Strength Capacity of Concrete Using Micro Steel Fiber: A Review

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Abstract. Concrete is widely used in the engineering field, particularly in construction. Despite its widespread use in the construction industry, concrete is brittle and has a number of drawbacks, including low tension and crack resistance. As a result, many researchers discovered a way to enhance concrete ductility through adding micro steel fibers (MSF) as a reinforcement. This study explores the impact of MSF on slump height, and the toughness of various concrete. To obtain relevant paper for this research, a systematic literature review was used. When 0.5% to 2% MSF were present in the concrete composite, the result shows a positive increment on its strengths. Meanwhile, the toughness impact of self-compacting concrete (SCC) is reduced depending on what type of water used during the mixing process. Aside from that, adding 0.5% to 2% MSF increases the tensile strength of SCC and ultra-high performance concrete (UHPC). Ultimately, incorporating MSF with concrete to increase the durability is a great idea.

1. Introduction
Concrete was widely utilized in construction industry for thousands of years. There are many kinds of concrete available in today's world, each with its own strength and application. Concrete is defined as a material made by adding a specific amount of water to a mixture of binding substances like cement, fine and coarse aggregates. Due to the increased use of concrete in construction, several studies have been conducted to improve concrete strength. In order to meet this requirement, many researchers have focused on the materials used in the concrete design mix. As a result, fibers was chosen as an additional material to improve concrete's mechanical properties.

Steel fibers have a higher demand worldwide, with three million tonnes required on a commercial basis each year, and this amount is expected to rise by 20% each year. Metal, rubber, glass, and other natural materials were used to make fibers, these raw materials are commercially available. Steel fibers is widely used in concrete and mortar mixing. Steel fibers were included as it is a ferromagnetic material [1]. Steel fiber with various length to diameter ratio and cross-sections will distribute uniformly in concrete matrix. To increase the fortitude of the concrete performance, fibers with short lengths and finesse cross-sections were used.
In civil engineering research, the use of micro steel fibers (MSF) had only recently begun. The results of the studies found that there were great differences in variation between concrete consists of MSF and normal concrete [2]. The presence of 4% MSF resulted in an increment in tensile and compressive strength [3]. These studies show that the percentage and shape of MSF in the design mix produce different results.

Cracking happens due to the presence of extra loads and exposure to harsh environment for a long period [4]. There are two types of cracks, that is surface cracks and internal cracks. Apart from that, concrete structures crack due to shrinkage and tension. Other than that, concrete that has been subjected to a long period of load without being reinforced has a tendency to creep. This is due to the fact that concrete was strong in compression but not in tension. The content in the concrete mixture is another factor that contributes towards the cracking.

The application of Portland cement as one of the materials in concrete causes several issues. Portland cement is brittle by nature and has a lot of shortcomings, including poor crack resistance in real situations and poor elastic modulus. Portland cement had a low tensile strength [5]. Many researchers suggested that using steel fibers as an additional material can overcome this issue. Fibers in cement composites had shown to be efficient and cost-effective in transforming cementitious materials into tough and ductile products.

MSF are new innovative building material that can be used to solve the problems of crack sensitivity and fragility. Cement composites incorporating with short and straight strands of MSF will improve the ductility of cement matrix. MSF has quite a significant impact on mitigating crack propagation, along with effectively increases the compressive and tensile strengths. The size of MSF had a major impact on concrete bending and compressive behaviour [3].

Moreover, water-cement (w/c) rate should take into consideration in concrete mix design. As the w/c ratio increases, the concrete matrix's strength decreases. Thus, several trial mixing should be done to obtain an exact w/c ratio to achieve the targeted concrete matrix strength. Furthermore, to assess the effect of MSF in mechanical properties, the volume fraction of MSF in different types of concrete is critical.

In a nutshell, main goal of this review has always been to examine the impact of MSF on various types of concrete. The following specific goals have been outlined in order to accomplish: identify both compressive and tensile strengths of various percentages of MSF in various types of concrete, and determine the optimal percentage of MSF in concrete.

