Experimental Investigation on Specimen Size Effect of Ferrous Tailings Concrete Compressive Strength

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Abstract
Concrete with ferrous tailings displacing natural sand is called ferrous tailings concrete. Cubic specimens of ferrous tailings concrete (strength grade C25-C50) with standard size(150mm side length) and with non-standard size(100mm side length) are tested for measuring compressive strength in this paper. The varied factors are the concrete strength grades with C25 to C50, and the ratio of *W*/(*C*+*P*) with the range of 0.75 to 0.3. Based on analyses of test data, it was concluded that the compressive strength of the standard size specimens are related closely with that of nonstandard size specimens, The ferrous tailings concrete compressive strength size correlation degree is linearly lowering with water-binder ratio (*W*/(*C*+*P*)), and the size scaling factor of standard size specimens to nonstandard size specimens is 0.88.
Key words: FERROUS TAILINGS CONCRETE, COMPRESSIVE STRENGTH, SIZE EFFECT, SCALING FACTOR

1. Introduction

The fine aggregate in common concrete is mainly natural sand. Natural sand is a non-renewable resource, which is either covering in mountain area or overlying in riverbed. Excessive exploiting of natural sand results in resource infertility and therefore the serious consequences of water loss and soil erosion. On the other hand, in the process of mining iron and steel ore, a great number of tailings are discarded. Those ferrous tailings not only occupy a lot of cultivated land, waste land resources but also pollute environments. In China, the comprehensive utilization rate of mine tailings is only about 7%. Meanwhile, in some developed countries, the mine tailings use rate has reached more than 60%, and is leading to 100% mine tailings use rate, that is, no mine tailing residue[1]. Hence, the mine tailing utilization has a long way to go in China.

Concrete with ferrous tailings displacing natural sand is called ferrous tailings concrete. The apparent characteristics of ferrous tailings are rough surface and more angular shape. With ferrous tailings displacing natural sand in concrete, the compressive strength of tailings concrete is little higher than that of common concrete[2]. Where the content of water and the water/binder ratio are the same, ferrous tailing concrete, compared with common concrete, is apt to take place separation of paste and aggregates, resulting in phenomenon of dissociation and bleeding[3]. In the term of concrete slump, with concrete hardening, ferrous tailings and paste absorb more free water, which causes the ferrous tailing concrete slump decreases distinctly. Test results shows that adding fly-ash and slag powder may overcome these shortcoming[4].

When the concrete strength grade is lower than C60, the compressive strength scaling factor of non-standard cube specimens with side length of 100mm to standard cube specimens with side length of 150mm is 0.95 according to the Concrete Code of China[5]. When the concrete strength grade is higher than C60, the scaling factor is 0.94, 0.90-0.92 for strength grade C60, C70-C100 respectively[6].

For investigating the size scaling factor of ferrous tailing concrete, concretes with 6 strength grades are batched in this program. The strength grades are C25, C30, C35, C40, C45, and C50. The total specimens are 324, in which one half is the standard size cube specimen of 150mm side length and the other half is the nonstandard size cube specimen of 100mm side length. The program goal is to investigate the ferrous tailing concrete size scaling factor based on test results, to provide technical support for ferrous tailings concrete practical utilization.

2. Experimental Materials

2.1 Cement.

Cement used in specimen is from Hebei Jidong Cement Group Co. LTD, production of ordinary Portland cement, its strength grade is P.O 42.5 R.

2.2 Slag powder.

Slag powder is the production of Hebei Gangjian Building Materials Company Limited.

2.3 Fly ash.

Fly ash is the production of Tangshan Doudian Fly-ash Company.

2.4 Water reducing agent.

Water reducing agent is polycarboxylate high performance water-reducing admixture produced by Tangshan Huarong Building Material Company Limited, PH value of which is 6-8, with water reducing ratio of 20%-40%.

2.5 Ferrous tailing sand.

Ferrous tailing sand is from Qian'an iron mine tailings, with fineness modulus of 2.10. While, fine aggregate of ordinary concrete is from Qian'an ordinary river sand, with fineness modulus of 2.50. The appearance comparison of ferrous tailings and natural sand is showed as Figure 1.

The ferrous tailings sieving performance is showed in Table 1.

The detection index of ferrous tailings sand and natural sand are showed in Table 2.

