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Study on the mechanical properties of desert sand concrete

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Abstract. In this paper, the manufactured sand was replaced by desert sand with contents to prepare desert sand concrete with different grades. Then the compressive strength, axial compressive strength, static compressive elastic modulus and axial tensile strength of desert sand concrete were tested to analyze the influence of desert sand replacement rate on the mechanical properties of concrete at different ages and different grades. It was shown that the negative influence of desert sand on the compressive strength of concrete would be increased with the increase of concrete grade, and the influence increased with the increase of age. The addition of sand would be resulted in the decrease of axial compressive strength and static elastic modulus of concrete, and with the increase of concrete grade, the strength would be decreased obviously. The addition of desert sand had no significant effect on the axial tensile strength of concrete in general.

Keywords: desert sand concrete, compressive strength, axial compressive strength, static compressive elastic modulus, axial tensile strength.

1. Introduciton

With the continuous development of China's economy and society, the construction project has also reached an unprecedented height, and the demand for concrete is also growing. As an indispensable part of concrete, sand is gradually depleted in the storage of river sand commonly used in concrete. At the same time, uncontrolled mining of river sand would affect the river direction and river bottom ecological environment. Therefore, looking for alternatives to river sand is an urgent problem to be solved. At present, manufactured sand(MS) is used to replace river sand in engineering projects, but there are also some problems in the use of MS. MS also needs to break rocks and cause ecological damage. From the perspective of sustainable development, MS is not a very perfect choice. At the same time, desert governance is also an important task of protecting the environment. Under the strategy of "West China Development", the infrastructure construction in the western region is continuously carried out. If the desert sand(DS) in a large number of deserts in western China can be used to produce concrete, then local materials can be obtained, which can not only protect the environment and reduce the desertification rate, but also reduce the cost of concrete, and alleviate the current situation of insufficient supply of river sand. If this idea is realized, a lot of money can be saved. Therefore, the study of DS concrete is significant.

In this paper, DS was used to replace MS with different dosages to prepare concrete with different grades, and the mechanical properties tests were carried out under different curing ages.

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2. Experimental program

2.1 A. Materials

Ordinary Portland Cement (Jidong cement) conforming to GB175-2007 was used in all mixes.

Fly ash: grade II commercial fly ash conforming to GB / T 1596 - 2017 was used in all mixes.

Fine aggregate: MS and desert sand were selected as fine aggregate in this paper. MS is limestone MS with the fineness modulus of 2.8 ; DS was selected from Maowusu Desert with the fineness modulus of 0.29.

Coarse aggregate: This paper selected two kinds of continuous gradation of coarse aggregate. Concrete below C50 used continuous graded coarse aggregate with the particle size range of 5-31.5 mm; C50 ~ C100 concrete used continuous graded coarse aggregate with the particle size range of 5-20mm.

Admixture: polycarboxylates high performance water-reducing admixture was selected in this paper, and the water reduction rate was 28%.

Water: urban tap water was selected in this paper.

2.2 Preparation of desert sand concrete

The strength grades of concrete were C30, C50, C60, C80 and C100, respectively. The substitution rates of DS replacing MS with desert sand concrete are 0%, 20%, 40%, 60%, 80% and 100%. The slump of fresh concrete was adjusted to the range of 170–230mm with great cohesiveness.

The preliminary foundation test found that the water demand of DS mortar was large (but the sensitivity of desert sand in mortar to water is less than that of desert sand in concrete). In order to meet the workability as much as possible, the sand ratio of concrete with high replacement rate of DS was appropriately reduced. Strength grade is divided into C30, C50, C60, C80, C100, replacement levels of DS are 0, 20%, 40%, 60%, 80%, 100%. When the replacement level of DS is 0, the mix proportion is shown in table1.

Table 1. Mix Proportion of Desert Sand Concrete

Strength grade	Cement (kg)	Fly ash (kg)	Silica fume (kg)	Water(kg)	Sand(kg)	Gravel(kg)	Water-reducing admixture (kg)	Slump (mm)
C30	283	94	0	168	735	1200	3.77	230
C50	381	95	0	146	640	1280	4.76	225
C60	419	74	0	138	549	1280	4.93	210
C80	493	58	29	135	464	1321	5.80	190
C100	500	61	49	132	398	1591	6.10	190

3. Result and discussion

3.1 A. Compressive Strength Test

The compressive strength is the first quality control of concrete in construction project management. It is also one of the most important properties of concrete for designers and quality control engineers. It is the basic basis of building structure design and the basic technical requirements of concrete pouring construction. If the concrete strength cannot be evaluated scientifically, it will affect the normal construction of the project, affect the final acceptance of the project structure, and affect the durability and safety of the structural engineering.

