

# Experimental Research on the Mechanical Properties of Steel Slag Recycled Aggregate Concrete

Yun Dong<sup>1,2</sup>, Hui Wang<sup>1</sup> and Junjie Gong<sup>1</sup>

<sup>1</sup>Key Laboratory of Solid Waste Recycling and Utilization of Huai'an, Jiangsu, China, 223001

<sup>2</sup>Faculty of Civil Engineering and Architecture, Huaiyin Institute of Technology, Jiangsu, Huai'an, China, 223001

**Abstract**—This article is aimed to discover the effect of replacement rate of slag recycled aggregate on the compressive strength of recycled concrete. The slag has been crushed and sieved to regenerate recycled aggregate, than replaced the different ratio of natural aggregate with recycled aggregate in premixed recycled concrete, carried out compressive strength test. The test results show that partially replace the natural aggregate with recycled aggregate regenerated from steel slag in concrete is feasible, and it can improve the early age compressive strength of recycled concrete. The appropriate replacement ratio of natural aggregate is about 20% consider the long-term strength. The research results have been applied in recycled concrete which used in foundation engineering, and it has been proved that it can bring good economic and environmental benefits.

**Keywords**—steel slag; coarse aggregate; recycled concrete; compressive strength

## I. INTRODUCTION

Steel slag is a kind of industrial tailings which produced in the process of steelmaking, its discharge is about 15% to 20% of the crude steel production. As a result of the fluctuations of the steel slag composition is changing unusually, the recycle of its high added value has been more difficult. But the producer research on efficient utilization of steel slag has not stopped, invested a lot of people, money and material resources to the development and application. European and American developed countries, the recycling of steel slag are relatively high, but is only limited to the iron and steel industry, are generally use various methods to recovery of these metals, and in related industries such as construction concrete of steel slag utilization is seldom involved<sup>[1]</sup>. Many

domestic scholars have also committed to the efficient utilization of steel slag, and done some research in steel slag recycled materials and its application<sup>[2-6]</sup>, but because of the stability and durability of the steel slag concrete issues not been completely resolved, such as using steel slag recycled aggregate instead of natural aggregate in concrete of the research and application of recycled concrete has been stagnant. In order to promote the closure of the end of the steel slag recycled materials applied in concrete, this study from the study of the strength of the steel slag recycled aggregate concrete change rule, through different steel slag content of recycled aggregate replace the natural aggregate strength test of steel slag concrete, steel slag recycled aggregate content on the influence of steel slag recycled concrete strength are studied.

## II. EXPERIMENTAL OF THE RAW MATERIAL

(1) The cement used in this experiment is composite Portland cement 42.5 R made in Huaian Conch Cement Co. Ltd. And the physical performance index are shown in table 1, chemical components are shown in table 2.

(2) The sand used in experimental is natural river sand, measured the silt content is 2.3%, fineness modulus is 2.6, which belong to medium sand. The aggregate used in this study are come from Huaian stone material factory, specific technical indicators as shown in table 3.

(3) The steel slags used in this study are come from Huaigang Special Steel Co. Ltd, the appearance of steel slag recycled aggregate after crushing and sieving are shown in figure 1.

TABLE I. INDEX OF CEMENT

Density (g/cm <sup>3</sup> )	Requirement of normal consistency (%)	Time of setting		Age (d)	Rupture strength		Compression strength	
		Initial setting time (min)	Final setting time (min)		Measured value (MPa)	Standard set value (MPa)	Measured value (MPa)	Standard set value (MPa)
3.1	27.9	196	247	3	5.1	≥3.5	21.5	≥17.0
				28	9.6	≥6.5	45.9	≥42.5

TABLE II. CHEMICAL COMPOSITION OF CEMENT

Chemical composition	SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	CaO	MgO	Na <sub>2</sub> O	K <sub>2</sub> O	Fe <sub>2</sub> O <sub>3</sub>	SO <sub>3</sub>	TiO <sub>2</sub>	MnO	P <sub>2</sub> O <sub>5</sub>
Content (%)	20.73	3.72	63.11	1.62	0.48	0.73	3.15	0.86	0.16	0.06	0.05

TABLE III. MAIN SPECIFICATIONS OF AGGREGATE

Grain size	Dense packing density	Close void ratio	Bulk density	Loose porosity	Crushing value	Sediment percentage
5mm~31.5mm	1.58g·cm <sup>-3</sup>	42.3%	1.5g·cm <sup>-3</sup>	45.3%	8.1%	0.79%

TABLE IV. PHYSICAL INDICATORS OF SLAG RECYCLED AGGREGATE

grain size	apparent density	Bulk density	Loose porosity	Dense packing density	Close void ratio	water absorption	crushing value
5 ~25 mm	3392 kg/m <sup>3</sup>	1984 kg/m <sup>3</sup>	41.5%	2062 kg/m <sup>3</sup>	39.2%	4.55%	9.4%



FIGURE I. STEEL SLAG RECYCLED AGGREGATE USED IN THIS ARTICLE

It can be seen that the surface of recycled aggregate is rough, and distributed many micro pore, the specific physical indicators of steel slag recycled aggregate are shown in table 4.

