Development of Controlled Low Strength Material (CLSM) by utilising Fly ash, M-Sand, Effluent Treatment Plant Sludge, and Cement.

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Abstract: *The study involves the development of controlled low strength material (CLSM) by utilising fly ash, M-Sand, effluent treatment plant sludge, cement. Various tests were conducted to test the properties of the materials used in the development of CLSM. The tests for M-Sand includes Specific gravity and Fineness, the tests for Cement were Specific gravity, Consistency, setting time, and Fineness, the tests for Fly ash were Specific gravity and Sieve testing. The test for CLSM has test for Fresh property i.e. Flow table test and test for hardened property is unconfined Compression strength of CLSM at 7 days and 28 days. The CLSM moulds were prepared by varying the proportion of cement, M-Sand, fly ash, Sludge and water. This paper narrates the utilisation of CLSM with an importance on the use of waste materials like industrial sludge, fly ash for infrastructure development.*

KEY-WORDS: Controlled Low Strength Material (CLSM), fly ash, M-Sand, effluent treatment plant sludge, cement, Specific gravity, Consistency, setting time, Fineness, Sieve testing, Flow table test, unconfined compression strength.

1.INTRODUCTION

Controlled low-strength material (CLSM) is a self-compressed, adhesive substance which is utilized principally as a refill in substitution to compacted fill. Various words are presently used to describe this substance, including flowable fill, unshrinkable fill, controlled density fill, flowable mortar, fly ash slurry, soil cement slurry, and various different names. This research work consists of information regarding implementation, qualities of the substance, blend ratios, manufacturing, and standard maintaining systems. The inspiration for this investigation is to give some fundamental and essential data on CLSM development, with accentuation on CLSM substance qualities and its performance over regular compacted fill.

Controlled low-strength materials are characterized by American Concrete Institute (ACI) 116R as substances which shows a compaction value of 8.3 MPa or lesser.

This lesser quality prerequisite is important to take into consideration of future removal of CLSM and the substance is flowable, permitting ideal covering of any void.

2. OBJECTIVE OF THIS PAPER

The major intent of this experiment was carried with the intention of utilising Common Effluent Treatment Plant sludge (CETP sludge) in the development of Controlled Low Strength Material. Controlled Low Strength Material is a self-levelling and self-compressing blend with the compaction quality of less than 8.3MPa. The industrial by product sludge which otherwise is discarded as landfill is tested to match the accessibility of its implementation as in the development of CLSM and to examine the resulting properties.

1. To characterize each material utilised in the CLSM blends by conducting suitable experiments as per the guidelines of Bureau of Indian Standards (BIS).

2. To find out the qualities of CETP sludge by conducting physical and chemical analysis.

3. To proportion the CLSM blending as per ACI 229R-99 standards.

4. To replace cement in CLSM by industrial by product i.e. CETP sludge by 5 %, 10%, 15%.

5. To find out the properties of fresh qualities of CLSM.

6. To find out the different qualities, and properties of the hardened CLSM mixtures and compare the results.

3. MATERIALS USED AND TESTS CONDUCTED

In the current chapter, the work is focused on determining and evaluating different parameters and qualities of the components and their mixture as per the specified standards. CLSM mixtures utilised in the current experimental work consisted of different quantity of fly ash, CETP sludge, Ordinary Portland cement, fine aggregates(M-Sand) and water.

3.1 Fine Aggregates:

Fine Aggregates are more often the major component of a CLSM mixture. The quality, Class, and shape of aggregates can impact the physical qualities, such as flow ability and compaction quality. In this research work M-sand was utilised for the experimental works. Specific gravity test and sieve analysis were carried on and completed according to IS:2386-1963 and the requirements as per IS 383-1970 is satisfied and is as showed in the table 3.1.

Table 3.1 Properties of Fine aggregates (M-Sand)

Serial No	Properties	Results
1	Specific gravity	2.80
2	Fineness	4.44

3.2 Cement:

Cement provides the cohesion and quality for various CLSM batches. For most applications, cement is normally used. Various sorts of concrete, including mixed blends, can be utilised if earlier testing shows satisfactory outcomes. The Portland cement content for excavatable CLSM is normally used in the extent of 30 to 120 kg/m^3 as per ACI229R-99.

In the current experiment, Cement of 43 grade is utilized affirming to IS: 8112- 1989. The physical qualities of bond are acquired by directing suitable experiments as per IS 269:4831 and requirements as per IS 8112:1989 are as indicated in the table 3.2.

