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An Experimental Study on the behavior of Concrete by Partial Replacement of Cement by Silica Fume and Coarse Aggregate by River Pebbles

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Abstract - *In this study, the behavior of the concrete by partial replacement of cement by silica fume and coarse aggregate by river pebbles were studied under strength criteria. Due to increase in the construction activities, the materials needed for the concrete works are depleting. Hence there is a requirement for an alternative material for the coarse aggregate used in the concrete. River pebble is one of the suitable materials which fulfill the requirement for the coarse aggregate by this study. The strength of the concrete can also increase by the suitable percentage of silica fume for achieving high strength. In this experimental study the coarse aggregate was replaced by river pebbles in the range of 20%, 30%, 40% and cement was replaced by silica fume in the range of 5%, 10% and 15% for M-30 grade of concrete. The different concrete tests such as slump test and compressive strength test were carried out for the concrete to know the workability and strength criteria. The results showed that an increase in the percentage of river pebble reduces the strength in small increments and also increases the workability of concrete. The optimum strength achieved for the replacement of cement by 10% of silica fume.*

Key Words: River Pebbles, Silica Fume, Workability, Compressive Strength, split tensile strength, flexural strength.

1. INTRODUCTION

In day today life the concrete is the most essential material for every construction work. Concrete is nothing but the mixture of cement, fine aggregate, coarse aggregate, water etc with required proportion. As the days goes on rapid development has taken place in the construction field. So many constructions are going on in the present days. For the major construction works such as multi-floor buildings, bridges, commercial buildings etc high grade concrete is required. So from the recent years many experiments are carried out in the field of concrete technology to achieve high strength in concrete. So for all these reasons concrete plays a major role in the construction works. Now a day's common people have started for using the concrete for the different purposes. The necessity of concrete in construction has made the people to do more innovations in the field of concrete technology. In olden days the strength of concrete is limited to M-20 grade. But in the present days from the innovations made in the field of concrete, the strength of concrete is well above M-60. To achieve high strength some related admixtures are to be used in the concrete. Due to the increase in the field of construction works the materials which are used in concrete are depleting. So there are many experiments are going on for the replacement of concrete materials. Some replacement materials which can be used for the making of concrete are river pebbles, tile aggregate, lime stone etc. In the field of concrete, cement plays a major role which can binds all the other material in concrete. So the cement is called as binder material in concrete. For achieving high strength in concrete some material are to be used as partial replacement for cement such silica fume, fly ash, ground granulated blast furnace slag (GGBFS) etc.

1.1 Need of Study

The main intention of the research work is to replace the concrete material such as cement and coarse aggregate with suitable material. Silica fume is one of the promising pozzolonic materials which enhance the strength of concrete suitable for the partial replacement of cement. To obtain the high strength and performance in concrete the silica fume can be effectively used. In the same way the requirement of crushed granite stone is more due to heavy construction works. So it is depleting day by day and also it may produce dust during the crushing process which may lead air pollution. Because of these reasons it is essential work another promising replacing material for the crushed granite stone. River pebbles are the naturally available aggregates near the river beds can be used as the partial replacement of crushed granite stones. But in day-today life construction using river pebble is less. So the research work is to be needed to know the performance of concrete containing river pebble.

1.2 Objectives of Study

Based on the needs of construction works and by the literature study the objectives are framed.

- To determine the fresh properties of concrete containing river pebble and silica fume.
- To determine the hardened properties of concrete containing river pebble and silica fume.
- To optimize the partial replacement of coarse aggregates by river pebbles based on the strength criteria.
- To optimize the partial replacement of cement by silica fume based on the strength criteria.

2. MATERIALS AND METHODS

The various properties of the materials which are to be used in the concrete have great influence on the strength characteristics of the concrete. Hence some of the basic tests were conducted on the materials of concrete. The basic materials which are to be used in the concrete are:

- Cement (OPC 43 grade)
- Silica Fume (SF)
- Fine Aggregate
- Coarse Aggregate
- River Pebbles (RP)
- Water

2.1 Cement

The cement used for this experimental work was ordinary Portland cement of 43 grade (ACC) conforming to IS 8112-1989. Table 1 shows the physical properties of cement.

Table -1: Physical properties of cement

Properties		Cement
Specific gravity		3.02
Setting time	Initial (minutes)	65
	Final (minutes)	590
Standard consistency		31%
Fineness		320m²/kg
Compressive strength (MPa)	7 days	25
	28 days	34

2.2 Fine Aggregate

The river sand of size below 2.36mm conforming to zone 2 of IS 383-1970 was used as fine aggregate in this experimental work. The basic physical properties and particle size distribution of fine aggregates are tabulated in Table 2.

