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SEGREGATION OF CONCRETE OF DIFFERENT TYPES

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Abstract: *In this work the concrete free falling effect on segregation was investigated. Sixteen free falling specimens were tested by the non-destructive ultrasonic test for four types of concrete. In addition, twelve cube specimens were tested to check the accuracy of the ultrasonic test adopted in this study. Four types of aggregates (rounded gravel, crushed gravel, 10mm maximum size crushed gravel and porcelain aggregate) were used to study their effect on segregation of free falling concrete from different height. The test results show that no significant effect for the free falling on the compressive strength of concrete for the four types of aggregate and the results of the non-destructive ultrasonic test were of good agreement with those of compression machine test.*

Keywords*:* Segregation, Reinforced concrete, Free Falling, Porcelain Aggregate, ACI, BS, Codes of Practice, Compressive Strength.

INTRODUCTION

egregation is the separation of one ingredient from another. Concrete segregation may be of two types; the isolation of coarse aggregate from plastic mixture, and secondly the separation of grout from the mix for high water content mixtures. [1]

Concrete is a mixture of various materials. These materials are different in particle size and specific gravity so that they tend to separate from each other. [1]

Also there are some other parameters affecting segregation such as unsuitable placing and unsuitable vibration.

Till this moment no one of the certified codes recommended a specific maximum free falling height of concrete to avoid segregation, while there are at least four studies talking about free falling of concrete from large distances without reducing its quality. [2,3,4,5]

The main objective of this study is to investigate the effect of free falling of concrete on the compressive strength for heights up to 4m using different types of coarse aggregate.

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1. CODES OF PRACTICE

The American concrete standards (ACI 318-08)[6] and (ACI 301-08) do not refer directly to the issue of concrete free falling. The (ACI 304R-00)[7] states that there is no restrictions on the vertical drop distance of concrete to the final position, but that its flow must not separate by falling over reinforcement bars, spacers or rods.

The ACI 336.1[8] states that for free falling height up to 60 ft; concrete not segregate for piers of 3ft in diameter. No significant effect of hitting reinforcement cages on segregation but it may be more effective in small diameter piers for depths more than 65 ft. [5]

Sometimes a limit is produced for the maximum free falling of concrete to minimize segregation of concrete. Inspectors limit that to a distance of 3 to 5 ft and its preferred to be as less as 2 ft. No one of the ACI 318-08 and ACI 301-08 constraint the free falling distance of concrete. The ACI 304R-00 reported that for open clear forms so that the concrete can fall vertically without disturbance; it is preferred not to use hoppers and chutes. However the ACI 304R-00 and ACI 318-08 recommended pouring concrete at or close to the final depositing place to prevent flowing segregation.

The American society of concrete contractors(ASCC)[9] refers to the fact that the free falling of concrete is often permitted in concrete works. Using some techniques like chutes or making openings in forms may reduce free falling effect, but the use of these techniques unnecessarily may increase coast without improving quality.

Contractors usually permit free falling of concrete in caissons to depths up to 46 m. Core tests for about one hundred points and for a period of thirty years show no significant effect on concrete quality or strength. [9]

In 1994, the Federal Highway Administration(FHWA)[5] and for the available tests data concluded that no effect for striking of concrete with reinforcement bars on segregation.

In 1999, the FHWA excluded its 25 ft distance of concrete free falling and stated that the concrete is allowed to fall freely for unlimited distances and that the free falling of concrete for distances up to 150 ft and hitting rebar cages directly does not lead to segregation and has no effect on strength.

The British standard of building construction code [10] recommended taking a care for concrete falling through rebar cages to prevent the isolating of cement paste from the mix.

Generally the concrete mixtures contain no less than 300 kg/m^3 of cement. The use of concrete admixtures to reduce water content, which is necessary for workability, may prevent bleeding segregation and other defects. The rate of fine contents may increase to give an adequate cohesion to the mix. [10]

The Indian code [11] states that concrete handling and conveying must be as soon as possible to prevent segregation. The free falling distance for concrete conveyed by belts or chutes is limited to 5 ft.

A steady uniform flow of concrete must be ensured when using chutes with a slop not less than 1:2 vertical to horizontal respectively to prevent separation of ingredients. When the free fall of concrete is likely to happen in conveying process, segregation, splashing, and ingredients loosing must prevented by using down spots and baffle plates. Flexible pipes must be used for depositing concrete when the distance of free falling is more than 10 ft. Extra vibration may cause segregation. [11]

The Chinese code of practice in 2013 [12] stated that concrete depositing and compacting must be in a suitable manner and within a suitable period after mixing. Special care must be given in case of free falling concrete to prevent segregation and to keep rebar and molds in their positions. The use of vibrators is necessary for good compaction but inappropriate vibration may result in segregation of concrete.

