International Journal of Current Engineering and Technology
E-ISSN 2277 – 4106, P-ISSN 2347 – 5161

Available at http://inpressco.com/category/ijcet

Research Article

Experimental study on lower cement content (LCC) concrete using continuous packing model: An Eco-Friendly and Sustainable Alternative for Construction Industry

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Received 08 July 2020, Accepted 01 Sept 2020, Available online 02 Sept 2020, **Vol.10, No.5 (Sept/Oct 2020)**

Abstract

Now a day's pressure is escalating on the construction industry to adopt more environmentally sustainable methods to reduce CO2 emissions. Portland cement often constitutes to quite two-thirds of the embodied energy of concrete, and its production generates 5% of worldwide greenhouse emission. One efficient strategy to scale back the cement content without sacrificing performance is that the use of particle packing models (PPM) to mix- proportion concrete mixtures with low cement content. This study aims to analyze and quantify the behavior of concrete mixtures designed with the use of the continuous PPM to increase binder efficiency in concrete. Three q factors were selected in this study and properties in the fresh (i.e. slump test) and hardened state (i.e., compressive strength) are measured and analyzed.

Keywords: *low cement concrete, packing model, q factor, compressive strength, slump test*

1. Introduction

As the rate of development of infrastructure in world expands day by day, the demand for additional civil infrastructure rises, and since concrete is one of the most common materials used for such types of structures, the use of concrete has increased 400% between 1990 and 2002, which causes a significant environmental impact worldwide. The Cement manufacture subsidize greenhouse gases both directly over the formulation of carbon dioxide when calcium carbonate is thermally break down, producing lime and CO2, and also through the use of energy, especially from the combustion of fossil fuels. Portland cement (PC) is the most commonly used binder in concrete, and its production requires high amounts of energy releasing a considerable amount of CO2.

In standard concrete mix designs, the cement content used is typically high and is selected empirically as a function of the consistency targeted (i.e., slump), water-to-cement ratio needed to build a required strength along with the maximum size and volumetric amount of the coarse aggregate. In such methods, there is no thorough evaluation and selection of the particle size distribution.

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It has been found that the use of packing model theories (either discrete or continuous) could lead to a significant reduction in the cement content by improving the aggregate skeleton distribution.

2. Fundamentals of particle packing theories

The packing of an aggregate for concrete is the degree of how good the solid particles of the aggregate measured in terms of 'packing density', which is defined as the ratio of the solid volume of the aggregate particles to the bulk volume occupied by the aggregate. The particle packing models may be subdivided as (a) discrete model (b) continuous model.

2.1 Discrete model

The fundamental assumption of the discrete approach is that each class of particle will pack to its maximum density in the volume available.

2.2 Continuous models

Continuous approach assumes that all possible sizes are present in the particle distribution system, that is, discrete approach having adjacent size classes ratios that approach 1:1 and no gaps exist between size classes. Fuller et al showed that the packing of concrete aggregates is affecting the properties of the produced concrete. Feret as well as Fuller and Thomsen wind up that the continuous grading of the composed concrete mixture can help to improve the concrete properties.

In the current study we are using continuous packing model approach.

3. Material Used

3.1Cement

Bureau of Indian Standards (BIS) classified various kinds of cement according to their physical as well as chemical properties as Ordinary Portland Cement (OPC). OPC is produced in large quantities than other cements. OPC is classified into three grades, namely 33 grade, 43 grade and 53 grades depending upon the compressive strength of cement at 28 days. In this study, Ordinary Portland Cement (OPC) conformed to BIS: 8112-2013 was used.

3.2 Coarse aggregate

The coarse aggregates were free from dust and dried to surface dry condition. As specified by BIS: 383-1970, all required properties were determined. The physical properties such as colour, shape, sieve analysis and fineness modulus were calculated and are given in Table 1.

Table 1. Properties of coarse aggregates

Colour	Grey
Shape	Angular
Maximum size	20mm
Specific gravity	2.65
Water absorption (%)	0.61

3.3 Fine aggregates

Natural sand was used as fine aggregates. It was brown in colour with coarser shape of particles.

