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Study on Mechanical Character of C50 Box-beam Concrete with Natural Pebbles

Mingqiang Qin[1,2,3,a] , Guozhi ZHANG[3,b] ,Wen Zhan[1,2,3,c], Shunkai LI[1,2,3,d]

1. CCCC Wuhan Harbor Engineering Design & Research Institute Co., LTD, Wuhan, Hubei 430040

2. Key lab of large-span Bridge Construction Technology, Ministry of Communication, Wuhan, Hubei 430040

3. Hubei Key Laboratory of Advanced Materials & Reinforcement Technology Research for Marine Environment Structures, Wuhan, Hubei 430040

[a]dzqinmq@tom.com,[b]zhangguozhi@sina.com,[c]zhanwen1121@sina.com,[c]xuwenbing520520@163.com, [d]lishunkai@163.com

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Abstract: The mechanical character of natural Pebbles concrete and crushed stone concrete is studied in this study. The results show that compared with the aggregate concrete, the W/B can reduce the crushed stone concrete to a certain extent. For the C50 box beam concrete, the water cement will decrease by about 0.04-0.06. The density is adjusted according to the loose bulk density or the measured value of the aggregate. Under the condition of the same compressive strength, pebble concrete has similar flexural strength, axial compressive strength, elastic modulus to the crushed stone concrete. The tension and compression ratio of pebble concrete is lower than that of crushed stone concrete, and the compressive strength of pebble concrete is less than that of crushed stone concrete.

Introduction

As China carry on “The Belt and Road Initiative” stratagem, domestic design and construction company has taken a great numbers of overseas projects, The Danube Bridge in Serbia is one of the typical project. The Danube Bridge is variable cross-section prestressed concrete continuous girder bridge, a project loaned by Chinese Export Import Bank, and contracted to be designed and constructed by the Chinese company. It is a special project that the concrete used to make the pile foundation, caps and piers are all made by natural pebbles. Despite the fact that there are minor mine resources in Serbia, there are actually abundant and available pebble resource in the Danube River. The Serbia has been producing cement concrete with natural pebbles for environmental protection. Serving for more than 70 years, the Cypress Bridge, in which concrete aggregate is natural pebbles, is still playing an important role as a combined highway and railway bridge.

So far, a majority of concrete usually use crushed stone or crushed pebble as coarse aggregate. As usually known, compared to crushed stone, natural pebble has less particle gradation, higher porosity, less angular surface and less bond force of cement paste[1-4]. And that is the reason why natural pebble are not commonly apply in the concrete that requires high-strength and impermeability. The high quality stone resources are running out due to the massive civil engineering construction, advocating innovation and sustainable development, the authority pays more and more attention to environmental protection by going on the path of “Green economy,

green industry and green building". Based on this point, and on the foundation of The Danube Bridge, the study is mainly discussing natural Pebbles being aggregate to prepare C50 Box-beam Concrete. The mechanical character of natural Pebbles concrete and crushed stone concrete is studied .

Raw Material for Experiment

Box girder concrete to be formulated: Grade of compressive strength is C50,Slump required between 160~220mm,Initial setting time not less than 10h,The aggregate diameter of concrete is 0~20mm. The raw material for the experiment are the following:

⑴Cement: Lafarge cement is PC42.5R,which specific surface area is 400m^3/kg,28d compressive strength is 57.8MPa.

⑵Fine aggregate: River sand, Fineness modulus is 2.3,Apparent density is 2667kg/m^3,Bulk density is 1840kg/m^3,Sediment percentage is 0.92%,mud percentage is 0.1%.

⑶Admixture: Sika polycarboxylic acid admixture, solid percentage 27.4%,water reducing rate 34.3%.

⑷Pebble: Two kinds of size 4.75-9.50 mm, 9.50-19.0 mm, after Laboratory grading gradation test, mix by 3:7 and the lowest gravel grade was obtained. The Physical performance index of pebbles for the experiment are shown in table 1.

Table 1 The physical performance index of pebble stone and crushed stone

Types	Apparent density / kg.m^{-3}	Bulk density / kg.m^{-3}	Porosity /%	Crushed value /%	Clay lump content /%	Diameter /mm
Natural pebble	2597	1515	41.7	15.0	0.28	5-20
Crushed stone	2610	1530	41.4	18.4	0.30	5-20

⑸Gravel for comparative testing. 5~20cm Continuously graded crushed stone. The Physical performance index of crushed stone for the comparative testing are shown in table 1.