Table 3.2 Qualities of Cement

Sl No	Properties	Results obtained	Requirements as per IS: 8112-1989.
1	Fineness	3.5%	Not more than 10%
2	Normal consistency	30	27 to 33
3	Initial setting time	160(in minutes)	Not lower than 30
4	Final setting time	220(in minutes)	Not more than 600
5	Specific gravity	3.4	-


Figure 3.1, 3.2 Vicat apparatus and conducting test on Consistency, Setting time of Cement

3.3 Fly ash:

CLSM is regularly proportioned with fly ash or slag to enhance workability and pumpability, and reduce segregation, bleeding, shrinkage, or settlement. Coal combustion fly ash is utilised to improve flowability. High fly ash components blend following in bring down density of CLSM when contrasted with blends and large aggregate quantity. Trial blends are done to decide if the blend meet the predetermined prerequisites. Class F fly ash components are regularly utilised in the extent of 60 to 1200 kg/m^3.

Table 3.3 Properties of Fly ash

S. NO	Properties	Results obtained
1	Specific gravity	2.1
2	Percentage retained on 45 µm Sieve	22.5%
3	Percentage retained on 90 µm Sieve	4%

3.4 Common effluent treatment plant sludge:

Nonstandard materials are utilised in CLSM mixtures, depending upon project requirements after testing their acceptability in CLSM mixtures. Examples of nonstandard materials that are substituted for any of the constituent for CLSM incorporates various coal ignition items, disposed foundry sand, glass cullet, and recovered crushed cement. In the current experiment, Common Effluent Treatment Plant (CETP) sludge used is a non-standard material. It was acquired from an effluent treatment plant source in Bengaluru. The specific gravity for CLSM obtained is 1.95.


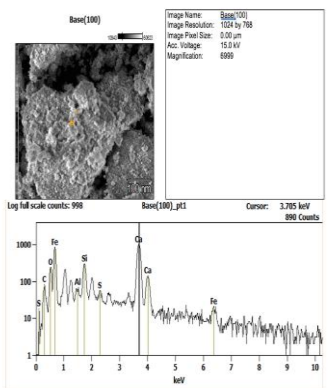

Figure 3.3, 3.4 Industrial Sludge and results of SEM test on CETP Sludge

4. MOULDS PREPARATION

4.1 Mix Proportioning:

Mix proportioning is a progression of choosing suitable constituents and finding their proportions which would create a blend that satisfy the job requirements. The mixing of the materials of concrete is a significant section of concrete technology as it protects standard and money saving. Since self-compaction is largely impacted by the description of components and the blend ratios, it becomes requisite to discover a method for blending of CLSM. ACI 229R-99 have proposed a mix proportioning system based on trial and error until blended with appropriate qualities are attained.

4.2 Mixing:

The mix formulation added in the experiment is shown in the tables below (Table 4.1 to Table 4.5). The formulation of the CLSM compound were prepared for OPC constituents varying from 30 to 120 kg/m³ with an increase in 20 kg/m³ of cement content. Fly ash compound is kept as invariable at 500 kg/m³. Water content is used fixed for every blend at 500 kg/m³. Cement was partially replaced by CETP sludge (5 %,10 %and 15%).

4.3 Mix Proportioning

	A	B	C	D	E
Mix number	A1 A2 A3 A4	B1 B2 B3 B4	C1 C2 C3 C4	D1 D2 D3D4	E1 E2 E3 E4
Sludge (%)	0 5 10 15	0 5 10 15	0 5 10 15	0 5 10 15	0 5 10 15
Cement	30 kg/m³	50 kg/m³	70 kg/m³	90 kg/m³	120 kg/m³

SERIES A: Cement = 30 kg/m³, Fly ash = 500 kg/m³ and Partial replacement of cement.

In the tables below the following abbreviations are used.

Se No – series number,

Sl – sludge,

OPC – cement,

H20 – water.

Table 4.1 Mix design of series A

Se No	Sl (%)	Unit Weight (Kg/m³)				
		OPC	Fly ash	Sand	H20	Sl
A1	0	30	500	700.44	500	0
A2	5	28.5	500	700.44	500	1.5
A3	10	27	500	700.44	500	3
A4	15	25.5	500	700.44	500	4.5

SERIES B: Cement = 50 kg/m3, Fly ash = 500 kg/m3 and Partial replacement of cement.

Table 4.2 Mix design of series B

Se No	Sl (%)	Unit Weight (Kg/m³)				
		OPC	Fly ash	Sand	H20	Sl
B1	0	50	500	684.88	500	0
B2	5	47.5	500	684.88	500	2.5
B3	10	45	500	684.88	500	5
B4	15	42.5	500	684.88	500	7.5

SERIES C: Cement = 70 kg/m³, Fly ash = 500 kg/m³ and Partial replacement of cement.

Table 4.3 Mix design of series C

Se No	Sl (%)	Unit Weight (Kg/m³)				
		OPC	Fly ash	Sand	H20	Sl
C1	0	70	500	668.31	500	0
C2	5	66.5	500	668.31	500	3.5
C3	10	63	500	668.31	500	7
C4	15	59.5	500	668.31	500	10.5

SERIES D: Cement= 90 kg/m³, Fly ash = 500 kg/m³ and Partial replacement of cement.

