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Experimental investigation on Strength and Durability Properties of Paper sludge concrete

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Abstract

Cement is inevitable in the construction industry however large scale production of cement is causing environmental problems on one hand and depletion of natural resources on other hand. A lot many alternatives are tried out to replace cement so as to provide an aid to the rising environmental issues caused due to cement production. This paper studies the use of paper pulp as a replacement for cement. The innovative use of waste paper sludge in concrete as a supplementary cementitious material was tested as an alternative to traditional concrete. In this study waste paper sludge was partially replaced as 2.5%, 5%, 7.5% and 10% in place of cement in concrete for M20 mix and tested for its compressive strength, split tensile strength and flexural strength up to 7 days and 28 days of strength and compared with conventional concrete and an attempt has been made to study the strength and durability characteristics of concrete.

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I. INTRODUCTION

Concrete is the most largely consumed construction material worldwide. The production of concrete requires bulk quantities of cement and aggregates. Concrete has better resistance in compression while steel has more resistance in tension. Conventional concrete has limited ductility, low impact, less abrasion resistance and little resistance to cracking. Cracks in concrete are a main issue due to low tensile strength. A huge amount of energy is required for cement manufacturing that causes various environmental impacts at all stages of the production. The release of CO2 in the atmosphere is the main problem in Cement manufacturing. Sand is a major component of concrete. The properties of concrete depend mainly on type of sand used for construction. Manufactured sand (M-Sand) is a substitute of river sand produced from hard granite stone by crushing. The major reason for using M-sand is easy availability and low cost of transportation.

The availability of cement and fine aggregate has become an important problem now a days. Thus now a days lot of alternatives are tested so as to replace cement and fine aggregates in concrete making.India uses about 7.3 million cubic meters of ready-mixed concrete each year .Green house gas like Carbon Dioxide contributes to about 65% of total global warming. Global cement industry emits about 7% of green house gas to the atmosphere. Alternative binders are introduced. In this work the suitability of using waste paper sludge as an alternative to Cement is studied and an attempt has been made to study the strength and durability characteristics of concrete as well as the quality using Ultra sonic Pulse Velocity (UPV) test.Paper sludge mainly consists of cellulose fibre and inorganic

materials. The wetness content normally present in paper sludge may vary from 60-75% .Paper sludge behaves like cement because of silica and magnesium properties which improve the setting of the concrete. Paper mill sludge can be used as an alternative material applied as partial replacement of fine aggregates in manufacturing fresh concrete. About 300 kg of sludge is produced for each tone of recycled paper. Paper sludge is an industrial waste produced in large amount during the paper production. The disposal of those wastes found to be a main issue. The usage of paper sludge as an alternative to cement in concrete is possible. It can reduce the environmental problem as well as make the concrete eco friendly. Papercrete is a construction material which consists of re-pulped paper fibre with Portland cement or clay and/or other soil added. First patented in 1928, it was revived during the 1980s. The material lacks standardization, and proper use therefore requires care and experience. Papercrete gets its name from the fact that most formulas use a mixture of water and cement with cellulose fibres. The fibre is usually acquired from recycled newspaper, lottery tickets and phone books. The mixture has the appearance and texture of oatmeal and is poured into forms and dried in the sun. Dried, ready-to-use papercrete has a rough surface. This increases its surface area and provides a very strong bond from one block to the next. Its plastic nature makes it adaptable to a wide range of shapes or forms; it can be shaped into building blocks or poured into forms. It is used in buildings in the form of papercrete bricks, panels, filling materials in composite walls etc. Domed ceilings/roofs may be commonly constructed with this material.

Papercrete is a tricky term. The name seems to imply a mix of paper and concrete, hence papercrete. But more accurately, only the Portland cement part of concrete is used in the mix-if used at all. Arguably, it could have been called "paperment" papercrete may be mixed in many ways. Different types of papercrete contain 50-80% of waste paper. Up to now, there are no hard and fast rule, but recommended standard will undoubtedly be established in feature. The basic constituents are waste nearly any kind of paper, board, glossy magazine stock, advertising brochure, junk mail or just about any other types of "mixed grade" paper is acceptable.

II. MATERIALS PROPERTIES AND MIX PROPORTIONS

For this study OPC 53 grade cement (Maha gold brand) of specific gravity 3.15 was used. Coarse aggregates of size less than 20 mm of specific gravity 3.128 were used and Locally available M sand of specific gravity 2.82. Paper sludge of specific gravity 2.10 was collected from Hindustan Newsprint Limited, Kotayam. Potable quality water is used for the mix. The pH value shall not be less than 6 .

