The effect of hybrid fibers with various dimensions on the impact strength of concrete containing mineral additives

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ABSTRACT

Improving the mechanical characteristics of concrete as the most basic material in the construction of various structures, especially its tensile, bending and impact resistance, has long been the focus of various researchers. In this research, the effect of adding different steel fibers along with polypropylene fibers in different dimensional ratios together with commonly used mineral additives to improve the impact resistance of concrete has been investigated. The considered parameters included the percentage of polypropylene and steel fibers, the ratio of length to diameter of steel fibers (L/D), the percentage of fly ash, microsilica and epoxy additives, and the age of specimen. Experiments aimed at determining the impact, tensile, bending and compressive strength of the studied concrete specimens were carried out. To determine the impact resistance, a new laboratory method was introduced and used. The results obtained from the strength of concrete samples at different ages of 7, 28 and 90 days show the significant effect of using composite fibers with optimal aspect ratio on increasing the tensile and impact resistance and to a lesser extent on the compressive and bending strength of concrete. These values have increased by 23% for tensile strength and 11% and 18% for compressive and bending strength, respectively, compared to the control sample in 28-day samples. Also, it was observed that the use of mineral additives is more effective in increasing the flexural strength of concrete than the use of fibers. Comparison of samples with L/D ratio of different steel fibers showed that fibers with lower L/D ratio lead to greater improvement in the mechanical properties of concrete. Finally, using combined fibers with optimal L/D and mineral additives has increased the impact resistance and energy absorption by 4.97 times of the optimal concrete samples compared to the witness concrete sample.

KEYWORDS

Fiber concrete, Impact resistance, mechanical properties, Hybrid fibers, Aspect ratio, Mineral additive.

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1. Introduction

Concrete is a brittle material that, in addition to its desirable compressive strength, to improve its tensile properties, steel rebars are used to withstand tensile forces after cracking in concrete structures. The strain of concrete in the crack is much less than the yield stress of steel bars, which causes the concrete to crack before the bars are significantly loaded. Also, one of the other applications of rebars is to limit the width of cracks in service loads. Fibers have advantages over rebars in concrete, such as being spread uniformly in the concrete composition, the presence and reinforcement of concrete coating, the distance between fibers being less than the distance of rebars, and the performance of fibers in controlling the width of cracks can be expressed. In the issue of using composite fibers to improve the performance of concrete, several researches have been conducted, and the positive effects of the combined use of fibers to improve the performance of concrete have been reported. In concretes containing metal fibers and polypropylene, the ratio of 85% to 15% has been suggested as the optimal ratio to improve concrete performance [1]In the investigation carried out on concretes containing different mineral additives along with fibers, positive results were obtained and the triple combination of 15% by weight of air gray, 12% of microsilica and 1% of steel fibers relative to the weight of cement was suggested to improve the mechanical behavior of concrete with different strengths [2]. In the comparison of the results of the drop ball impact tests conducted with the tests of others, they provide 2 to 3 times the numbers compared to the standard criteria, which indicates the mismatch between the regulations and the test.For fiber concrete reinforced with polypropylene fibers, the impact resistance test shows a weak correlation with normal distribution, so a new method should be devised to perform the impact test [3]. By examining various articles among the above methods, the most common method is the weight drop test, according to ASTMD 1557 [4], in which a 4.54 kg weight is placed on a steel ball and falls on the concrete sample, and the number of times it falls until the first crack And it is counted until the failure of the sample.One of the drawbacks of this test is the high dispersion of the results, which have different percentages in different articles and show a weak correlation with the normal distribution [5-6]. In the current research, the main goal is to achieve concrete with high resistance to impact loads. In this regard, in addition to introducing and using a new concrete impact loading test, the optimal length-to-diameter (L/D) ratio of steel fibers combined with polypropylene fibers in the concrete matrix containing mineral additives was obtained. Based on previous research, the mineral additives used in concrete samples included fly ash and microsilica, which were used as a partial substitute for cement [2]. In order to achieve the best performance, three types of steel fibers with different L/D ratios and one type of polypropylene fibers have been used to prepare the concrete mixture. The mechanical properties of concrete were obtained under static and dynamic loading conditions.The amount of cement, water-cement ratio, granulation and volume ratio of fibers (the appropriate values of which were obtained from previous researches) were kept constant in all the samples of this article, and only the L/D ratio of metal fibers was included as a variable. Also, to investigate the effect of research parameters on the process of increasing concrete strength, all tests were performed on samples aged 7, 28 and 90 days. Among the applications of this concrete can be mentioned for slabs resistant to dynamic loads including projectile impact and explosion, pavement and even some beams and columns with special use.

