Hindawi
Advances in Civil Engineering
Volume 2018, Article ID 6715813, 10 pages
https://doi.org/10.1155/2018/6715813

Research Article

Mechanical Properties of Steel Fibers and Nanosilica Modified Crumb Rubber Concrete

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Received 2 February 2018; Accepted 24 April 2018; Published 3 June 2018

Academic Editor: Song Han

Crumb rubber concrete (CRC) is an environment-friendly material using crumb rubber as a composition of cement concrete. It provides an alternative method for recycling of waste tires scientifically. CRC exhibits numerous advantages compared to ordinary concrete. However, the application of CRC is limited due to its low compressive and tensile strengths. This paper puts forward a new modified method by adding steel fibers and nanosilica in CRC. Material properties' testing of eighteen concrete mixtures was investigated, considering different strength grades of CRC and crumb rubber contents. In addition, four different steel fiber contents (0%, 0.5%, 1.0%, and 1.5%) and three different nanosilica content (0%, 1%, and 2%) were taken into consideration. The brittle failure of the CRC can be improved and the mechanical properties can be enhanced according to the test results. More importantly, the modified CRC with 1.0% steel fiber content has relatively high compressive and splitting tensile strengths. Furthermore, the noncompactness of CRC can be effectively improved by nanosilica, enhancing the efficiency of steel fibers simultaneously. Finally, the failure mechanism of the modified CRC is discussed in this paper.

1. Introduction

With the development of automotive industry in recent years, a large amount of waste tires are produced. As a global problem, every year more than half of waste tires were discarded with no treatment [1]. These nonbiodegradable waste tires can provide breeding places for flies and mosquitoes. Besides, these tires pose high danger of fire, threatening the environment, human lives, and property [2]. Hence, this black pollution becomes an inevitable problem raising concerns worldwide.

Crumb rubber concrete (CRC), also called rubberized concrete, is an environment-friendly material using crumb rubber as a composition of cement concrete. After a series of treatments, such as mechanical crushing, grinding, dust removal, and cleaning, crumb rubbers can be obtained from the waste tires. According to previous studies, many aspects of concrete performance have been greatly improved after adding crumb rubbers. Khaloo et al. [3] indicated that the increase of rubber content weakened the brittleness of concrete. Zheng et al. [4] found that the crack propagation in the concrete with CRC was obviously slower than that in the plain concrete, which was consistent with the results obtained from other experiments [3, 5]. The concrete energy-absorbing capacity was enhanced by adding crumb rubber, which was found by Li et al. [6]. Moreover, CRC has been proven to have crack resistance [7], dynamic behavior and fatigue behavior [8], superior acoustical properties, better resistance to abrasion [9], and electrical resistivity [10]. Thus, CRC provides sufficient environmental benefits and economic significance.

As mentioned above, CRC exhibits numerous advantages compared to ordinary concrete. However, the application of CRC is limited, such as pavements layers, parking lots, and tennis courts, due to its low compressive and tensile strengths. The lower strength and elasticity modulus of rubber aggregate and the weak interface between the crumb rubbers and surrounding mortar due to hydrophobic properties of crumb rubbers [11] may lead to low strength of CRC. The uncompetitive strength makes CRC seldom used in the structural members.

Thus, it is very important to find a method improving the mechanical properties of CRC to expand its practical application and widen its universality in the engineering construction. Recently, a number of researchers have been focused on the modification of mechanical properties of CRC. The methods can be divided into physical and chemical modifications. In terms of the physical modification, copper slag has been added into CRC, and the strength and durability of concrete have been increased [12]. Hesami et al. [13] had used polypropylene fibers to modify CRC, which resulted in significant increases of compressive, flexural, tensile, and abrasion strengths. Many scholars used steel fibers as additives, and steel fiber has been proven to have good effect on modification of CRC. Turatsinze et al. [14] found that steel fibers can enhance the cracking resistance of CRC. Xie et al. [15] investigated the compressive and flexural properties of crumb rubber- and steel fiber-reinforced concrete with recycled aggregates. Noaman et al. [16] found that the compression toughness has improved after adding steel fibers and the brittle failure changed to a ductile one. Previous studies have proved that steel fibers improved tensile strength, durability, impact resistance, and toughness of concrete considerably, at the same time, preventing the crack propagation [17, 18]. Other researchers have used the chemical process on the surface of the rubbers or improved the strength of interface between the crumb rubbers and mortar. Ismail and Hassan [19] suggested adding metakaolin in CRC, and Fakhri and Saberi used silica fume [20]. Many researches chose nanosilica as additives [21–23]. Results showed that both the compressive strength and tensile strength of CRC were insignificantly improved after adding nanosilica [24].

However, there are very few studies available for investigating the combined modified effect of steel fibers and nanosilica on the CRC. To this end, an investigation on the mechanical properties of steel fibers and nanosilica modified CRC (or SFNS-CRC, for short) is presented in this paper. An extensive discussion on additives' content effects on strengths (compressive and splitting tensile) of modified CRC is included. Furthermore, the optimum efficiency of the additives' content could be found.

