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Fractional Substitute of Cement by Waste Lime Sludge (Hypo-Sludge)

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Abstract: *In recent years, there has been a considerable interest in resolving one of the important environmental problems like the solid waste management. Out of the variety of common solid waste, the waste lime sludge from paper industries, abundantly found in the landfill as well as in river disposal, has been found as a non-biodegradable type. However, it is known that the waste lime sludge material shows the hysteresis behaviour under cyclic loading and offers a possibility for its re-usage as a filler material whenever high damping is required. An effort has been made to study experimentally the feasibility of using the waste lime sludge as a replacement of cement in cement concrete.The present investigation has been started with M-25 grade vibrated concrete as control mix or reference mix. A test program has been carried out to identify the necessary information about the mechanical and chemical properties of waste lime sludge concretes. Waste lime sludge has been used as fine binding material in the production of cement concrete mixtures by partially replacing the cement with lime sludge. In order to keep the verity, five designated sludge contents varying from 2%, 4%, 6%, 8% and 10% by total cement volume have been used in the present investigation. Initially concrete was prepared without sludge.*

Keywords: *M25Grade, sludge, split tensile, rebound hammer, limes sludge, ultrasonic test.*

1. Introduction

A very serious problem now a day is to dislocate the wastes coming out from industries, not only this, the problem is increasing day by day. Sludge from paper mills is produced in large quantities in most industrial nations of the world today due to the large usage of paper, and electrical energy requirements constitute one of our most serious environmental problems. The worst thing about paper sludge is that it can never be use as other industrial work because of its non-utility, the paper mill sludge is merely discarded, along with other waste cellulosic fibre, creating a tremendous disposal problem. The characteristics of bio-solids are variable and directly related to the technology used to pulp, the wood and manufacture the paper and to the type of effluent treatment that is employed. Solid wastes generated from industrial sources are heterogeneous in composition, ranging from inert inorganic (such as produced in mining and collieries) to organic (in industries producing basic consumer products) and may include even hazardous constituents (as in pesticide industry). It was predicted that a global shift in paper and paperboard production would result in the Asia-Pacific region emerging as a major producer of paper mill sludge. Global production of paper mill sludge was predicted to rise over the next 50 years by between 48 and 86% over current levels. The nature of waste generated from parental industries is mainly depends on the raw materials used in different unit processes. These wastes generated from the industrial sources contain a large number of ingredients, some of which are toxic.

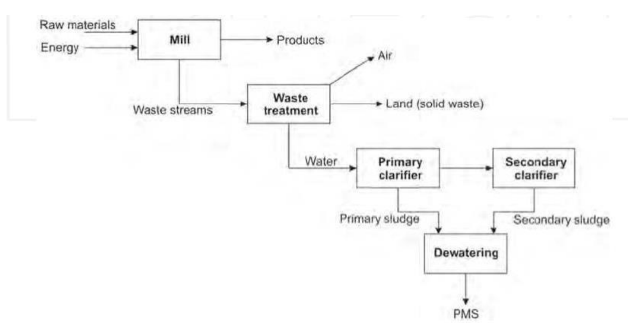

Fig.1

2. Methodology

2.1 Introduction

General
The present chapter deals with the presentation of results obtained from various tests conducted on material used for the concrete. In order to achieve the objectives of present study, an experimental programme was planned to investigate the effect of lime sludge on compressive strength and split tensile strength of concrete.

2.2 Materials

The properties of material used for making concrete mix are determined in laboratory as per relevant codes of practice. Different materials used in present study were cement, coarse aggregates, fine aggregates, and lime sludge from Paper Mill. The aim of studying of various properties of material is used to check the appearance with codal requirements and to enable an engineer to design a concrete mix for a particular strength. The description of various materials which were used in this study is given below:

2.3 Ordinary Portland cement

This type of cement is made by intergrinding not less than 35 percent of ordinary Portland cement clinker and granulated blast-furnace slag. The slag can also be used together with limestone as a raw material for the conventional manufacture of Portland cement resulting in clinker which when ground gives Portland slag cement. This cement is less reactive than OPC and gains strength a little more slowly during the first 28 days. It has the advantages in generating heat less quickly than OPC. It is suitable for mass concreting but unsuitable in cold weather. Because of its fairly high sulphate resistance it is used in sea-water construction [Ghambhir, Concrete technology (2ndedition)].The cement used for the investigation was Portland slag cement (33-grade). It conformed to the requirements of Indian standard specification IS: 455(1989)[22e].