2. Literature Review
Concrete is widely used in building because of its intensity and toughness properties. Concrete was important in construction material which it had been used for many purposes such as for structural application and residential uses. It really was a cost-effective and dependable material because it has the greatest compressive strength value, is less expensive, and has a long service life [6]. Cement, aggregates, water and admixtures are the main composite material which consist in fresh concrete. Although most of the concrete consists of 75% of the aggregates, properties of cement paste are the main factor that determined the active constituent of concrete [7]. Unfortunately, the existing plastic and mechanical shrinkage with the creation of irregular micro and macro cracks contribute poor tensile strength [8]. Although concrete occurs weak in tensile but it still high in compressive strength. There was various kind of concrete included in this research which was normal concrete, UHPC and SCC.

Concrete is classified as normal concrete where certain specific materials such as aggregate, water or cement are used. Normal concrete is essentially made up from mortar and aggregates. The w/c ratio affects a significant part of the concrete’s performance [9]. The greater the cement volume, the bigger the concrete strength while, the higher the water volume and the less workable concrete. Normal concrete is more vulnerable to damage and crack due to its lack of tension strength compared to UHPC.

Next, UHPC is an engineered construction substance with a technical and reliability improvement compared to conventional concrete. Also identified as an average compressive strength cement composite over approximately 150 MPa. It has outstanding mechanical properties and durability and has various advantages to build and using innovation in different circumstances [10]. The term UHPC
refers to the fibre-reinforced, superplasticizer, supplementary cementitious materials (SCMs) mixture in extremely small amount of w/c ratio, involving 0.15 to 0.60 mm in diameter of very fine quartz sand rather than the usual aggregate [11].

The last type of concrete was SCC is a fluid concrete that requires no vibration and should not indeed vibrated. It uses superplasticizers and stabilizers to increase the ease and flow rate substantially. Compaction of any portion of the mold or form may be accomplished purely by its own weight without any isolation of the field aggregate. It is developed to be compacted when placed by its own weight without vibrators. It has low cultivation tension, persistent viscosity and strong distortion while, the strong fluidity of compacting concrete enables it to be used in congested regions [12].

Aside from that, according to the literature view, steel fibre increased compressive strength, but a significant amount of fibre is required. Next, additional steel fibers contribute to ductile failures which can prolong concrete collapse. There is no substantial change in the performance because the inclusion of steel fiber to a limit of 0.5% increases the compression strength from 36.69 Mpa to 37.37 Mpa [13]. The inner structure of concrete, rather than steel fibres, can be concluded to be the primary determinant of concrete strength at a small fraction of steel fibres.

The analysis showed that the application to concrete, tensile splitting ability by volume of recycled steel fiber and hybrid steel fiber of 0.75% can be improved by 28%t and by 26% relative to basic concrete [13]. The length and diameter of variable fibers appear to have an effective interlocking feature, as tensile strength was improved by 50%, with 0.75% by recycled steel fiber volumes in the pavement mix. Steel fibers below an appropriate fraction have an effect on the efficiency for tensile fracturing by adding defects in the composition of the matrix as the inclusion of steel fibers equivalent to the threshold amount decreases porosity and strengthens the cement matrix.

Furthermore, the properties of MSF are it was strong tensile strength, minimal ductility and poor cracking resistance [14]. It also has a very high advantage in the field of reinforcing concrete, normal concrete and UHPC. It has been shown that the presence of small, close range and evenly dispersed fibers to concrete reacts as crack arresters and improved the properties of compressive and tensile strengths.

Finally, steel fiber can be classified in to different type depending on their size and shape which was used highly on the engineering field. Steel fiber can be classified into a few types which was micro steel fiber, end hooked and corrugated [15]. For this research, the types of steel fiber which was used are micro steel fiber. Micro steel fibers are manufactured with a diameter of less than 100 micrometers and their length is between 5 and 30 mm.

3. Critical Review Analysis and Discussion
The primary goal of this research is to see the effectiveness of MSF in the composition of concrete. There has been a lot of paper reviewed in this research which using concrete with MSF as additional material. The strength of normal concrete has been evaluated in order to compare with concrete strength contains MSF as additional material. Moreover, the percentage of MSF also needed to be evaluated so that conclusion on the relationship between concrete and micro steel fiber can be determined.

3.1. Slump test
To ascertain the rheological ability of fresh concrete, a slump test was performed, in which the height of the slump was measured. It was one of the standard tests applied to obtain the consistency and flowability of a concrete.
Figure 1. Slump result versus the fiber volume for normal concrete.