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2. EXPERIMENTAL WORK

The type of aggregate is one of the most important parameters affecting segregation of concrete. Four types of aggregate were used to study the aggregate type effect. A 1:2:4 mixing proportion by volume were adopted in this work for all types of concrete to investigate the behavior of each type in free falling from different heights. The quantities used for all types of concrete were given in Table 1.

A concrete mixer of 0.2 m^3 volume was used. The materials were mixed well in a dry state, and then mixing water was added gradually until a homogeneous mix was produced.

Table 1.Materials Proportioning

Concrete Type According to Aggregate Type	Notation	Cement (kg/m^3)	Sand (kg/m^3)	Coarse Aggregate (kg/m^3)	Water (l/m^3)
Crushed Gravel	N	304	630	1260	152
Rounded Gravel	R	304	630	1260	152
10 mm Max. size Crushed Gravel	S	304	630	1260	152
Porcelain Aggregate	P	304	630	0.76 m^3 (*)	152

(*) Equal volume was taken for light weight aggregate

2.1. TEST SETUP

The mixtures were fallen under the influence of gravity into 235 mm diameter plastic molds of 1m, 2m, 3m, and 4m heights and for each type of concrete. The free falling height was the same of the mold height. The concrete was placed without vibration, Fig.1. The specimens of about 0.013m^3 then covered with plastic sheets for the first 24 hrs, and then put in water for 28 days. Three 150mm cubes were cast for each type of concrete. Table 2 shows the tested specimens notations.

The compressive strength of the tested specimens was determined using the non-destructive ultrasonic test; Fig.2.

The accuracy of the ultrasonic test results were checked against the results of compression machine for the cube samples, and given in Table 3.

3. RESULTS

3.1. RESULTS

Table 3 illustrates the test results for the compressive strength of the 150mm cubes by two methods while Table 4 gives the results for the tested specimens by the ultrasonic test.

The relative compressive strength with the free falling height was illustrated in Figs.3 to 6 for all types of concrete.

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Fig.1 Test Setup

Fig.2 Ultrasonic Test

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Table 2. Tested Specimens Notations

Concrete Type	Free Falling Height	Notation
Crushed Gravel Concrete (max.20mm)	1m	N1m
	2m	N2m
	3m	N3m
	4m	N4m
Rounded Gravel Concrete (max.20mm)	1m	R1m
	2m	R2m
	3m	R3m
	4m	R4m
10mm max. Size Aggregate Concrete	1m	S1m
	2m	S2m
	3m	S3m
	4m	S4m
Light Weight Aggregate Concrete (max.20mm)	1m	P1m
	2m	P2m
	3m	P3m
	4m	P4m

Table 3. Compressive Strength of Cubes

Concrete Types	Ultra Sonic Test			Compression Machine Test	
	Time (Sec)	fcu (MPa)	Average	fcu (MPa)	Average
N1	32	33.58	25.40	47.13	25.43
N2	41.8	18.76		12.58	
N3	37.1	23.87		16.58	
R1	32	33.58	31.81	42.18	37.48
R2	32.9	31.38		31.91	
R3	33.3	30.48		38.36	
S1	34	29.02	28.78	26.04	26.16
S2	33.7	29.63		24.71	
S3	34.7	27.68		27.73	
P1	45.7	15.95	16.08	12.49	11.41
P2	44.7	16.58		10.49	
P3	46.1	15.71		11.24	

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Table 4. Compressive Strength of Tested Specimens

Specimen	Time (Sec)*	fcu (MPa)
N1m	52.2	15.22
N2m	55.2	13.37
N3m	53.4	14.42
N4m	55.1	13.42
R1m	40.5** (15.5cm)	10.64
R2m	55.1	13.42
R3m	55.6	13.15
R4m	55.2	13.37
S1m	42.2**(13.5cm)	7.63
S2m	63	9.91
S3m	61	10.31
S4m	62.5	10.27
P1m	89.1**(12.5cm)	2.94
P2m	105	6
P3m	78.5	7.74
P4m	74.2	7.50

*Direct test (distance of test is 235mm)