2.4. Tests on Cement

(a)Normal Consistency (IS:4031-PART4-1988)[22f]
Standard consistency of a cement paste is defined as that consistency which will permit a vicat plunger having 10 mm diameter and 50 mm length to penetrate to a depth of 33-35 mm from top of the mould.

Procedure
Take 300 g of cement and place it in the enamelled tray.
Mix about 25% water by weight of dry cement thoroughly to get a cement paste. Total time taken to obtain thoroughly mixed water cement paste i.e. “Gauging time” should not be more than 3 to 5 minutes.
Fill the vicatmould, resting upon a glass plate, with this cement paste.
After filling the mould completely, smoothen the surface of the paste, makingit level with top of the mould.
Place the whole assembly (i.e. mould + cement paste + glass plate) under therod bearing plunger.
Lower the plunger gently so as to touch the surface of the test block andquickly release the plunger allowing it to sink into the paste.
Measure the depth of penetration and record it.
Prepare trial pastes with varying percentages of water content and follow the steps (2 to 7) as described above, until the depth of penetration becomes 33 to 35 mm.

2.5 Calculation

Calculate percentage of water (P) by weight of dry cement required to prepare cementpaste of standard consistency by following formula, and express it to the first place of decimal.

$$P = \ \times 100$$

Where,

P= Normal Consistency =35%

Table-1. The tests on cement were carried out as per IS: 4031(1988)[22f]

S. No.	Characteristics	Values obtained Experimentally	Value SpecifiedBy IS:8112-1989
1.	Specific Gravity	3.15	_
2.	Standard Consistency, percent	35	_
3.	Initial Setting Time, minutes	52	30 Min. (Minimum)
4.	Final Setting Time, minutes	550	600 Min. (Maximum)
5	Compressive strength		
	3 days	24.8 n/mm2	23 (Minimum)
	7 days	37.5 n/mm2	33 (Minimum)
	28 days	47.6 n/mm2	43 (Minimum)

3. Experimental Analysis

3.1 Cement Fineness Test:-

The present chapter focuses to study the effect of partial replacement of cement by waste lime sludge on the fresh concrete property (e.g. slump test) and hardened concrete properties e.g. compressive strength, split tensile strength, modulus of elasticity, flexural strength, ultrasonic pulse velocity and NDT test (rebound hammer and static ultrasonic pulse velocity). Experimental investigation was carried out infive stages as shown in Figure-4.1.1.

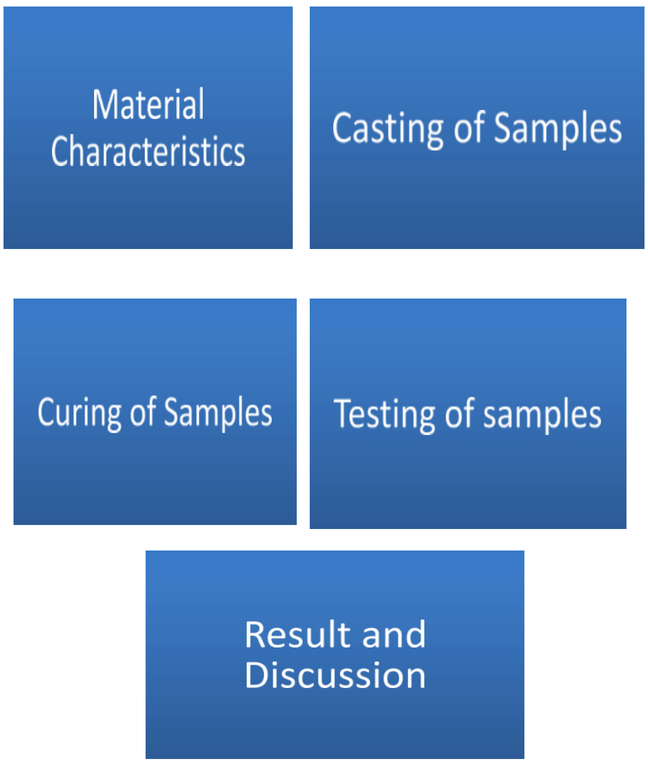

Fig. 2: Flow chart of Experimental Program

Material Testing
The material properties for all ingredient of concrete are given in below:

Mixing and Casting of samples

Mix proportion
There were six types of mix considered; of which One control mixture MC-00 (Without lime sludge) was designed as per Indian Standard Specification IS: 10262(1982) (1:1.34:2.85, W/C ratio = 0.43) to achieve target mean strength 31.6MPa. The other five concrete mixes were made by replacing the cement with 2%,4%, 6%, 8% and 10% of discarded lime sludge by volume; the details mixture proportions are given in Table 1.

