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Development of Controlled Low-Strength Materials using Class –F Flyash and Common Effluent Treatment Plant (CETP) Sludge

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Abstract: Large quantities of sludge generated from wastewater treatment plant are being disposed as landfills affecting the environment. This has prompted many investigations into alternative reuse techniques and disposal routes for sludge. The main focus of the present investigation was to explore the possibility of reuse of Common Effluent Treatment Plant (CETP) Sludge and also to determine its applicability in the construction sector. CETP sludge is tested for its suitability and included in proportioning of CLSM. ACI-229R defines Controlled Low Strength Material (CLSM) as a self-compacting material with a compressive strength of 8.2 MPa or less. It is a versatile and flowable mix whose proportions can be suitably adjusted to meet specified requirements.The present investigation aimed at developing the CLSM by utilizing CETP sludge in partial quantities. The mixes were subjected to fresh and hardened property tests. The experimental results showed the feasibility of partial replacement of cement by CETP sludge thus by highlighting the efficient reusability of industrial by-product as a construction material. A mixture of 10% CETP sludge, 90 kg/m^3 Cement, 600 kg/m^3 Class F FlyAsh with water provided unconfined compressive strength values within the range for classification as CLSM. This mixture satisfies the excavatability and walkability requirements as well as the hardening time and stability
Keywords: Controlled low strength material; Flyash; Common Effluent Treatment Plant (CETP) Sludge

I. INTRODUCTION

Technological development has led to high-speed industrialization, which is always related with the problem of waste disposal. Industrial activities generate huge quantities of wastes more than 300 million tons annually in India. This is associated with the problem of waste disposal, in turn creating the havoc of environmental degradation. There is indiscriminate disposal of the sludge from Effluent Treatment Plants (ETP) which deteriorate surface soil and contaminate ground and surface water. This becomes an important environmental and public health issue. Therefore, it is now a global concern to find a socio, techno-economic and ecofriendly solution to dispose industrial solid wastes. The recycling of industrial solid wastes by treating it as a substitute for building materials in construction is not only environment friendly but also a cost effective alternative way to sustain a cleaner and greener environment.

Industrial wastes generally will have a granular nature. These materials are, in general, unsuitable for use in the construction industry due to their high content of very fine particles, or due to their poor mechanical properties. Controlled Low Strength Materials (CLSM), can serve as an excellent means to utilize large quantities of fines without impairing its properties. CLSM is a self-leveling and self-compacting, cementitious material with an unconfined compressive strength of 1,200 psi or less as defined by ACI 229R . CLSM is used mainly for filling cavities in civil engineering works, in which the application of granular fill is either impossible or difficult production technology, however, is like the production of concrete. The mechanical strength of CLSM is generally low (unconfined compressive strength of 0.5–2 MPa) permitting re-excavation in the future, and the material is flowable, allowing perfect filling of any void.

Many researchers have discussed properties and applications of Controlled Low Strength Material using fly ash, fine aggregates & other by-products. Also, research on the use of industrial by-products in CLSM has been included. Investigations on the usage of Effluent Treatment Plant sludge as a construction material. Tarun R. Naik et al (1991) carried out research on the production of CLSM with High Fly Ash content and identification of optimum mix proportions for the same. The Proportion of Fly ash to cement was on a 2:1 weight basis. Based on the results obtained in this investigation, it was concluded that high-volume fly ash content low-strength concrete (CLSM) could be made with ASTM Class C fly ash. While some mixes did not reach the desired 10.3 MPa strength, a proper adjustment in cementations material content should result in compressive strengths that will reach this desired design strength levels. Research on the production of controlled low strength material using Fly Ash and AMD sludge was carried out by M.A. Gabr et. al. (1999) to develop a CLSM mix while maximizing by-product material utilization and satisfying workability and performance requirements. Results of this research demonstrated that CLSM composed upwards of 90% waste by-products, specifically Class F FA and AMD treatment sludge, can be utilized as structural fill. Development of soil-based controlled low-strength material was carried out by Brian H. Green (1999). Feasibility of soil-based CLSM was determined with some combinations of Class F and Class C fly ashes, Portland cement, a CL or ML soil, an SP sand sized material, and water. The results showed that it is possible to produce CLSM mixtures that are fluid enough for placement and that exhibit a gain in unconfined compressive strength with age. This application of CLSM can extend to fill large volumes of space created by lock wall construction which would normally be filled with conventional compacted soil backfill. The CLSM will allow the use of the excavated materials from the construction site and other by-product. David Trejo et al (2003) carried out research on a comprehensive investigation of CLSM, funded by the National Cooperative Highway Research Program (NCHRP), United States. Surveys on the use of CLSM have been conducted and the analysis reveal the use of CLSM by state Departments of Transportation (DOTs) in the United States mainly for backfill, utility bedding, void fill, bedding for granite curbs, engineered fill, and as a lightweight fill to cover swamp areas and bridge approach applications. CLSM usage has been on a significant rise in the United States. Thus, controlled low-strength materials have come to the forefront as viable means for efficient usage of by-product and waste materials in infrastructure applications. Amnon Katz et al (2004) carried out research on the utilization of industrial byproducts to produce controlled low strength materials (CLSM). CLSM has been evaluated to use as a replacement of compacted soil. In this study cement kiln dust, asphalt dust, coal fly ash, coal bottom ash and quarry waste have been tested for the possibility of producing CLSM with large proportions of those wastes. The results have shown that in most cases, CLSM with good properties could be made with significant amounts of dust (25–50%w), especially when the dust has some cementing or Pozzolanic potential as do fly ash and cement kiln dust. The production of Controlled Low Strength Materials (CLSM) utilizing Fly Ash from Thermal Power Plant was conducted by Suresh Kumar et al (2005). The properties of CLSM that have been investigated include bleeding, density of hardened CLSM, Permeability and unconfined Compressive strength of CLSM at 7 days and 28 days age. The results conclude that CLSM using industrial waste fly ash can be successfully used and designed for excavate-able and structural filling application like soil and structural filling, utility bedding and sub-base. Yinan Weng et al (2006) presented a study on Controlled Low Strength Material (CLSM). The aim of this research has been to address CLSM's engineering properties and chemical resistance. Various tests have been done to quantify the workability, strength and chemical resistance. Cement contents have been varied between 0 to 3.0% to study the effect of cement. The compressive strength at 28 days have been found to range from 0.14 MPa to 5.5 MPa and a linear relationship has been established between compressive and tensile strength. V. R. Marjive et al (2016) conducted experimental studies on controlled low strength material using stone dust and EPS beads. This paper pertain the results of the compressive strength experimental study carried out on controlled low strength material (CLSM) prepared using stone dust and expanded polystyrene beads (EPS). Compressive strength values of CLSM have found to be significantly influenced by the mix ratios and curing period. These values found to decrease with increasing mix ratio values. Curing period of 14 days CLSM specimen have higher compressive strength with respect to curing period of 7 days. The density of CLSM was decreased with increasing EPS beads percentages. The results indicate that CLSM with acceptable strength is attainable using stone dust and EPS beads. From the study on Controlled low strength materials and CETP Sludge, it has been found that CLSM can allow efficient use of large quantities of industrial wastes. CLSM with suitable properties can be made with significant amounts of industrial wastes up to 25–50% by weight. Industrial wastes, like class F fly ash can be utilized up to 1200 kg/m3 with satisfying workability and performance requirements. High quantities of water up to 350 kg/m3 can be utilized to achieve good workability without significant effect on the strength parameters of CLSM. Low quantities of cement of 50 kg/m3 can produce CLSM of required strength. Effluent treatment plant wastes can be utilized in large quantities in CLSM mixes up to 50 % after testing their suitability, especially if they possess Pozzolanic properties

