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ADDITIONAL STEEL FIBERS IN CONCRETE MIXTURE: STUDIES OF COMPRESSIVE AND TENSILE STRENGTH OF CONCRETE

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Abstract. Test results for average compressive strength of 200.81 kgF/cm^2 were obtained for 3-day age of concrete at the fraction of steel fibers equal to 2.5%; for 7-days concrete we obtained the corresponding value of 263.97 kgF/cm^2 at the fraction of steel fibers equal to 2.5%; for 14-day concrete this value was 183.84 kgF/cm^2 at the fraction of steel fibers of 7.5%; and for 21-day concrete the average compressive strength of 345.99 kgF/cm^2 was attained at the fraction of steel fibers of 7.5% steels. Test results for average tensile strength of 40.46 kgF/cm^2 were obtained for 3-day age of concrete at the fraction of steel fibers equal to 2.5%; for 7-days concrete we obtained the corresponding value of 48.95 kgF/cm^2 at the fraction of steel fibers equal to 2.5%; for 14-day concrete this value was 54.38 kgF/cm^2 at the fraction of steel fibers of 5%; and for 21-day concrete the average compressive strength of 56.27 kgF/cm^2 was attained at the fraction of steel fibers of 7.5% steels.

Keywords: steel fibers; concrete mixture; compressive and tensile strength.

1. Introduction

The beginning of studies of this problem was the occurrence of cracks at the college building facade, where the author lectures in the framework of the Civil Engineering Study Program. This was the initial moment for carrying out research to improve the properties of concrete. One of the directions in this research field is related to the improvement of the behavior of concrete, which is unable to withstand tensile stresses at forces exceeding the concrete strength, which is within 9 – 15% of its compressive loading [1].

Every loading, improving compressive strength, is accompanied by some increase in tensile strength. This value, obtained from the results of repeated tests, reaches the strength of 0.50 – 0.60 σ_c, therefore for ordinary concrete it is chosen the value of 0.57 σ_c [2]. Other assumption propose that concrete is considered capable to withstand the applied loading at the tensile stress of 27 kgF/cm^2, so it is considered inefficient, especially in tension and in the form of plastering. The displacements in concrete can lead to cracking even if stress is not so large. This is due to the cracking, caused by the nature of the concrete. This structural condition is often ignored because the tensile stress a fully restricted by the reinforcement in sufficient quantities and placed correctly. Rapid development of technology, at present, demands alternative effective approaches. One of the alternative methods is connected with the using steel fibers (stainless fibers). The main idea consists in reinforcement of concrete with uniformly dispersed steel fibers with random orientation. So that concrete does not experience cracks, which easily initiate due to loading or heat hydration [3]. Thus it is

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expected that the ability of concrete to resist to internal stresses (axial, flexural, and shear) will increase.

2. Experiment

The method applied in this research is experimental method aimed to investigate causal relationship and compare the results. Tests conducted include material testing, namely compressive and tensile strength testing. The research materials used in this research are as follows: water, cement, aggregate, fibers of Fiber Steel (Dramix®3D) with the material properties: tensile strength is R_m = 1.345 N/mm^2), average tolerances are ± 7.5%, Young's modulus is ± 210,000 N/mm^2, geometric sizes of fibers, length is l = 35 mm, diameter d = 0.55 mm, aspect ratio is l/d = 65.

As the parameters in this study, we consider cement volume weight 350 kgF/m^3 with a fiber content 2.5%; 5%; 7.5%; 10% (of the weight of cement). The variables are present in Table 1.

Table 1. Sample parameters.

Cement volume weight (kg/m^3)	Length of fibers Dramix®3D (mm)	Water factor of cement	Fiber content (%) of the weight of cement	Number of specimens	
				For test (σ_c & E_c)	For test (σ_t)
350	35	0.5	0	3	3
			2,5	3	3
			5	3	3
			7,5	3	3
			10	3	3
Number of specimens				15	15

We tested cylindrical specimens with height of 150 and 300 mm at testing on compressive and tensile strength. The sampling number consisted of 30 specimens and for each composition, 3 test samples (15 samples were tested on compression and tension in each case) are used.

Compressive strength of concrete (σ_c). The compressive strength of concrete according to SNI 03-1974-1990 [4] is the parameter, defining quality of a structure. The compressive strength of concrete can be calculated as

$$\sigma_c = P_{max}/A, \quad (1)$$

where σ_c is the applied compressive stress (N/mm^2), P_{max} is the maximum compressive load (N), A is the surface area of the test sample (mm^2).

Tensile strength (σ_t). Tensile strength becomes an important part in the study of concrete to resist cracks due to moisture content and temperature, affecting the ability of the concrete in overcoming the effect of initial cracking before final failure. Roughly, normal concrete tensile strength values are only about 9 – 15% of the compressive strength and can be computed as

$$\sigma_t = 2P/(\pi l d), \quad (2)$$

where σ_t is the applied tensile stress (N/mm^2), P is the time load for concrete (N), l and d are the length and diameter of cylindrical sample (mm).