Mix Identity Mix Proportions

MC-00 M25 concrete with 100% cement
MCR-3 M25 concrete with 98% cement + 2% lime sludge
MCR-6 M25 concrete with 96% cement + 4% lime sludge
MCR-9 M25 concrete with 94% cement + 6% lime sludge
MCR-12.

The summary of all literature reviews was that growth in strength can be seen at the earlier stages like10%, 15% or20%, but at no study any one mentioned that what about the earlier stages (below 10 %).This was the main concern of my study, On the basis of what designing has been done.

Procedure

- The control mix was M20 designed as per the design mix in the IS: 10262(1982).
- For all other mixes the proportions of sand aggregate and water remained constant with various proportions of cement was replaced by waste lime sludge
- All replacement was carried out by volume.
- Normal tap water was used for casting and curing.
- Workability of fresh concrete was measured by slump test immediately after mixing.
- The test specimen was cast in steel moulds and dimension of specimen is as per the standard specimen. All specimens are compacted by using needle vibrator.
- All specimens were removed from moulds after 24 hours.
- All measurement was made by weight and mechanical mixing of the concrete is done.
- The testing of specimens was carried after specimens were surface dry.
- Tests carried out for compressive strength, flexural strength, Split tensile strength, modulus of elasticity, soundness of concrete with help of ultrasonic pulse velocity, workability.
- For each test three specimens was used.
- The complete mixing procedure is shown in Figure-3.

- •Designing of concrete
- •Mixture
- •Preparing Materials
- •& Mixing Process
- •Slump Test
- •Casting of samples
- •testing of samples
- •results

Fig. 3: Flow chart of concrete mixing process

1. Test Sample Details

The information about the tests, size of specimens, and number of specimens used in this investigation is shown in Table-8. The picture of casting of specimens is shown in Figures-3, and 4.

2) Table 4.2: Test Samples Details.

Tests	Sample size	No.
7 days Compressive strength	150 × 150 × 150 mm (Cube)	3
28 days Compressive streng.	150 × 150 × 150 mm (Cube)	3
28 days Compressive strength	300 × 150 mm (Cylinder)	3
28 days Split tensile strength	300 × 150 mm (Cylinder)	3
N.D.T (Rebound hammer)	150 × 150 × 150 mm(Cube)	3
Dynamic U.P.V	150 × 150 × 150 mm (Cube)	2

Curing

It is must that one should perform curing action before testing of material specimen. After casting the cubes and the cylinders, Casted specimen was kept in the tub with full of water weather some for 7 days & other are for 28 days.

This time period is the one where the concrete gains its overall strength. To gain 70% of its strength it takes 7 days where in 28 days it reaches at its design strength.

The specimen was cured till the day of testing in water under normal temperature and humidity.

Experimental Tests

Experimental tests procedure and tests conducted on fresh and hardened concrete isshown in Figure-4.4.1.

M25 grade concrete

3) Tests

Fresh concrete **Hardened concrete**

4) Slump cone test

Destructive testing **Non- Destructive testing**

- **Compressive strength test** **Rebound hammer test**
- **Split tensile strength test** **Ultrasonic pulse velocity test**

Fig. 4: Flow chart of Experimental test procedure

Experimental Setup

(a) Compressive strength test on cubes and cylinder were carried out using the universal testing machine. Compressive test was carried out on cubes of dimensions 150×150×150 mm after 7 days and 28 days and on Cylinder of dimensions 300 mm length and 150 mm diameter after 28 days only. For each test and for each mix three specimens were tested. The compressive strength was computed using the expression Fc = P/A for cubes and Fc = P/πr2 where Fc is the compressive stress in MPa, P is the maximum applied load in Newton and r is the radius of the cylinder in mm. The compressive strength test setup for cubes and cylinders is shown in Figures: 5, and 6.

