the improvement in compressive strength value ranges between 5 to 20 %. The 50% CE to 50% GB combination of these fibers at 1.5 % volume fraction ratios yields the higher increase."

Waqas et al. (2014) performed an experiment, In their research locally available coarse and fine aggregates were used. Coarse aggregate used was ¾ inch down, with the fineness modulus of 2.77, fine aggregate (sand) having fineness modulus 2.68 along with the Ordinary Portland cement were the main ingredients of both mixes with and without steel fibers. The result found that in case of fiber reinforced concrete cylinders the compressive strength was improved as compared to the normal concrete. Compressive strength increase from 2% to 6% with the addition of steel fibers. Tensile strength of concrete beams increase from 7% to 49% with the addition of steel fibers in the concrete mix from 0% to 1%. A strong mechanical interlocking force in fiber reinforced concrete cylinders was observed because of steel fibers which held the matrix stronger, and concrete remained intact even after failure loading, whereas the control sample without steel fibers after failure split into large concrete pieces. Similar behaviour was observed in case of tensile strength, samples without fibers were split into two portions but beams having steel fibers remain intact due to strong interlocking force between steel fibers and concrete matrix. Steel binding wires showed enormous effect especially in tensile testing as Steel fibers and are also cost effective.

Furthermore, a research (Jacek et al.2018; Kamran et al. 2014; Dahake 2016; Milind 2012; Yuanxun et al. 2018; P.S. Song et al. 2004) has been done in terms of comparing between engineered and waste steel fiber used as reinforcement for concrete.

2. Materials and Method

The experiment was performed in the laboratory using Ordinary Portland Cement (O.P.C.) ASTM type I class strength of 42.5 with crushed size of aggregates maximum of 20 mm, fine aggregates, cut steel binding wires into stripes of 2 inch (50.8mm) with diameter approximately ±1mm (Figure 1).

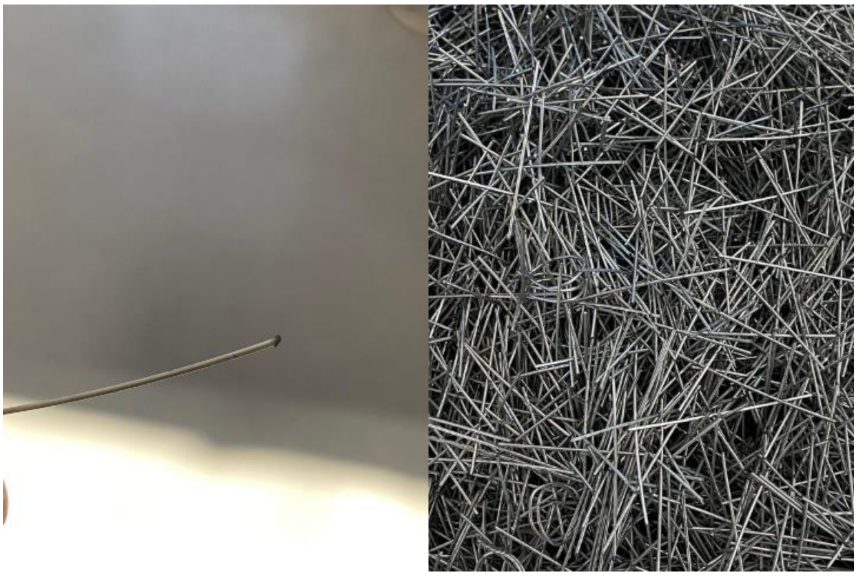

Figure 1 The 2-inch cut steel binding wire used in the concrete

2.1 Design Mixture

Design of experiments (D.O.E.) method is used in this project consisting eight fundamentals and data followed according to the British standards for material and testing. The quantities for all ingredients for the mix of this project are calculated by the British standards (B.S.) 8500 with some modifications.

2.1.1 Design stipulations for proportioning

The details of the mix design are given below in the Table1 and Table.

