Optimization for Strength Characteristics of Self Compacting Concrete by Statistical Analysis by Taguchi Approach

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Abstract— With growing population, industrialization, and urbanization, there is corresponding growth in the demand for infrastructure. Insufficient compaction dramatically lowers ultimate performance of concrete in spite of good mix design. Placing the fresh concrete requires skilled operatives using slow, heavy, noisy, expensive, energy-consuming and often dangerous mechanical vibration to ensure adequate compaction to obtain the full strength of the hardened concrete. Self-compacting concrete (SCC) is an innovative concrete that does not requires vibration for placing and compaction. The performance of concrete depends on method of curing also. In conventional curing spraying of water/ keeping under wet condition is followed. An attempt has been made in optimizing the strength of self-compacting concrete by statistical analysis by Taguchi approach by selecting water to binder ratio, packing factor, fly ash and super-plasticizers as variable parameters for the study.

Keywords: Self Compacting Concrete, Taguchi Approach

I. Introduction

Concrete is the most widely consumed material in the world, after water. Placing the fresh concrete requires skilled operatives using slow, heavy, noisy, expensive, energy consuming and often dangerous mechanical vibration to ensure adequate compaction to obtain the full strength and durability of the hardened concrete. Self-compacting concrete (SCC) is an innovative concrete that does not requires vibration for placing and compaction. It is able to flow under its own weight, completely filling formwork and achieving full compaction, even in the presence of congested reinforcement. The hardened concrete is dense, homogeneous and has the same mechanical properties and durability as traditional vibrated concrete. "Self-Compacting Concrete is defined as a concrete in which it is having a passing ability, filling ability and segregation resistance along with which can flow under its own weight without any application of external energy". The performance and durability of concrete depends on method of curing also. In conventional curing spraying of water/ keeping under wet condition is followed. There are two major methods available for self-curing, namely, internal curing and external curing. These methods use materials which may either be added in concrete during manufacturing process or after casting the structural elements depending on the application. In the recent past, the researchers showed interest to investigate the performance of SCC and SC for various applications in civil engineering.

Ganesh & Rama Kumar (2000) [1] carried out the cementitious efficiency of ground granulated blast furnace slag (GGBS) at 28 days was tested at various replacement levels and concluded that it is possible to design GGBS concrete for a desired strength up to an optimum replacement percentage of 50%.

Gaywala & Raijiwala (2011) [2] carried an experimental study for concrete to be self-compacting it should have filling ability, passing ability and resistance against segregation. These properties are obtained by limiting the coarse aggregate content and using lower water-powder ratio together with super plasticizers

Navaneethakrishnan & Shanthi (2012) [3] carried out an experimental investigation on SCC containing silica fume it is clear that cement can be replaced with 15% silica fume effectively, thereby reducing the consumption of cement, which in turn reduces the cost.

Amir & Ramar (2012) [4] effectively used Rice husk ash as a highly reactive Pozzolanic material to improve the microstructure of the interfacial transition zone between the cement paste and the aggregate in SCC. Research shows that the utilization of rice husk ash in SCC mix (less than 20%) produced desired results and also provided an environment friendly disposal of agro-industry waste product.

Pai & George (2013) [5] emphases the advantages of using shell lime powder which blends in the concrete mix easily and forms a very good cohesive mix. It also acts as a good viscosity modifier for fresh concrete paste. The research shows that utilization of shell lime powder less than 30% in concrete gives satisfactory results.

Nirmala & Raviraj (2016) [6] present the application of Taguchi approach to obtain optimal mix proportion for Self Compacting Concrete (SCC) containing spent foundry sand and M-sand. The SCC mix has seven control factors namely, Coarse aggregate, M-sand with Spent Foundry sand, Cement, Fly ash, Water, Super plasticizer and Viscosity modifying agent. Modified Nan Su method is used to proportion the initial SCC mix. L18 Orthogonal Arrays (OA) with the seven control factors having 3 levels is used in Taguchi approach which resulted in 18 SCC mix proportions were studied.

The objective of the study is to

1) To develop a design mix for self-compacting concrete by using Taguchi approach
2) To ascertain the strength characteristics of M20 grade self-compacting concrete
3) To determine the durability characteristics of M20 grade self-compacting concrete
4) To optimize the relative amount of ingredients in making the self-compacting concrete cost effective by using statistical analysis
5) To determine the influence of each parameter on performance value of self-compacting concrete

II. MATERIALS

A. Cement:

Portland cement is the most common type of cement in general usage. It is a basic ingredient of concrete, mortar and plaster. In this project OPC 43 grade cement is used for the study

B. Fly Ash:

Fly ash is the notorious waste product of coal based electricity generating thermal power plants, known for its ill effects on agricultural land, surface and sub-surface water pollution, soil and air pollution and diseases to mankind. Researchers have proposed few ways of reusing fly ash for variety of application. One of the most common reuse of fly ash is in cement concrete.

