Mechanical Characterstics of Hardened Concrete with the Usage of C.E.T.P. Sludge as Replacement of Cement

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***Abstract*—In the present age, the waste generated from the industries is the major concern for the environment, health and cause of land filling. To reduce disposal and pollution problems emanating from these industrial waste, it is essential to develop profitable building material from them. Recycling of such wastes and using them in construction materials appears to be viable solution not only to the pollution problem but also an economical option in construction. In view of utilisation of such waste in construction materials, this paper reports on the mechanical properties of utilisation of waste sludge obtained from Common Effluent Treatment Plant(C.E.T.P) in concrete. To evaluate the effect of dry sludge on concrete performance, its physical and mechanical properties were studied. In this research an attempt is taken to bring a comparison of the sludge waste in various proportions so that the final product property of concrete mixture is same as the reference (with 0% sludge) mix. Waste sludge material was replaced with cement in various percentages as 2%, 5%,10%. Reference concrete mix is also made for comparative reasons. To characterise the mechanical behaviour of the concrete, compressive strength test was conducted by means of Universal Testing Machine (destructive) after interval of 28 days, 90 days, 180 days respectively. Water absorption test was also conducted at interval of 28, 90 , 180 days so as to get an idea of change in the water percolation property of concrete. Tests results indicated the positive relationship between 2% 5% replacement of C.E.T.P. sludge with compressive strengths. The same results obtained for 10% replacement for Water absorption ratios likely to be unfavourable.**

***Index Terms*—C.E.T.P. sludge, mechanical properties, industrial waste**

I. Introduction

[1] India is one of the major developing countries in the world. The country has the 7th largest landmass and a population of about 1.3 billion people. With a Gross Domestic Product (GDP) of almost 2.26 lakh crores USD (2016), India is attempting to continue its growth while meeting the demands of its population (World Bank, 2016).

[2] India is the second largest producer of cement in the world. No wonder, India's cement industry is a vital part of its economy, providing employment to more than a million people, directly or indirectly. Ever since it was deregulated in 1982, the Indian cement industry has attracted huge investments, both from Indian as well as foreign investors. (I.B.E.F Report, 2017)

[3] India has a lot of potential for development in the infrastructure and construction sector and the cement sector is expected to largely benefit from it. Some of the recent major initiatives such as development of 98 smart cities are expected to provide a major boost to the sector.(GOI, Ministry of Housing & Urban affairs, 2015 Report)

[4] Releasing sludge into the rivers can cause silting, which kills river life and negatively affects the environment .The application of sludge in the soil on farming plantations has received a negative response due to the metals present in the sludge, but research is still underway to find a beneficial way to place the sludge within soil. Currently sludge placed in the soil has negative impacts on the surrounding environment facilitating the emergence and increasing the soil surface sealing process and crust thickness, with consequent negative influence on seed germination and surface cracks.(Water Quality Assessments , A guide to Use of Biots, Sediments and water in Environmental monitoring-Second Edition , W.H.O. 1996)

[5] Another option is to burn the sludge, but this does not solve the environmental problem, due to emission of greenhouse gases and the final destination of the sludge embers. The sanitary landfill has been the primary disposal for the toxic sludge. Disposing the sludge in sanitary landfills has a high cost due to the transportation of the residue and the necessary fees to release the sludge into the landfill. Sludge placed in concrete has no environmental disadvantages, while sludge placed in landfills creates toxic areas of biohazard that effect the surrounding environment and the ozone.
.(Water Quality Assessments , A guide to Use of Biots, Sediments and water in Environmental monitoring-Second Edition , W.H.O. 1996)

The technological development led to industrialization which is always a concern for environmental degradation.

Manuscript received May 1, 2019; revised August 11, 2019.

doi: 10.18178/ijscer.8.4.357-363

With help of pollution control technologies, the industries are able to combat air and water pollution. [6] However, the treatment of industrial effluents is still a major concern

[7] Considering the environmental concern, the use of industrial solid wastes, especially, use of CETP sludge as a partial supplement to building materials plays an important role and it is gaining a great momentum. The exhaustive review on the utilization of hazardous wastes and by-products as a supplementary green concrete material concluded that the partial substitution of solid hazardous wastes in the place of conventional construction materials such as gravel, sand, blue metal, etc do not strongly affect the strength of concrete and other properties (Smita Badur et al., 2008, Rubina Chaudhary et al., 2008).