Comparison of performance of different aggregate concrete in same Water binder ratio

In order to compare natural Pebbles and crushed stone as coarse aggregate preparation of concrete, select the amount and proportion of the fixed cementing material. By adjusting the amount of water and the amount of admixture to achieve close slump. In different situation of W/B, figure out the slump flow, air content, density and 7d 28d compressive strength in each situation. The testing mix ratios are shown in Table 2. The properties of the mixtures in different ratios are shown in table 3.

Table 2 Mix ratio of Natural pebble(NP) and crushed stone(CS) concrete

Number	Amount of cementitious material /kg.m^{-3}	W/B	Sand ratio /%	Material dosage/ kg.m^{-3}							Remarks
				Cement	Fly ash	Sand	Aggregate		Water	Admixture /%	
							4.75-9.50 mm	9.50-19.0 mm			
L1	440	0.44	42	308	132	740	404	606	194	0.40	CS
L2	440	0.44	42	308	132	740	305	705	194	0.28	NP
L3	440	0.42	42	308	132	740	310	710	185	0.30	NP
L4	440	0.40	42	308	132	745	410	615	176	0.36	CS
L5	440	0.40	42	308	132	745	310	715	176	0.40	NP
L6	440	0.38	42	308	132	745	310	715	167	0.40	NP
L7	440	0.36	42	308	132	750	412	618	158	0.50	CS
L8	440	0.36	42	308	132	750	310	720	158	0.50	NP
L9	440	0.34	42	308	132	750	315	725	150	0.60	NP
L10	440	0.32	42	308	132	755	315	725	141	0.70	NP

Table 3 Comparison of performance between pebble and crushed stone concrete

Number	Amount of cementitious material /kg.m^{-3}	W/B	Sand ratio /%	Admixture /%	Slump /mm	Slump flow /mm	Air content /%	Density /kg.m^{-3}	Compressive strength /MPa		Remarks
									7d	28d	
L1	440	0.44	42	0.40	200	480	2.8	2365	29.7	45.2	CS
L2	440	0.44	42	0.28	200	450	2.5	2340	24.2	37.0	NP
L3	440	0.42	42	0.30	190	450	2.4	2355	25.5	41.6	NP
L4	440	0.40	42	0.36	190	460	2.9	2368	32.4	48.6	CS
L5	440	0.40	42	0.40	200	460	3.0	2350	29.3	45.3	NP
L6	440	0.38	42	0.40	190	440	3.0	2373	28.0	44.2	NP
L7	440	0.36	42	0.50	185	450	3.2	2380	32.0	50.1	CS
L8	440	0.36	42	0.50	195	450	3.0	2392	30.8	46.5	NP
L9	440	0.34	42	0.60	185	450	3.3	2396	32.8	49.3	NP
L10	440	0.32	42	0.70	185	430	3.5	2405	39.8	55.1	NP

Workability. Only when the amount of admixture is changed, under the same conditions of other mixture parameters and the W/B of crushed stone and pebble concrete is 0.44, pebble concrete using less admixture dosage, can basically reach the same workability as crushed stone concrete; The workability of pebble concrete is better than that of crushed stone under the same mixing ratio. There are mainly two reasons: The surface of the pebbles is smooth and the shape of the granules is mellow. The cement paste has better flowability, but the crushed stones are many edges and corners[5-7]. The friction resistance of the cement paste is large and its flowability is not good; Secondly, the water absorption rate of pebbles is less than that of crushed stone, and the amount of free water of pebble concrete is higher than that of crushed stone concrete in the same amount of concrete.

Compared with other mixing parameters, the difference of air content and bulk density between pebble concrete and crushed stone concrete is not obvious.

Compressive strength. Table 3 is the compressive strength of crushed stone concrete and pebble concrete 7d and 28d at the same W/B. From the Table 3, in line with the same W/B (respectively 0.44, 0.40 and 0.36), stone group (L1, L4, L7) 7d and 28d compressive strength are higher than that of pebble group (L2, L5, L8) compressive strength. The factors are following: The specific surface area of the crushed stone is larger than the pebble , and it has a rough surface and pebble surface is smooth, for which makes contact cement hydration products better. And cement hydration produced by Calcium hydroxide and Calcium silicate hydrate is more easily generated and attached to the rough surface of the pebble and crushed stone surface reaction, so that the bone strength of crushed stone aggregate is better than that of pebble and paste. In addition, the compressive strength of concrete at 7d and 28d ages increase when the W/B in the pebble group(L1, L4 and L7) is decreasing .