Table -2: Physical properties of Fine Aggregate

Properties		Fine Aggregate	Test Conforming to
Specific gravity		2.65	IS 2368 (part 3)- 1963
Water absorption		1%	
Bulk density (kg/m³)	Loose	1453	
	Compact	1740	

2.3 Coarse Aggregate

Natural crushed granite stones of 20mm below size were used as coarse aggregates for this experimental work. The basic physical properties and sieve analysis of coarse aggregates are tabulated in Table 3.

Table -3: Physical properties of Coarse Aggregate

Properties	Coarse Aggregate
Specific gravity	2.7
Water absorption	0.48%
Aggregate crushing value	26.58 %
Aggregate impact value	23.5%
Elongation index	26.5%
Flakiness index	28%

2.4 River Pebbles

River pebbles of 20mm down size are collected from Payaswini river side in Sullia. The basic physical properties of river pebbles are tabulated in Table 4.

Table -4: Physical properties of RIVER PEBBLES

Properties	Coarse Aggregate
Specific gravity	2.62
Water absorption	1.55%

Aggregate crushing value	33%
Aggregate impact value	28.58%
Elongation index	18.23%
Flakiness index	17.93%

2.5 Water

Potable water which is available in concrete laboratory was used for the present investigation of study.

2.6 Concrete Mix Design

Different trail mixes are done and tested to find out for the suitable mix proportion of materials for the concrete. The fresh and hardened properties of concrete depends up on the material properties, mixing method, compaction method, curing method etc. the mix design of M30 grade of concrete was done as per the guidelines of IS10262-2009 with constant water-cement ratio of 0.48 for the present work of study. In order to compare the results of various concrete mixes, control mix was made without the replacement of materials. The various mix designations are tabulate in Table 5.

Table -5: Various Mix Designations

Mix Designation	Types of mixes
M	Control Mix
M1	20% RP+0% SF
M2	30% RP+0% SF
M3	40% RP+0% SF
M4	0% RP+5% SF
M5	0% RP+10% SF
M6	0% RP+15% SF
M7	20% RP+5% SF
M8	30% RP+5% SF
M9	40% RP+5% SF
M10	20% RP+10% SF
M11	30% RP+10% SF
M12	40% RP+10% SF
M13	20% RP+15% SF
M14	30% RP+15% SF
M15	40% RP+15% SF

2.7 Results and Discussion

The concrete tests like compressive strength test, split tensile strength test, flexural strength test and modulus of elasticity test were carried out on the various concrete mixes in order to know the strength of the concrete in this present investigation. The various test results obtained from these tests are tabulated in table and as well as in the graphical form.

2.7.1 SLUMP TEST RESULTS

Slump test was conducted in order to know the workability of various concrete mixes containing river pebble and silica fume. The slump values obtained in the different concrete mixes are tabulated in table 6. It can be seen that as the percentage of river pebble increases, the slump value of concrete increases and also as the percentage of silica fume increases the workability of concrete reduces. From the table it can be seen that the slump values increases as the percentage of river pebble increases for the constant value of silica fume, but the slump value is less compared to the control mix because of the presence of silica fume in the concrete.

Table -6: Slump values obtained in the different concrete mixes

Mix designation	Slump (mm)
Control Mix	70
20% RP+0% SF	78
30% RP+0% SF	83
40% RP+0% SF	87
0% RP+5% SF	30
0% RP+10% SF	19
0% RP+15% SF	12
20% RP+5% SF	35
30% RP+5% SF	38
40% RP+5% SF	42
20% RP+10% SF	28
30% RP+10% SF	33
40% RP+10% SF	38
20% RP+15% SF	23
30% RP+15% SF	27
40% RP+15% SF	31

2.7.2 Compressive Strength Results

The compressive strength test was conducted on the cube specimen of size 100X100mm in this present work of study. The concrete was placed in the moulds after 24 hours the concrete cubes were demoulded from the moulds and placed for the curing in the water for the period of 7, 28 and 56 days. After the curing period these cubes were tested in compressive testing machine. The compressive strength results of the cubes of various mixes are tabulated in Table 7. The compressive strength results of concrete mixes containing river pebble 20%, 30%, 40% along with control mix are there in Fig 1. From the figure it can be seen that the compressive strength of concrete mixes containing 20%, 30%, 40% river pebble decreases by 3.8%, 5.2%, 6.25% respectively at 7 days, 2.81%, 7.4%, 9.78% at 28 days and 3.67%, 9.0%, 13.77% at 56 days respectively than the concrete mix. So from the graph as the percentage of river pebble increases the compressive strength of concrete mixes reduces.