C. Water:

Combining water with a cementitious material forms a cement paste by the process of hydration. Impure water used to make concrete can cause problems when in setting or in causing premature failure of the structure. Hydration involves many different reactions, often occurring at the same time. As the reactions proceed, the products of the cement hydration process gradually bond together the individual sand and gravel particles and other components of the concrete, to form a solid mass.

D. Manufactured Sand:

With the world wide decline in the availability of construction sands along with the environmental pressures to reduce extraction of sand from rivers, the use of manufactured sand as a replacement is increasing.

With the ban on sand mining implemented by different states, and with the increasing demand for river sand for construction works, many civil engineers have expressed the need to promote use of manufactured sand in the construction industry. "Manufactured sand is crushed fine aggregate produced from a source material and designed for use in concrete or for other specific products". Only source materials with suitable strength, durability and shape characteristics should be used.

E. GleniumB233:

GLENIUM B233 is an admixture of new generation modified poly carboxylic ether. The product has been primarily developed for the applications in high performance concrete where the highest durability and performance is required. It is a free chloride and low alkali.

F. Polyethylene Glycol:

The condensed polymer of ethylene oxide and water is polyethylene glycol. PEG 400 is used in this study where 400 is the molecular weight. It has general formula H (OCH2CH2) nOH. They are soluble in water. It is nontoxic, odourless, non-volatile and non-irritating. It has wide variety of uses in medicine.

III. METHODOLOGY

Specific Gravity	3.0
Fineness	9.33%
Standard Consistency	31%
Initial Setting Time	25min
Final Setting Time	285min

Table 1: Test Results for OPC43 Grade Cement

1) Physical Properties

Specific Gravity	2.2
Specific surface (cm^2 /g)	2680
Color	Dark Grey

Table 2: Test Results for Class F Fly Ash

2) Chemical Properties

Calcium oxide (CaO)	4.74
Silicon oxides (SiO_2)	46.80
Aluminium oxide (Al_2O_3)	23.89
Iron oxide (Fe_2O_3)	15.77
Magnesium oxide (MgO)	0.9
Sulphur oxide (SO_3)	1.18
Sodium oxide (Na_2O)	0.62
Potassium oxide (K_2O)	0.11
Loss on ignition (LOI)	2.36
Chemical Formula	$C_{2n}H_{4n+2}O_{n+1}$
Density	1.27 g/mL at 25 °C

Table 3: Physical properties of PEG

Specific Gravity	2.65
Fineness Modulus	4.2
Bulk Density	1550kg/m^3

Table 4: Test Results for Fine Aggregates

Specific Gravity	2.78
Fineness Modulus	4.04
Bulk Density	1340kg/m^3

Table 5: Test Results for Coarse Aggregates

Variable	Water to powder Ratio	Packing factor	Fly Ash	PEG
1	0.30	1.12	0	0
2	0.35	1.14	20%	0.5
3	0.40	1.16	40%	1.0

Table 6: Parameters for Study

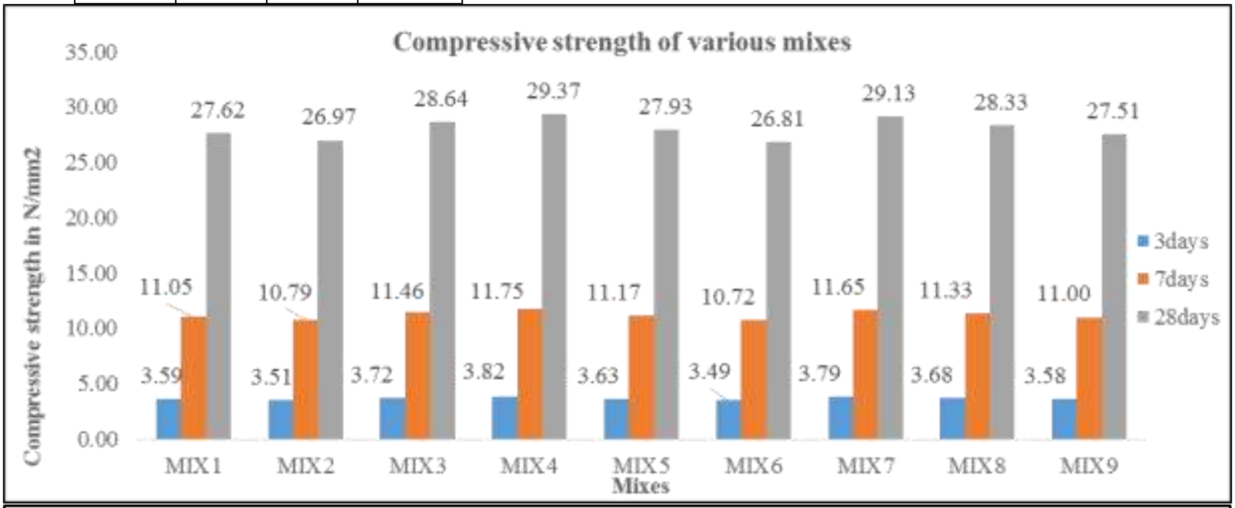
Sl. No	Cement	Fly Ash	% of Fly Ash	Total Powder content	Water	CA	FA	PEG	SP
1	268.63	208.27	0.00	476.90	181.65	875.51	788.36	0.00	2.86
2	214.90	193.78	53.73	462.41	177.35	891.14	802.44	1.07	2.77
3	161.18	179.29	107.45	447.91	173.05	906.78	816.51	1.61	2.69
4	214.90	195.33	53.73	463.96	187.58	875.51	788.36	2.15	2.78
5	161.18	181.74	107.45	450.36	182.87	891.14	802.44	0.00	2.70
6	268.63	168.14	0.00	436.77	178.16	906.78	816.51	1.34	2.62
7	161.18	183.90	107.45	452.53	192.81	875.51	788.36	0.81	2.72
8	268.63	171.10	0.00	439.73	187.74	891.14	802.44	2.69	2.64
9	214.90	158.31	53.73	426.93	182.67	906.78	816.51	0.00	2.56

