Experimental Study of High Performance Concrete Using Portland Pozzolana Cement with Silica Fume and Replacing Natural River Sand with Quarry Dust

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Abstract - *Concrete is one of the most widely used constructional material in the world. Along with this, the utilization of natural resources has been increased. This is leading to vanishing of them. Also due to ever increasing quantities of waste materials and industrial by-products, solid waste management is one of the prime concern in the world. There are several types of industrial by-products and waste materials. The utilisation of such materials in concrete not only makes it economical but also helps in reducing disposal concerns. The main aim of the thesis is to produce the high performance concrete of M60 grade using Portland pozzolana cement with silica fume and replacing natural river sand with quarry dust. The tests will be performed to check the compressive strength, flexural strength and tensile strength of concrete.*

Keyword: High performance concrete, Silica Fume, Quarry Dust, Replacement

1. INTRODUCTION

Reinforced-concrete (RC) structures constitute about 70% of today's infrastructures and for economic reasons structural engineers are under tremendous pressure to design smaller and shallower reinforced- concrete members. Such practice usually leads to heavily reinforced elements especially in beam-column joints and in structures located in highly seismic regions.

Concrete is the most widely used construction material in civil engineering industry because of its high structural strength, stability, and malleability. It is placed at second position after water. The Indian construction industry consumes approximately 400 million tons of concrete every year and is expected to reach the billion-ton mark in less than a decade. Human activities on earth produce solid wastes in considerable quantities of more than 2,500 million tons per year, including industrial and agricultural wastes from rural and urban societies. Recent technological developments have shown that these materials can be used as valuable inorganic and organic resources to produce various useful value-added products. The concrete industry is constantly looking for supplementary cementitious material with the objective of reducing the solid waste disposal problem.

Steel, cement, glass, aluminium, plastics, bricks, etc. are energy-intensive materials, commonly used for building construction. Generally these materials are transported over great distances. Extensive use of these materials can drain the energy resources and adversely affect the environment. On the other hand, it is difficult to meet the ever-growing demand for buildings by adopting only energy efficient traditional materials (like mud, thatch, timber, etc.) and construction methods. Hence, there is a need for optimum utilization of available energy resources and raw materials to produce simple, energy efficient, environment friendly and sustainable building alternatives and techniques to satisfy the increasing demand for buildings.

Fine aggregate is an essential component of concrete. The most commonly used fine aggregate is natural river or pit sand. The global consumption of natural sand is very high due to the extensive use of concrete owing to rapid infrastructural growth. In this situation, the construction industries of developing countries are in stress to identify alternative materials to lessen or eliminate the demand for natural sand. So, quarry waste fine aggregate could be an alternative of natural sand. It is a by-product generated from quarrying activities involved in the production of crushed coarse aggregates. Quarry waste fine aggregate, which is generally considered as a waste material after the extraction and processing of rocks to form fine particles less than 4.75mm, causes an environmental load due to disposal problem. Hence, the use of quarry waste fine aggregate in concrete mixtures will reduce not only the demand for natural sand but also the environmental burden. Moreover, the incorporation of quarry waste fine aggregate will offset the production cost of concrete. In brief, the successful utilization of quarry waste fine aggregate will turn this waste material into a valuable resource.

It was realized that the high strength alone will not be an effective method for achieving high performance and that the durability of these materials in various environments needs a better understanding to achieve an appropriate solution. These necessitated the utilization of industrial wastes having pozzolanic property in concrete and showed the possibility of obtaining improvements in durability, besides attaining HSC composites. The improvement milestone of these works is probably the introduction of silica fume.

2. MATERIALS

The basic material for mortar is cement, sand and/or sand stone dust, and water.

1. Cement

Portland pozzolana cement(PPC) of Ultratech Cement Satisfying all the required specification of Indian standard IS 1489 part I(1991) was used.

2. Natural River Sand and Coarse Aggregate

Table-I: -properties of natural river sand and coarse aggregate

Properties	River sand	Coarse Aggregate
Bulk Density	1661 kg/m^3	1577 kg/m^3
Fineness Modulus	2.67	7.03
Grading zone	II	II
Specific Gravity	2.65	2.7
Water absorption	2.45	0.4%
Moisture Content	0.8%	-

3. Super-plasticizer

To study cement super plasticizer compatibility and to determine optimum super-plasticizer dosage of a specific cement-super plasticizer combination, marsh cone test was used. . Super plasticizer of Conflow-CP from Contech Chemicals has been used.

4. Quarry Dust and Silica Fume

Sample of quarry dust(QD) and silica fume(SF) was tested in Modi Laboratory, Ahmedabad. The results are shown in table.