The remaining of this paper is organized as follows. An introduction of the experimental program is illustrated in Section 2. Section 3 details the failure modes, compressive and splitting tensile test results, and the workability of concrete mixtures. Section 4 discusses the effects of steel fiber and nanosilica contents on the modified CRC and the failure mechanism of SFNS-CRC. Finally, Section 5 lists some concluding remarks of this paper.

2. Experimental Program

2.1. Raw Materials. The raw materials in this test were cement, fine aggregate, coarse aggregate, steel fibers, nanosilica, water, and crumb rubbers with a diameter of 1-2 mm. The workability of the concrete mixing was insured by the naphthalene formaldehyde water reducer.

Here, the cement was chosen Portland cement of 42.5 MPa (P.O. 42.5). The coarse aggregate (crushed stone) was adopted continuous grading with 5 mm–20 mm in sizes, and its specific gravity was 2.66. The fineness modulus of fine aggregate (river sand) was 3.40, and its gravity was 2.65. The tensile strength of steel fibers (hooked at both ends) was 1345 MPa. The length of the steel fiber was 35 mm, and the aspect ratio was 64. The nanosilica was white powder with an average particle size of 30 nm, and its apparent density was 30–60 g/l. The naphthalene formaldehyde water reducer with 25% water-reducing ratio was adopted to guarantee that most of the concrete mixtures had slumps within the range of 40~80 mm. The rubbers, steel fibers, and nanosilica used in this test are shown in Figure 1.

2.2. Experimental Design and Mixture Proportion. The modification effects of the steel fibers and the nanosilica on the CRC are the main purpose of this test, especially on the aspect of the specimens' compressive and splitting tensile strengths. The mix proportions of crumb rubbers and steel fibers followed the volume percentage method, while that mixed method of the nanosilica was an equivalent substitute to the cement, meaning the replacement ratio of the cement.

Thus, we chose the strength grade C35 of CRC with 5% crumb rubber (namely, 50 kg/m^3, meaning adding 50 kg crumb rubbers in 1 m^3 concrete) as a basic group, and here, this group was called C35CR5. Here, C35 means the compressive strength of concrete is within the range of 35–45 MPa. Four different steel fiber contents, 0%, 0.5% (39 kg/m^3), 1.0% (78 kg/m^3), and 1.5% (117 kg/m^3), were taken into consideration. When the volume percentage of the steel fiber was 1.0%, two different nanosilica contents, 1% and 2%, were chosen. On this basis, a higher strength CRC of C45 with the same rubber content was designed to investigate effects of the different strength grades. Here, this second basic group was called C45CR5. Moreover, in order to involve the effect of different rubber contents, the third basic group with 10% (100 kg/m^3) crumb rubber which still belongs to the C45 strength grade was designed and called C45CR10.

Hence, there were two kinds of strength grades: C35 and C45 and two different rubber contents: 5% and 10%. The three basic groups were C35CR5, C45CR5, and C45CR10. Similarly, the latter two basic groups considered different steel fibers and nanosilica contents. The optimum concrete mixture proportion was achieved based on 39 group of testing. Details of mixture proportion of the eighteen concrete mixtures are listed in Table 1.

2.3. Specimen Preparation and Test Procedures. The specimens were mixed through a shaft mixer. First, aggregate materials were put together and mixed for 90 seconds, and then the steel fibers were added gradually and mixed for 180 s to guarantee steel fibers dispersed uniformly. The steel fibers may be balled, as shown in Figure 2, while the appearance of this situation indicates that mixing should be continued. Then, crumb rubbers and cement (if this mix proportion includes nanosilica, nanosilica is added to cement) were added sequentially, insuring the uniformity of the mixture as well. Finally, water together with the water-reducing agent was added, which was mixed for another

(a) (b) (c)

Figure 1: The (a) crumb rubbers, (b) steel fibers, and (c) nanosilica used in this test.

Table 1: Concrete mixture proportion (unit: kg/m^3).

Group	Crumb rubber	Cement	Coarse aggregate	Fine aggregate	Water	Water-reducing ratio	Steel fiber	Nanosilica
C35CR5								
1SF0	50	400	703	1004	169	4	0	—
1SF0.5	50	419	705	1060	177	4.5	39	—
1SF1	50	438	654	1045	185	5	78	—
1SF1.5	50	457	604	1029	193	5	117	—
1SF1NS1	50	433.62	654	1045	185	5	78	4.38
1SF1NS2	50	429.24	654	1045	185	5	78	8.76
C45CR5								
2SF0	50	550	703	1004	180	7	0	—
2SF0.5	50	574	630	957	188	5	39	—
2SF1	50	599	572	931	196	5	78	—
2SF1.5	50	623	514	905	204	5	117	—
2SF1NS1	50	593.01	572	931	196	5	78	5.99
2SF1NS2	50	587.02	572	931	196	5	78	11.98
C45CR10								
3SF0	100	590	1192	400	168	6	0	—
3SF0.5	100	618	1117	388	176	6	39	—
3SF1	100	646	1041	376	184	6	78	—
3SF1.5	100	674	966	365	192	7	117	—
3SF1NS1	100	639.54	156	358	189	6	78	6.46
3SF1NS2	100	633.08	1056	358	189	6	78	12.92

(a) (b)

Figure 2: The ball of steel fibers.