[8] From previous studies, its been examined the potential use of textile ETP sludge in building materials and concluded that the substitution of textile ETP sludge for cement upto a maximum of 30 percent, may be possible in the manufacture of non-structural building materials.(Anupam Singhal et al., 2008)

[9]The substituted cement with lime treated spent pickling liquor sludge (7.5 percent by weight) and fly ash (15 percent by weight) in M 20 concrete and found that the concrete thus prepared gave optimum compressive strength and effected complete removal of toxicity. (Tewari, V. K. et al., 2008 and SatyaPrakash et al., 2008)

[10] Manufacturing bricks from dried sludge collected from an industrial wastewater treatment plant. The study concluded that the condition for manufacturing good quality bricks is 10 weight percent sludge with 24 percent moisture content prepared in the molded mixtures and fixed at 880-960 0C. (Chin- Haung Weng et al., 2008)

[11] Besides ETP sludge, utilization of copper slag (Pereira Gonclaves et al., 2007), ground granulated blast furnace slag (Swaroopa Rani et al., 2009) and municipal solid waste incineration ash (Pai-Haung Shih et al., 2003) as a partial replacement of cement in concrete is already reported in the literature.

TABLE I. YEARLY PRODUCTION OF CEMENT IN DIFFERENT COUNTRIES (IN MILLION METRIC TONNES)

Countries (→) Year (↓)	China	India	U.S.A	Japan	Saudi Arabia
2017	2400	280	86.3	53	63
2016	2410	290	85.9	56	61
2015	2350	270	83.4	55	55
2014	2480	260	83.2	53.8	55
2013	2420	280	77.4	57.4	57
2012	2210	270	74.9	51.3	50

II. MATERIALS USED

A. Cement

Portland pozzolanic cement PPC class-F(70% O.P.C. + 30 % FA, Ambuja Cement) was used in mix(Table 2). The properties of cement are

TABLE II. PHYSICAL PROPERTIES OF CEMENT

SI. No.	Properties	Results
1.	Specific gravity	3.11
2.	Initial setting time	46 minutes
3.	Fineness	2.14%

B. Fine Aggregates

Locally available river sand, passing through 4.75mm sieve and retained on 150 micron and free from impurities is used in concrete mixes(table no 3 , 4).

TABLE III. SIEVE ANALYSIS RESULT OF FINE AGGREGATES

SI No.	IS Sieve Size	% cumulative passing
1.	10 mm	100
2.	4.75 mm	97
3.	2.36 mm	92.4
4.	1.18 mm	69.2
5.	600 micron	39.8
6.	300 micron	3.4
7.	150 micron	0.02
8.	Pan	00

TABLE IV. PHYSICAL PROPERTY OF FINE AGGREGATE

Specific Gravity	2.67
Fineness modulus	2.62

C. Coarse Aggregate

Crushed stone of 20mm down size and 10mm were used in this present work (70:30). The sieve analysis result and physical properties of coarse aggregate of 20mm down and 10mm size are shown in following tables.(table no . 5,6)

TABLE V. SIEVE ANALYSIS RESULT OF COARSE AGGREGATES TABLE

SI No.	IS Sieve Size	% cumulative passing
1.	40mm	100
2.	20mm	97
3.	12.5 mm	92.4
4.	10 mm	69.2
5.	4.75mm	39.8
6.	Pan	3.4

TABLE VI. PHYSICAL PROPERTY OF COARSE AGGREGATES

Specific Gravtiy	2.61

D. *C.E.T.P Sludge*

Common Effluent Treatment Plant (C.E.T.P) sludge was collected in solid form. It was kept for a week to get dried. Water Absorption value was calculated in raw sludge. It was make fine to pass through 120 micron sieve so as to get fineness as that of cement by means of mechanical grinding. Particle size distribution for raw sludge was also performed to get the physical state of sludge (Table VII, VIII, IX).

