Studies on Strength of Concrete by Partial Replacement of Cement with Saw Dust Ash

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Abstract— In this project we have dealt with the use of saw dust ash as replacement for cement by some percentage in concrete in order to minimize the amount of cement and enhance concrete properties. We have various pozzalanic materials and saw dust ash is one among them. The basic motto of the present program is to determine the change in the properties of concrete for the amount of saw dust ash replaced. In the present study the materials taken are Cement of 53 grade, aggregate of size suitable to obtain good mix, sand pertaining to zone II, water for through mixing, main ingredient of saw dust ash. Saw dust is initially carbonized and sieved. And various tests are conducted on the material like sieve analysis, fineness modulus, specific gravity for aggregate, fineness test for cement etc. The concrete mix corresponding to M20 is chosen for the study. The mix design yielded a proportion of 1:1.49:3.08 which represent cement: fine aggregate: coarse aggregate respectively. The water cement ratio considered is 0.5.Thus using the proportion the materials are mixed. Two mixes with varying proportions of saw dust ash are considered. They are mix1 is obtained by mix1 is obtained by replacing 5%of cement by weight with saw dust ash and mix2 is obtained by replacing 10 %of cement by weight with saw dust ash. The concrete is thoroughly mixed in a concrete mixer and placed in the moulds by compacting it using a plate vibrator. The specimens are named and the date of casting is noted. The specimens are removed from the mould after duration of one day and are placed in water for curing. Tests are carried out on the specimens in duration of 1 day,7days,14days and 28 days and the test results are noted .Various tests carried out on the specimens are for cubes compression tests are done and the cube compressive strength is determined, for cylinders split tensile test is done in order to know the tensile strength. Hence the test results obtained for the two mixes chosen are compared and also compared with the results with that of the actual mix when no proportion of cement is replaced by saw dust ash.

Key words: Concrete, Cement, Saw Dust Ash

I. Introduction

A. General

Housing for all by the year 2020 will continue to be a mirage given the present escalating trend of cost of building materials. Chiefly among the widely used materials for the construction of buildings in India is concrete; which according to Neville (1983) is composed of granular inert material held together by the action of cement and water.

Cement is widely noted to be the most expensive constituent of concrete. It could be asserted that both the limited raw materials and the industrial processes undergone by cement during the manufacturing stage may have accounted for its high cost. If this rise in the cost of building materials, especiallycement, is not checked, may bewilder the noble objective associated to the golden year (2020).

In the bid to solving the problem, many researches are being done on the possible use of locally available materials to partially replace cement; in concrete. These materials are called pozzolanas. According to the American Society for Testing Materials (ASTM) C 618-78,pozzolana is a siliceous or siliceous aluminous material which contains little or no cementitious value, but in finely divided form and in the presence of moisture or water, chemically reacts with calcium hydroxide at ordinary temperature to form compound possessing cementitious properties. Commonly met pozzolanas include fly ash, calcined diatomaceousearth, rice husk ash, saw dust ash and pulverized burnt clay.

Extensive research has shown that the use of pozzolanas can produce concrete of better resistance to sulphate attack, reduce concrete permeability and improve water tightness, heat of hydration. The use of pozzolanas can also reduce alkali aggregate reaction except when high soluble alkalis are present.

Cement according to Nevile is composed primarily of silica and lime ,which forms the essential compounds ,Tricalcium and dicalcium silicate .Any alteration in the silica content will invariably affect the strength characteristics of cement, which is expected when saw dust ash is used to partially replace cement in concrete. Therefore the fundamental premises of the study cannot be underscore as it is aimed at sourcing local materials for construction in the bid to reduce the overall cost of construction.

This is also in consonance with the clarion call for the development of locally available materials for construction in other to achieve housing for all by the year 2020.

B. Need for Study

The present study is taken up with an aim to utilize more saw dust ash as replacement to cement. This procedure uses more saw dust ash than it is utilized in cement only, as replacement on which aspect maximum literature is available. Hence there is a need for this study to find the optimum percentage of saw dust ash.