2. Methodology

2.1. Concrete mixing plan

Two groups of mixing designs were used for the tested concrete samples. The mixing plan of the first group included samples without epoxy to determine the optimal concrete mixing plan, which was prepared based on the ACI 211.4R standard. In the second group of samples, the resulting optimal mixing plan was used, and in order to determine the effect of the ratio of epoxy resin and hardener on the mechanical characteristics of concrete, samples with different ratios of these two materials were made.

2.2. Experiments

Concrete static tests including compressive strength test were performed according to B.S. 1881.16 standard, for this purpose, 10×10×10 cubic samples processed under standard conditions at different ages were made and tested. Tensile strength test based on ASTM C496 standard . on samples with a height of 20 cm and a diameter of 10 cm, which were brought under standard conditions, and ASTM C1018 standard was also used to measure the flexural strength of fiber concrete. Samples with dimensions of 50×10×10 cm were placed under concentrated load at two points in the middle third of the distance between the supports, and the loading continued until the sample broke, and the flexural breaking capacity of each sample was obtained.

Among the methods of testing the impact resistance of fiber concrete, the most common method is the weight drop test, according to ASTMD 1557 [4], in which a 4.54 kg weight from a height of 457.2 mm is placed on a steel ball placed on a concrete sample. it falls, and the number of times it falls and the total energy input until the first crack and until the failure of the sample are counted and calculated. One of the drawbacks of this test is the high dispersion and poor correlation of the results with the normal distribution [5-6]. Another drawback of this test is the dependence of the results on individual judgment regarding the initiation of cracking and the final destruction of concrete.Other disadvantages of this test include the need for a large number of hits and the lack of concentration of the impact point and the time-consuming test, the impactor's spherical shape and light weight, the small dimensions of the samples, and not considering the support conditions. But perhaps the most important form of this test is the filling under the concrete sample and the complete reliance of its bottom on a sheet that absorbs most of the incoming energy. Considering the above defects in the conventional impact test, in this research, instead of a concrete sample resting on the floor, a concrete slab with a linear support on the two opposite edges, which was empty underneath, was used. The test was carried out on concrete slab samples with dimensions of 10 × 40 × 40 cm, which are rigidly restrained in the supports on the two facing edges, and the edges of the slab are free on the other two sides. To test the impact resistance of the concrete slab sample, a new device based on the fall of a heavy cone-shaped weight was used. In this test, the metal ball on the concrete sample was removed and a conical impactor weighing 57 kg made of steel was used along with a chassis weighing 80 kg in order not to deviate the impactor from a free fall elevator with a load capacity of 120 kg and height The height is 7.5 meters, the impactor moves in the straight path of the rail and has the ability to release at different heights and create different energies. The purpose of introducing this new test system with a conical impactor is to create a concentrated and point load in the center of the slab. The reduction in the number of blows was due to the creation of adjustable energy and finally the creation of more obvious ruptures due to the dimensions and support conditions of the slab.

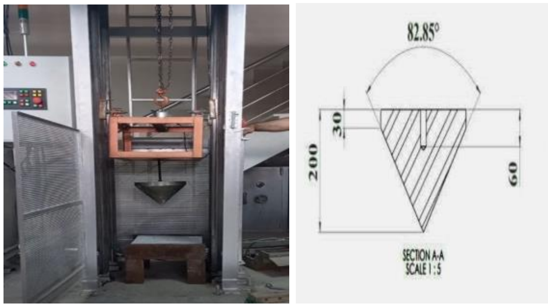

Figure 1- How to place concrete samples in the introduced impact test system

3. Results and discussion

The results of averaging the compressive strength of three cubic samples made for each mixing plan at the age of 7, 28 and 90 days in comparison of the control concrete with the concrete containing microsilica mineral additive and fly ash in the 7, 28 and 90 day test show an increase of 2,11,18% respectively It is a percentage of compressive strength compared to the control sample.