180 s. After the mixing process, the slumps of concrete mixtures were tested immediately, as shown in Figure 3. For each group, twelve standard concrete test cubes ($150 \times 150 \times 150\,\mathrm{mm}^3$) were cast to test the compressive strengths of 7 d, 14 d, and 28 d and tensile strength of 28 d (d refers to days). The specimens were cured in

Figure 3: Concrete slump test.

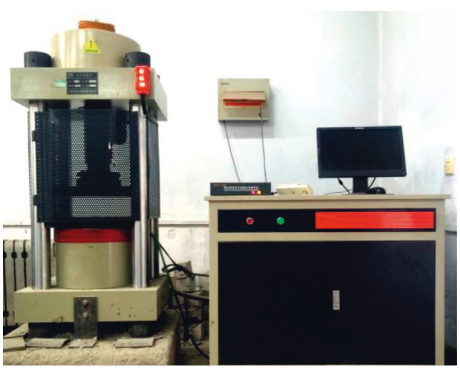


Figure 4: Test setup.

a standard curing room for 28 days at 20°C temperature, and the relative humidity was above 95%.

Both the strength tests of compressive and splitting tensile were conducted in an electrohydraulic servo-controlled machine with a capacity of 2000 kN, as presented in Figure 4. The data of loads and displacements of specimens were obtained through the computer-controlled test system automatically, and the speed of the load can be controlled efficiently. The load procedure followed the Chinese Standard (GB/T50081-2002) [25]. The constant loading rate of compression and splitting tensile tests was 0.5 MPa/s and 0.05 MPa/s, respectively.

3. Test Results

3.1. The Workability of the Concrete Mixtures. The workability of tested eighteen mixtures of concrete was basically good. The optimum result that most of the concrete mixtures had slump within the range of 40~80 mm was achieved. The slumps of the concrete mixtures are shown in Table 2 and Figure 5.

Table 2: The slumps of concrete mixtures (unit: mm).

Group	C35CR5	C45CR5	C45CR10
SF0	64	57	52
SF0.5	70	65	56
SF1.0	73	55	40
SF1.5	52	45	**30**
SF1NS1	43	41	**26**
SF1NS2	**30**	**23**	**20**

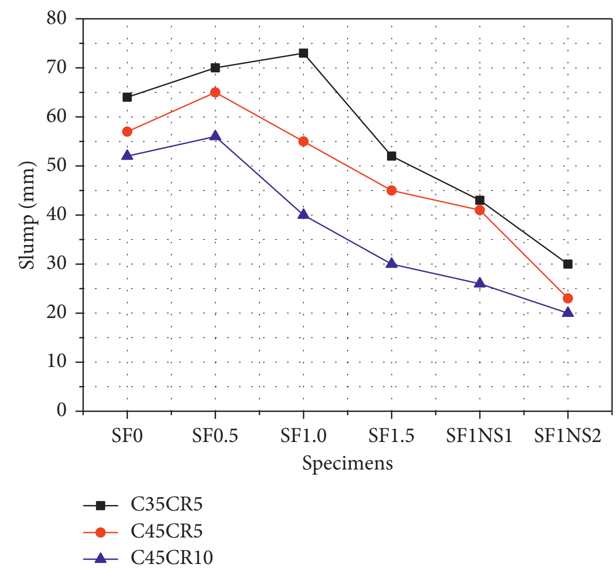


Figure 5: The slumps of concrete mixtures.

It can be seen intuitively from Figure 5 that, with the increased steel fiber contents, the slumps of the tested mixtures showed basically a downward trend. When the content of steel fiber reached 1.5%, the fluidity had a great drop, especially in the third group. The fluidity had been further sacrificed after adding nanosilica. When the nanosilica content reached 2%, the fluidity of all the concrete mixtures from the three groups was no more than 30 mm. In the third group, the liquidity got worse because of the higher rubber content.

3.2. Compressive and Splitting Tensile Strengths. The strength result of each group was calculated from the average test result of three test samples. Table 3 presents the compressive strengths of specimens at the age of 7 d and 14 d. The test results of the specimens' strengths at 28 d are listed in Table 4.

According to Table 3, there is a general improvement of the early age compressive strength of modified CRC. Test results indicated that adding steel fibers can significantly improve the strengths of the CRC under the same water-binder ratio, as seen in Tables 3 and 4. The three groups had consistent results. On this basis, nanosilica can further enhance the strengths in the first two groups when crumb rubber content was 5%. The strengths of SFNS-CRC in the third group decreased compared with the CRC with 1% steel

Table 3: Test results of the specimens' compressive strengths at 7 d and 14 d (unit: MPa).