C. Present Study Programme

Saw dust ash in the present study program is obtained by carbonation of saw dust. OPC 53 grade (Ultratech) cement, Fine aggregate conforming to zone-ii, Corse aggregate of 20 mm size had been used. The concrete mix corresponding to M_{20} is chosen for the study. The mix design yielded as proportion of 0.5:1:1.49:3.08

Mix	Constituents
B_1	(0.95%cement+0.05% SDA)+F.A+C.A
B_2	(0.9% cement+ 0.1% SDA)+F.A+C.A

Table 1:

F.A -> Fine Aggregate
SDA -> Saw Dust Ash
C.A -> Coarse Aggregate

For each mix 6 cubes were casted and two cubes were casted at 1 day two cubes at 7 days, two cubes at 14days and 2 cubes at 28 days. Similarly for each mix two cylinders are casted at 28 days. Two cylinders are tested for compressive strength and two for split tensile strength. The results were tabled as shown

D. B_1 Mix

In this mix cement is replaced by 5% saw dust ash, fine aggregate and coarse aggregate are considered.

E. B_2 Mix

In this mix cement is replaced by 10% saw dust ash, fine aggregate and coarse aggregate are considered.

II. Materials

Plain concrete is made by mixing cement, fine aggregate (sand), coarse aggregate (metal) and water. The above materials may be blended with Portland cement in fixed proportions after burning it to produce blended cement. Alternatively these same materials may be introduced into concrete mixes separately as mineral admixtures. Chemical admixtures may also be added in the concrete mixer to improve some of the properties. Strength durability, Surface texture and economy of concrete are all influenced by choice of materials, by the manner they are proportioned in the concrete and the precision with which the concrete can be produced. The quality of concrete can be assured through the quality audit of materials for concrete, workshop in each stage of production in concrete and related plant, machineryand equipment.

A. Cement

Cement is a material that has cohesive and adhesive properties in the presence of water. It consists primarily of silicates and aluminates of lime obtained from limestone and clay. The cement combines chemically with water to form a hardened mass. The hydraulic mass is usually known as Portland cement because of its resemblance upon hardening to the Portland stone found in new dourest England.

The raw materials used in the manufacture of cement consist mainly of lime, silica, alumina and iron oxide. These oxides interact with one in the kiln at high temperature to form more complex compounds. The relative proportions of these oxide compositions are responsible for influencing the various properties of cement; in addition to the rate of cooling and fineness of grinding. Table below shows the approximate oxide composition limits of ordinary Portland cement.

Oxide	% content
CaO	60-67
SiO_2	17-25
Al_2O_3	3.0-8.0
Fe_2O_3	0.5-6.0
MgO	0.1-4.0
Alkalies	0.4-1.3
SO_3	1.3-3.0

Table 2:

Four major compounds are formed due to the reaction of oxide at high temperatures. The identification of the major compounds is largely based on R.H.Bogue's work and hence they are termed as "Bogue's compounds". The four major compounds formed are:

Name of compound	Formula	Abbreviation
Tricalcium silicate	$3CaO.SiO_2$	C_3S
Dicalcium silicate	$2CaO.SiO_2$	C_2S
Tricalcium aluminate	$3CaO.Al_2O_3$	C_3A
Tetracalcium alumino ferrite	$4CaO.Al_2O_3.Fe_2O_3$	C_4AF

Table 3:

Tricalcium and dicalcium silicate are the most important compounds responsible for strength. Together they constitute 70 to 80% of cement.

There are 3 different types of cement as classified by Bureau of Indian Standards (BIS)

1) 33 grade ordinary Portland cement (IS: 269 - 1989)
2) 43 grade ordinary Portland cement (IS: 8112 - 1989)
3) 53 grade ordinary Portland cement (IS: 1229 - 1987)

In the present context, OPC conforming to 53grade had been utilized.

B. Aggregates

Aggregates are the important constituents in concrete. They give body to the concrete, reduce shrinkage and effect economy. Earlier aggregates were considered as chemically inert materials but now it has been recognized that some of the aggregates are chemically active and also that certain aggregates exhibit chemical bond at the interface of aggregate and paste. The mere fact that aggregate occupy 70 to 80 percent of the volume of concrete, will greatly impact on various characteristics and properties of concrete is undoubtedly considerable. Cement is the only factory made standard component in concrete, other ingredients namely water and aggregate are natural materials and can vary to any extent in many of their properties.