Table 1 Mix Design Parameters for the concrete

Concrete grade:	C30
Free water cement Ratio:	0.5
Cement type:	ASTM TYPE I OPC
Type of coarse aggregate:	Crushed
Slump:	10 – 30 mm
Maximum aggregate size:	20 mm

Table 2 Finalized proportion and concrete mixture design

Materials	Quantity (Kg/m^3)
Water	190
Cement	380
Fine Aggregate	575
Coarse Aggregate	1300
Total content mixture	2445

2.3 Waste steel fibre proportion in various percentage.

In the mix design, the proportion of the waste steel fibres with their percentage like 1%,1.5%, and 2% are given below in Table 3

2.3.1 Final mix for each percentage of fiber

1.Cube dimension: 0.15m x 0.15m x 0.15m

2.Type of sample: 6 cubes volume = 6 x 0.15 x 0.15 x 0.15= 0.0203 m^3

3. Add 10% for waste: 0.0203 + (0.1*0.0203) = 0.0223 m^3

4. Total mix weight = 54.46 kg

Note: Proportion of fiber content is based on weight content * percentage of fiber

Table 3 Final mix for each fibre percentage

Ingredients / Fiber %	0%	1%	1.5%	2%
Cement (Kg)	8.47	8.47	8.47	8.47
Fine Aggregate (Kg)	12.8	12.8	12.8	12.8
Coarse Aggregate (Kg)	28.99	28.99	28.99	28.99
Water (Kg)	4.2	4.2	4.2	4.2
Fiber content (Kg)	0.00	0.545	0.817	1.089

2.4 Testing Method

After preparation of mix design (standard C30 final trial) proportion were set for 6 cubes total of 24 cubes within 4 samples of 0%, 1%, 1.5% and 2% by fraction of total weight of concrete and test for slump and compressive strength development only.

2.4.1 Slump Test

The slump test was also conducted to check the workability of the concrete in response of the various percentages of the steel. The test is proceeded using a steel cone of 12 inches (30 cm) in hight and diameter of the base opening is 8 inches (20 cm) and the top opening is 4 inches (10 cm). The cone is filled with fresh concrete in three layers, each time, each layer is tamped 25 times with a steel rod (usually 24" long and has a diameter of 5/8" diameter) (Figure 2).

Figure 2 Tampering of concrete with slump test performed during the concrete casting.

3. Results and Discussions

3.1 Slump test results

The results show as the percentage of steel fiber (i.e., 1%, 1.5% and 2%) increases the workability reduces. The zero percentage of steel fiber shows slump test reading as 20 cm while with 1% of steel gives 19 cm and 1.5 % results in 18 cm and 2 % of steel gives as the lowest 17 cm which mean low workability (Figure 3).

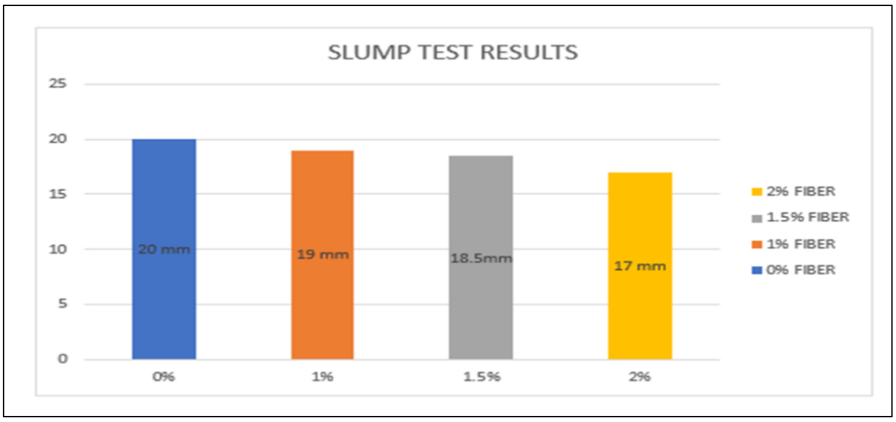

Figure 3 Slump test results for the various percentage of waste steel fiber.

3.2 Crushing results of 7, 14 and 28-days curing concrete

After casting the cubes in standard dimension of 150 mm X 150 mm X 150 mm moulds, curing process divided into 3 groups of inspection which are 7, 14 and 28 days. After that it is tested using the crushing machine in concrete laboratory (Figure 4).

Figure 4 Crushing machine in the concrete laboratory.

Table 4 shows the results of the crushing test where it is found that as the curing days increases the strength of the concrete increases. It is also observed that as the percentage of steel increases between 1% to 2%. The 1% steel fiber with 7, 14 and 28-days curing shows the best result between all type of combination of percentage of steel with different curing days.