Strength is the most important mechanical property of concrete, because the concrete structures are mainly used to withstand loads or resist various forces. At the same time, other properties of concrete, such as elastic modulus, impermeability and frost resistance, are related to the strength of concrete[1]~[5].In Ferro-concrete structures, concrete is mainly used to resist pressure. At the same time, considering that the compressive strength test of concrete is simple and feasible, the compressive strength is the most important and commonly used strength index.

The compressive strength of desert sand concrete is tested according to GB/T 50081-2019. Through a comprehensive analysis of the compressive strength of concrete, the feasibility and actual effect of desert sand as a substitute for fine aggregate are evaluated[6],[7].

Concrete was prepared according to the mix proportion in Table 1, and its compressive strength was tested. The test results are shown in Figs.1to Figs. 5.

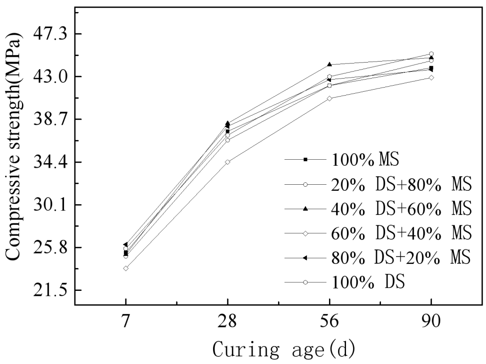

Fig .1 Effect of different replacement levels of DS on compressive strength of C30 concrete at different ages

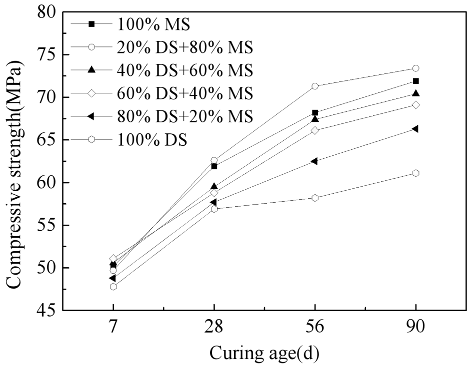

Fig .2 Effect of different replacement levels of DS on compressive strength of C50 concrete at different ages

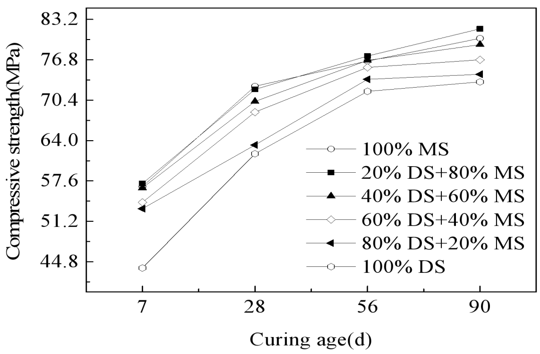

Fig .3 Effect of different replacement levels of DS on compressive strength of C60 concrete at different ages

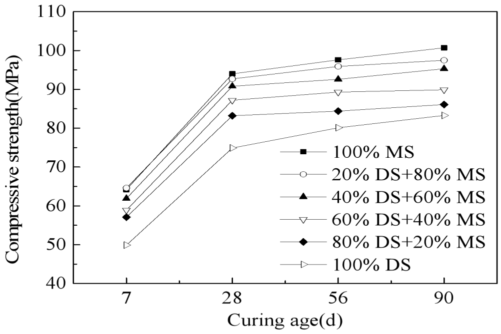

Fig .4 Effect of different replacement levels of DS on compressive strength of C80 concrete at different ages

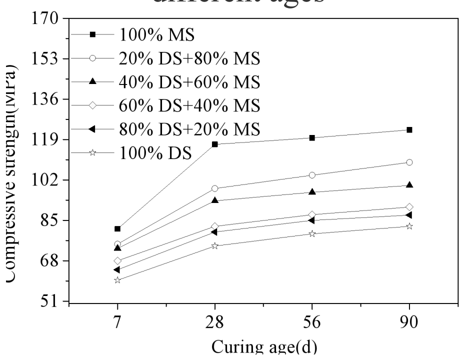

Fig .5 Effect of different replacement levels of DS on compressive strength of C100 concrete at different ages

In terms of compressive strength, desert sand concrete has the general commonness of ordinary concrete. Compared with medium and low strength concrete, replacement levels of DS have greater influence on high strength concrete.

