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Compressive Strength of Micro Steel Fiber Concrete

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Abstract: This study investigated the compressive strength of micro steel fiber concrete (MSFC). To this end, the different micro steel fibre content (0.5%, 0.75%, 1.0% and 1.25%) were used. This study aims to determine the compressive strength behavior in concrete and the optimum micro steel fiber to be used. The slump test and compression test were conducted. The slump test 30 mm to 60 mm resulted that the workability of the specified concrete mix is accepted. From the analysis, the highest compressive strength of 74.5% MPa was obtained on concrete specimens which contain 1,25% MSF(SF1.25) at the aged curing of 28 days. Generally, as the percentage of MSF increases, the compressive strength will increase meanwhile reduce the workability of concrete. The optimum percentage for the MSF was 1.25% (SF1.25). In conclusion, the presence of MSF in concrete can increase the value for compressive strength for MSFC.

Keywords: Micro Steel Fiber Concrete (MSFC), Compressive Strength, Superplasticizer (Sp.)

1. Introduction

Micro steel fiber concrete (MSFC) behavior is governed by mix-design, where it plays a fundamental aspect. The correct and optimum constitutive has to properly design the better MSFC. Since the last decade, researchers have been studying the mechanical qualities of concrete strength, particularly when it comes to adding fiber materials with concrete. The characteristics of plain concrete, such as poor tensile strength, low crack resistance, and classification as brittle material [1], have prompted researchers to conduct various studies in order to improve the concrete's characteristics. The mechanical behavior of concrete is usually determined by the aggregate characteristics and the amount of additive mixture present in part. The addition of steel fiber to the concrete mixture will alter the final

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composite behavior, particularly during the cracking phase. Steel fiber was presented as a good crack resistance material that will extend the life of the concrete. Because of the steel fibbers' capacity to transfer tension across cracks, the final flexure strength of the concrete is increased, and significant cracks are avoided [2]. The size and quantity of the steel fiber also affected the behavior of concrete in terms of strength, feasibility, and durability [3]. The microcracking will be borne by short, discrete steel fiber that provides three-dimensional reinforcement.

When utilizing steel fiber in concrete, a higher percentage in the mix will reduce or harm the workability of the concrete [2]. This problem was uncovered by researchers, who discovered that adding steel fiber has a negative influence on new concrete. To avoid this issue, a predetermined amount of superplasticizer must be added to the concrete to ensure that there is no significant difference in workability in fresh concrete [4]. The presence of superplasticizer in the mixture of concrete will reduce or prevent the effect of steel fiber and increase the workability in fresh concrete. The slump test is carrying out to understanding workability in MSFC with the presence of a superplasticizer.

Furthermore, concrete is more widely utilized in the construction of superstructures such as beams, columns, slabs, and foundations and has a greater demand than steel. Concrete, unfortunately, has high compressive strength but low tensile strength. The improvement in the mechanical performance of concrete, especially in compressive strength, was investigated for better MSFC produced. This is due to the fact that high-loading structures, such as skyscrapers necessitate the use of concrete that can withstand tremendous stress and tension. Present steel fiber in concrete will reduce concrete cracking due to tensile stress therefore, the compressive strength increase [5]. It has established the knowledge on the compressive strength in concrete important to avoid the costing design and excessive deformation of concrete.

Micro Steel Fibre (MSF) will be used in this experiment, and it will have a distinct percentage composition in concrete. In steel fiber, MSF was evaluated as having a low cost and high effectiveness [1]. The objective for this study was to determine the compressive strength value for MSFC with several percentages and determined the optimum value for MSF contain with the micro size of steel fiber, and it will determine the optimum percentage of MSF in the mixture of concrete and the mechanical behavior in terms of compressive strength. This study will contribute for increasing the strength for concrete to withstand with high load for the concrete structure. Increasing compressive strength in MSFC lead various study on effect of MSF in concrete. The novelty in this study was change the cement water ratio with various percentage of steel fibre. Effect of water ratio for in concrete also effect the concrete strength in concrete[6]. The optimum condition for the mixture design concrete will produced the better strength concrete compare with applying admixture in the concrete.