Table 4 Final crushing results for all samples for 7, 14 and 28-days curing

Fiber content	Days	Samples	Loads (kn)	Loads (n/mm²)	Average (n/mm²)
0%	7	Sample 1	592.9	26	25.92
		Sample 2	581.4	25.84	
0%	14	Sample 1	610.3	27.12	28.18
		Sample 2	658.0	29.24	
0%	28	Sample 1	667.9	29.68	32.04
		Sample 2	774	34.4	
1%	7	Sample 1	714.3	31	33.5
		Sample 2	825.9	36	
1%	14	Sample 1	984.9	43.77	38.83
		Sample 2	762.4	33.88	
1%	28	Sample 1	884.2	39.297	38.884
		Sample 2	865.6	38.47	
1.5%	7	Sample 1	580.2	25.79	27.52
		Sample 2	658.0	29.24	
1.5%	14	Sample 1	831.9	36.97	36.69
		Sample 2	818.9	36.4	
1.5%	28	Sample 1	745.6	33.14	32.575
		Sample 2	720.3	32.01	
2%	7	Sample 1	698.6	31.05	32.14
		Sample 2	747.5	33.22	
2%	14	Sample 1	769.3	34.19	30.165
		Sample 2	588.2	26.14	
2%	28	Sample 1	962.2	42.76	37.563
		Sample 2	728.3	32.369	

Figure 5 depicts the results distinctly for all the tested samples for the project. Where blue colour shows the 0 % steel wires, orange 1%, grey 1.5% and yellow shows the 2% of the steel wire for 7, 14 and 28 days.

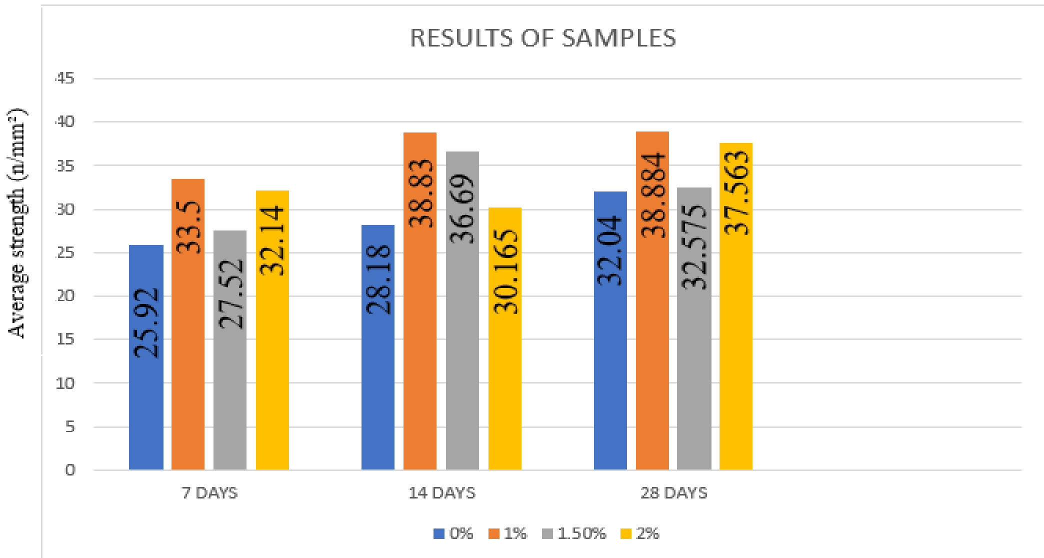

Figure 5 Comparison of the results of all the samples with 1%,1.5% and 2% percentage of steel fibers with 7, 14 and 28 days.

3.3 Percentage change in the strength after 28 days

The percentage change = (Final value - Initial value) / (Initial value) x 100

Positive sign indicates the increase in the strength of concrete while the negative sign indicates the decrease in the strength. Table 5 and Figure 6 shows the percentage changes occurred in the strength after 28 days.

Table 5 increase of strength per average results after 28 days

Fiber content % by weight	Average compressive strength (N/mm^2)	% Increase and decrease in compressive strength
0%	32.04	-
1%	38.884	+ 21%
1.5%	32.575	- 16%
2%	37.563	+ 15.31