Fig .1 shows that DS replacing MS has no significant indigenous effect on the strength of C30 concrete at 7d, 28d, 56d and 90d, and the compressive strength of C30 concrete with 100% DS is even slightly higher than that with 100% MS.

Under certain desert sand replacement rate, DS concrete not only has no strength loss, but will increase the strength with the analysis of different strength grade and different age of two cases. C30 concrete has the optimal strength when the substitution rate of desert sand is 40%; while C50 and C60 are 20%.

But in many cases, the setting of allowable strength may be more reasonable. Based on the 90d curing age, if the strength of DS concrete should not be less than 8 % of the compressive strength of pure MS concrete, then, the substitution rates of all desert sands under C30 strength meet the requirements; the allowable range of DS substitution rate of C50 and C60 concrete is 0-80%; C80 concrete 0- 40%, C100 concrete 0-20%.

In the long curing age, with the increase of mass fraction of DS, the compressive strength of concrete shows a downward trend. Although DS has no obvious chemical activity, it also plays a role in cement hydration due to heterogeneous nucleation effect. First of all, DS plays a role of crystal nucleus in cement hydration, including inducing crystallization of cement hydration products, accelerating cement hydration and participating in cement hydration reaction. Secondly, DS produces hydrated calcium aluminate in cement hydration and prevents the conversion of ettringite to monosulfide hydrated calcium aluminate. Thirdly, the existence of DS in bonding component can obviously improve the pore characteristics of concrete, improve the interface structure of slurry and aggregate, and change the crystal phase of concrete to varying degrees.

In addition, the existence of DS increases the compactedness of cement stone, which can inhibit the shrinkage of hydration products C-S-H and C-A-H to a certain extent. The reason is that in the process of early hydration of concrete, compared with ordinary fine aggregate, the water absorption of DS makes the water temporarily stored in the aggregate, thereby reducing the local water-binder ratio in the micro-area around the aggregate. With the hydration reaction going on, when the concrete rock is short of water, the stored water will be released to maintain the existence of cement at the interface, thus forming a stronger interface than ordinary concrete. This is likely to be the reason why the compressive strength of DS concrete samples is higher than that of ordinary concrete when the replacement rate of DS is low under partial proportions.

3.2 B. Static compressive elastic modulus

According to the specification GB / T 50081 - 2019, prisms with side length of 150 mm × 150 mm × 300 mm were made. A total of four grades and five kinds of DS content were taken, including C50, C60, C80 and C100. Three standard specimens in each group were tested for static compression elastic modulus. The stress-strain curve of DS concrete in elastic stage tends to be basically consistent. After entering the elastic-plastic stage, the stress of DS concrete increases faster than that of benchmark concrete, and the brittleness of concrete increases at this stage.

The measured axial compressive strength and static compression elastic modulus are shown in Figs. 6 and 7. From figure 6 and figure 7, it can be seen that in the above four strength grades, with the increase of desert sand replacement rate in the same ratio, the axial compressive strength decreases, and the static compression elastic modulus decreases overall.

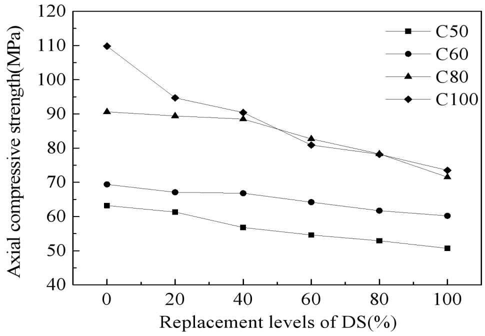

Fig .6 Effect of replacement levels of DS on axial compressive strength of concrete with different strength grades

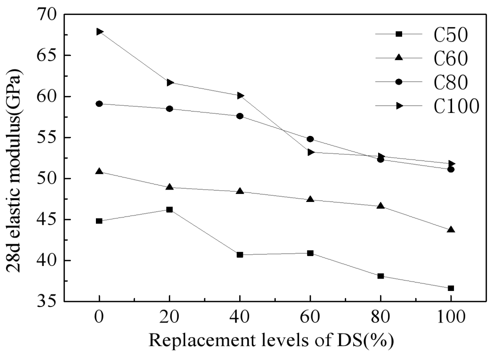

Fig .7 Effect of replacement levels of DS on static compression elastic modulus of concrete with different strength grades