3. Experimental Observations

3.1 Specimens fabricating

The standard test specimen size is 150mm-150mm-150mm, while the non-standard specimen size is 100mm-100mm-100mm, which are formed in iron molds respectively. Strength grades are six, that is, C25, C30, 35, C40, C45 and C50. In each grade, there are 3 kind of the water to binder (or cement plus paste) ratio, so the test specimens groups are 18, with each group including 9 specimens to detect the compressive strength on concrete ages of 3d, 7d and 28d. Hence, the total specimen number is 324.

(a) Ferrous tailing (b) Natural sand

Figure 1. Appearance comparison

Table 1. Sieving performance index of ferrous tailings sand

Screen size(mm)		4.75	2.36	1.18	0.60	0.30	0.15	Screen bottom(g)	Total(g)
First	Screen residue（g）	31	35	56	45	149	94	90	498
	（%）	6.2	7.0	11.2	9.0	29.8	18.8	18.0	
	Add up（%）	6.2	13.2	24.4	33.4	63.2	82.0		
Second	Screen residue（g）	22	50	72	44	149	94	68	500
	（%）	4.4	10.0	14.4	8.8	29.9	18.8	13.6	
	Add up（%）	4.4	14.4	28.9	37.7	67.5	86.4		

Table 2. Tailings sand and natural sand detection index comparison

Detection Item	Ferrous tailings	Natural sand
Moisture content (%)	3.627	2.775
Apparent density (kg/m^3)	2885	2727
Stacking density (kg/m^3)	1700	1452

After form removal, the specimens are placed in the standard curing room for curing. At the curing ages of 3d、7d、28d, the compressive strengths are tested at test machine as showed in Figure 2.

3.2 Experimental Results

After the curing time of 3d, 7d and 28d, specimens are tested to measure the compressive strength individually according to the standard test method[5]. The test results are listed in Table 3.

4. Results Analysis

The compressive strength comparison of standard specimens and non-standard specimens are showed in Figure 3, in which (a), (b),(c), (d), (e) and (f) illustrate the results of concrete grade of C25, C30,C35, C40, C45 and C50 respectively. The results indicate that the compressive strength values of standard specimens and non-standard specimens at curing age of 3d and 7d in each concrete grade are nearly similar, while the 28d strengths are different distinctly.

Figure 2. The loading apparatus and experimental phenomena

Table 3. Test results of concrete compressive strength

Grade	*W*/(*C*+*P*)	$f_{cu,150}$（MPa）			$f_{cu,100}$（MPa）		
		3d	7d	28d	3d	7d	28d
C25	0.75	8.42	15.75	26.80	10.05	17.91	30.23

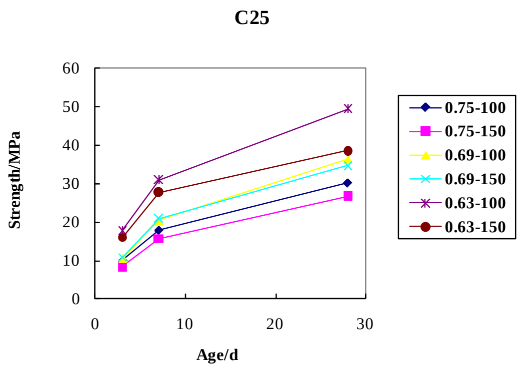
C25	0.69	10.89	20.98	34.73	10.62	20.42	36.42
C25	0.63	15.99	27.85	38.62	17.91	31.08	49.49
C30	0.6	16.52	28.89	44.30	18.08	30.00	48.13
C30	0.56	22.82	33.90	46.37	19.93	32.36	51.28
C30	0.53	23.73	35.64	51.25	21.81	36.99	56.09
C35	0.58	23.01	33.10	45.85	22.70	33.89	50.83
C35	0.54	22.84	35.12	46.79	24.90	38.99	56.53
C35	0.51	27.72	39.45	52.00	27.88	38.22	57.42
C40	0.55	23.40	35.52	51.47	24.41	38.28	57.85
C40	0.50	25.14	41.21	54.61	24.12	40.01	58.87
C40	0.45	27.85	43.39	55.53	26.60	38.72	59.30
C45	0.44	28.49	42.62	53.30	27.97	42.30	61.60
C45	0.4	35.46	48.07	58.26	34.19	50.03	65.95
C45	0.35	41.42	58.99	62.82	37.57	56.42	72.81
C50	0.4	32.13	48.58	58.31	36.50	51.34	68.69
C50	0.35	35.42	53.07	62.02	33.96	50.13	71.79
C50	0.3	43.54	56.67	61.65	46.84	65.73	75.72