Table -7: Compressive strength results of the cubes of various mixes

Mix designation	Compressive strength (MPa)		
	7 days	28 days	56 days
Control Mix	27.34	37.3	44.3
20% RP+0% SF	26.49	36.25	42.73
30% RP+0% SF	25.97	34.52	40.36
40% RP+0% SF	25.63	33.65	38.25
0% RP+5% SF	31.45	41.69	46.36
0% RP+10% SF	33.45	44.93	48.93
0% RP+15% SF	30.83	40.25	45.78
20% RP+5% SF	31.23	40.35	43.79
30% RP+5% SF	29.54	39.23	41.36
40% RP+5% SF	27.36	38.45	40.05
20% RP+10% SF	32.056	42.35	45.36
30% RP+10% SF	30.486	41.13	43.26
40% RP+10% SF	29.036	39.75	41.97
20% RP+15% SF	32.45	39.05	42.34
30% RP+15% SF	30.46	37.96	40.9
40% RP+15% SF	30.23	36.23	38.7

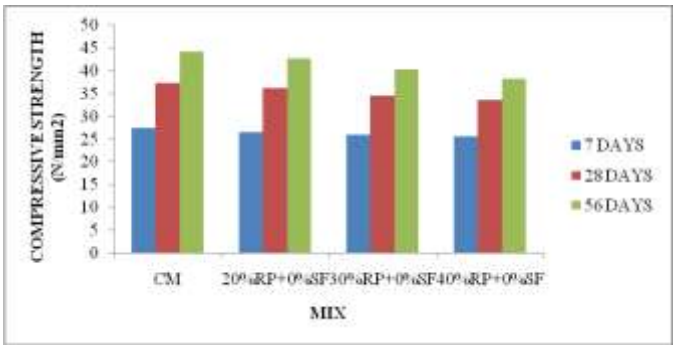

Fig-1: Effect of River Pebble on Compressive Strength of Concrete

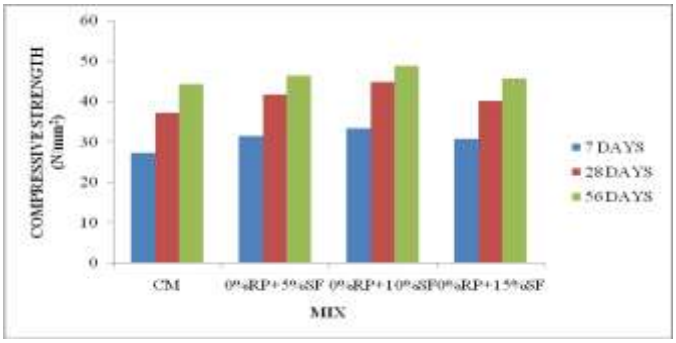

Fig-2: Effect of Silica Fume on Compressive Strength of Concrete

The compressive strength results of concrete mixes containing 5%, 10% and 15% silica fume along with control mix are there in Fig 2. From the figure it can be seen that the compressive strength of concrete mixes containing 5%, 10%, 15% silica fume increases by 15.03%, 22.34%, 12.76% at 7 days, 11.76%, 20.45%, 7.09% at 28 days and 4.5%, 10.3%, 3.2% at 56 days respectively than the control mix. From the graph maximum compressive strength obtained for the concrete mix containing replacement of cement by 10% silica fume.

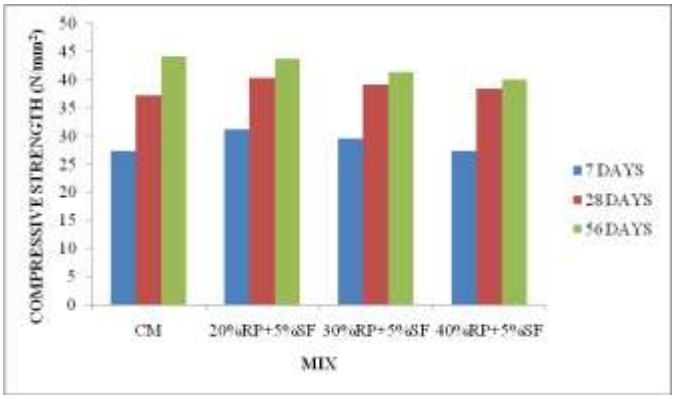

Fig-3: Effect of River Pebble and Silica Fume on Compressive Strength of Concrete