Table-II: -Chemical and Physical properties of QD and SF

Parameters	QD(%)	SF (%)
SiO_2	38.31	53.11
Al_2O_3	30.4	21.2
Fe_2O_3	7.9	10.36
Na_2O	1.1	1.39
K_2O	1.1	1.27
MgO	3.03	2.65
CaO	1.41	1.09
LOI	16.24	8.35
Specific gravity	2.21	2.49
Specific gravity	2.12	2.49
Bulk Density	1719 kg/m^3	1820kg/m^3
Water Absorption	4.21%	1.09%

3. EXPERIMENTAL PROGRAM

I. Mix Design

Mix design of M60 concrete has been done as per IS 10262:2009

Table-III: -Mix Design of M60 Concrete

Water (Liter)	Cement (kg/m^3)	Sand (kg/m^3)	Aggregate (kg/m^3)	Super plasticizer (1.5%) (Liter)
177	507	608	1151	7.6
0.35	1	1.2	2.27	0.0015

Cubes specimens of 150x150x150 mm, beam specimens of size 150mm X 150mm X 700mm and cylinder specimens of size 300mm long and 150mm dia. are used as per the specification of Indian standards. Experimental program has been done in 2 phases. In the 1st phase, optimization of quarry dust was done while in the 2nd phase, the optimization of silica fume has been carried out.

II. Optimization of Quarry Dust

The quarry dust was replaced by weight against natural river sand as fine aggregate in 0%, 25%, 50, 75% and 100% and the concrete mix was prepared to make 45 cubes (9 cubes for each percentage).

Moulds were cleaned, oiled and bolted properly before pouring of concrete. Concrete was prepared in concrete mixer. Water being w/c ratio as 0.35 was added in two phases : 70% of required water was added while concrete mixing and remaining 30% was added with the dosage of super plasticizer during mixing but after sometime. Cubes were de-moulded after 24 hours and cured in the curing tank. Out of 9 cubes, 3 were taken out after 7 days and others were taken out at 28 and 56 days. These cubes were tested on the Compression Testing Machine for their compressive strength.

Fig. 1 Bolting and oiling of Specimens

Fig. 2 Compressive strength of specimens

Table-IV: -Mix Design of M60 Concrete

QD %	Compressive Strength (Mpa)		
	7 Days	28 Days	56 Days
0%	29	52	72
25%	31	50	69
50%	32	58	77
75%	30	52	72
100%	23	44	64

From the results, the concrete with 50% of quarry dust as partial replacement of river sand was selected as optimum percentage and used for further experiments.

III. Optimization of Silica fume

After getting the optimum percentage of QD as 50%, 3 mix proportions have been prepared having QD as 40%, 50% and 60%. Each proportion having SF as 10%, 13% and 16% replacement of cement in it. Beams and cylindrical specimens were tested after 56 days of curing while cubes were tested after 7, 28 and 56 days of curing. Slump Cone and Compaction factor test has also been carried out to check the workability of the concrete mix.

4. RESULTS AND DISCUSSIONS

I. Workability Test

Fig. 3 Slump cone test of concrete

Table-IV: -Results of Workability tests

Sr. no.	QD (%)	SF (%)	Sand (%)	Cement(%)	Slump Value (mm)	Compaction Factor
1	0	-	100	100	105	0.94
2	25	-	75	100	120	0.949
3	50	-	50	100	117	0.942
4	75	-	25	100	108	0.94
5	100	-	0	100	93	0.931
6	0	0	100	100	101	0.94
7	40	10	60	90	97	0.938
8	40	13	60	87	116	0.943
9	40	16	60	84	131	0.952
10	50	10	50	90	128	0.949
11	50	13	50	87	109	0.941
12	50	16	50	84	116	0.942
13	60	10	40	90	105	0.939
14	60	13	40	87	98	0.935
15	60	16	40	84	107	0.939

Results showed that all of the mixtures achieved high workability having slump of around 100mm and compaction factor of more than 0.935. Concrete containing 40% of QD and 10% of SF achieved highest workability than others.

II. Compressive strength test

Table-V: -Results of Compressive strength test after 56 days of curing

Batch.no.	QD (%)	SF (%)	Sand (%)	Cement (%)	Compressive strength (Mpa)
1	0	0	100	100	72
2	40	10	60	90	68
3	40	13	60	87	73
4	40	16	60	84	78
5	50	10	50	90	72
6	50	13	50	87	76
7	50	16	50	84	82
8	60	10	40	90	70
9	60	13	40	87	74
10	60	16	40	84	75

From the results above, we can say that the concrete containing 50% of quarry dust and 16% of silica fume is achieving higher strength than other batches.