The Figure 1 represents the result of a slump for the fiber-reinforced concrete and ternary concrete, which contain MSF. Result show that the slump will be decreased when the percentage of MSF in concrete increased [16]. This was approved in the figure in which the slump is reduced when it contains 0.5% to 2% of MSF. According to Gholampur and Ozbakkaloglu [16], the percentage reduction from 1% to 2% of concrete includes MSF is 11%, which proved that the MSF volume, affects the flowability of fresh concrete.

Figure 2. Slump test versus fiber volume for self-compacting concrete.

Based on the Figure 2, the slump values decreased for concrete containing 0.5% to 0.75% of micro steel fiber. The slump value will be reduced when the number of micro steel fiber in the concrete increased [17]. The percentage of the difference between 0.5% to 0.75 of micro steel fiber can be determined as 6%. Meanwhile, the result indicated that the reduction of 5% had been noticed in the concrete containing 0.5% to 0.75% [18]. The effect from the percentage of MSF is reduced at 0.5% to 75% by 12% of the reduction. The result shows that there are improvements in the slump in concrete consist of 0.75% to 1.0% of MSF [19]. The percentage of the increase can be determined by 11% for the slump result, but the result shows different for concrete containing 0.5% to 0.75% of MSF because the percentage of a slump is reduced at 12%. Next, previous study also show the effect that the concrete slump increased when the micro steel fiber contains are 1% to 1.25%, which the percentage of increasing is 1.6% [20]. It was observed that slump value will be decreased when the value of fiber volume in the range of 0.5% to 0.75%.
3.2. Compressive strength

The critical analysis performed based on the concrete specimen that had been done by other researchers. The results for sample of concrete aged 7 and 28 days presented on the graphical plots (Figure 3).

![Figure 3. Compressive strength versus fiber volume.](image)

The compressive strength increased for normal concrete react with the MSF. The pattern of graph show that the strength increased when the number of fiber steel content in the range of 0.5% to 2%. Meanwhile, the MSF with SCC show that the increase number of MSF content will decline the ductility of concrete matrix. It shows that the presence of 0.75% to 1% MSF slightly decreased the toughness of the SCC. Thus, it shows that the MSF can only increased the properties of normal concrete compare to SCC. The design mix ratio is different which normal concrete contained higher water content compare to low water content in self-compacting concrete which effecting the fiber volume and mixture of concrete. The factor seems to be that the air in SCC is increased along the increment of steel fibers, which significantly decreases compressive strength.

3.3. Tensile strength

All the data obtained from the previous researcher which had undergo this test. The relevant information from the research paper compared in term of the percentage of MSF in concrete and the result of tensile strength. All the data which had been analyse are based on the result of specimen at 28 days.

![Figure 4. Tensile strength fiber volume for normal and self-compacting concrete.](image)
The pattern for tensile strength values of normal and SCC can be seen in Figure 4. The bar graph result is based on prior research into the tensile strength of concrete with MSF. The data obtained shows that when more MSF is added, the normal and SCC tensile strength values will increase.

Figure 5 shows the tensile strength of UHPC contain MSF and not containing MSF. The strength of tensile was increased linearly when there are an addition number of MSF content in the concrete [21]. The data shows that the tensile strength was achieved the highest value at 2% of MSF value which shows 26.5Mpa. However, it shows the different from the observation of Park et al 26.5% [22]. This is due to the type of MSF use from both researchers are different which Chkheier & Kadim use hooked steel fiber while Park et al., use the straight type of MSF. Although it was different, the pattern of graph still showed that the concrete contain more MSF value will make the value of tensile strength become higher. The explanation was that the fibers are closer spaced at higher fiber contents, which was reduced the air entrapped on the concrete and cover every crack.

4. Conclusion

The following conclusion can be drawn for both compressive and tensile strength based on critical analysis observations: i) The overall result from research paper showed that the present of MSF content only can increase strength with normal concrete while SCC, the strength was decreased. As for the tensile strength, it was found that the addition of MSF into the mixture will increase the strength value. ii) The normal concrete, SCC and UHPC showed that the tensile strength will increase linearly in the range of 0.5% to 2%. Based on the review analysis data, it has been shown that when MSF content is added to concrete, the tensile strength increases.

5. References

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