2. Methodology

2.1 Material preparation

CEM I 42.5N Portland cement is utilized in this project. The proportion that contains for combination and mixing of the product depending on the range of strength class that constituents in cement is defined in BS EN 19-1 (2011). Mechanical, chemical, and physical requirements must also be met. The strength for two days (early strength) must be greater than 10 MPa, and the strength for 28 days (standard strength) must be in the range of 42.5-62.5 MPa for CEM I 42.5N.

Coarse and fine aggregates manufactured according to BS 882 specifications. It has been separated into two types of coarse aggregates: graded aggregates and single-sized aggregates. The size range for coarse aggregates was 10-20 mm. Meanwhile, the 5 mm fine aggregates are utilized.

The size for MSF use is 12.5 mm length and 0.25 mm in diameter. The unit weight for MSF is estimated as 865 kg/m^3. The density for steel was determined by placed the steel micro steel fibe (1) container with a volume of 100 ml that equa1 to 0.0001 m3. The calculation to find density micro steel fiber has shown in equations (1) and (2).

$$mass\ off\ MSF\ per\ m^3 = 100\ ml = 0.0001 m^3$$

$$= A\ 100\ ml\ cylindical\ container\ is\ loaded\ with\ MSF$$
$$= 0.0865\ Kg$$

$$Density\ for\ MSF \quad = (mass\ MSF\ for\ 100\ ml\ in\ Kg)/(volume\ 100\ ml\ in\ m^3) \qquad (2)$$
$$= (0.0865\ Kg)/(0.0001\ in\ m^3)$$
$$= 865\ Kg/m^3$$

The quantity used for MSF can be calculated by using equation (3)

$$MSF\ content, Kg = \frac{Volume\ fraction}{100\%}\ x\ total\ vol. specimen\ x\ 865\ Kg/m^3 \qquad (3)$$

By applying the formula, the quantity for MSF for every specimen can be calculated in the weight of MSF. The volume fraction MSF for this experiment is 0%, 0.5%, 0.75%, 1.0% and 1.25% where every specimen is denoted by SF0, SF0.5, SF0.75, SF1.0 and SF1.25 respectively.

2.2 Mix design

The department of environment (DOE) approach was utilized to design concrete with a strength of 40 MPa and a curing time of 28 days in this investigation. The total mass required for raw materials was calculated using DOE. To create a concrete design, there are numerous methods that must be followed, which are grouped into five parts. The free-water/cement ratio for the desired mean strength was determined in the first stage. The free-water content for the goal workability was determined in the second stage. The third stage was the cement content, which was obtained by integrating the results of stages 1 and 2. Stage four dealt with the evaluation of the total content of the aggregate. The last stage was dealing with the selection of fine and coarse aggregates content. The quantities of the material (water, cement, coarse and fine aggregate) have been calculated by the DOE method precisely, as shown in Table 1. The water-cement ratio for this study is 0.48.

Table 1: Mix design per m3 of normal concrete

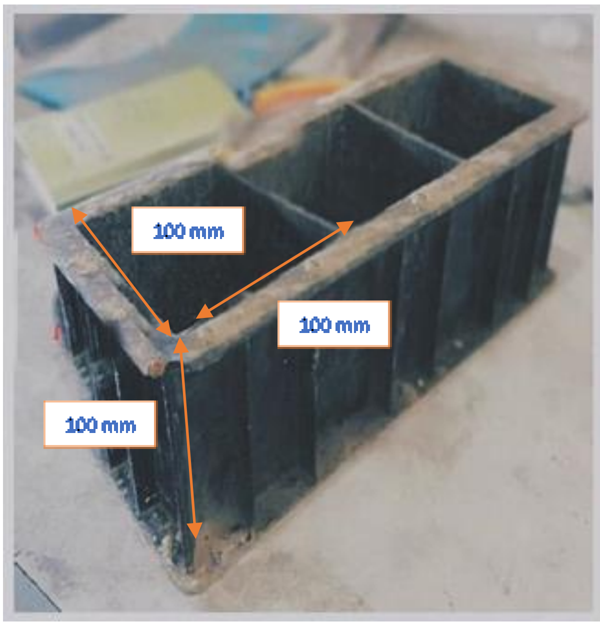
Quantities	Cement (Kg)	Water (Kg)	Fine Aggregates (Kg)	Coarse Aggregates (Kg)
Per m^3	405	195	545	1265