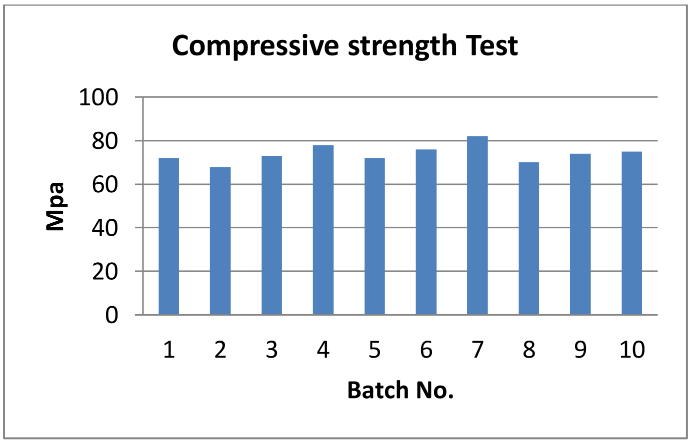

Fig. 4 Chart showing Compressive strength of concrete

III. Flexure test

Fig. 5 Flexural strength testing of concrete

From the above results, concrete having 50% of quarry dust and 16% of silica fume showed higher strength comparing to other batches.

Table-V: -Results of Flexure test

Batch no.	QD (%)	SF (%)	Sand (%)	Cement (%)	Flexural strength (Mpa)
1	0	0	100	100	5.85
2	40	10	60	90	5.70
3	40	13	60	87	5.89
4	40	16	60	84	6.07
5	50	10	50	90	5.86
6	50	13	50	87	6.00
7	50	16	50	84	6.25
8	60	10	40	90	5.75
9	60	13	40	87	5.90
10	60	16	40	84	5.96

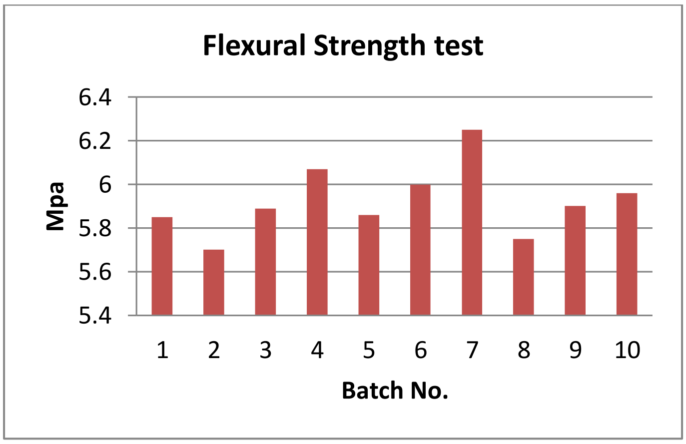

Fig. 6 Chart showing flexural strength

IV. Split tensile test

Fig. 7 Split tensile strength testing of concrete

Table-V: -Results of Split tensile test

Batch no.	QD (%)	SF (%)	Sand (%)	Cement (%)	Tensile strength (Mpa)
1	0	0	100	100	5.27
2	40	10	60	90	4.89
3	40	13	60	87	5.02
4	40	16	60	84	4.97
5	50	10	50	90	4.79
6	50	13	50	87	5.13
7	50	16	50	84	6.73
8	60	10	40	90	5.98
9	60	13	40	87	5.27
10	60	16	40	84	6.37

From the results, it showed that all the batches performed well in the test but the concrete with 50% of quarry dust and 16% of silica fume outperform all the others.

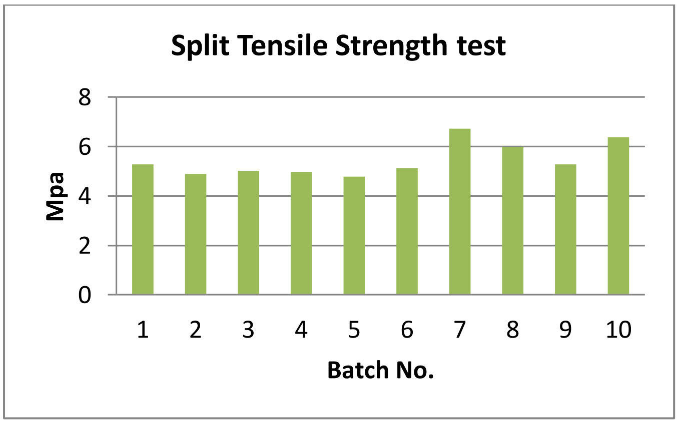

Fig. 5 Chart showing split tensile strength of concrete

5. CONCLUSIONS

- From the compression test of the cubes at 7 days,28 days and 56 days, we can conclude that concrete having 50% of quarry dust and 16% of silica fume achieves optimum compressive strength.
- From the Slump test and Compaction Factor test, all the concrete mixes achieved high workability but concrete having 40% QD and 16% SF showed highest workability.
- Concrete having 50% QD and 16% SF again showed the best results in both Flexure test and Split Tensile test.
- From this experimental program, we can conclude that the high performance concrete can be made by partially replacing natural river sand with optimum of 50% of quarry dust and cement with 16% of silica fume without any loss in its strength.

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