Table 4.4 Mix design of series D

Se No	Sl (%)	Unit Weight (Kg/m³)				
		OPC	Fly ash	Sand	H20	Sl
D1	0	90	500	659.86	500	0
D2	5	85.5	500	659.86	500	4.5
D3	10	81	500	659.86	500	9
D4	15	76.5	500	659.86	500	13.5

SERIES E: Cement = 120 kg/m³, Fly ash = 500 kg/m³ and Partial replacement of cement.

Table 4.5 Mix design of series E

Se No	Sl (%)	Unit Weight (Kg/m³)				
		OPC	Fly ash	Sand	H20	Sl
E1	0	120	500	632.06	500	0
E2	5	114	500	632.06	500	6
E3	10	108	500	632.06	500	12
E4	15	102	500	632.06	500	18

5. RESULTS AND DISCUSSIONS

5.1 General

This chapter consists of results and discussions on fresh properties and hardened qualities of CLSM. Fresh properties include workability and density. Hardened properties include the level of compaction achieved at 7 days and 28 days by the various blends of CLSM. The results were tested for their conformance with the needed standards and study of the results have been made.

5.2 FRESH PROPERTIES

5.2.1 Flowability

It is the quality that differentiates CLSM with another fill substance. It allows the substance to be self-levelling, and enter into the voids and gets self-compacted without the need of compaction machines. This quality shows a high benefit of CLSM in comparison with traditional fill substance which needs to be compacted by using conventional equipment. The Flowability is done by using Flow Table Test of IS (1199-1959). The apparatus used for Flow table test were of standard IS (5512-1983).

Figure 5.1 Conducting Flow table test

Table 5.1 Flow table test values for different mixes (in cms)

SERIES	A1	A2	A3	A4
RESULTS	21.9	21.7	21.5	21.3

SERIES	B1	B2	B3	B4
RESULTS	20.7	20.5	20.3	20.1

SERIES	C1	C2	C3	C4
RESULTS	19.5	19.3	19.1	18.9

SERIES	D1	D2	D3	D4
RESULTS	18.4	18.2	18.0	17.8

SERIES	E1	E2	E3	E4
RESULTS	17.5	17.3	17.1	17.0

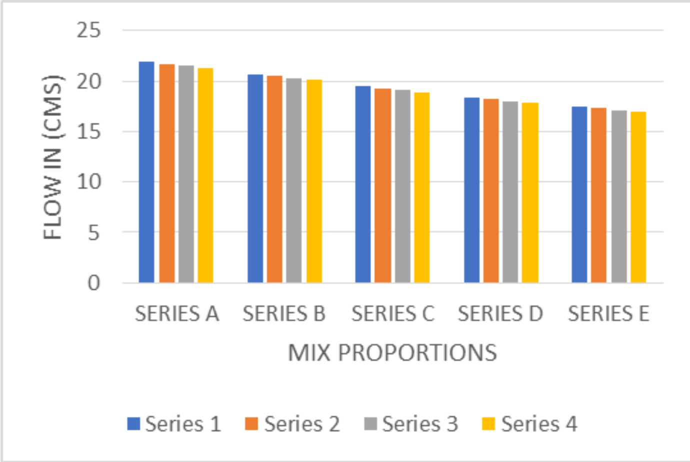

Figure 5.2 Flowability of different blends

Flowability was tested and flow of the mixes in this experimental work have achieved values equal to 17 cm or more as given in the table 5.1. This indicates the proportioned CLSM blends have a good flowability. Comparing the flowability of different mixes, it is seen that flowability reduces with the increment of squander, and cement contents as indicated in the Figure 5.1.

5.3 Unconfined Compression Test values for different mix series

Figure 5.3 Hand mixing of CLSM

Figure 5.4, 5.5 After demoulding the moulds

Figure 5.6, 5.7 Conducting Unconfined Compression Test

SERIES A: Cement = 30 kg/m³, Fly-ash = 500 kg/m³, Partial replacement of cement

Table 5.2 Test results for Series A

Series No	Compressive Strength at 7 Days (N/mm²)	Compressive Strength at 28 Days (N/mm²)
C1	1.38	2.98
C2	1.250	2.784
C3	1.139	2.55
C4	1.028	2.180

DISCUSSION: It is observed that for a cement quantity of 30kg/m³, with the decrease of Cement content and increase in sludge proportions the Compressive Strength has been decreased. It is seen that there is about 37.03% and 39.21% decrease in Compressive Strength at 15% of Sludge at 7 days and 28 days respectively.