Aggregate can be classified as coarse and fine aggregate based on their size. The size of aggregate bigger than 4.75mm is considered as coarse aggregate and aggregate whose size is 4.75mm and less is considered as fine aggregate.

The shape of aggregates is an important characteristic since it affects the workability of concrete. It is difficult to really measure the shape of irregular body like concrete aggregate which are derived from various rocks. The shape of the aggregates is very much influenced by the type of crusher and the reduction ratio. Based on shape aggregates are classified as rounded, irregular or partly rounded angular and flaky. Round shaped aggregate has good workability, angular aggregate have good interlocking, flaky and elongated are not desirable.

One of the methods of expressing angularity qualitatively is by the figure called angularity number. The normal aggregates which are suitable for making the concrete may have angularity number anything from 0 to 11.

Angularity number 0 represents the most practicable rounded aggregates and the angularity number 11 indicates the most angular aggregates that could be tolerated for making concrete not so unduly harsh and uneconomical.

Surface texture is the property, the measure of which depends upon the relative degree to which particle surfaces are polished or dull, smooth or rough. Surface texture depends on hardness, grain size, porestructure, structure of the rock and the degree to which forces acting on the particle surface have smoothed or roughened it. Hard, dense, fine grained material will generally have smooth fracture surface. As surface smoothness increases, contact increases, hence highly polished particle will have less bonding area with the matrix than a rough particle of the same volume. Based on surface texture aggregates are classified as glassy, smooth, granular, crystalline, honeycombed and porous.

For making strong concrete, strong aggregate are an essential requirement. In other words, froma weak rock/aggregate strong concrete cannot be made. By and large naturally available mineral aggregate are strong enough for making normal strength concrete.

C. Water

Water is an important ingredient of concrete as it actively participates in the chemical reaction with cement. Since it helps to form the strength giving cement gel, the quantity and quality of water is required to be looked into very carefully. A popular yard-stick to suitability of water for mixing concrete is that, if water is fit for drinking it is fit for making concrete. This does not appear to be a true statement for all conditions. Given below is a table indicating the tolerable levels of various impurities for water which can be used in making concrete.

Algae in mixing water may cause a marked reduction in strength of concrete either by combining with cement to reduce the bond or by causing large amount of air entrainment in concrete. Algae which are present in the surface of the aggregate have the same effect as in that of mixing water.

D. Saw Dust Ash

Sawdust is a waste product from the timber industry. Research work carried out on the ash derived from the sawdust has confirmed its pozzolanic properties with a pozzolanic index value of 75.9%. This material compares favorably with fly ash and wastes from the oil palm industry. The only difference noticed is in the low content of Al_2O_3 (0.04%). Concrete mixes has been proportioned to have various percentages of cement replacement with sawdust ash (SDA) 5% and 10% by mass. Performance of the ash–Portland cement mixture has been evaluated with respect to setting time, workability and compressive strength. From the results obtained, 10% replacement of cement with SDA shows good performance giving the desired workability and strength.

III. DESIGN

A. Details of Mix Design (Durability Criteria) As Per Is: 456-2000:

1) *Design stipulations*
   - Characteristic compression strength required in the field at 28 days: 20MPa
   - Maximum size of aggregate: 20mm (angular)
   - Degree of workability: 0.90 compacting factor
   - Degree of quality control: good
   - Type of exposure: mild
2) *Test data for materials*
   - Specific Gravity of Cement: 3.15
   - Compression strength of cement at 7 days: satisfies the requirement of IS: 269-1989
   - Specific gravity of coarse aggregates: 2.6
   - Specific gravity of fine aggregates: 2.6
   - Water absorption:
     Coarse aggregate - 0.5%
     Fine aggregate - 1%
   - Free (surface) moisture content:
     Coarse aggregate - Nil

Sieve analysis
Fine aggregate:

Sieve sizes	Fine aggregate (% passing)	remarks
4.75mm	100	Conforming to grading Zone II of Table 4 IS: 385-1970
2.36mm	100	
1.18mm	81	
600micron	40	
300micron	12	
150micron	2	