The compressive strength results of concrete mixes containing 20%, 30%, 40% river pebble and a constant value of 5% silica fume are there in Fig 3. From the figure it can be seen that the compressive strength of concrete mix decreases as the percentage of river pebble increases for the constant value of 5% silica fume. This is because as the percentage of river pebble increases the bonding between the aggregate and cement paste reduces, so that the compressive strength reduces. In the figure the maximum compressive strength of 31.23MPa, 40.35MPa, 43.79MPa obtained for the concrete mix containing 20% river pebble and a constant value of 5% silica fume at 7, 28 and 56 days respectively.

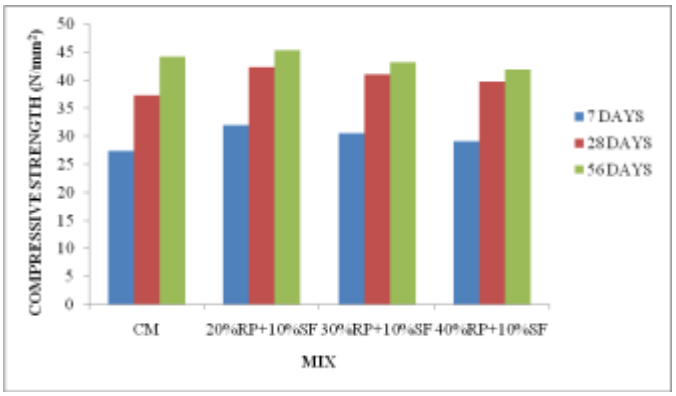

Fig-4: Effect of River Pebble and Silica Fume on Compressive Strength of Concrete

The compressive strength results of concrete mixes containing 20%, 30%, 40% river pebble and a constant value of 10% silica fume are there in Fig 4. From the figure it can be seen that as the percentage of river pebble increases the strength reduces for a constant percentage of silica fume. In the figure the maximum compressive strength obtained for the concrete mix containing 20% river pebble and a constant value of 10% silica fume. In the figure the compressive strength obtained for the curing period of 28 and 56 days are more when it is compared with 7 days of curing, because during the initial days the strength obtained from pozzolonic reactivity of the mixes containing silica fume is less. As the curing days increases the rate of the reaction is faster, so the gain of strength also more.

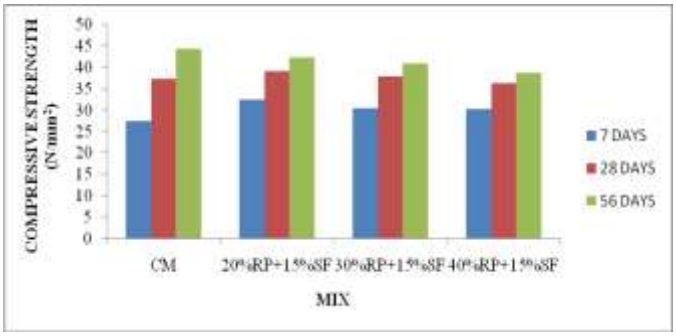

Fig-5: Effect of River Pebble and Silica Fume on Compressive Strength of Concrete

The concrete mixes containing 20%, 30%, 40% river pebble and constant value of 15% silica fume are there in Fig 5. From the graph, it can be seen that as the percentage of river pebble increases the compressive strength decreases and the maximum compressive strength obtained for concrete mix containing 20% river pebble and a constant value of 15% silica fume.

3. CONCLUSIONS

- The replacement of coarse aggregate by river pebble increases the workability of concrete due to smooth surface texture and round shape of river pebbles. Increase in the percentage of silica fume decreases the workability of concrete. This is mainly due to fineness of silica fume which requires more water to wet the surface.
- As the percentage of river pebble increases in the concrete the compressive strength of the concrete decreases due to the poor bonding between aggregate and cement paste.
- The maximum compressive strength obtained for the concrete mix containing the replacement of cement by 10% silica fume due to dilution of silica fume in saturated solution of $Ca(OH)_2$ produces more C-S-H gel.
- From the study it can be concluded that the replacement of coarse aggregate by 20% river pebble gives the maximum compressive strength for the concrete. Because as the percentage of river pebble increases bonding between cement paste and aggregate goes on reduces.

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