4. Result and Discussion

Three concrete types presenting different q factors (0.26, 0.31 and 0.37) were selected to fabricate 25 MPa mixtures. The idea was to choose q factors that would provide the mixes with a high, moderate and low amount of fines, respectively. A fourth concrete mixture is 25MPa mixes following the conventional method. The below table represent the ratio of different constituent of concrete per metre cube with different q factors

Table 2. 25 MPa mix design and w/c ratio for distinct q factors.

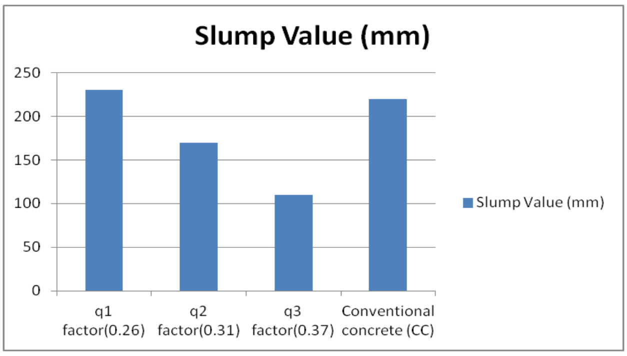
q Factor	Cement	Fine Aggregate	Coarse Aggregate	25 Mpa
	Kg/m^3			w/c
q1:0.26	401	811	1010	0.62
q2:0.31	343	810	1135	
q3:0.37	275	787	1282	
25Mpa	360	370	750	

4.1 Slump Test

The slump tests were carried out at the fresh state of concrete. Slump test were carried out for different q factors as well as for conventional 25 MPa conventional concrete. The result of slump test carried out for 25 MPa are shown in table below:

Table 3. Slump value of 25MPa Mix

S.No.	Particulars	Slump Value (mm)
1	q1 factor(0.26)	230
2	q2 factor(0.31)	170
3	q3 factor(0.37)	110
4	Conventional concrete (CC)	220



From above data it may be noticed that at minimum q factor slump value is greater than conventional concrete slump value. At minimum q factor the slump value of concrete mix is minimum.

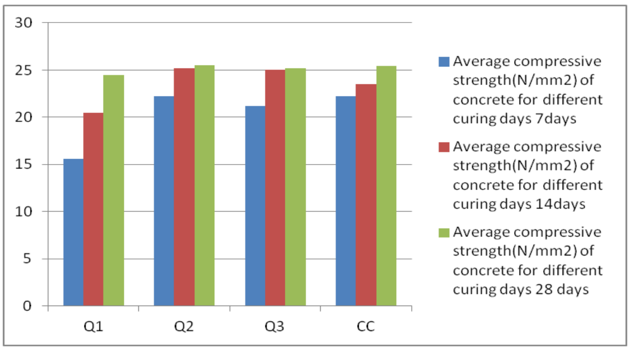
4.2 Compressive Strength Test

The compressive strength of the concrete was found on 7 days, 14 days and 28 days. The cubes of size 150x150x150 mm were casted to perform the test. After testing it is found that all the designed 25 MPa concrete mixtures reached or overcame the targeted strength much before 28 days. The q3 and q2 mixes having higher packing density reached the targeted strength at lower ages of 14 days.

The values of compressive strength at different days were shown in table below:

Table 3. Compressive strength of cubes of 25MPa Mix with different Q factor

Mix	Average compressive strength(N/mm^2) of concrete for different curing days		
	7days	14days	28days
Q1	15.6	20.5	24.5
Q2	22.2	25.2	25.5
Q3	21.2	25	25.2
CC	22.2	23.5	25.4



* CC-Conventional Concrete

Conclusions

This study aimed to evaluate and quantify the behavior of concrete mixtures designed with the use of continuous PPMs to increase binder efficiency in concrete. Three q factors were selected in this study and properties in the fresh and hardened states were measured and analyzed. The main conclusions on the above investigations are:

1. The use of PPMs showed capability of improving the hardened state i.e. compressive strength properties of conventional concrete mixtures.

2. Particular attention should be taken in very well-packed mixtures in the fresh state, since very low consistency may be achieved.

3. The consistency may be expected to be highly improved while the use of fillers and chemical admixtures.

4. It is identified that at q2 factor we can achieve targeted compressive strength and slump value is also not very low.

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