(b) Split Tensile Strength test was used to determine the tensile strength of concrete. The test was performed on cylinder with the same dimension as given above after 28 days on the UTM. The split tensile strength was computed using the expression Fct =2P/πld, where Fct is the split tensile strength in MPa, P is the maximum compressive load on the cylinder (in Newton), l is the length of the cylinder (in mm), and d is the diameter of the cylinder (in mm). The split tensile strength test setup is shown in Figure-5

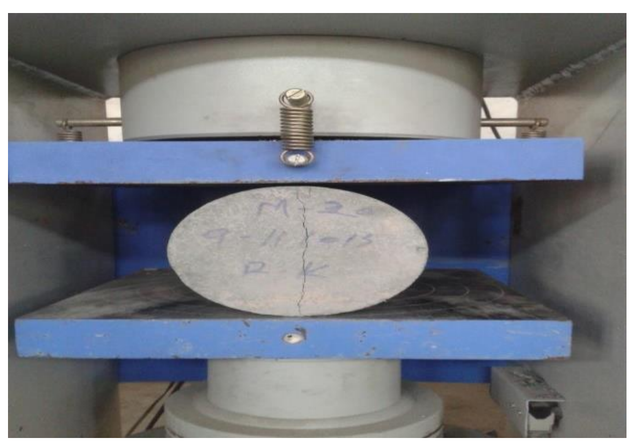

Fig. 5: Test set up for Split Tensile Test

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(c) In addition to the above tests, Non-destructive tests like Ultrasonic Pulse Velocity were also carried out. This test is carried out for static samples of cubes, and dynamically for cubes (while applying load across two faces and taking readings across the other face). Care was taken during the test for no gap between the two faces. The ultrasonic pulses were calculated and graphs were plotted for ultrasonic pulse velocity versus compressive stress. And also carried out Rebound Hammer Test. This test was carried out for Cubes. The experimental test setup for non-destructive testing is shown in Figures: 7 & 8. The velocity criterion for concrete quality grading according to Indian Standard IS: 13311(Part-1)[22i]-1992 is shown in Table-2.

Fig. 6 Static UPV Test on Cubes

(A) Determination of Specific Gravity & Water Absorption

Source of material:
Crusher Plant Size of aggregate:
20mm

Table 3

Longitudinal Pulse Velocity (m/sec)	Quality of concrete
> 4500	Excellent
3500 – 4500	Good
3000 – 3500	Doubtful
2000 – 3000	Poor
<2000	Very Poor