Group	C-7 d			$C_{Avg\text{-}7}$	C-14 d			$C_{Avg\text{-}14}$
C35CR5								
1SF0	28.1	32.5	31.2	31.4	34.6	36.4	38.0	36.3
1SF0.5	32.7	32.3	31.3	32.1	42.2	40.3	42.2	41.6
1SF1	38.0	35.9	37.2	37.1	40.4	37.3	40.3	39.3
1SF1.5	32.0	30.2	31.6	31.3	35.4	38.1	38.7	37.4
1SF1NS1	38.1	39.1	38.2	38.5	43.5	42.7	42.9	43.1
1SF1NS2	43.4	42.1	43.3	42.9	47.9	43.1	45.3	45.5
C45CR5								
2SF0	38.4	41.3	42.5	40.8	43.8	42.7	41.1	42.6
2SF0.5	47.6	46.3	49.4	47.8	48.7	49.3	47.6	48.5
2SF1	48.9	48.3	50.7	49.3	52.4	53.3	50.3	52.0
2SF1.5	45.9	52.8	47.8	48.8	47.7	46.2	54.1	49.3
2SF1NS1	45.8	46.8	45.7	46.1	49.2	49.1	48.3	48.9
2SF1NS2	48.5	51.8	54.5	51.6	54.3	55.6	57.5	55.8
C45CR10								
3SF0	41.2	39.3	38.2	39.6	46.6	46.7	49.8	47.7
3SF0.5	47.7	46.2	45	46.3	48.3	46.5	48.8	47.8
3SF1	50.7	48.4	51	50.1	51.9	49.5	49.7	50.4
3SF1.5	50.4	49.4	42.7	47.5	48.5	49.6	50.9	49.6
3SF1NS1	42.0	42.9	42.1	42.3	45.3	44.0	44.5	44.6
3SF1NS2	43.0	43.9	40.1	42.3	41.1	45.3	41.2	44.5

Table 4: Results of the specimens' compressive and splitting tensile strengths tests at 28 d (unit: MPa).

Group	C-28 d			$C_{Avg\text{-}28}$	T-28 d			$T_{Avg\text{-}28}$
C35CR5								
1SF0	40.0	37.7	38.3	38.7	2.8	2.9	3.0	2.9
1SF0.5	44.0	42.9	41.6	42.8	3.3	3.6	3.1	3.3
1SF1	46.8	44.5	42.4	44.6	4.9	4.7	5.2	4.9
1SF1.5	38.9	38.8	42.3	40.0	4.6	4.0	4.6	4.4
1SF1NS1	47.1	47.9	46.3	47.1	5.3	4.8	5.2	5.1
1SF1NS2	49.0	46.6	46.4	47.3	5.2	4.9	5.5	5.2
C45CR5								
2SF0	50.1	51.1	50.8	51.3	3.4	3.3	3.4	3.3
2SF0.5	54.7	51.9	51.8	52.8	3.7	3.4	3.8	3.6
2SF1	53.3	54.8	52.5	53.5	4.2	4.9	4.3	4.4
2SF1.5	57.6	54.6	50.7	54.3	4.8	4.9	5.4	5.0
2SF1NS1	54.1	55.1	55.0	54.9	4.8	5.3	5.3	5.1
2SF1NS2	56.1	58.4	53.7	56.1	4.9	5.2	4.6	4.9
C45CR10								
3SF0	50.0	49.8	52.7	50.8	3.6	2.9	3.0	3.2
3SF0.5	53.6	49.2	50.9	51.2	4.3	4.2	3.3	3.9
3SF1	55.0	53.5	51.7	53.4	4.5	3.6	4.0	4.0
3SF1.5	50.0	48.8	51.1	50.0	4.0	4.9	3.7	4.0
3SF1NS1	52.7	51.5	49.7	51.3	3.9	3.8	3.9	3.9
3SF1NS2	51.5	52.1	53.6	52.4	3.7	3.9	3.5	3.7

fiber content. However, the strengths were still higher than those of CRC with 10% crumb rubber content.

3.3. Modes of Failure. Some certain regularities of failure modes are presented with the increasing steel fiber and nanosilica contents after the material properties' tests. Here, the chosen specimens of six concrete mixtures from the first basic group and typical damage shapes of the test cubes are shown in Figures 6 and 7, respectively. Note that these pictures were selected randomly from one of the three cubes in each group.

The typical failure mode of CRC with 5% rubber content after compressive tests is shown in Figure 6(a). There were several penetrating cracks on CRC, and right part of the sample was badly damaged. When the bearing capacity was reached, fragments ruptured from the CRC samples, while there were less ruptured fragments of the latter modified groups. During the loading process, the more the steel fibers added in CRC, the slower the cracks appeared and propagated. It can be seen from Figure 6(b) that the failure mode of CRC with 0.5 steel fiber content had improved. Moreover, with the increasing steel fiber contents, multiple microcracks could be seen and no fatal penetrating crack appeared when damage happened, as shown in Figures 6(c) and 6(d). The SFNS-CRC samples maintained integrity with microcracks evenly distributed. The width of cracks became thinner, and there were hardly any big cracks, as shown in Figure 6(e). The damage situation of SFNS-CRC samples was even better with 2% nanosilica content, as shown in Figure 6(f).

In the splitting tensile tests, the load was applied to the middle of specimen's up and down surface through two curved steel shims. Cracks firstly appeared at the bottom and top of all the test cubes, and then, the cracks developed gradually. It can be seen from Figure 7(a) that the vertical crack ran across the entire height of the specimen, and the specimen split into half. The fracture damage occurred suddenly without a signal and accompanied by a loud noise, showing a clear brittle failure, while this situation has been significantly improved with incorporation of steel fibers. All of the residual specimens did not separate into two parts when damage happened. This is because when the concrete was invalidated and the steel fibers bore the tension. The crash sound of steel fiber's fracture could be heard at the later stage of loading. Furthermore, with the increasing steel fiber contents, more microcracks appeared, and it took more time for the process of load and damage. In addition, the microcracks reduced, and the fatal cracks ran through the specimen changed into multiple shorter cracks of the last two specimens containing nanosilica.