The results of the average tensile strength indicates that the best tensile strength results are obtained from metal fibers with the lowest ratio of length to diameter. The results obtained from the average tensile strength of cylinder samples that mineral additives at the ages of 7, 28 and 90 days have caused an increase of 9, 12 and 9% respectively in the tensile strength of concrete. Also, the optimal combination of metallic composite fibers with mineral additives in the best sample has led to an increase in tensile strength of 23, 29 and 23% respectively at the ages of 7, 28 and 90 days compared to the control samples. Also, the optimal combination of metallic composite fibers with mineral additives in the best sample has led to an increase in tensile strength of 23, 29 and 23% respectively at the ages of 7, 28 and 90 days compared to the control samples.

The flexural strength of concrete samples with the presence of mineral additives alone at the ages of 7, 28 and 90 days has increased by 4, 18 and 37%, respectively, compared to normal concrete. Also, the bending strength in the presence of composite fibers with mineral additives has increased compared to the samples that are 5, 18 and 44 respectively. These results all confirm the insignificant effect of fibers compared to mineral additives at different ages. It can be concluded that mineral additives have the main effect in improving the bonds between different components of the concrete matrix compared to fibers. The presence of mineral additives due to their micrometer size as well as the adhesion and filling properties of such materials occupy the very small holes in the matrix, which is a weak point in ordinary concrete, and cause the integration of the concrete matrix and ultimately improve the bending strength.

In the examination of the results obtained by adding epoxy in different proportions on the compressive, tensile and bending strengths of the 28-day samples, 16, 42 and 47%, respectively, are observed in the strengths compared to the optimal samples. These results show that the decrease in bending strength increases with the increase in the ratio of hardener to resin.

One of the main goals of this research, besides examining the mechanical properties in static conditions, was to study its behavior against dynamic loading with low strain rate. Using the new test system, the test was performed on the samples made with different mixing designs. The total potential energy of weight falls on each sample until crack formation in the slab sample was calculated.Three samples of slabs with the characteristics of the reference concrete were tested to determine the critical height of cracking by trial and error, and in other slabs, the weight was dropped from the critical height and the subsequent falls were made from higher heights with increments of 50 millimeters until the first sign of failure appeared. The slab continued and finally, the total potential energy of the weights until the occurrence of cracks was calculated according to equation 1 [7].

$$E=\sum mgh \quad (١)$$

The presented results show the very impressive effect of using fibers and mineral additives on the impact resistance of concrete slab. In the meantime, it seems that the fibers have increased the cohesion and tensile strength and energy absorption of concrete against dynamic loads, and mineral additives have been able to help increase the energy absorption capacity of concrete by creating better adhesion and integrity of the concrete matrix, and in general, the simultaneous use of fibers with additives Minerals cause much greater impact resistance of concrete samples against dynamic loads. It should be noted that in comparison of the used metal fibers, the metal fibers with a smaller length to diameter were more effective in absorbing energy.

4. Conclusions

The used composite fibers and mineral additives both have a positive effect on increasing the compressive, tensile and impact strength in all ages of concrete, and the small amount of their positive effect was investigated in different parts of the article; But in increasing the bending strength, mineral additives were much more effective than the used composite fibers. The increase in flexural strength of concrete containing mineral additives at the age of 90 days compared to the control sample was about 37%, and the addition of fibers to this concrete could only increase this increase to 44%, which indicates that it is less effective than mineral additives.

The triple static compressive, tensile and bending resistances are completely dependent on the ratio of length to diameter of steel fibers. In fibers with different lengths and the same diameter, fibers with shorter lengths are more effective, and compared to fibers with equal lengths and different diameters, fibers with larger diameters improve resistance. Being more effective, therefore, according to the defined fraction of the length to the diameter of the fibers, the fibers with the lowest aspect ratio (L/D) lead to the greatest increase in triple resistances.

In slabs under dynamic impact load, the use of fibers by increasing the tensile strength and limiting the crack width and the use of mineral additives by increasing the adhesion and filling of the concrete matrix led to an increase in the impact energy absorption capacity; Therefore, the simultaneous use of composite fibers and mineral additives causes a significant increase in the impact resistance of concrete slabs against dynamic impact loads.

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