Fig. 7 Static UPV Test on Stone

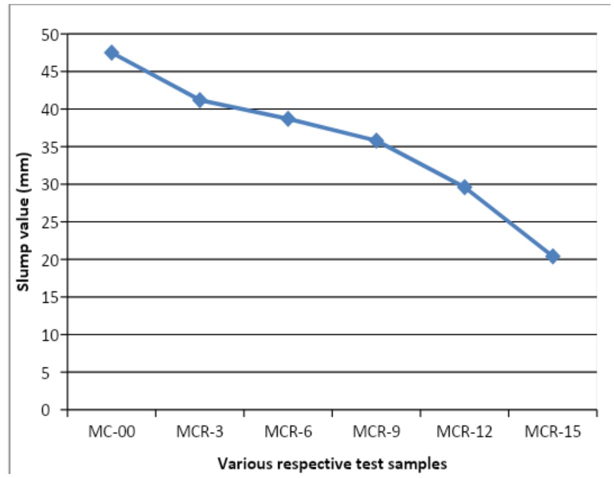

Fig. 8: Effect of lime sludge addition(replacement) ratio on slump of concrete

Hardened Concrete Properties

Compressive Test

The compressive tests were carried out after 7 days and 28 days for cube and after 28 days for cylinders. Compression test specimens, 150 mm cubes and 150/300 mm cylinders were casted according to IS: 516(1959)[22j]. These specimens were cast in steel forms and wet cured. Compression test according to IS: 516(1959)[22j] was carried out on cubes and cylinder. The specimens were loaded at a constant strain rateuntil failure. The compressive strength is increase up 4% of replacement than decreased with an increase in the percentage of the waste lime sludge. The results of compressive strength of cubes for 7 days and 28 days and cylinder for 28 days are given in Figures: 5.2.1, and 5.2.2. It can be seen from Figure-5.2.2 that the compressive strength of cubes at 28 days curing for control mixture (MC-00) achieved 47.50MPa. Mixes MCR-6, and MCR-9, showed increment in strength of MCR-12, and MCR-15 showed reduction of 29.6and 20.4 Mpa respectively, in comparison with the control mix (MC-00), but mix MCR-3 gives better result than thecontrol mix.
The ratio of cylinder compressive strength and cube compressive strength for normal concrete (MC-00) is 0.73, which is close to the commonly accepted cylinder/cube compressive strength ratio for normal concrete. For lime sludge concrete at sludge content of 2%, 4%, 6%, 8%, and 10%, the ratio became 0.723, 0.73, 0.727, 0.726, and 0.735respectively. The results indicate that lime sludge concrete has a sufficientstrength up to replacement of 4% than after 4% cylinder/cube strength ratio reduced than that of normal concrete.

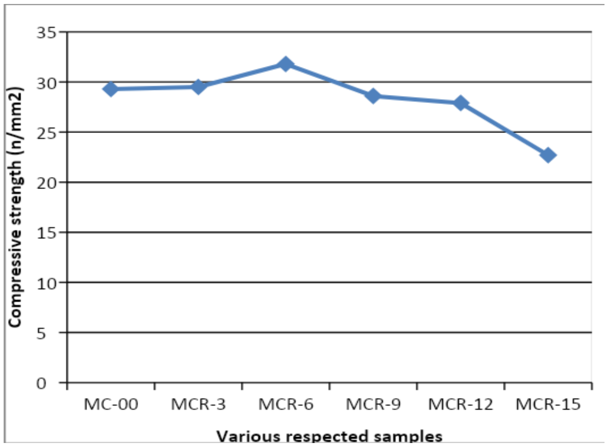

Fig.9 Compressive strength of Cube in 7 days

Closing Remarks

The following observations were made based on the present study for the replacementof Waste lime sludge in place of cement in cement concrete.

- Slump value is decreases as the percentage of replacement of lime sludge increased.
- The compressive strength is increased up to 4% than decreased as the percentage of replacement increased, but lime sludge (MCR-3) concrete developed slightly higher compressive strength than those of lime sludge(MC-00) concrete.
- The split tensile strength is increased up to 4% and decreased after 4% replacement.

4. Discussion

The reasons for reduction in the strength of concrete when lime sludge was used. These factors include:

- Due to a lack of proper bonding between lime sludge particles and the cement paste as compared to cement paste and aggregates.
- Due to replacement of the cement by lime sludge, the volumes was reduces. On the other hand, compressive strength of concrete depends on physical and mechanical properties of the materials.
- During casting and vibrating of test specimens, the lime sludge particles tend to move toward the top surface of the mould. The high concentration of sludge at the top layers the specimens. This is because of the lower specific gravity of the lime sludge particles.
- Due to non-uniform distribution of lime sludge in the concrete produce non-homogeneous samples and results in reduction in concrete strength.
- The stiffness of sludge is lower as compared to stiffness of cement, the presence of lime sludge particles in concrete is reduce concrete mass stiffness and decreases load-bearing capacity of concrete.

5. Conclusions

- The workability generally with the increase in lime sludge content.
- The compressive strength, split tensile strength, modulus of elasticity, and flexural strength of the lime sludge concrete increases with 4% Replacement than decreased with the increasing amount of lime sludge content.
- Compressive strength of concrete depended on two factors: grain size of the replacing cement and percentage added. In general, compressive strength was reduced after 4% with increased percentage of lime sludge replacement in concrete.
- Tensile strength of concrete was also reduced with increased percentage of lime sludge (after 4%) replacement in concrete. The most important reason being lack of proper bonding between sludge and the paste matrix, as bonding plays the key role in reducing tensile strength.
- In the lime sludge concrete the loss of strength was found after replacement of 8% and 10% replacement of cement by lime sludge.

Future Scope

Determine the effect of lime sludge on concrete with the replacement ofcombination of cement and fine aggregate. Replacement of cement with the waste lime sludge having center anchorage hole must be studied in various percentages. Replacement of fine aggregate with lime sludge in different water-cementratio. Though the study stopped with the 10% lime sludge replacing cement, higher replacement percentage may be carried out. In the present study the ordinary Portland cement was used. Further its mechanical properties can be compared by using other cement. Replacement of cement with the treated waste lime sludge must be studied. The durability experiments may be performed on lime sludge concrete.

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