TABLE VII. PROPERTIES OF SLUDGE

SI No.	Properties	Results
1.	Specific gravity	1.91
2.	pH	8.69
3.	Solubility	Insoluble
4.	Odour	Pungent smell
5.	Water content(raw sample)	36%

TABLE VIII. SIEVE ANALYSIS RESULT OF COARSE SLUDGE (2000 GMS)

SI No.	IS Sieve Size	Weight retained (gm)	% Retained	Cumulative Retained %	% cumulative passing
1.	80 mm	0	0	0	100
2.	40 mm	0	0	0	100
3.	20 mm	95	4.75	4.75	95.25
4.	10 mm	42	2.1	6.85	93.15
5.	4.75mm	162	8.1	14.95	85.05
6.	Pan	1700	85	100	0

TABLE IX. SIEVE ANALYSIS RESULT OF FINE SLUDGE (500 GMS)

SI No.	IS Sieve Size	Weight retained (gm)	% Retained	Cumulative Retained %	% cumulative passing
1.	4.75 mm	0.8	0.16	0.16	99.84
2	2.36 mm	110.4	22.08	22.24	77.76
3.	1.00 mm	297.4	59.48	81.72	18.28
4.	600 micron	82.2	16.44	98.16	1.84
5.	300 micron	9.1	1.84	100.00	0.00
6.	90 micron	0	0.0	100.00	0.00
7.	Pan	0	0.0	100.00	0.00

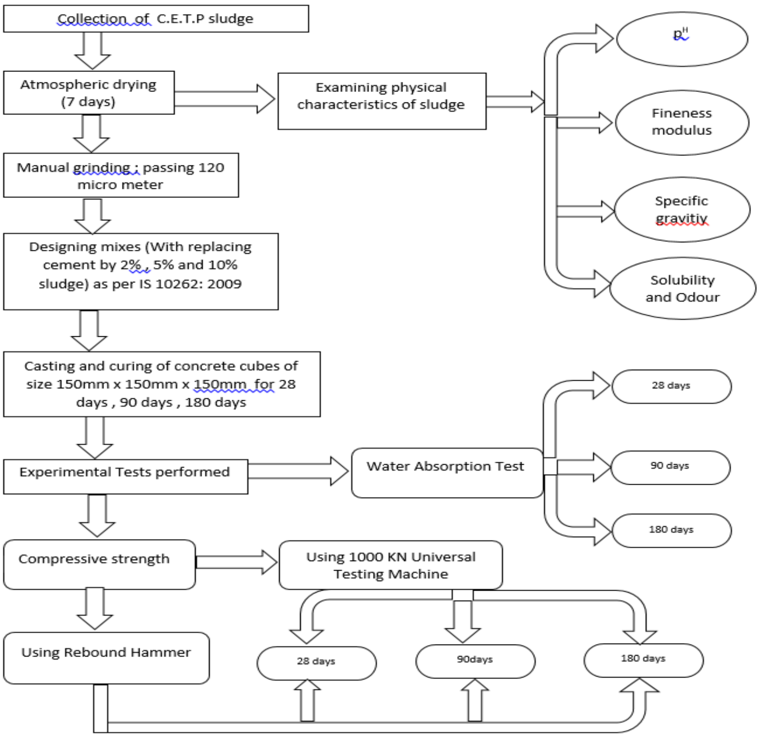
E. *Mixes for Casting of Concrete*

Cement used in concrete is PPC–class F with 30% fly ash. M30 design for concrete is been done as per IS 10262:2009. Cubes of 150mm * 150mm * 150mm with different proportions of 2%, 50%, 10% sludge was casted by replacement of cement by weight. The water cement ratio was kept 0.50.(refer Table X) The slump value obtained at this water content was in the range 90mm-110mm , where our target was 100mm.

TABLE X. VARIOUS MIX DESIGNS AS PER IS 10262:2009 FOR M30 GRADE

Mix	Cementitious material (kg/m3)		Water (kg/m3)	Fine aggregate (kg/m3)	Coarse aggregate (kg/m3)
	Cement	Sludge			
S 0 C 100	394.00	0.00	97.00	732	1139
S 2 C 98	386.12	7.88	193.06	732	1139
S 5 C 95	374.43	19.70	187.15	732	1139
S 10 C 90	354.60	39.40	177.30	732	1139

III. RESEARCH METHODOLOGY



IV. RESULTS AND DISCUSSIONS

A. Workability

For proper placement of concrete the concrete paste should be workable enough. With proper water binder ration the workability of the paste can be maintained within the range as given in IS 456 – 2000.