Table 4:

3) *Target Mean Strength*

The target mean strength at 28 days is given by

$$f'_{ck} = f_{ck} + t*S$$

where f_{ck} = characteristic compression strength at 28 days.
S is the standard deviation. The value of the standard deviation has to be worked out from the trails conducted in the laboratory or field. In the absence of such trails the value of standard deviation can be adopted can be adopted from the below table, to facilitate initial mix design. As soon as enough test results become available, standard deviation should be worked out and the mix design is modified accordingly.

t = a statistical value depending on expected proportion of low results (risk factor). According to IS: 456-2000 and IS: 1343-80, the characteristic strength is defined as that value below which not more than 5 per cent results are expected to fall, in which case the above equation reduces to

$f'_{ck} = f_{ck} + t*S$

Target mean strength $f_{ck} = f_{ck} + t*S$
= 20+1.65*4 = 26.6 MPa

Tolerance level. No of Samples	1 in 10	1 in 15	1 in 20	1 in 40	1 in 100
10	1.37	1.65	1.81	2.23	2.76
20	1.32	1.58	1.72	2.09	2.53
30	1.31	1.54	1.70	2.04	2.46
Infinite	1.28	1.50	1.64	1.96	2.33

Note: Under conditions of major concreting Job, where large number of samples are tested, it would be appropriate to adopt a tolerance factor corresponding to infinite number of samples.

Table 5: Values of Tolerance Factor (t) (Risk Factor)

Assumed standard deviation as per IS 456-2000

Grade of concrete	Assumed standard Deviation in N/mm^2
M 10	
M 15	
M 20	3.5
M 25	4.00
M 30	
M 35	5.00
M 40	
M 45	
M 50	

Table 6:

4) Selection of Water-Cement Ratio

Various parameters like types of cement, aggregate, maximum size of aggregate, surface texture of aggregate etc. are influencing the strength of concrete, when water/cement ratio remain constant, hence it is desirable to establish a relation between concrete strength and free water cement ratio with materials and condition to be used actually at site. In absence of such relationship, the free water/cement ratio corresponding to the target strength may be determined from the relationship shown in the graph.

Generalized relation between free water-cement ratio and compression strength of concrete

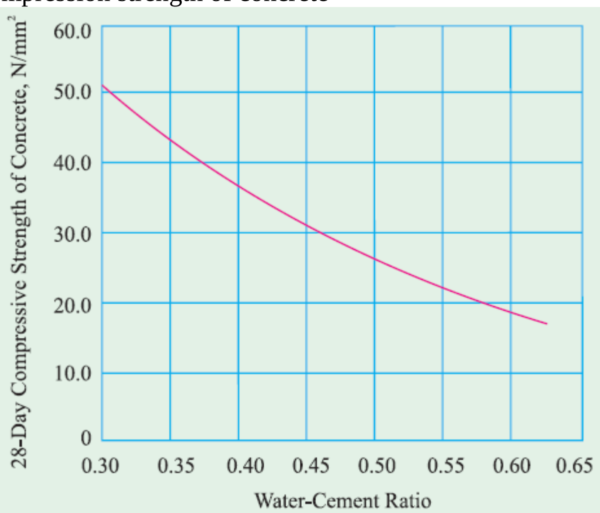

Fig. 1: Water-Cement Ratio

From graph, for target mean strength of 26.6 MPa is 0.5. This is lower than the maximum value of 0.55 prescribed for Mild exposure. Adopt w/c ratio 0.50

5) Selection of Water and Sand Content

The water content and percentage of sand in total aggregate by absolute volume are determined from the below tables. These tables are based on following conditions.