Normally, the size effect of concrete compressive strength takes on compressive strength lowering with specimen side length. The side length 150mm specimen is defined standard specimen according to the China concrete code [7], so the 100mm side length specimen is non-standard specimen. Hence, the cube compressive strength size effect degree is calculated as Formula (1):

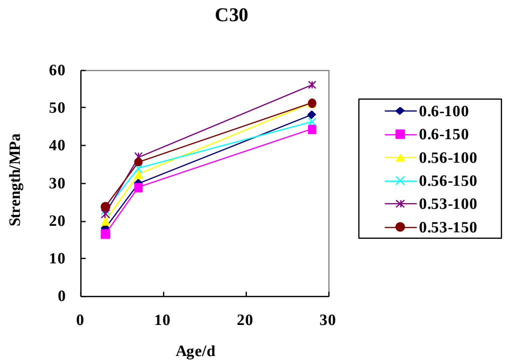
$$\gamma_{150}=\frac{f_{cu,100}-f_{cu,150}}{f_{cu,100}}\times 100\% \qquad (1)$$

Here : γ is the cube compressive strength size effect degree of side length 150mm, $f_{cu,100}$ and $f_{cu,150}$ are the 28d cube compressive strength of 100mm and 150mm respectively。

Based on the test data, the cube compressive strength size effect degrees are calculated, and the results are indicated as Figure 4.



(a)



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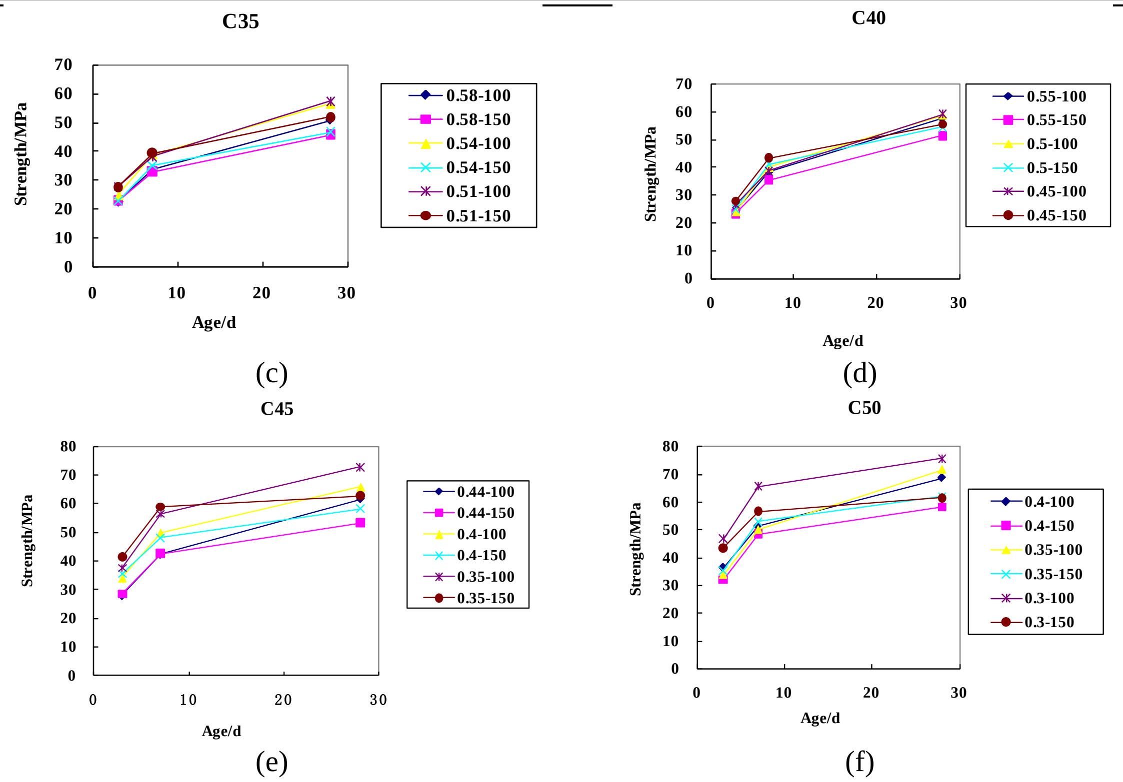

Figure 3. Age-strength relations in different strength levels

As showed in Figure 4, based on the experimental data, the linear regression formula of the size effect degree γ_{150} is Formula (2).

$$\gamma_{150} = -27.66W/(C+P) + 24.021 \quad (2)$$

With data calculation, correlation index of γ_{150} is R=0.814, which indicates its correlation is great.