TABLE XI. SLUMP VALUES FOR VARIOUS MIXES

MIX	SLUMP VALUE(mm)
S 0 C 100	125
S 2 C 98	130
S 5 C 95	153
S 10 C 90	161

Table (11) indicates the slump value in mm of the various concrete mixes used in study for water cement ratio of 0.5. It can be noted from the table the value for the mix without any sludge content is lower to that of all other mixes. As sludge is coarser in comparison to cement, the surface area will be more in cement so the water , the water consumed by mixes with cement will be more. The mix with 10 % sludge content have maximum slump value. The more the cement replaced, more is the slump value.

B. Compressive Strength Using Universal Testing Machine

Compressive strength was measured as per I.S. 516 – 1959 using 1000 KN capacity universal testing machine with 150mm x 150mm x 150 mm standard concrete cubes on period of 28 , 90 , 180 days. The load was applied as rate of 125 KN/min. The average of the 3 specimens are tabulated and respective figures are listed –

TABLE XII. COMPRESSIVE STRENGTH ON UTM (28 DAYS)

SAMPLE	COMPRESSIVE STRENGTH (KN/mm2)	MEAN COMPRESSIVE STRENGTH (KN/mm2)
S 0 C 100	27.656 26.954	27.305
S 2 C 98	25.450 25.139	25.294
S 5 C 95	22.451 21.414	21.904
S 10 C 90	18.165 19.444	18.804

Figure 1. Compressive strength at 28 days.

TABLE XIII. (A) COMPRESSIVE STRENGTH ON UTM (90 DAYS)

SAMPLE	COMPRESSIVE STRENGTH (KN/mm^2)	MEAN COMPRESSIVE STRENGTH (KN/mm^2)
S 0 C 100	37.589 24.460 27.360	29.80
S 2 C 98	24.000 30.489 28.311	27.60
S 5 C 95	24.091 25.484 25.067	24.88
S 10 C 90	22.900 23.333 23.312	23.18

Figure 2. Compressive strength at 90 days.

TABLE XIII. (B) COMPRESSIVE STRENGTH (180 DAYS)

SAMPLE	COMPRESSIVE STRENGTH (KN/mm^2)	MEAN COMPRESSIVE STRENGTH (KN/mm^2)
S 0 C 100	28.973 28.330	28.656
S 2 C 98	28.820 29.573	29.196
S 5 C 95	23.820 24.091	23.955
S 10 C 90	24.030 24.300	24.165

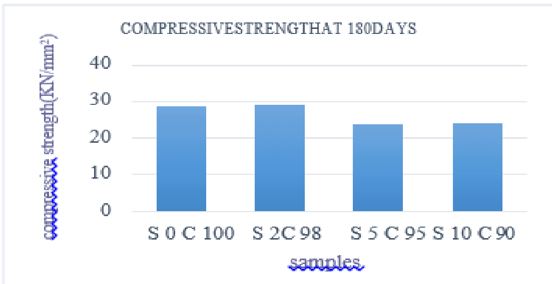


Figure 3. Compressive strength at 180 days.

The test conducted at 28 days shows decrease in characteristic strength for the cubes using 10% of C.E.T.P sludge whereas it was much similar in the case of 2% sludge content mix .At 90 days , there was increase in the strength of concrete , the strength for the concrete with 10% sludge content was not as that of 2% sludge content mix. At 180 days, the increment in the strength of 2% cubes was noted whereas there was no significant strength gain in 5% as well as 10 % sludge content concrete mixes. The compressive strength of mix with 2% sludge content increases by 15.42% at 180 days. This is acceptable compared as to the reference mix(table 12, 13(a),13(b)).

C. Water Absorption Test

Water absorption test was conducted for casted concrete cubes after 28 days , 90 days , 180 days as per discussed in the methodology . The initial weight of cubes was taken at so and so days of casting kept for curing in curing tank. Later, the final weight of the cube was taken after 24-48 hours of drying in sunlight, amount of water is calculated from the difference of these weights and hence water content is calculated.(refer table 14 15 16)

The fineness of cement and sludge are different. The sludge particles due to their discrete size than cement acts as a better filler materials so the voids would have been filled. The proper grading leads to non-increase in the water absorption value. But in case of 10% cement replacement, an increase of 29% was observed in early stage of 28 days but in later results this increase was not seen. As in case of 10% sludge, the water percolation is maximum due to increase in voids as the replacement may have exceeded the optimum limit.