Based on the properties of aggregates and cement, the mix proportion for M20 concrete is designed as per provisions in IS Code 10262-2009 for 0%,2.5%,5%,7.5% and 10%, replacement of cement with Paper sludge. No admixtures were used in this investigation. Five mixes were done for strength and durability tests. Control concrete (PS(0)) with 0% PS, 100% cement. Mix 1 (PS (2.5)) with 2.5% Paper sludge. Mix 2 (PS(5)) with 5% PS. Mix 3 (PS(7.5)) with 7.5% Paper sludge and Mix 4 (PS(10)) with 10% Paper sludge. The mix proportion is given in Table 1.

Table 1: Mix proportion of M20 concrete

Water	Cement	Fine aggregate	Coarse aggregate
197 L	394 kg	726.544 kg	1314.88 kg
0.5	1	1.84	3.33

III. BEHAVIOUR OF CONCRETE WITH PAPER SLUDGE

The properties of concrete with different percentage combinations of Paper sludge as replacement to cement was studied. Tests were conducted to determine the workability, compressive strength, split tensile strength and flexural strength. The compressive strength test, split tensile strength test and flexural strength test of the specimens were tested on 7 days and 28 days. Workability test is carried as per IS 1199:1959 using a slump cone having 300mm height and base 200mm diameter and top cone diameter is 100mm.Cube specimens (150 mm x 150 mm x 150 mm), cylinder specimens (150 mm diameter and 300 mm height), beam specimens (100 mm x 100 mm x 500 mm) were casted for all the 5 mixes. Durability tests were also conducted which includes acid attack test. These tests were performed on cube specimens. First concrete cubes were cast and cured in mould for 24 hrs for all mixes. Cubes were demoulded and cured for 7 days in water and kept in atmosphere for 2 days and is weighed. Later cubes are kept in 5% Sulphuric acid solution (for acid attack test) separately for 60 days. The percentage weight loss is determined after exposing it to atmosphere for 2 days.

IV. RESULTS AND DISCUSSION

4.1 Workability of concrete

Test results are shown in Table 2. From the test results, The slump decreased as the paper pulp content in the concrete mixtures was increased. When slump is between 50-100 mm it is medium workable. The workability is higher for 2.5% replacement. The nature of collapse obtained was true slump and mix have medium workability in all cases. Hence the concrete is workable and used for construction process. First 3 mixes have almost same slump value. So workability is almost same.

Table 2: Slump values

Sl No	Concrete Mix	Slump (mm)
1	PS(0)	90
2	PS(2.5)	87
3	PS(5)	83
4	PS(7.5)	69
5	PS(10)	58

4.2 Compressive strength

The test results of the compressive strength test are shown in Table 3. From compressive strength test results an increment of strength is observed for concrete with PS than conventional concrete. Test results shows that Compressive strength of concrete with 5% of paper sludge gives 15.33% strength more than conventional concrete on 7 day and 13.80% on 28 day. The strength gets reduced on further increment of PS in mix. The possible reason for the reduction in strength is weak interface of PS with coarse aggregate, create micro crack.

Table 3: Compressive strength values

Sl No	Concrete Mix	Compressive strength (N/mm²)	
		7 days	28 days
1	PS(0)	21.33	29.7
2	PS(2.5)	24.44	32.77
3	PS(5)	24.6	33.8
4	PS(7.5)	22.6	29.33
5	PS(10)	20.88	29.11

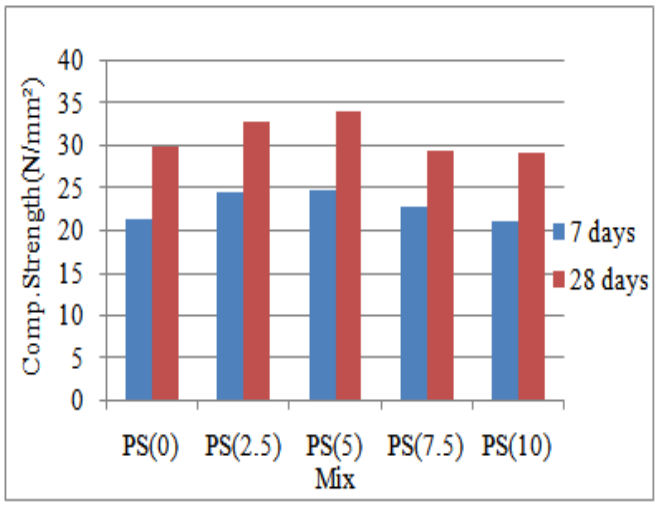

Fig 1.Compressive Strength vs Mix

4.3 Split tensile strength

From the test results shown in Table 4, Optimum percentage of replacement obtained as 5%.13.5% increase in strength for 5% replacement compared to conventional concrete. Further increment in percentage addition of PS results in reduction of strength.

