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CARPET FIBRES EFFECT IN IMPROVING THE RESISTANCE PROPERTIES OF RECYCLED CONCRETE

EFEKAT VLAKANA TEPIHA U POBOLJŠAVANJU SVOJSTAVA OTPORNOSTI RECIKLIRANOG BETONA

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Ključne reči
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- pritisna čvrstoća
- zatezna čvrstoća
- reciklirani beton

Abstract

This research aims to investigate the effect of using carpet waste fibres in improving the resistance properties (slump, density, compressive and tensile strengths) of concrete. The fibres used in this research include sinuous fibres with black colour and 40 mm length and 0.4 mm diameter, which has a specific gravity of 0.91. Samples used in this research include sample A as a control sample, sample B containing 0.25 %, sample C with 0.75 %, sample D with 1.25 %, and sample E with 1.75 % of carpet waste fibres. Results of the slump test show that concrete slump decreases due to the addition of carpet waste fibres, and the higher the percentage of carpet waste fibres the greater the resistance. The density of fresh concrete will decrease due to the addition of carpet waste fibres. Results of the concrete strength test show that compressive and tensile strength and modulus of elasticity increase due to the addition of carpet waste fibres. Flexural strength increases the most due to the addition of 1.75 % of waste fibres. Water absorption of concrete decreases by adding different percentages of carpet waste fibres.

Izvod

Ovo istraživanje ima za cilj utvrđivanje efekta otpadnih vlakana tepiha u poboljšavanju svojstava otpornosti betona (konzistencija, gustina, pritisna i zatezna čvrstoća). Vlakna upotrebljena u radu su crna uvijena vlakna, dužine 40 mm i prečnika 0.4 mm, sa specifičnom težinom 0,91. U radu su korišćeni uzorci: A kao kontrolni uzorak, uzorak B koji sadrži 0,25 %, C sa 0,75 %, D sa 1,25 %, i uzorak E sa 1,75 % otpadnih vlakana tepiha. Rezultati ispitivanja metodom sleganja pokazuju da konzistencija opada usled dodavanja otpadnih vlakana tepiha, i što je veći procenat otpadnih vlakana, to su veća svojstva otpornosti. Gustina svežeg betona opada dodavanjem otpadnih vlakana tepiha. Rezultati ispitivanja čvrstoće betona pokazuju da pritisna čvrstoća, zatezna čvrstoća i modul elastičnosti rastu dodavanjem otpadnih vlakana tepiha. Najveći porast savojne čvrstoće postiže se dodavanjem 1,75 % otpadnih vlakana. Dodavanjem različitih procenata otpadnih vlakana dovodi do pada apsorpcije vode u betonu.

INTRODUCTION

For various reasons, some of this concrete cracks. The reason for cracking can be structural or non-structural. However, the main cracks are caused by the inherent weakness of concrete in tension /1, 2/. For example, shrinkage in concrete creates cracks. In general, fibres prevent the spread of cracks in concrete by providing greater integrity and softness /3/. Fibres significantly increase the tensile strength and ductility of mortar and concrete and change the behaviour of concrete from brittle to soft and malleable /4/. High strength concrete (HSC) has disadvantages such as fragility and low ductility. Fibres can be added to HSC concrete to fix these disadvantages and increase the plasticity of concrete with high strength /5/. Also, the use of different fibres in concrete is considered as an effective step in preventing the propagation of micro-cracks and the weakness of the tensile strength of concrete /6/. Carpet consists of components such as top thread, primary back layer (polypropylene), glue, secondary back layer (polypropylene and polyester), which has been used as fibre concrete (FC) /7/.

Ahmed et al. /8/ investigate the use of recycled waste fibres in concrete. In this research, a comprehensive investigation is conducted on the effect of recycled plastic fibres (RPFs), recycled carpet fibres (RCFs) and recycled steel fibres (RSFs) on fresh, mechanical and ductility properties of concrete. In addition, they also developed experimental models using mechanical properties. They concluded that RPFs, RCFs, and RSFs can be safely used in concrete composites because they have satisfactory fresh, physical, and mechanical properties.

Alabduljabbar et al. /9/ used industrial wastes in concrete that deals with the physical and mechanical properties of green concrete containing waste polypropylene carpet fibres (PCF) and palm oil fuel ash (POFA). In this study, six different volumetric fibre models of 20 mm length are used for ordinary portland cement (OPC) concrete mixtures. Another six mixtures are cast, whereby 20 % POFA replaced OPC. Carpet fibres combined with POFA have been found to reduce the workability of concrete. Experimental results also show that the combination of waste carpet fibres and POFA increases the long-term compressive strength of concrete.

The compressive strength was in the range of 43-54 MPa in 365 days. Therefore, the combination of waste carpet fibres and POFA increases the tensile and flexural strength of concrete. The effects of POFA on increasing the strength of concrete at the final ages of curing are more significant. Hossieni et al. /10/ developed a new PAFRC reinforced with waste polypropylene (PP) carpet fibres and investigate its strength and transport properties.