As can be seen from Table 3, compressive strength of crushed stone concrete can be the same as that of crushed stone concrete by reducing the W/B of pebble. The common strength grade of bridge concrete is generally C35-C50, which is consistent with the range of compressive strength shown in this study. In order to prepare the same compressive strength of concrete, compared with crushed stone concrete, the W/B needs to be reduced to some extent, and the reduction range is about 0.04~0.06.

Mechanical characters of concrete under the same compressive strength

Under the same W/B, the compressive strength of pebble concrete is lower than that of crushed stone concrete; however, the compressive strength of concrete can be greatly improved by using high performance water reducing agent, lowering W/B and increasing the amount of cementitious material. By adjusting and optimizing the mix ratio, using pebbles can also be prepared with crushed stone concrete compressive strength of the same to achieve the design requirements of box girder concrete. As a prestressed box girder component, not only the requirements of the compressive strength must be high grade, but the flexural strength, modulus of and elasticity tensile strength as well. These are all important mechanical index of box girder, prestressed construction and post structural safety is crucial, therefore, the flexural strength, elastic modulus and other mechanical properties should be necessarily compared.

Based on the above test mix further adjusted, reducing the cementitious materials content and W/B, using crushed stone and pebble are prepared with C50 box is suitable for the engineering application of the beam concrete mix ratio, compared with the compressive strength under the different condition of flexural strength, axial compressive strength and modulus of elasticity. The test shows that the ratio of W/B is reduced by 0.05. After proper adjustment of admixture content, the compressive strength of pebble concrete at different ages is close to that of crushed stone concrete. Concrete mixture ratio with same compressive strength, as shown in Table 4.

Table 4 Concrete mixture ratio with same compressive strength

Number	Amount of cementitious material /kg.m^{-3}	W/B	Sand Ratio /%	Material dosage/ kg.m^{-3}						Remarks
				Cement	Sand	Aggregate		Water	Admixture /%	
						4.75-9.50 mm	9.50-19.0 mm			
L11	410	0.40	42	410	760	420	630	165	1.0	CS
L12	410	0.35	42	410	760	326	724	143	1.2	NP

The compressive strength, flexural strength, axial compressive strength and modulus of elasticity are tested by using LS11 and LS12 mixture ratio. The mechanical properties of crushed stone and pebble concrete under the same compressive strength are studied. The test results are shown in Fig.1-4.