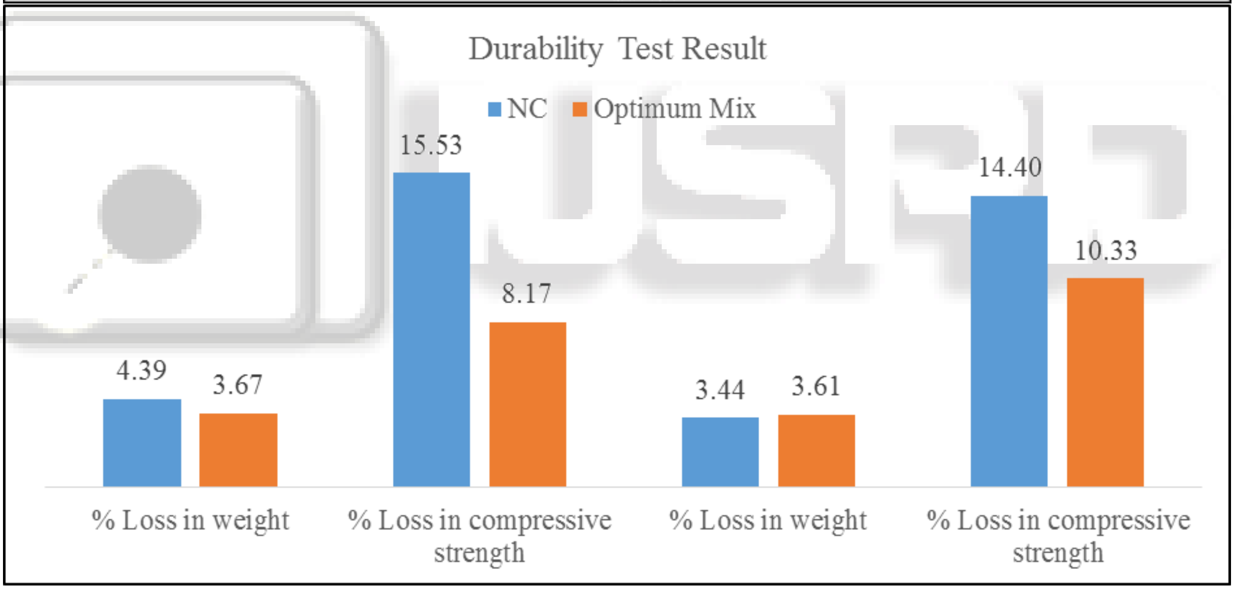
Table 7: Mix proportions

IV. RESULTS & DISCUSSIONS

	3days	7days	28days
MIX 1	3.59	11.05	27.62
MIX 2	3.51	10.79	26.97
MIX 3	3.72	11.46	28.64
MIX 4	3.82	11.75	29.37
MIX 5	3.63	11.17	27.93
MIX 6	3.49	10.72	26.81
MIX 7	3.79	11.65	29.13
MIX 8	3.68	11.33	28.33
MIX 9	3.58	11.00	27.51

Table 8: Compressive strength (in N/mm^2) for Design mixes after 3days, 7days & 28days of curin





V. CONCLUSIONS

Mineral admixtures like Fly ash will reduce the carbon foot print in manufacturing process of cement.

Addition of PEG into the concrete, promotes high rate of hydration which speed up the development of strength in concrete

Compressive strength of SCC for an optimum mix (w/p=0.35, packing factor =1.14, PEG by wt. of cement =1% & Fly ash by wt. of cement = 20%) was observed to be 6.33% more than compared to that of conventional concrete.

The percentage loss in compressive strength for optimum mix was observed to be less than compared to normal concrete for both acid and alkalinity test.

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