TABLE XIV. WATER ABSORPTION (28 DAYS)

Sample	Mean value Of water absorption
S 0 C 100	0.427
S 2 C 98	0.450
S 5 C 95	0.501
S 10 C 90	0.608

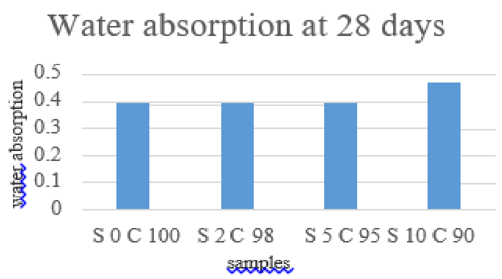


Figure 4. Water absorption at 28 days.

TABLE XV. WATER ABSORPTION (90 DAYS)

Sample	Mean value of water absorption
S 0 C 100	0.388
S 2 C 98	0.379
S 5 C 95	0.393
S 10 C 90	0.469

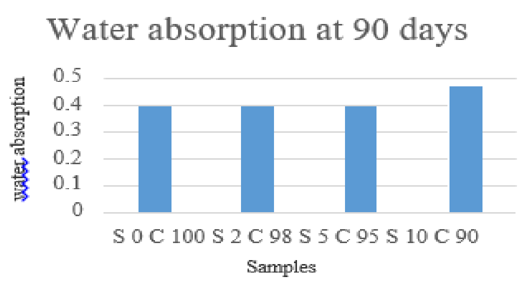


Figure 5. Water absorption at 90 days.

TABLE XVI. WATER ABSORPTION (180 DAYS)

Sample	Mean value of water absorption
S 0 C 100	0.428
S 2 C 98	0.406
S 5 C 95	0.462
S 10 C 90	0.482

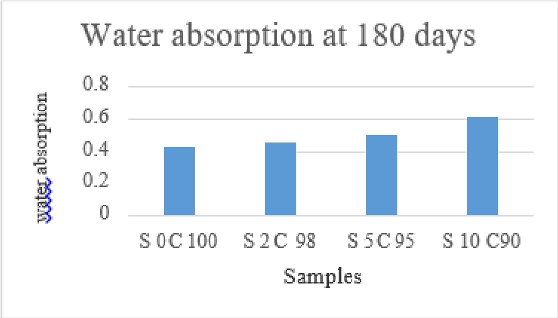


Figure 6. Water absorption at 180 days.

Graph 7 water absorption values for all mixes

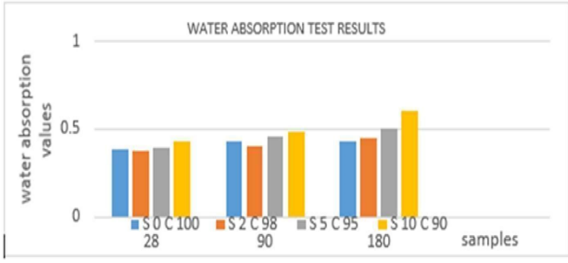


Figure 7. Water absorption values for all mixes.

V. Conclusions

Extensive experimentation on the mechanical characteristics of concrete was carried out by the utilization of C.E.T.P sludge as cement replacement . Based on the above results the following conclusions can be drawn

1) The result indicates that the slump values of different mixes got increased on increasing the sludge content in the mix as cement replacement. This signifies increase in the flow ability and workability of concrete mix on increasing the sludge content.
2) Cement replacement is limited to 2-5% as at 10% replacement the compressive strength get reduce to an undesirable values. The compressive strength decreases on increasing the sludge content in the concrete mix. But the replacement upto 2-5% replacement of cement is acceptable to get required strength.
3) In the initial stages 28 days the percolation of water was more in all the mixes with respect to the reference mix with 0% sludge content. But it gets compensated in the later stages i.e. 90 days and 180 days as the water absorption values appears to be similar.

This study demonstrates the potential for use of C.E.T.P sludge as replacement for cement in concrete mix. The use of sludge in concrete will reduce the problem of degradation of land due to dumping of such industrial waste. This seems to be a viable solution to this environmental concern of recycling of waste.

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