** Indirect Test (distance of test)

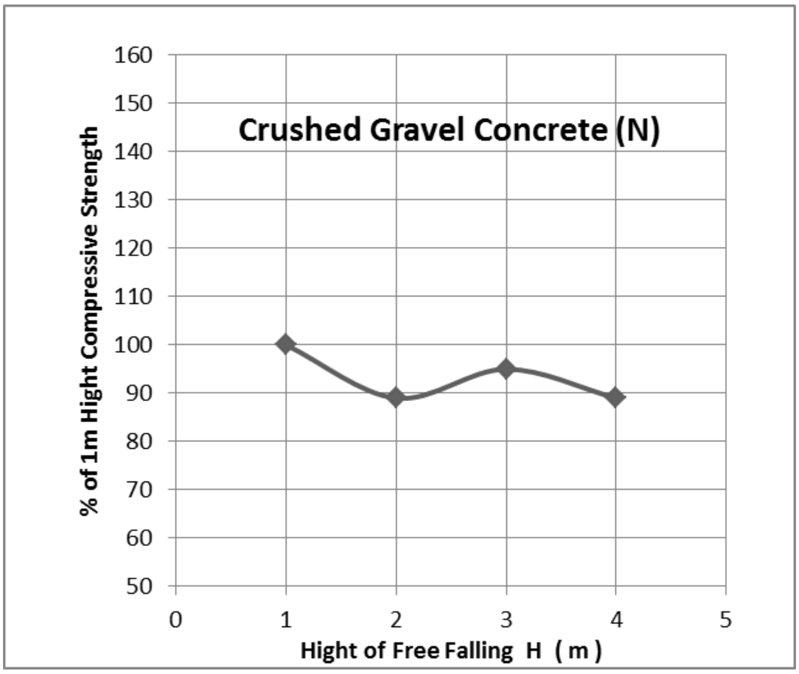

Fig.3 Relative Compressive Strength of Crushed Aggregate Concrete with Free Falling Height

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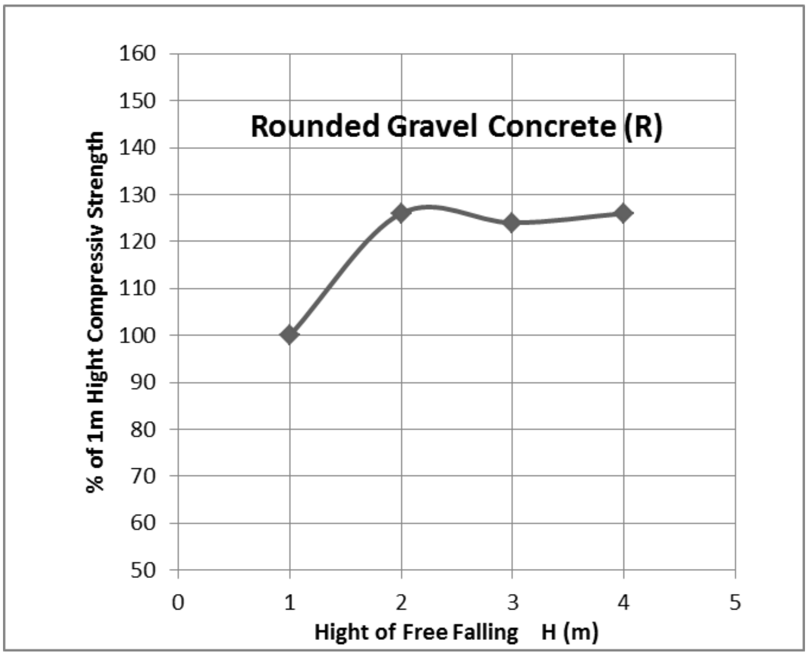

Fig.4 Relative Compressive Strength of Rounded Aggregate Concrete with Free Falling Height