Table 2: The material quantities

Quantities	Cement (kg)	Water (kg)	Fine Aggregates (kg)	Coarse Aggregates (kg)	MSF (kg)
Per m^3	405	195	545	1265	865
0.006 m^3	2.43	1.17	3.27	7.59	5.19
Control	2.43	1.17	3.27	7.59	0.00
0.5 %	2.43	1.17	3.27	7.59	0.034
0.75%	2.43	1.17	3.27	7.59	0.051
1.00%	2.43	1.17	3.27	7.59	0.067
1.25%	2.43	1.17	3.27	7.59	0.084
Total	12.15	5.85	16.35	37.95	0.236

2.3 Specimen preparation

BS EN 12390-1 is referred to for preparing the shape and dimension of specimens. For this study, the shape used for the test is cube shape. The total specimen used was 30 molds. The compressive strength test was used for the cube specimen. The cube mold with the dimension 100 mm x 100 mm x 100 mm was used.



2.4. Testing method

2.4.1 Slump test

The workability of fresh concrete can determine by conducting the slump test. The slump test must be done before the fresh concrete has been poured into the mold. Based on BS EN 12350-2:2009 (2009), several procedures need to follow to determine the workability of fresh concrete. The dimension for the slump cone has been measure before the start of the test. The base of the cone has measured with the dimension is 203 mm (8 in). For the height of the cone, the dimension is 305 mm (12 in), and the top of the opening for the cone is 102 mm (4 in). After measure, the slump cone needs to place at the flat surface withstanding the two-foot pieces. The fresh concrete was poured into a slump cone. There are three layers for every compaction where every layer must fill one-third of cone height with 25 strokes of compacting rod. After all the layer has been compacted, the surface of the fresh concrete must be rolled by compacting rod. The cone must be removed from the fresh concrete slowly, and it must steadily raise vertical direction in 2-5 seconds. The result of the slump cone was obtained by measuring the height of the slump cone with the specimen slump. The entire procedure should be complete within 150 seconds.

2.4.2 Compressive strength test

According to the BS 1881-116:1983 testing procedure, Section 116: Method for evaluating the compressive strength of concrete cubes, compression testing was performed on a compressive test machine at the Material Engineering Laboratory of the UTHM Faculty of Civil and Environmental Engineering. Before the maximum compressive load could fail, the specimen was subjected to increasing compressive loads. The sample dimensions were acquired before the tests. The compressive strength test was done on the concrete cube after seven days and 28 days of curing.

3. Results and Discussion

3.1 Slump test

The slump test was carried out to identify the working properties of fresh concrete and tests the strength of freshly mixed concrete. The researcher was usually doing the slump test in the early stage for concreting. This is because the slump test is one of the tests that is widely used to measure the strength and operability of the concrete in a new mixture. However, some of the parameters that can influence the workability of the mix did not include the result of this slump test. The slump test is carrying out to observe the workability of the concrete mix. The results of Table 3 show that the addition of MSF in concrete brings to decreasing in the corrosion rate of ordinary concrete, thus decreasing the workability of fresh concrete. Table 3 and Figure 1show the result for slump test with different MSF content.

The average slump height of different content of micro steel fiber concrete cylinder specimens is given in the table. The slump height increases directly proportional to the increasing percentage contain for MSF in the specimen. The normal concrete (control) shows that the slump test was 58.0 mm. By addition 0.5% MSF in fresh concrete, the slump height increases to 52.0 mm, which is a 10.34% difference from the normal concrete. The remaining level of fibre concrete have shown decreasing values 0.75% MSF, 1.0 MSF and 1.25 MSF, respectively 48.0 mm (17.24%), 45.0 mm (22.4%) and 41.0 mm (29.31%) of slump height. The specimen that contains 1.25% MSF has the lowest height for the slump test, followed by the specimen that contains 1.0% MSF. Specimen with 0% MSF (control) shows the highest height for the slump test with a height of 58.0 mm.

Wang et al., 2019[7] were carried out an experiment including the steel fiber in the concrete mixture. The result for the slump test shown that a decrement pattern produces by increasing the steel fiber content. The slump for the normal concrete produces 98 mm. By applying steel fiber content cause, the low workability concrete was the lowest slump produce was 25 mm for 1.5% steel fiber content. The restriction to workability increases by increasing the volume fraction for steel fiber. Workability low also causes by the dispersion of steel fiber in fresh concrete that will produce the fiber-cement matrix network [3].