4. Discussion

4.1. Effects of Steel Fiber Contents. The test results showed that the compressive strengths of the first modified CRC group (C35CR5) with 0.5%, 1.0%, and 1.5% steel fiber content increased to 10.59%, 15.25%, and 3.36%, respectively, while the growing rate of the splitting tensile ones were 13.79%, 68.97%, and 51.72%, respectively. The latter two groups (C45CR5 and C45CR10) showed relatively constant tendency. Figure 8 shows the effect of steel fibers on strengths on the three basic CRC groups.

With the increasing steel fiber content, the compressive strength gradually increased, except when the content of steel fibers reached 1.5%, and the first (C35CR5) and the third groups (C45CR10) showed a downward trend, as shown in Figure 8(a). This is due to the easy balling of steel

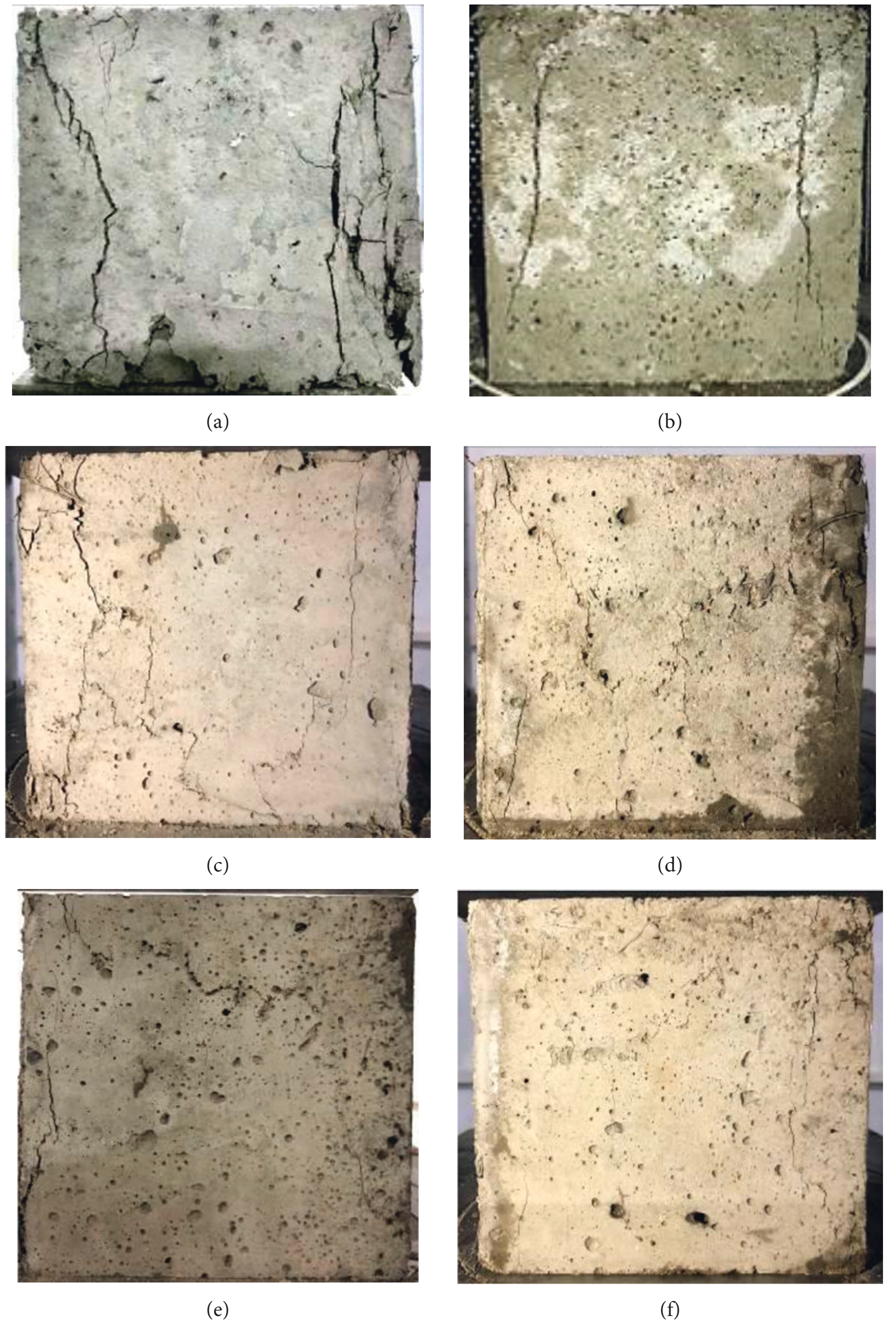


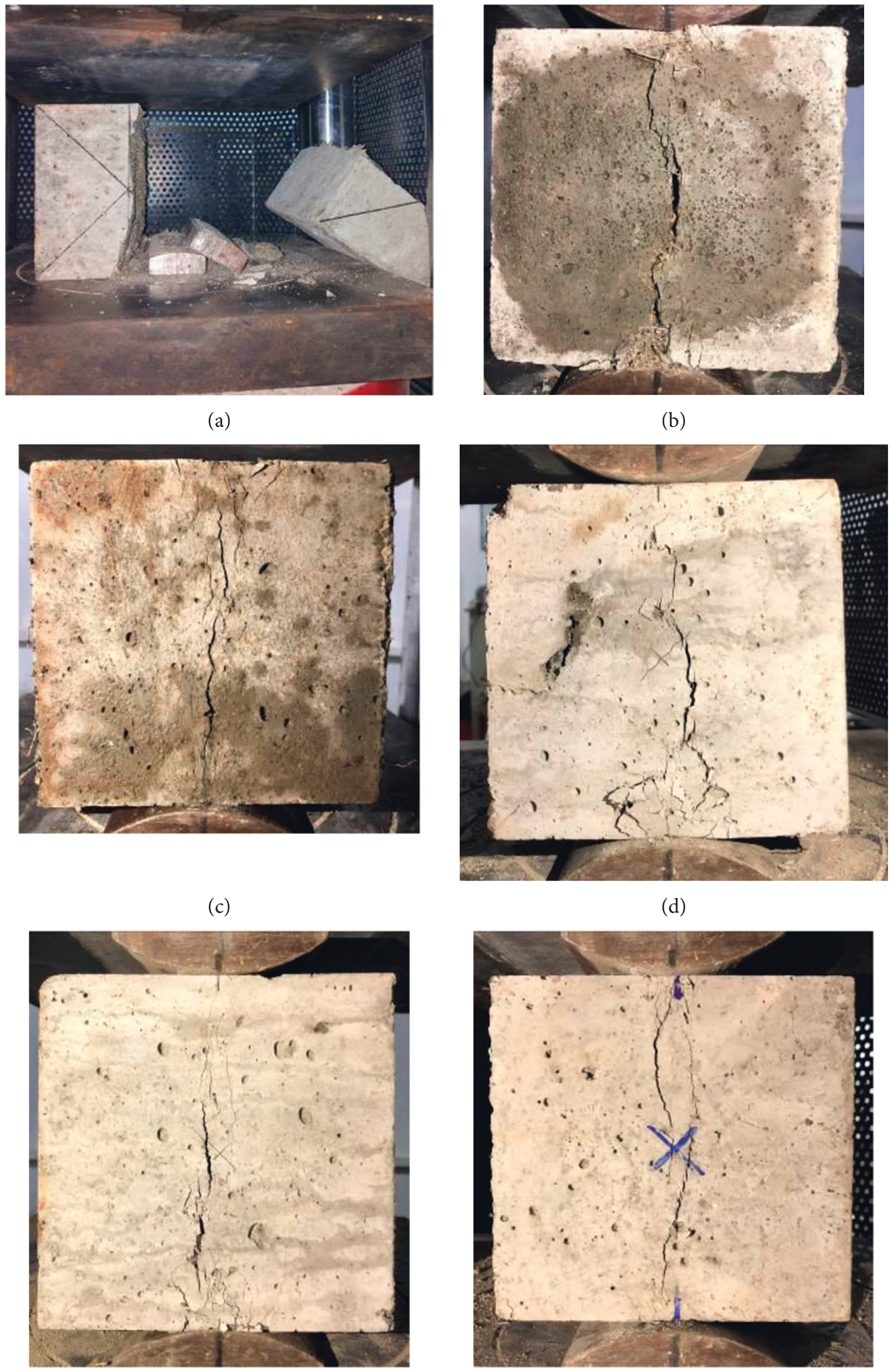
Figure 6: Typical damage shapes of concrete cubes after compressive tests. (a) SF0; (b) SF0.5; (c) SF1.0; (d) SF1.5; (e) SF1NS1; (f) SF1NS2.

fibers during the mixing process when meeting the high dosage, which reduces the quantity of uniformly distributed steel fibers. Thus, the test results failed to show the optimum performance as expected. Similarly, as shown in Figure 8(b), because of the uneven distribution of the steel fibers, there was a slight difference in the effect on the splitting tensile strength when the steel fiber content was 1.5%. Besides, the splitting tensile strength showed a steady promotion along with the increasing steel fiber content.

By comparing the first two groups (C35CR5 and C45CR5), the conclusion that the enhancement function of steel fibers on the compressive and splitting tensile strengths is more significant on the lower strength CRC with the same crumb rubber content can also be drawn.

In addition, by comparing the latter two groups (C45CR5 and C45CR10), the splitting tensile strength of concrete varies inversely to the rubber contents. The line of the third group (C45CR10) ascended first and then approximately remained stable, demonstrating that the change of the steel fiber content (>0.5%) has little influence on the splitting tensile strength of CRC with 10% crumb rubber.

Furthermore, the lines of the three groups had the largest slope when the steel fiber content ranged from 0.5% to 1.0%. This also proves that the most effective strength



(a) (b) (c) (d) (e) (f)

Figure 7: Typical damage shapes of concrete cubes after splitting tensile tests. (a) SF0; (b) SF0.5; (c) SF1.0; (d) SF1.5; (e) SF1NS1; (f) SF1NS2.

improvement content of steel fibers is 1.0%. Hence, the modified CRC with 1.0% steel fiber content has relatively high compressive and splitting tensile strengths.