Flow point determination. The flow point is the point at which the gradient changes from the incline form to almost flat on the load – displacement plot for reinforced concrete. Fig. 1 shows that, at the first stage the arising strain is still small so the plot is almost vertical in this region. Then the slope of the plot will be few reduced because the concrete is not sufficiently stiff, compared with the previous stage before the concrete subjected to cracking.

After that, the plot will experience gradient changes from inclined to almost horizontal behavior. In order to reinforced concrete to flow, additional large load is required to increase displacements in the reinforced concrete. More details can be seen in Fig. 1.

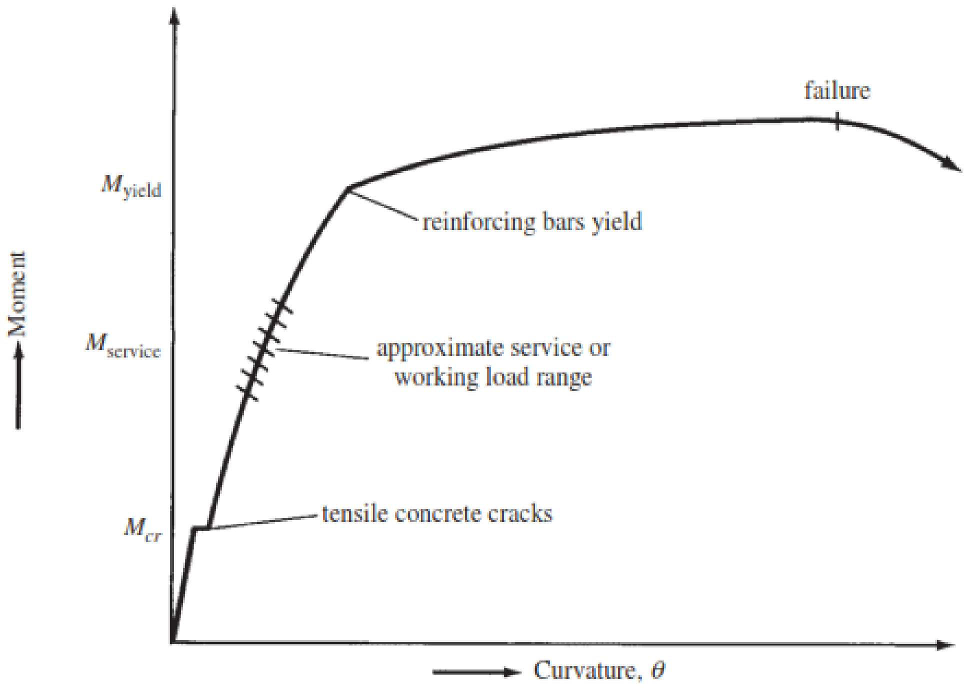

Fig. 1. Moment – curvature plot for reinforced concrete beam.

Bending. The bending of the beam is caused by strains arising from external loads. This test uses SNI 03-6861.1-2002 [5] and ASTM C-78 [6] standards, that is, the testing of tensile strength with two applied loads acting on a beam cross-section at the points dividing the beam into 3 sections. The magnitude of concrete bending strength for testing with using two loads can be calculated as

$$\sigma_l = Pl/(bh^2), \quad (3)$$

where σ_l is the stress of rupture (MPa), P is the applied load (N), l is the length of span (mm), b is the width of the specimen (mm), h is the height of specimen (mm).

3. Results

Research results are present in Tables 2, 3 and Figs. 2, 3; the testing process – in Fig 4.

Table 2. Percentage of steel fibers mixture and Average Compressive Strength.

Percentage of steel fibers mixture	Average compressive strength (Kg/cm^2)			
	3 Days	*7 Days*	*14 Days*	*21 days*
0%	181.95	224.38	157.44	263.03
2.50%	200.81	263.97	175.35	290.37
5%	150.84	150.84	121.62	268.69
7.50%	124.44	164.98	183.84	345.99
10%	151.78	137.64	179.12	296.03

Table 3. Percentage of steel fibers mixture and Average Tensile Strength.