SERIES B: Cement = 50 kg/m³, Fly-ash = 500 kg/m³, Partial replacement of cement

Table 5.3 Test results for Series B

Series No	Compressive Strength at 7 Days (N/mm²)	Compressive Strength at 28 Days (N/mm²)
B1	0.979	1.77
B2	0.870	1.60
B3	0.803	1.45
B4	0.713	1.306

DISCUSSION: It is observed that for a cement quantity of 70 kg/m³, with the decrease of Cement content and increase in sludge proportions the Compressive Strength has been decreased. It is seen that there is about 25.50% and 26.84% decrease in Compressive Strength at 15% of Sludge at 7 days and 28 days respectively.

SERIES C: Cement = 70 kg/m³, Fly-ash = 500 kg/m³, Partial replacement of cement.

Table 5.4 Test results for Series C

Series No	Compressive Strength at 7 Days (N/mm²)	Compressive Strength at 28 Days (N/mm²)
C1	1.38	2.98
C2	1.250	2.784
C3	1.139	2.55
C4	1.028	2.180

DISCUSSION: It is observed that for a cement quantity of 70 kg/m³, with the decrease of Cement content and increase in sludge proportions the Compressive Strength has been decreased. It is seen that there is about 25.50% and 26.84% decrease in Compressive Strength at 15% of Sludge at 7 days and 28 days respectively.

SERIES D: Cement = 90 kg/m³, Fly-ash = 500 kg/m³, Partial replacement of cement

Table 5.5 Test results for Series D

Series No	Compressive Strength at 7 Days (N/mm²)	Compressive Strength at 28 Days (N/mm²)
D1	1.77	4.11
D2	1.70	3.98
D3	1.58	3.54
D4	1.54	3.27

DISCUSSION: It is observed that for a cement quantity of 90 kg/m³, with the decrease of Cement content and increase in sludge proportions the Compressive Strength has been decreased. It is seen that there is about 13.00% and 20.43% decrease in Compressive Strength at 15% of Sludge at 7 days and 28 days respectively.

SERIES E: Cement = 120 kg/m³, Fly-ash = 500 kg/m³, Partial replacement of cement

Table 5.6 Test results for Series E

Series No	Compressive Strength at 7 Days (N/mm²)	Compressive Strength at 28 Days (N/mm²)
E1	2.16	4.62
E2	2.12	5.055
E3	2.10	4.78
E4	2.064	4.52

DISCUSSION: It is observed that for a cement quantity of 120 kg/m³, with the decrease of Cement content and increase in sludge proportions the Compressive Strength has been decreased. It is seen that there is about 4.44% and 2.164% decrease in Compressive Strength at 15% of Sludge at 7 days and 28 days respectively.

5.4 Comparing A, B, C, D and E mixes:

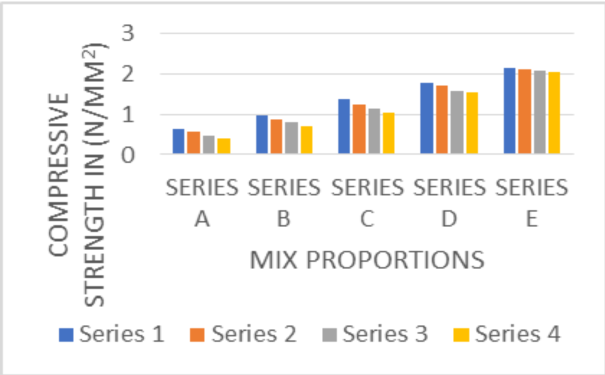

Figure 5.8 Comparing compressive strengths of different blends for 7 Days

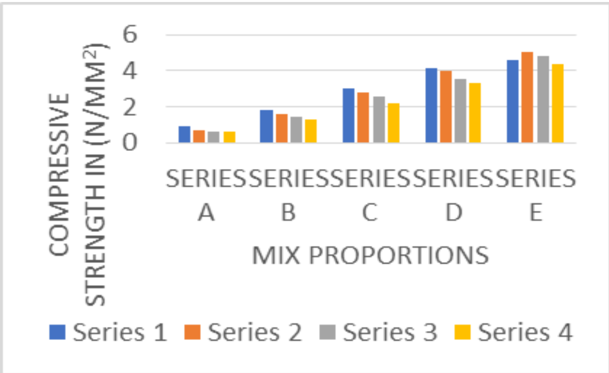

Figure 5.9 Comparing compressive strengths of different blends for 28 Days

6. CONCLUSION

The preliminary intention of this experiment was to develop a CLSM blend with industrial by-product utilization and satisfying workability and performance requirements. Results of this experimental study showed that CLSM comprises of high contents of industrial squander by-products, cement, Fly-ash and Common Effluent Treatment Plant sludge, which could be utilised as structural fill.

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