4.2. Effect of Nanosilica Contents. As mentioned before, the optimum content of steel fiber is 1.0%. Figure 9 shows the effect of nanosilica on strengths of the three SFNS-CRC groups when the steel fiber content was 1.0%. In addition, the strengths of unmodified CRC of the three groups are marked in Figure 9. The modification effect is obvious since the strengths of SFNS-CRC are much higher than that of CRC.

It can be seen from Figure 9(a) that the compressive strength of SFNS-CRC in the first two groups improved with the increase in the nanosilica contents. In Figure 9(b), the first group exhibited steady growth with the increasing nanosilica content. Conversely, both the compressive and

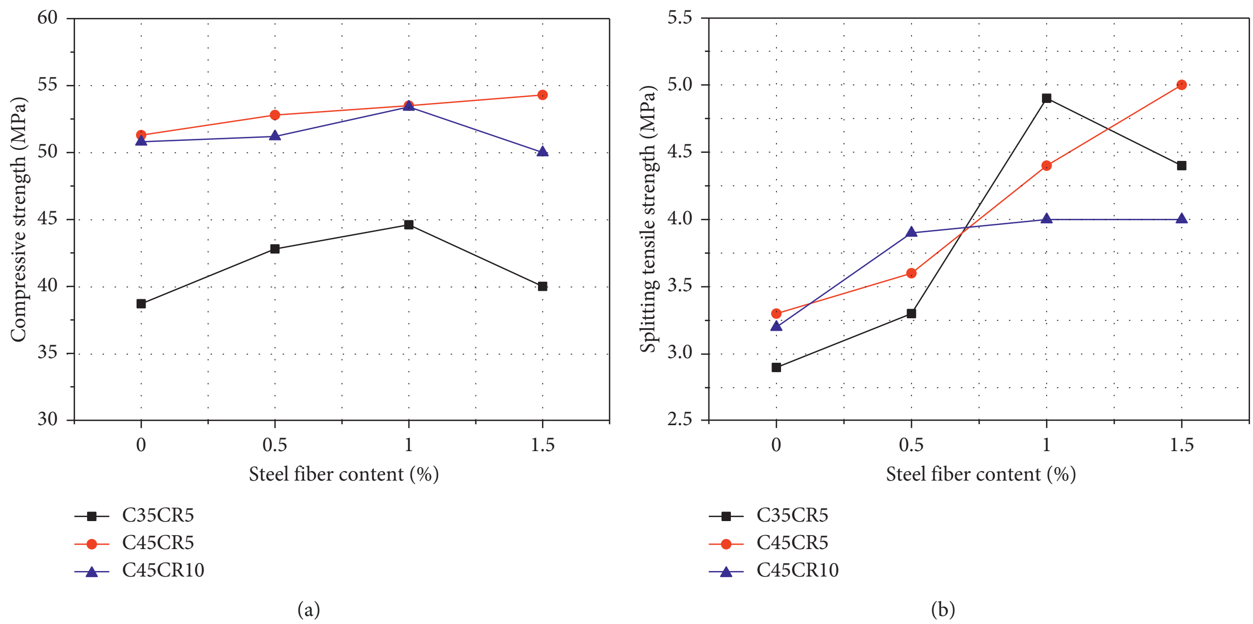


Figure 8: The effect of steel fibers on (a) compressive and (b) splitting tensile strengths.