By increasing the steel fiber in the concrete mixture will reduce the workability of concrete. De Figueiredo & Ceccato, 2015 [8] have run the experiment to determine the workability of concrete with steel fiber content. The result shows that concrete contains more than 0.7% steel fiber will reduce the workability. Two suggestions had been made by [9], 2011 in order to improve the working of fiber concrete. The first suggestion had been made is adding more water in mixed concrete while reducing the volumetrically content of fiber to 0.1% to 1.0%. However, increasing the water ratio will adversely affect the strength of concrete. This problem has come out with a second solution by adding plasticizer or water reduction. Plasticizers are often used to increase working efficiency without increase the water content.

Table 3: Slump test for normal concrete and different percentage MSF content

Micro steel fibers content, (%)	Slump (mm)
0.00	58.00
0.50	52.00
0.75	48.00
1.00	45.00
1.25	41.00

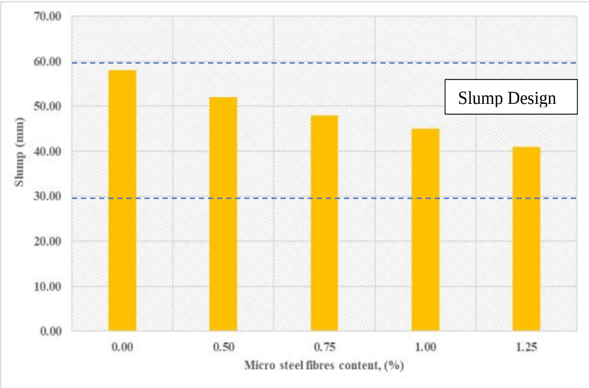


Figure 1: Graph Slump versus MSF content

3.2 Compressive strength

The compressive strength has been performed for the normal concrete and concrete with various volume-based fiber content according to BS EN 12390-3:2009(2009). The concrete performance on compressive strength has been shown in Table 4. The average compressive strength of different content of micro steel fiber concrete cylinder specimen at seven days and 28 days are given in Table 4. On the seven days, the normal concrete (control) result for the compressive strength test was 28.2 MPa. In addition, MSF in concrete by 0.5%, 0.75%, 1.0%, and 1.25% showed increase in compressive strength were. The result for the test was 35.4 MPa, 40.7 MPa, 50.1 MPa, and 56.3 MPa, respectively, to the percentage of MSF. For concrete curing for 28 days, the normal concrete (control) shows an increasing value to 40.2 MPa. The age curing for 28 days for concrete mix with MSF also show the increasing value where 40.2 MPa (0.5%), 54.5 (0.75%), 69.5 MPa (1.0%) and 74.5 MPa (1.25%). An experiment about steel fiber with compressive strength has been done[10]. The result of the experiment showed increasing the load-carrying ability in all percentages. The result showed higher compressive strength achieves for higher steel fiber content.

The amount of micro steel fiber is directly proportional to the compressive strength of the concrete. The higher compressive strength is concrete contains 1.25% MSF, 56.30 MPa, and 74.50 MPa for both seven days and 28 days, respectively. Meanwhile, the lowest compressive strength is concrete, contains 0.0% MSF, 28.20 MPa, and 40.20 MPa for both seven days and 28 days, respectively. The design grade of concrete is 40 MPa for 28 days. The result shows that all the specimen has achieved the design grade concrete where the highest value is 74.50 MPa for concrete contain 1.25% MSF. Meanwhile, the lowest value is 40.20 MPa for concrete contain 0.0% MSF. There were only have two specimens that exceed the targeted strength (55.0 MPa) for 28 days. 1.25% MSF and 1.0% MSF that exceed the target strength, 74.50 MPa, and 69.50 MPa, respectively.

Anike et al., 2020[4] had brought the research on the steel fiber in mixture concrete. The result shows that the increment value got in this research from the normal concrete (0%) to 1.5% volume fraction for steel fiber. The normal concrete had 38 MPa in the compressive strength test and an increase to 47 MPa for a 1.5% volume fraction of steel fiber. A similar result also gains from Feng et al., 2018[1] for the volume fraction steel fiber. The result shows that the normal concrete had a compressive strength of 39 MPa and increased to 43 MPa for steel fiber content 2%. This study also shows that the increment for the steel fiber content 1% to 2% only has a small increasement compare to the steel fiber content 0% to 1% that show huge increment in compressive strength

During the analysis, concrete that contains 1.25% MSF shows the best possible fiber distribution between other fiber concrete[11]. The increasing the MSF in concrete cause the increase in compressive strength until it's have reached the optimum percentage (3%) for the concrete mixture [12]. The optimum percentage for the fiber concrete also depends on the size of the MSF. Long fiber causes the compressive strength to decrease compare to short fiber [13]. Short fibers, unlike long fibers, are extensively mixed with other components and so do not produce a mesh-like structure [3].