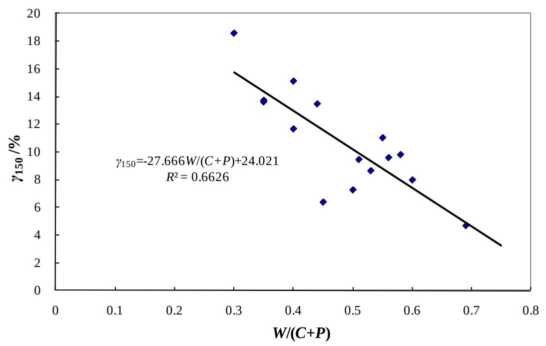

Figure4. Comparison of concrete size effect degree γ with W/(C+P) ratio

According to the same strength grade test results, the non-standard specimens strength of $f_{cu,100}$ and the standard specimens strength of $f_{cu,150}$ are presented in Figure 5. The linear fitting formula is Formula (3):

$$f_{cu,150} = 0.8097 f_{cu,100} + 3.9561 \quad (3)$$

R is defined as the correlation factor of $f_{cu,100}$ and $f_{cu,150}$, R=0.9588, which is indicated that $f_{cu,100}$ and $f_{cu,150}$ of ferrous tailing concrete are greatly correlated. Hence size scaling factor of standard and non-standard specimen could be obtained.

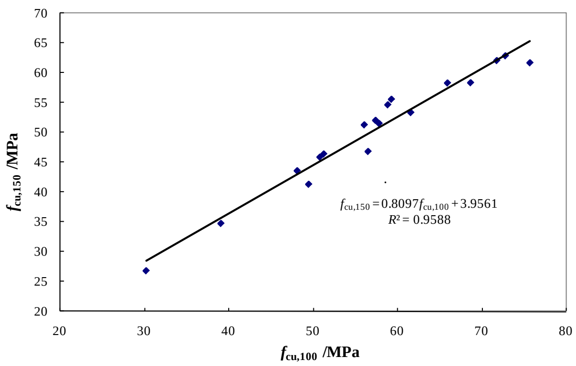

Figure 5. The fitting curve between $f_{cu,100}$ and $f_{cu,150}$ in different strength levels

with $W/(C+P)$ values as the horizontal coordinate, the ratio of $f_{cu,150}$ to $f_{cu,100}$ are illustrated in Figure 6, which indicated that the average of size scaling factor $f_{cu,150}/f_{cu,100}$ is about 0.881, standard deviation is equal to 0.034, Coefficient of variation is about 3.9%. Then, it is can defined the size scaling factor ($f_{cu,150}$ to $f_{cu,100}$) of ferrous tailings concrete is 0.88.

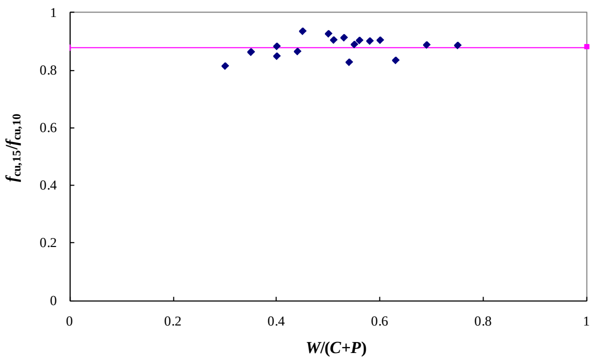

Figure 6. Size scaling factor

5. Conclusions

The 324 ferrous tailings concrete cube specimens compressive tests were conducted to examine the size scaling factor of standard and non-standard cube specimens. Major findings obtained from the study are summarized as follows:

(1)The 3d and 7d compressive strengths of standard size(150mm side length) and non-standard size (100mm side length) ferrous tailings concrete specimens are nearly similar. The main difference is 28d compressive strength.

(2)The ferrous tailings concrete compressive strength size correlation degree is linearly lowering with water-binder ratio ($W/(C+P)$) .

(3) The ferrous tailing concrete size scaling factor of standard size to non-standard size could be 0.88 within concrete strength grade of C25 to C50.

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