Palm oil fuel ash (POFA) is used as a partial cement replacement. Six PAFRC mixes with different fibres from 0 to 1.25 % with a length of 30 mm are made by gravity method. Another six batches are made with similar fibre dosages where the pumping method is used to inject the slurry into the voids between the aggregates. The results show that by adding carpet fibres, the compressive strength of PAFRC samples decreases. Zareei et al. /11/ investigate the properties of green concrete with high strength containing recycled ceramic aggregates and waste carpet fibres. This paper investigates the combined use of recycled waste ceramic aggregates (RWCA) and waste carpet fibres (WCFs) in high strength concrete (HSC). Concrete mix containing different percentages of RWCA including 20, 40, 60 % (by weight) is prepared as a partial replacement of natural coarse aggregate (NCA).

WCF is added to the mixtures to increase the tensile and flexural strength of concrete. The slump and density of fresh concrete are evaluated, both of which show a decreasing trend with the incorporation of RWCA and WCF. The current research is done in order to combine different percentages of carpet fibres with recycled concrete in order to find the optimal percentage to prevent the weakness of concrete in microcracks, pressure, tension and flexural strength, and also to check the efficiency of recycled concrete with carpet fibres.

MATERIALS AND LABORATORY PROGRAMME

Specifications of materials

Cement

The cement used in this research is type 2 Portland cement /12/. Table 1 shows the characteristics of cement and its chemical compounds.

Table 1. Specifications of used cement /12/.

Cement compounds	SiO_2	MgO	CaO	SO_3	Fe_2O_3	Al_2O_3	K_2O	Na_2O
%	21.32	3.44	62.02	2.09	2.98	3.83	0.12	0.73

Aggregates

The types of used aggregates in tested concrete are natural sand, pea sand, and almond sand. The amount and type of granulation are shown in Tables 2 and 3.

Fibres

In this research, two different types of fibres are used in a hybrid form. Also polycarboxylate lubricant is used to reduce the ratio of water to cement and increase slump and efficiency of concrete. The fibres used in this research include waste and seam carpet fibres. The used waste fibres are a mixture of pieces of different types of carpets, the specifications and sizes of each of which are given in Fig. 1.

Table 2. Specifications of used aggregates.

Natural sand	Pea gravel	Almond sand	Sieve score
Residue on the sieve			
-	0	0	1#1/2
-	0	41	#1
-	0	1950	#3/4
-	189	2282	#1/2
0	1030	211	#3/8
58	1052	7	#4
493	2	2	8#
404	0	0	16#
417	-	-	30#
423	-	-	50#
172	-	-	100#
33	27	7	bottom tray
2000	2300	4500	Total

Table 3. Physical characteristics of used aggregates.

Maximum aggregate diameter (mm)	Modulus of elasticity	Density (gr/cm^3)	Water absorption (%)	Aggregate
19	6.6	2.57	1.74	sand
10	3.3	2.56	2.3	fine

Figure 1. a) Chopped carpet fibres; b) carpet waste fibres under the microscope; c) carpet waste fibres; d) and e) size of used carpet waste fibres.

Sinusoidal fibre is a fibre produced from pure polyolefin and polypropylene modified polymer. The shape of these fibres is ribbed which increases the contact surface and engages more with concrete components. These fibres are usually used in concrete to increase bending strength, tensile strength, increase resistance against loads on concrete /13/. Figure 2 shows the image of these fibres.

Figure 2. Sinusoidal fibres used in concrete.

The characteristics of sinuous fibres used in this research are according to Table 4.

Table 4. Specifications of sinuous fibres used in this research.

Specific gravity (g/cm^3)	Drop (mm)	Length (mm)	Colour	Shape
0.91	0.40	40	black	jagged

Additives in concrete

In this research, polycarboxylate super-lubricant has been used to reduce the water-cement ratio and increase the slump and fluidity of concrete. The amount of consumption of these lubricants is based on the weight percentage of cement materials, and it is calculated in litres. In Fig. 3, the super lubricant used is displayed.

Figure 3. Super lubricant used in concrete.

CONCRETE MIXING PLAN

In this research, the mixing plan for one cubic metre of concrete is obtained as Table 5.

Table 5. Plan of mixing for one cubic metre of concrete.

Concrete category (MPa)	Super lubri cant (l)	Fine (kg)	Sand (kg)	Cement (kg)	Water (l)
C25	3.2	800	1050	400	180

Three types of templates have been used to conduct in this research. The forms used in this research include cubic, cylindrical and prismatic forms. Parallel samples have been used for the compressive strength test. cylindrical samples have been used to measure the tensile strength, and prismatic samples are used to measure the bending strength.

EFFICIENCY OF CONCRETE

In this research, the slump method is used to determine the efficiency of concrete. Slump test is a common and important method for concrete fluidity and consistency measurement of fresh concrete before use /14/. Figure 4 shows the concrete slump test.