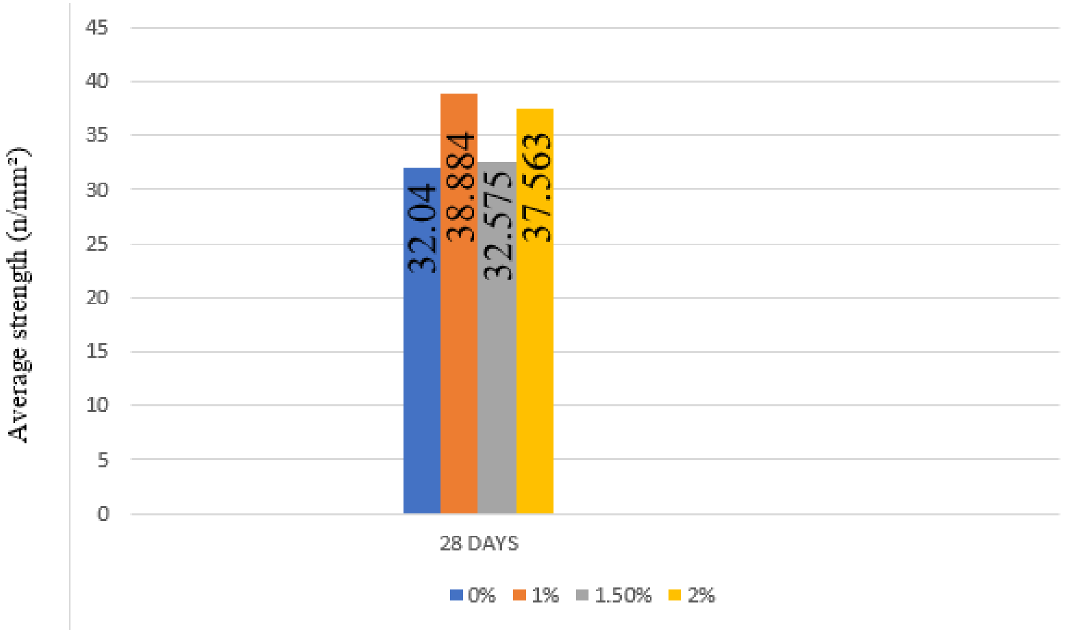

Figure 2 The comparison of the percentage change of strength after 28 days.

4. Conclusions

1. According to the results it proves that 1 % of steel fibre in the concrete by its weight is the sufficient steel wire percentage to gain the maximum strength in the concrete than any other percentage of steel. Fluctuations in strength value started to occur after the 1 % of steel fibre hence the research can be done between 0.5% to 1% of steel fibre to gain the maximum strength.

2. The concrete is normally subjected to cracking in different conditions with respect to an extent of factors from the material quality used for mixture to the proportioning variations with the various specified used materials and percentage used in the mix.

3. The materials used for the tests may increase and reduce the strength of the reinforced concrete with respect to proportioning of the mix designed.

References:

1) Ashish Shukla, Nakul Gupta, Kamal Kishore (2020), Experimental investigation on the effect of steel fiber embedded in marble dust based concrete, Materials Today: Proceedings 26 DOI: 10.1016/j.matpr.2020.02.607.
2) Dahake Ajay. (2016). Effect of Steel Fibers on Strength of Concrete. Journal of Engineering, science and Management Education. 9. 45-51.
3) Jacek Domski, Jacek Katzer, Mateusz Zakrzewski, Tomasz Ponikiewski, (2017), Comparison of the mechanical characteristics of engineered and waste steel fiber used as reinforcement for concrete, Journal of Cleaner Production 158, 18-28.
4) Kamran Aghaee, Mohammad Ali Yazdi, (2014), Waste Steel Wires Modified Structural Lightweight Concrete, Materials Research 17(4):958-966, DOI: 10.1590/1516-1439.257413.
5) M.C. Nataraja, N. Dhang, A.P. Gupta (1999), Stress–strain curves for steel-fiber reinforced concrete under compression, Cement and Concrete Composites, Volume 21, Issues 5–6,pages 383-390, ISSN 0958-9465.
6) Milind V. Mohod, (2012), Performance of Steel Fiber Reinforced Concrete, International Journal of Engineering and Science ISSN: 2278-4721, Vol. 1, Issue 12, PP 01-04.
7) Song P.S., S Hwang, (2004), Mechanical properties of high-strength steel fiber-reinforced concrete, Construction and Building Materials, Volume 18, Issue 9, Pages 669-673, ISSN 0950-0618.
8) Targum Gehlot ,Divanshu Seervi , Peeyush Chowdhary, (2017), Study of the Compressive Strength Behaviour of Steel Fibre Reinforced Concrete Using Various Percentage of Steel Fibre. International Journal of Advanced Research, 5(7):1940-1950, DOI: 10.21474/IJAR01/4925
9) Waqas Arshad Tanoli, Amjad Naseer, Fazli Wahab (2014), Effect of Steel Fibers on Compressive and Tensile Strength of Concrete, International Journal of Advanced Structures and Geotechnical Engineering ISSN 2319-5347, Vol. 03, No. 04, October 2014.
10) Yuanxun Zheng, Xiaolong Wu, Guangxian He, Qingfang Shang, Jianguo Xu, and Yikai Sun, (2018), Mechanical Properties of Steel Fiber-Reinforced Concrete by Vibratory Mixing Technology, Fiber Reinforced Concrete with Application in Civil Engineering.Volume 2018 |Article ID 9025715 | https://doi.org/10.1155/2018/9025715.