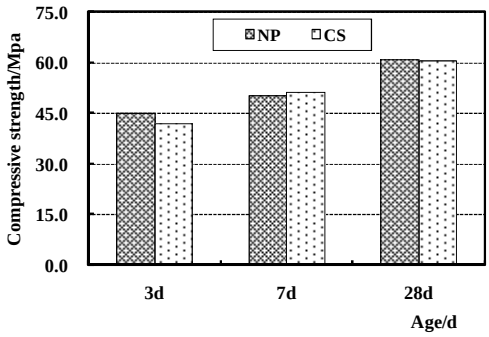

Fig.1 Compressive strength

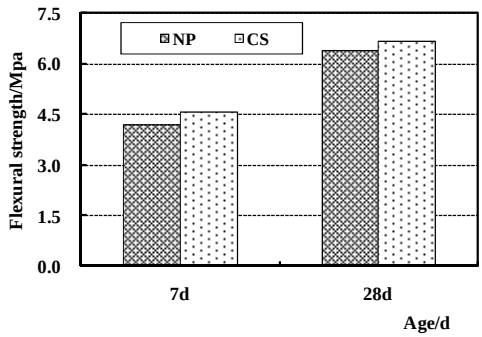

Fig.2 Flexural strength

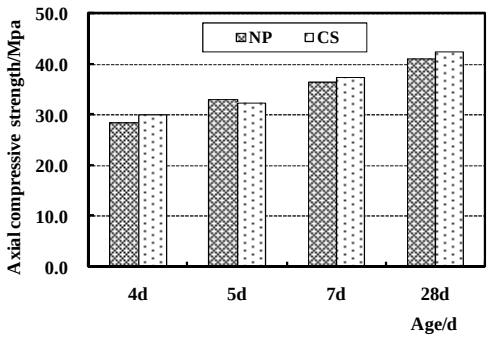

Fig.3 Axial compressive strength

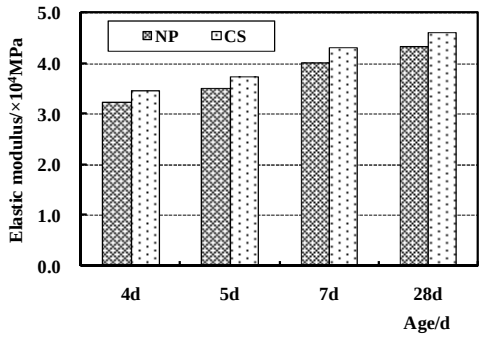

Fig.4 Elastic modulus

As shown in Fig.1-4, the compressive strength and axial compressive strength of crushed stone concrete at different ages are similar to those of pebble concrete. However, under the same strength condition, the flexural strength and modulus of elasticity of pebble concrete are slightly lower than those of crushed stone concrete. Compared with crushed stone concrete, they are reduced by 4.8%, 3.8% and 6.3% respectively, and the difference between them is basically negligible.

Using L11 and L12 mix ratio for pebble concrete and crushed stone concrete, 8 groups of compressive strength tests are carried out , in order to study the effects of different aggregate on mechanical properties and discreteness, and compared the different aggregate concrete tension compression ratio.

The test results are shown in Fig.5.

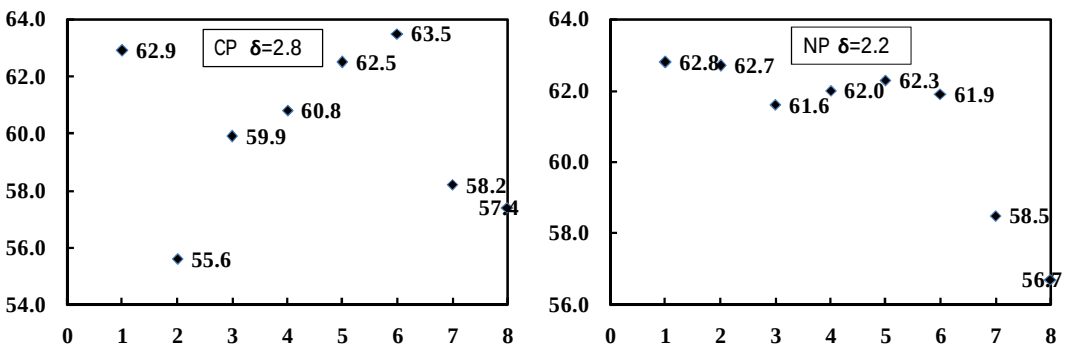

Fig.5 Distribution of compressive strength

The maximum, minimum, mean, standarddeviation and average ratiooftension and compression

to the 28d test mix are shown in Table 5.

Table 5 The compressive strength, standard deviation and average tension compression ratio of concrete mix ratio

Number	28d Compressive strength/MPa				Average tension compression ratio	Remarks
	Max	Min	Avg	Standard deviation		
L11	63.5	55.6	60.7	2.8	7.0	CP
L12	62.9	56.7	61.1	2.2	6.5	NP

As shown in Table 5, the compressive strength of similar cases, the pebble concrete has a lower ratio of tension and pressure than that of the crushed stone concrete ; at the same time, the standard deviation of pebble concrete is less than that of crushed stone concrete, which is to say, the compressive strength of pebble concrete is less dispersed, which is good for quality control.

Conclusion

⑴Compared with the aggregate concrete, the W/B can reduce the crushed stone concrete to a certain extent. For the C50 box beam concrete, the water cement will decrease by about 0.04-0.06. The density is adjusted according to the loose bulk density or the measured value of the aggregate.

⑵ Under the condition of the same compressive strength, pebble concrete has similar flexural strength, axial compressive strength, elastic modulus to the crushed stone concrete. The tension and compression ratio of pebble concrete is lower than that of crushed stone concrete, and the compressive strength of pebble concrete is less than that of crushed stone concrete.

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