- Crushed (angular) coarse aggregate, conforming to IS: 383-70
- Fine aggregate consisting of natural sand conforming to grading zone II of table of IS:383-70
- Workability corresponds to compacting factor of 0.80 (Slump 30mm approximately)

Approximate Sand and Water Contents Per Cubic Metre of Concrete W/C = 0.60, Workability = 0.80 C.F. (Slump 30 mm approximately) (Applicable for concrete upto grade M 35)

Maximum Size of Aggregate (mm)	Water Content including Surface Water, Per Cubic Metre of Concrete (kg)	Sand as per cent of Total Aggregate by Absolute volume
10	200	40
20	186	35
40	165	30

Table 7: Approximate sand and Water Contents Per Cubic Metre of Concreate W/C = 0.60, Workability = 0.80 C.f

Water content ratio in case of above table is 0.60(by mass) whereas for any departure in the above mentioned conditions, corrections have to be applied for water content and percentage sand in total aggregate by absolute volume based on below table.

Adjustment of Values in Water Content and Sand Percentage for Other Conditions

Change in Conditions Stipulated for Tables	Adjustment Required in Water Content	Adjustment Required in % Sand in Total Aggregate
For sand conforming to grading Zone I, Zone III or Zone IV of Table 4, IS: 383–1979	0	+ 1.5% for Zone I – 1.5 % for Zone III – 3% for Zone IV
Increase or decrease in the value of compacting factor by 0.1	± 3%	0
Each 0.05 increase or decrease in water-cement ratio	0	± 1%
For rounded aggregate	– 15 kg	– 7%

Table 8: Adjustment of Values in Water Content and sand Percentage for other Conditions

For 20mm aggregate , sand conforming to zone-II, water content per cubic meter of concrete =186kg and sand content as percentage of total aggregate by absolute volume = 35%. By considering the change in value in water-cement ratio, compacting factor

The required sand content as % of total aggregate by absolute volume = 35-2 = 33%

Required water content = 186+5.58 = 191.61 l/m^3

Change in condition	Percent adjustment required	
	Water content	Sand in total aggregate
For decrease in water-cement ratio by (0.6-0.5) that is 0.1	0	-2
For increase in compacting factor (0.9-0.8).that is 0.1	+3	0
Total	+3	-2

Table 9:

6) Determination of cement content

Water cement ratio = 0.5

Water = 191.61 litre

Cement = 191.61/0.5 = 383 kg/m^3

7) Determination of Coarse Aggregate and Fine Aggregate

For the specified maximum size of coarse aggregate of 20mm, the amount of entrapped air is 2 percent. Taking this into account applying the below mentioned equations.

$$V = [W + (C/S_e) + (f_a/P*S_{fa})]/1000$$

$$C_a = (1-P/P)*f_a*(S_{ca}/S_{fa})$$

Where

V = absolute volume of fresh concrete, which is equal to gross volume (m^3) minus the volume of entrapped air,

W = Mass of water (kg) per m^3 of concrete

C = Mass of cement (kg) per m^3 of concrete

S_c = specific gravity of cement

P = ratio of FA to total aggregate by absolute volume

f_a, C_a = Total masses of FA and CA (kg) per m^3 of concrete respectively and

S_{fa} ,S_{ca} = specific gravities of saturated, surface dry fine aggregate and coarse aggregate respectively.

$$0.98 = [191.6 + (383/3.15) + (f_a/0.33*2.60)]/1000$$

f_a = 546 kg/m^3

$$C_a = (1-0.33/0.33)*572.3*(2.7/2.65)$$
$$= 1183.8kg/ m^3$$

The mix proportion now becomes

Water Cement Fine aggregate Coarse aggregate

191.6 kg 383 kg 572.3 kg 1183.8 kg

0.5: 1:1.49: 3.08

IV. Results and Discussion

A. *Composition of Mixes*

1) (a) For Normal mix: 0.5 : 1 : 1.49 : 3.08

a) Materials for cubes and cylinders:

Quantity of cement added = 10.12 kg

Quantity of fine aggregate added = 15.16 kg

Quantity of coarse aggregate added = 31.38 kg

Fraction I (20 mm aggregate) = 0.6 * coarse aggregate = 0.6 * 31.38 = 18.82 kg

Fraction II (10 mm aggregate) = 0.4 * coarse aggregate = 0.4 * 31.38 = 12.550 kg

Water cement ratio = 0.5

Quantity of water added = 5.06 kg (add 5.5 kg of water considering water absorption by fine and coarse aggregate)