### III. MIX PROPORTIONS AND TEST RESULTS

This experiment take the C30 strength grade, 60 ~ 90 mm slump, 0% of the steel slag replacement rate as control group, named as YUA-01, the experimental group was 20%, 40%, 60%, 80% and 100% of natural aggregate replacement rate with steel slag recycled aggregate.

TABLE V. MIX PROPORTIONS OF SLAG RECYCLED AGGREGATE CONCRETE

Specimen number	Water cement ratio	Substitution rate of recycled aggregate (%)	Per cubic meter of slag recycled aggregate concrete material dosage(m <sup>3</sup> /kg)				
			Water	Cement	Sand	Natural aggregate	Recycled aggregate
YUA-01		0			599	1162	0
A-1		20			606	941	235
A-2	0.46	40	195	423	606	706	470
A-3		60			616	478	717
A-4		80			616	236	959
A-5		100			623	0	1209

These conclusions can be drawn According to the results reflected in the above chart:

(1) The strength of concrete specimens with 28-day age is generally higher than that of 7-day concrete specimens. This is due to the strength of concrete is related to the age of the molding. After the concrete is formed, the strength increases

This test select 7d and 28d compressive strength to disclose the change trend of the five groups between different age and replacement ratio.

The mix proportions of steel slag concrete are shown in the table 5.

The compressive strength of steel slag recycled concrete was shown in figure 2, 7d and 28d, respectively.

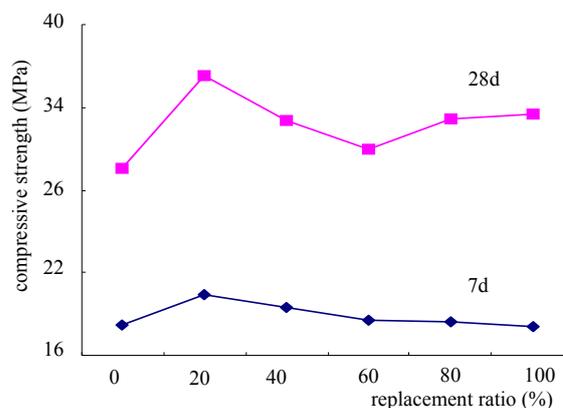


FIGURE II. TREND OF STEEL SLAG RECYCLED AGGREGATE CONCRETE'S COMPRESSIVE STRENGTH

with the time, and it begins to grow rapidly, and then gradually becomes slower. It takes 28 days to reach the design value of compressive strength of concrete.

(2) In the 28d age of concrete block, the rate of the compressive strength's growth in group A-1 is the largest one, A-4 group is Second, in addition, the group A-1 sets for the

maximum compressive strength of 36.3MPa. when the dosage of steel slag reach to 60%, the compressive strength of concrete reached minimum, but higher than YUA-01 group, as 31.0MPa, since then, with the increase of steel slag content, compressive strength of concrete has increased slightly.

(3) In the 7d age of concrete test block, in addition to the strength of the steel slag admixture of 100% lower than the group YUA-01, the other groups are higher than the group YUA-01, because the strength of the gravel is greater than the strength of the steel slag recycled aggregate. When concrete is subjected to external force, gravel itself can bearing part stress, weaken some external force, so as to improve the strength of the concrete.

(4) In addition, whether concrete is 28-day age or 7-day age, there is a common point, that is the compressive strength reaches a peak when steel slag recycled aggregate content is 20%. It should be due to that the specimens gravel content is more in group A-1, reducing the number of coarse aggregates' maximum particle size, and macadam's strength is greater than that of the steel slag recycled aggregate, so it is easy to make each aggregate distribution of concrete becomes more uniform in the mixing process, when subjected to external force, internal stress of concrete will be relatively dispersed, so it isn't easy to be damaged

#### IV. CONCLUSION AND DISCUSSION

The 7d and 28d age compressive strength test of different content of steel slag recycled aggregate concrete and natural concrete were carried out to seek the effect of the recycled aggregate replacement ratio on recycled concrete, and further to find out the optimized steel slag recycled aggregate replacement rate.

The test results proved that it is feasible to replace the natural aggregate with steel slag recycled aggregate. The compressive strength of the recycled concrete is larger than that of the ordinary concrete.

The suitable replacement rate of steel slag recycled aggregate is about 20% after taking into account the reliability and strength. Replace natural aggregate with recycled aggregate in concrete, can not only realize high added value use of iron tailings with considerable economic benefits instead of simple treated, but also reduce the environment pollution caused by steel plant.

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