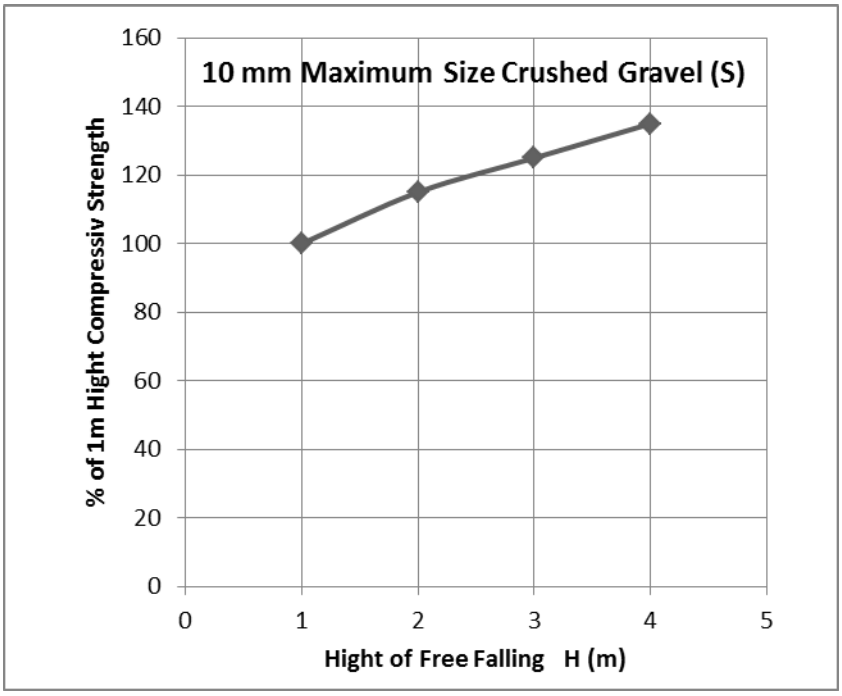

Fig.5 Relative Compressive Strength of (10mm) Maximum Crushed Aggregate Concrete with Free Falling Height

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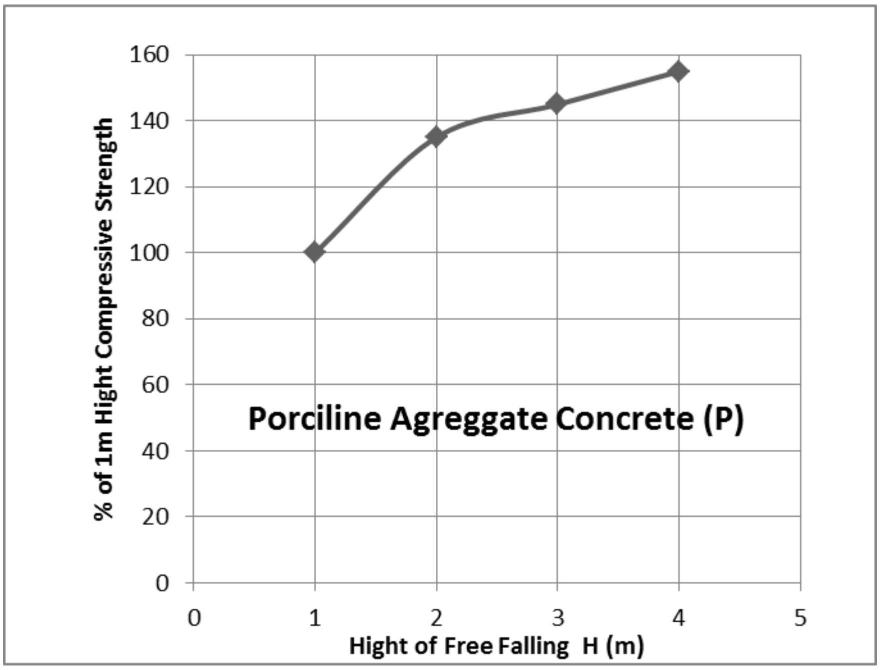

Fig.6 Relative Compressive Strength of Porcelain Aggregate Concrete with Free Falling Height

3.2. DISCUSSION OF RESULTS

In this research, the four types of concrete were tested to study the free falling effect from different heights on segregation. From the results, the following findings were drown:

1- The appearance of specimens was generally good but the compressive strength was relatively small because the concrete was cast without vibration.

2- In general, the compressive strength of the specimens was slightly increased with the height of free falling, probably because of the additional compaction of free falling process.

3- Only specimens of light weight (porcelain) aggregate show significant increase in compressive strength of about (55%) for the specimen of 4m falling height in comparison with the 1m, as shown in Fig.6.

4- The specimens of rounded (5-20mm) gravel aggregate show an increase of about (26%) in compressive strength as shown in Fig.4, while the specimens of (10mm) maximum size crushed gravel show a (35%) increase in compressive strength as shown in Fig.5 for specimens of 4m falling height in comparison with 1m falling .

5- The specimens of (5-20mm) crushed gravel show insignificant decrease of about (11%) in compressive strength for specimens of 4m free falling height in comparison with that of 1m, Fig.3.

CONCLUSIONS

From the results above, one can conclude that:

1- The free falling of concrete from different heights, up to 4m may generally increase the compressive strength of concrete for the aggregate types used in this research, specially for the light weight aggregate concrete due to the additional compaction occurs due to free falling.

2- For the structural elements such as columns and walls of height up to 4m; concrete can be fallen freely into molds without significant effects on compressive strength.

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3- The compressive strength of specimens was relatively small probably because that they were not vibrated. Vibration may increase the compressive strength significantly.

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