With the increase of mixing amount of DS, the axial compressive strength and static compressive elastic modulus of concrete will decrease, and the decrease is most obvious when the concrete strength grade is C100. The static elastic modulus of 100% DS concrete is 23.7% lower than that of 100% MS concrete ; 13.5% lower at C80 ; 13.9% lower at C60 ; 18.3% lower at C50.Thus, the low strength concrete (C50, C60) mixed with a small amount of DS (less than 20%) can ensure that the elastic modulus is not reduced.

3.3 C. Axial tensile strength

The failure modes of the axial tensile test of manufactured sand concrete and ordinary concrete with the same strength grade are basically the same. Through the observation of the cross section, it is found that the tensile failure usually occurs in the interfacial transition zone of aggregate and inside the cement paste.

The same strength grade of DS concrete tensile strength with curing age change rule is basically the same, they are roughly divided into three stages: 3-28d, tensile strength increases rapidly with curing age; 28-120d, the growth rate decreases with curing age; from 120d to 360d, the tensile strength growth is relatively slow. Because of the similarity of the compressive strength growth trend of DS concrete and ordinary concrete, the tensile strength of 56d curing age is selected as the reference.

According to the specification GB/T 50081-2019, the dumbbell-shaped specimen with the middle section size of 100×100 mm and the length of 550 mm was prepared. The proportioning of concrete was set according to Section 3.1. Five strength grades of C30, C50, C60, C80 and C100 were set. Five DS content gradients were set respectively. Five replacement levels of DS were set up, and six standard specimens in each group were tested for 56d axial tensile strength. The failure load was used as the evaluation index.

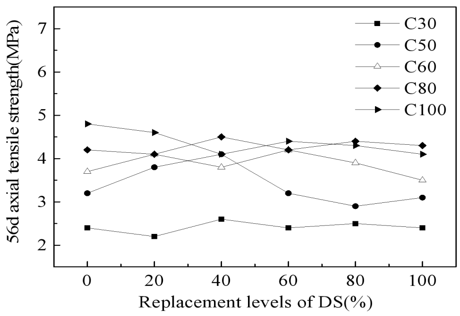

Figure .8 Effect of replacement levels of DS on axial tensile strength of concrete with different strength grades

Fig.8 shows that the addition of DS in any proportion of C100 concrete has played a role in reducing the axial tensile strength of concrete curing age for 56d. In addition, in other strength grades, desert sand has no significant effect on the axial tensile strength of concrete curing age for 56d. Based on the above test and analysis, it is determined that the replacement levels of DS have a negative effect on the long-term tensile strength. On one hand, the increase of compressive strength depends on the dense packing of DS. On the other hand, it depends on the micro-balloon effect of DS to make the unhydrated cement particles uniformly distributed in concrete. Thirdly, it depends on the heterogeneous nucleation effect of DS to assist the growth of cement stone, which is beneficial to the further hydration reaction of cement in concrete under long curing age conditions. It is found that the tensile strength of MS concrete with high replacement level of DS is higher, but the numerical dispersion is larger under medium and low preparation strength.

4. Conclusions

Through the analysis of the compressive strength, static compressive elastic modulus and axial tensile strength of desert sand concrete, the following conclusions are obtained.

（1）The compressive strength of DS concrete is more affected by DS content with the increase of strength grade. If the strength of DS concrete should not be less than 8% of the compressive strength of MS concrete with the same ratio, the replacement rate of all desert sand under C30 strength meets the requirements. The allowable range of desert sand substitution rate of C50 and C60 concrete is 0-80%; while the C80 concrete is 0-40 %and C100 concrete is 0-20%.

（2）With the increase of desert sand content, the axial compressive strength and static compressive elastic modulus of DS concrete will decrease, and the decrease is most obvious when the concrete strength grade is C100, the static elastic modulus of the concrete with 100% DS is 23.7% lower than that of the concrete with 100% MS;13.5% lower at C80; 13.9% lower at C60; 18.3% lower at C50.

（3）The addition of DS has no obvious effect on the 56d axial tensile strength of concrete, which increases slightly to a certain extent and does not show obvious effect on the whole.

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