Table 4: Split tensile strength values

Sl No	Concrete Mix	Split tensile strength (N/mm²)
		28 days
1	PS(0)	3.11
2	PS(2.5)	3.46
3	PS(5)	3.53
4	PS(7.5)	3.12
5	PS(10)	2.96

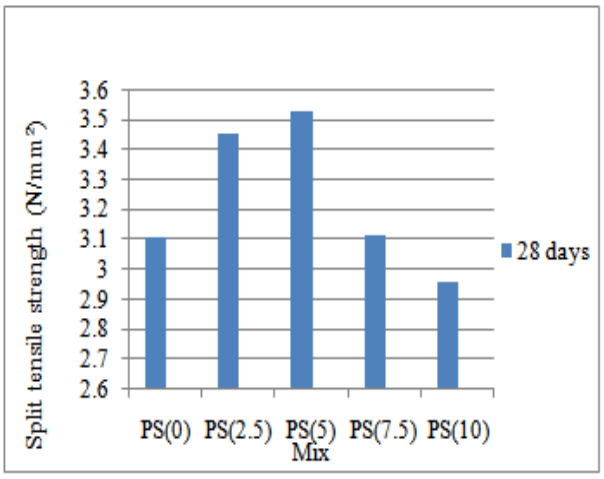

Fig 2. Tensile strength vs Mix

4.4 Flexural strength

From the test results shown in Table 5, an increase in flexural strength was observed with PS addition. The optimum percentage of replacement observed as 5%.3.7% increase in strength for 5% replacement compared to conventional concrete. Further increment in percentage addition of PS results in reduction of strength. The flexural strength of various mixes for 28 days is shown in Fig 3.Test results are shown in Table 5.

Table 5: Flexural strength values

Sl No	Concrete Mix	Flexural strength (N/mm^2) 28^{th} day
1	PS (0)	5.3
2	PS (2.5)	5.325
3	PS (5)	5.5
4	PS (7.5)	5.25
5	PS (10)	4.95

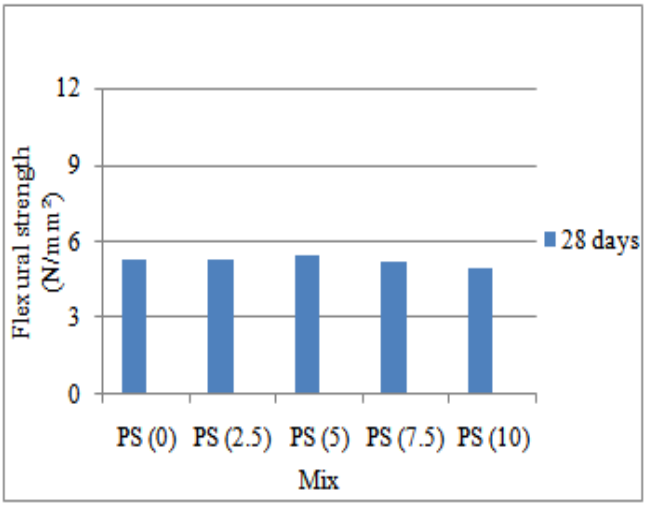

Fig 3.Flexural strength vs Mix

4.5 Durability test

The durability of the specimen is measured by percentage weight loss in cubes after immersing in acidic solutions.

Acid attack test:

Table 6: Percentage weight loss in acid attack test

Concrete mix	Weight before placing in Acidic Solution (kg)	Weight after placing in Acidic Solution (kg)	% weight loss
PS(0)	8223	8585	362
PS(2.5)	7904	8158	254
PS(5)	7748	7986	238
PS(7.5)	7627	7872	245
PS(10)	7549	7800	251

Fig 4. cubes after immersion

The test results show that 5% PS in the mix makes the concrete more durable since the weight loss is found to be least for such mixes. The specimen with 2.5% and 10% PS shows higher weight loss makes the concrete less durable. In acid attack test the specimen with PS 5% shows 34.2% lesser weight loss when compared with the conventional concrete.

V. CONCLUSIONS

From the results obtained, partial replacement of cement by paper sludge increases the strength properties. Therefore the utilization of waste material like paper sludge is possible.

- Compressive strength of concrete with 5% of paper sludge gives 15.33% strength more than conventional concrete on 7 days and 13.80% on 28 days.
- 13.5% increase in split tensile strength for 5% replacement compared to conventional concrete and 3.7% increase in flexural strength for 5% replacement compared to conventional concrete.
- The slump decreased as the paper pulp content in the concrete mixtures was increased.
- Generally, compressive, split tensile and flexural strength increased up to 5% replacement of waste paper pulp and further increase in percentage replacement reduces the strength gradually.
- Optimum percentage of replacement obtained as 5%.
- The specimen with PS 5% shows 34.2% lesser weight loss when compared with the conventional concrete.
- Lesser weight loss of concrete is found at 5% of cement replacement with paper sludge. So it can be considered as optimum percentage of durability.
- From the UPV test results it is found that the quality of the cube slightly decreases with increase in percentage of paper sludge. However the quality range lies within good or excellent.
- UPV test shows that concrete with paper sludge have good quality. Use of waste paper pulp in concrete gives a green concrete construction.

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