Percentage of steel fibers mixture	Average tensile strength (Kg/cm2)			
	3 Days	7 Days	14 Days	21 days
0%	40.23	41.41	53.2	55.56
2.50%	40.46	48.95	48.95	55.56
5%	34.09	38.34	54.38	52.02
7.50%	39.99	42.82	52.02	56.27
10%	35.51	43.53	44.94	51.08

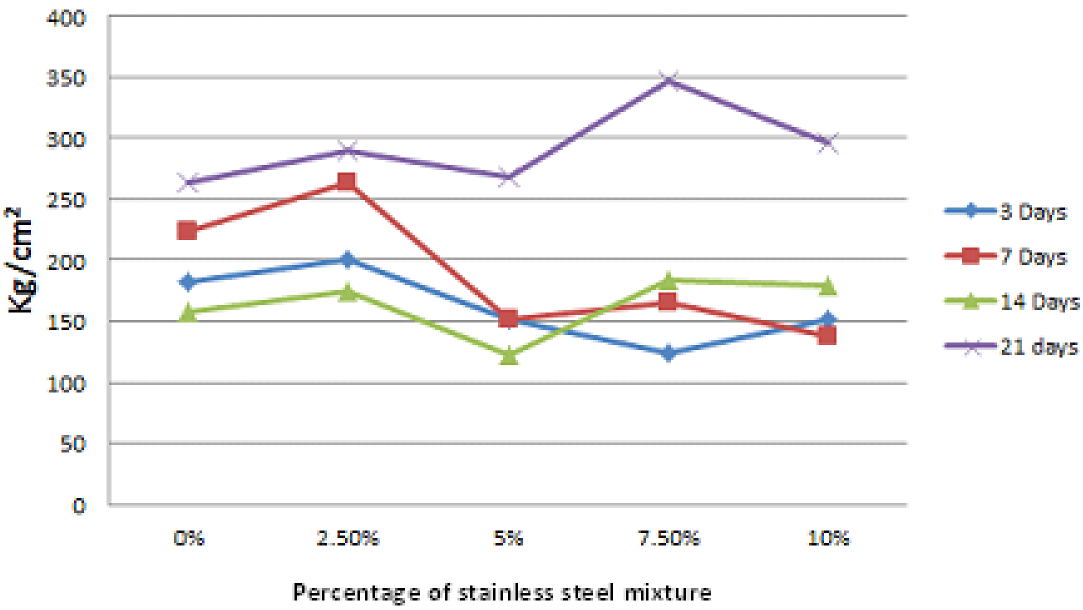

Fig. 2. Test results of concrete compressive strength.

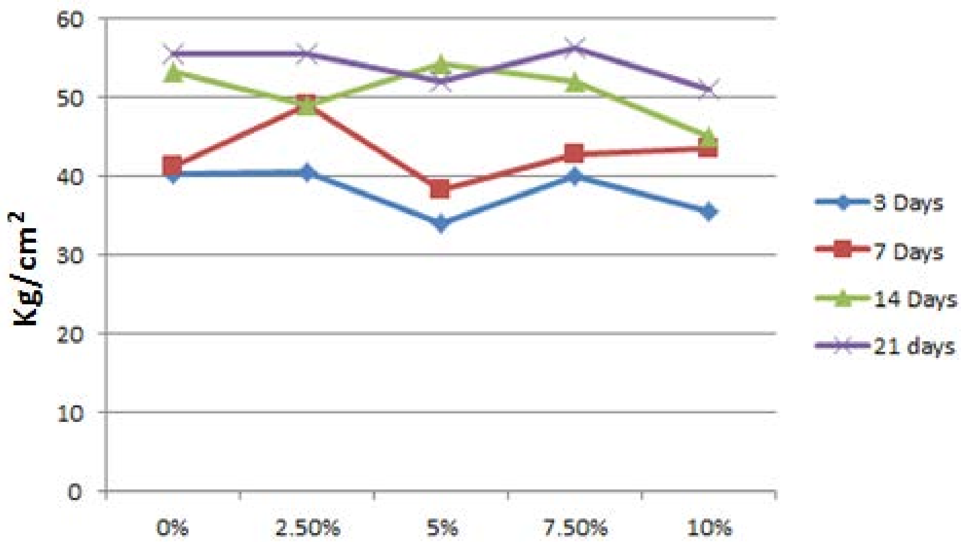

Fig. 3. Test result of concrete tensile strength.

Fig. 4. Photo of testing concrete cylinder.

3. Conclusions

Test results for average compressive strength of 200.81 kgF/cm^2 were obtained for 3-day age of concrete at the fraction of steel fibers equal to 2.5%; for 7-days concrete we obtained the corresponding value of 263.97 kgF/cm^2 at the fraction of steel fibers equal to 2.5%; for 14-day concrete this value was 183.84 kgF/cm^2 at the fraction of steel fibers of 7.5%; and for 21-day concrete the average compressive strength of 345.99 kgF/cm^2 was attained at the fraction of steel fibers of 7.5% steels. Test results for average tensile strength of 40.46 kgF/cm^2 were obtained for 3-day age of concrete at the fraction of steel fibers equal to 2.5%; for 7-days concrete we obtained the corresponding value of 48.95 kgF/cm^2 at the fraction of steel fibers equal to 2.5%; for 14-day concrete this value was 54.38 kgF/cm^2 at the fraction of steel fibers of 5%; and for 21-day concrete the average compressive strength of 56.27 kgF/cm^2 was attained at the fraction of steel fibers of 7.5% steels.

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