Figure 4. Slump test.

TEST OF COMPRESSIVE STRENGTH, TENSILE STRENGTH AND BENDING STRENGTH

In this research, the samples tested for their compressive strength are tested according to ASTM C39/C39 standard /15/. Figure 5 shows the compressive strength testing device.

Figure 5. Compressive strength test device.

Figure 6. Tensile strength test device using the bisection method.

Bisection method is used to perform the tensile strength test. For this test, a cylindrical mould is used with dimensions of 15×30 cm using a box-shaped metal piece with thickness at least 5 cm and a length of 30 cm, and a plastic piece with a thickness of 2 mm to prevent entering direct stress on the samples. Figure 6 shows the device for performing the tensile strength test.

In this research, the point loading method in the centre is used for the bending test and the results are analysed based on it. Figure 7 shows the bending test method in this research.

Figure 7. Flexural strength test with point loading in the centre.

DISCUSSION ON THE RESULTS

Average results of different tests are given in Table 6. The naming of the mixing scheme has been done in abbreviated form. It is the case that PC stands for witness concrete and refers to concrete without any additives. Also, CFR stands for concrete containing carpet fibres.

As shown in Table 6, adding fibres to concrete has no effect on the setting process of concrete. But it will have a significant effect on increasing compressive, tensile and bending strength of concrete, and it can be said that sample E, which has the highest amount of fibres, has the most positive effect in all resistance parameters. On the other hand, the influence of fibres has the greatest increase in tensile strength, so that the 28-day tensile strength of sample E is about 84 % higher than the tensile strength of sample A. Table 7 shows the amount of concrete slump of different samples.

The density of concrete is obtained by dividing the weight of concrete by the volume of the container in which it is poured. Specific weight is one of the important parameters of fibre concrete. The reason for the decrease in the specific weight of fibre concrete is the increase of empty spaces and porosity due to the addition of carpet fibres to it. Table 8 and Figure 8 show the laboratory results of the density of fresh concrete.

Table 6. Average results of different tests.

Mixing plan number	Mixing plan type	7-day compressive strength (MPa)	7-day compressive strength (MPa)	7-day tensile strength (MPa)	28-day tensile strength (MPa)	28- day modulus of rupture (MPa)	Modulus of elasticity (GPa)	Water absorption percentage
A	PC	17.62	26.10	7.23	12.87	65.70	3.27	12.3
B	0.25% CFRC	17.01	28.36	11.15	17.92	82.12	5.23	11.1
C	0.75% CFRC	18.39	31.21	12.43	18.37	8.88	6.16	10.8
D	1.25% CFRC	21.43	33.45	14.99	20.17	91.72	6.73	10.1
E	1.75% CFRC	24.10	36.67	16.33	23.74	96.28	7.19	9.3

Table 7. Amount of concrete slump.

E	D	C	B	A	Plan code
82	88	93	109	138	slump (mm)

Table 8. Laboratory results of density of fresh concrete.

E	D	C	B	A	Plan code
2203	2241	2280	2302	2345	density of fresh concrete (kg/m^3)

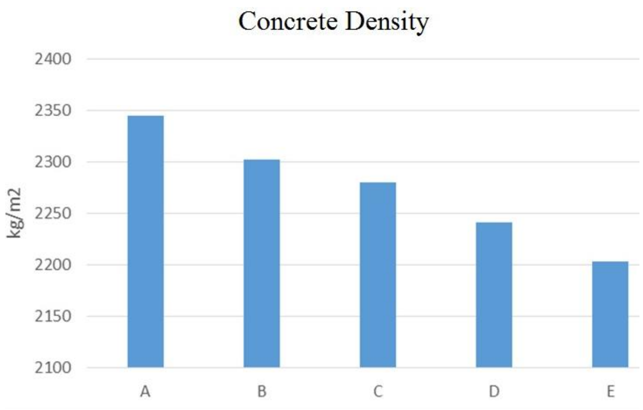

Figure 8. Changes in the density of fresh concrete against changes in the amount of recycled carpet fibres.

As shown in Figure 8, by adding carpet waste fibres, the density of concrete increases due to the increase of voids and porosity.

RESULTS

This research is aimed to investigate the use of carpet waste fibres on the characteristics of fresh and hardened concrete. The properties of elasticity and density have been investigated in fresh concrete. Compressive strength, tensile and bending strength have been investigated in hardened concrete. The following results have been obtained:
- concrete slump will be reduced by adding carpet fibres;
- the density of concrete has decreased with the addition of carpet waste fibres;
- optimum addition of carpet waste fibres increases the compressive strength of concrete by about 40 %;
- tensile strength has increased by adding carpet waste fibres, it is shown that the highest increase in tensile strength (about 84 %) is achieved in the sample containing 1.75 % of carpet waste fibres;
- modulus of elasticity as a function of compressive strength increases due to the addition of carpet waste fibres.

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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