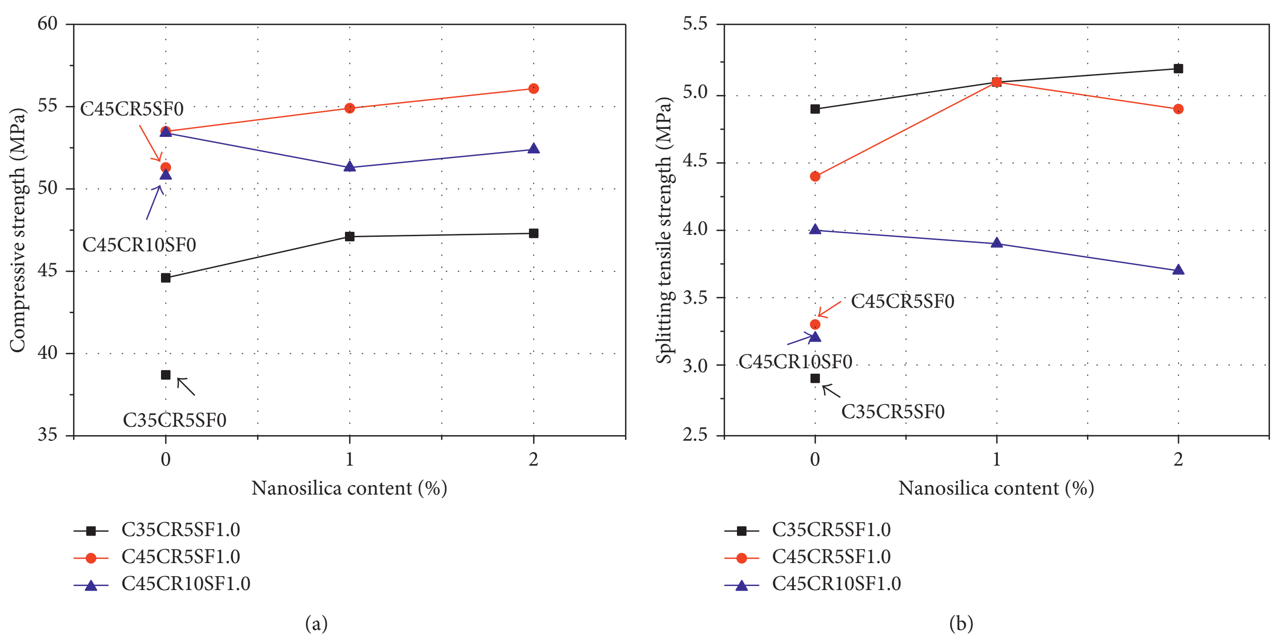


Figure 9: The effect of nanosilica on (a) compressive and (b) splitting tensile strengths.

splitting tensile strengths of the third group showed a downward trend. In addition, the splitting tensile strength of the second group only decreased when it met 2% nanosilica content. As mentioned before, since the workability of the third group was not very good, there must be some pouring defects in the third group, reducing the quantity of uniformly distributed steel fibers. Thus, when the rubber content reached 10%, the modification did not show up. It can be concluded that the compressive and splitting tensile strengths of modified CRC strengthened by nanosilica are more effective when the crumb rubber content is 5%.

4.3. Failure Mechanism of SFNS-CRC. The typical damage situation of specimens with different steel fiber and nanosilica contents varies significantly. The more the steel fiber mixed in CRC samples, the better the integrity the cubes maintained when damage happened. The fatal penetrating crack changed into multiple microcracks evenly distributed on the concrete. The damage situation of the test samples became better after adding nanosilica.

The role of crumb rubber in the CRC has been studied in our previous study [26]. Here, the steel fibers bear the force, and also they can be regarded as evenly distributed power transmission elements in CRC, just like the role of steel bars in the reinforced concrete. The steel fibers make the stress redistribution to occur, ensuring uniform force on CRC. The bond of concrete and steel fiber contributes to enhancing the deformation performance, and the fast fracture damage is postponed. The brittle failure mode is mitigated and changes into a ductile one. Hence, the ductility of CRC improved significantly with the increasing steel fiber content.

On the contrary, there are lots of pores in the CRC because of the hydrophobic nature of the crumb rubber. The nanosilica has two positive effects. It can fill the holes or refine the pores' size to make CRC more dense in physics. Moreover, because of the pozzolanic activity of nanosilica, the chemical reaction products, namely, calcium silicate hydrate (C-S-H gel), can densify the interfacial transition zone between aggregates and cement matrix. Hence, the noncompactness of the CRC can be effectively improved by nanosilica, enhancing the efficiency of steel fiber simultaneously. The combined effect of crumb rubber, steel fiber, and nanosilica resists further propagation and coalescence of cracks, ensuring the integrity of the specimens.

Hence, based on the failure mechanism analysis, the strengthening mechanism of mechanical properties can be drawn. The compressive and splitting tensile strengths of CRC are enhanced using steel fiber and nanosilica as additives. The improvement of steel fibers on the splitting tensile strength of modified CRC is more obvious, while the nanosilica plays an important role in the enhancement of compressive performance. The modified effects can achieve an optimum result when using the two additives together with the optimal amount.

5. Conclusions

Steel fibers and nanosilica were first introduced into CRC together to accomplish the modification on the compressive and splitting tensile strengths in this paper. Material properties' testing of eighteen concrete mixtures was conducted. Different concrete strength grades, rubber contents, steel fiber, and nanosilica contents were considered. The following conclusions can be drawn:

(1) The failure mode of CRC can be improved after adding steel fibers and nanosilica. The test samples maintained integrity when damage happened. The fatal penetrating crack changed into multiple microcracks uniformly distributed on the concrete surface.

(2) The compressive and splitting tensile strengths of CRC are enhanced using steel fiber and nanosilica as additives. The improvement of steel fibers on the splitting tensile strength of modified CRC is more obvious, while the nanosilica plays an important role on the enhancement of compressive performance.

(3) The steel fibers can be regarded as evenly distributed power transmission elements in CRC, and the ductility of modified CRC improved significantly. With the increased steel fiber content, the compressive and splitting tensile strengths gradually enhanced. More importantly, the modified CRC with 1.0% steel fiber content has relatively high compressive and splitting tensile strengths. Moreover, the lower the compressive strength of CRC, the better the modification effect of the steel fibers.

(4) The noncompactness of the CRC can be effectively improved by nanosilica, enhancing the efficiency of steel fibers simultaneously. Furthermore, nanosilica can further strengthen the compressive and splitting tensile strengths of modified CRC when the rubber content is 5%. On a negative side, the fluidity of the SFNS-CRC may have further sacrifice with the increasing nanosilica content.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

The authors would like to thank the Key Scientific Research Projects of Henan Province (18A560022) and Undergraduate Innovation and Entrepreneurship Program (32650007) for providing the funding to carry out this experimental work. Special thanks are due to Mingxin Tian, Zhu Yang, Rongya Chen, Tao Zhang, and Xinzhe Wang for their participation in this project.

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