Average compressive strength obtained in 7 days = 23.37 N/mm^2

Average compressive strength obtained in 14 days = 28.9 N/mm^2

Average compressive strength obtained in 28 days = 30.75 N/mm^2

Average compressive strength obtained in 28 days = 30.05 N/mm^2

Average split tensile strength obtained in 28 days = 3.2N/mm^2

2) (b) For S_1 mix : 0.5 : 1: 1.49 : 3.08

a) Materials for cubes and cylinders:

In S_1 mix 5% of cement is replaced with the Saw Dust Ash by Volume

Quantity of cement added = 9.62 kg

Quantity of fine aggregate added = 15.16 kg

Quantity of coarse aggregate added = 31.38 kg

Fraction I (20 mm aggregate) = 0.6 * coarse aggregate = 0.6 * 31.38 = 18.82 kg

Fraction II (10 mm aggregate) = 0.4 * coarse aggregate = 0.4 * 31.38 = 12.550 kg

Water cement ratio = 0.5

Quantity of water added = 5.06 kg (add 5.5 kg of water considering water absorption by fine and coarse aggregate)

Quantity of Saw Dust Ash added = 0.5 kg

Average compressive strength obtained in 7 days = 20.39 N/mm^2

Average compressive strength obtained in 14 days = 26.85N/mm^2

Average compressive strength obtained in 28 days = 28.32 N/mm^2

Average split tensile strength obtained in 28 days = 2.81 N/mm^2

3) (c) For S_1 mix : 0.5 : 1 : 1.49 : 3.08

a) Materials for cubes and cylinders:

In S_2 mix 10% of cement is replaced with the Saw Dust Ash by Volume

Quantity of cement added = 9.12 kg

Quantity of fine aggregate added = 15.16 kg

Quantity of coarse aggregate added = 31.38 kg

Fraction I (20 mm aggregate) = 0.6 * coarse aggregate = 0.6 * 31.38 = 18.82 kg

Fraction II (10 mm aggregate) = 0.4 * coarse aggregate = 0.4 * 31.38 = 12.550 kg

Water cement ratio = 0.5

Quantity of water added = 5.06 kg (add 5.5 kg of water considering water absorption by fine and coarse aggregate)

Quantity of Saw Dust Ash added = 1 kg

Average compressive strength obtained in 7 days = 17.8 N/mm^2

Average compressive strength obtained in 14 days = 20.43N/mm^2

Average compressive strength obtained in 28 days = 25.01 N/mm^2

Average split tensile strength obtained in 28 days = 2.3 N/mm^2

B. *Final results*

Target Mean Strength = 26.6 N/mm^2

Mix	Compressive Strength in N/mm^2								
	7days			14 days			28 days		
	I	II	Avg	I	II	Avg	I	II	Avg
Normal	22.4	24.34	23.37	28	29.8	28.9	30	31.5	30.75
S_1 Mix	21.5	19.28	20.39	25.57	28.14	26.85	28.65	28	28.32
S_2 Mix	16.26	19.34	17.8	20	20.87	20.43	25.57	24.5	25.01

Table 10: Compressive Strength in N/mm2

Mix	Split tensile strength in N/mm^2		
	I	II	Avg
Normal	2.6	3.8	3.2
S_1 Mix	2.92	2.7	2.81
S_2 Mix	1.69	2.91	2.3

Table 11:

V. Conclusion

From the above investigations, it is observed that the structural properties like compressive strength, and split tensile strength of concrete with replacement of cement by saw dust ash, which is close to strength of conventional concrete strengths. Test results indicate that the strength results of conventional mix is close to the strength of cement with 10% saw dust ash. It can be concluded that 10% saw dust ash can be replaced in cement which gives results equal to normal concrete. The utilization of by-products in the production of concrete has gained considerable interest among concrete technologists in the recent years. Mineral admixtures like saw dust ash are the most common type of by-product. The cost of conventional materials like cement is increasing gradually, by the economic considerations, saw dust ash which is an industrial waste available at low cost can be used. A proper mix design and use of plasticizers can further improve the acceptable quality of cement concrete for construction. When compared to other waste materials, it is very economical.

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