Table 4: The compressive strength with different MSF content

Micro Steel Fibres Content, %	Average compressive strength at 7th day (MPa)	Average compressive strength at 28th day (MPa)	Design Grade of concrete, (MPa)	Targeted strength, (MPa)
0.00	28.20	40.20	40.00	55.00
0.50	35.40	48.20	40.00	55.00
0.75	40.70	54.50	40.00	55.00
1.00	50.10	69.50	40.00	55.00
1.25	56.30	74.50	40.00	55.00

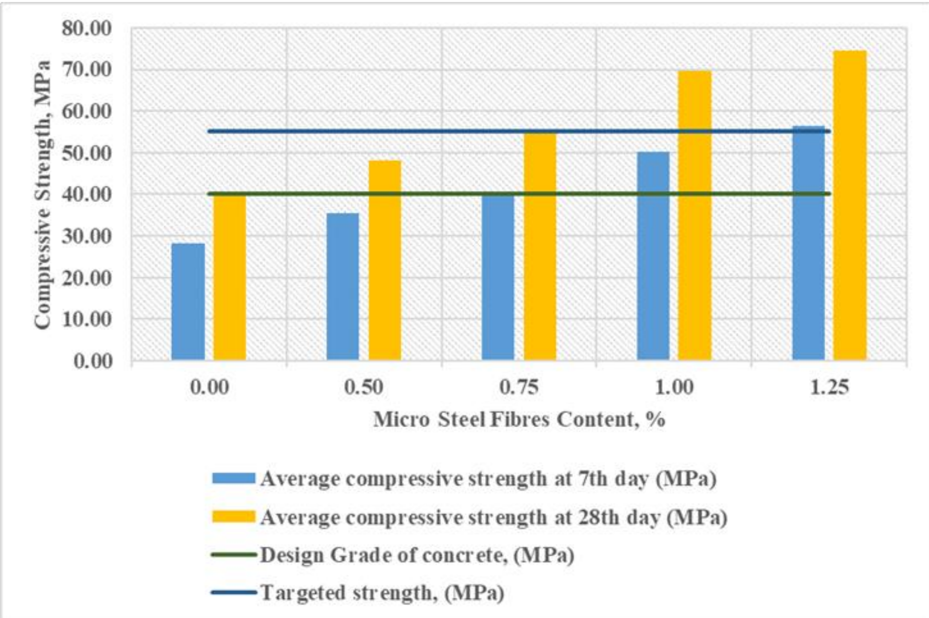


Figure 2: Graph compressive strength versus MSF content

4. Conclusion

The characteristic and micro steel fiber content that can assist in compressive strength was examined in this study. To accomplish this, different percentage content of MSF (i.e., 0%, 0.5%, 0.755, 1.0% and 1.25%) were adopted. Based on the slump test and compressive strength, the conclusion has been drawn:

i. Steel fiber in concrete affects the workability of fresh concrete. The workability of fresh concrete decreases as the percentage of substantial increases. The higher the percentage composition of steel fiber (1.25%), the lower the slump height (75 mm), with a 10% reduction in comparison to regular concrete.

ii. When steel fiber content was added to the cube, the compressive strength increased. The amount of MSF in the compression was proportional to the compression strength. Concrete content 1.25 percent MSF (SF1.25) had the higher compressive strength for both ages curing seven days and 28 days, with compressive strengths of 56.30 MPa and 74.50 MPa for 1.25

percent MSF content, respectively, for seven days and 28 days age curing. There was 18.2 MPa (32.3 MPa) of compressive strength have been increased.

iii. MSF has an optimal content of 1.25 percent. Several percentages of MSF contents were tested in this investigation. In comparison to the control and other specimens, SF1.25 exhibits the best performance in terms of modulus of elasticity.

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