The current study was conducted in view of the need using Common Effluent Treatment Plant sludge (CETP sludge) in the production of CLSM and to explore the possibility of using non-standard materials. The sludge which otherwise is disposed as landfill is tested to suit the possibility of its application as a by-product in the production of CLSM and to study the resulting properties.

II. MATERIALS PROPERTIES AND TEST METHODS

In the present research work, the exploratory examination focused on determining and evaluating various parameters and properties of the components and their mixture as per the specified standards. CLSM mixtures used in this research consisted of various proportions of Class F fly ash, CETP sludge (Fig. 2), Portland cement, fine aggregates and water. The required physical and chemical properties of the individual materials were tested according to the Indian Standard procedures and the conformity of the materials where checked as per the required standards

A. Cement

Cement is the principle bonding material in the mix. Cement provides the cohesion and strength for CLSM mixtures. For most applications, Ordinary Portland cement is normally used. Other types of cement, including blended cements, can be used if prior testing indicates acceptable results. The Portland cement content for excavate-able CLSM is typically in the range of 30 to 120 kg/m^3 as per ACI229R-99. In the present investigation, Ordinary Portland Cement of 43 grade is utilized affirming to IS: 8112-1989. The physical properties of bond are acquired by directing suitable tests according to IS 269:4831 and requirements according to IS 8112:1989 are as indicated in the Table 1

B. Fly ash

CLSM is often proportioned with fly ash or slag to improve workability and pumpability, and reduce segregation, bleeding, shrinkage, or settlement. Coal-combustion fly ash is used to improve flow-ability. High fly ash-content mixtures result in lower density CLSM when compared with mixtures with high aggregate contents. Trial mixtures are prepared to determine whether the mixture meet the specified requirements. Class F fly ash contents are typically in the range of 60 to 1200 kg/m3. In the present investigation, Class F fly ash was used. The fly ash was obtained from Raichur Thermal Plant, Karnataka India. Physical properties and chemical composition of fly ash that were tested and given in Tables 2 and 3

C. Common Effluent Treatment Plant Sludge

ACI -229R recommends the use of various nonstandard materials in the development of 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 include various coal combustion products, industrial sludge discarded foundry sand, glass cullet, and reclaimed crushed concrete.

In the present investigation, Common Effluent Treatment Plant (CETP) sludge, a non-standard material was acquired from an effluent treatment plant source in Bengaluru, India. Nearly 30-40 Tons of CETP sludge is being generated in a single common effluent treatment plant and around 11 CETP's are functioning in the state of Karnataka alone. The disposal of these huge quantities of generated sludge processes a big challenge as the sludge is considered as a hazardous material. With this back ground it was planned to utilize sludge generated in the development of CLSM. The sludge obtained was tested for its physical and chemical properties and the results are shown in the Table 4 and Table 5.

The CETP sludge from this site was analyzed using Energy Dispersive X-ray Spectroscopy and the chemical composition of the solids content is shown in Table 5 and it was evident that, Ca content was predominant and thus the pozzolonic reaction with the cement can the phenomenon from the observed results.

Fig 1 shows SEM image of CETP sludge indicating the morphology of the sludge agglomerated particles are observed. Fig 2 shows image of CETP sludge used in the present investigation.

D. Fine Aggregates

Aggregates are often the major constituent of a CLSM mixture. The type, grading, and shape of aggregates are considered. Generally, in CLSM only fine aggregates are used. Fine aggregates are used in the range of 1500- 1800 kg/m^3 as per ACI-229R-99. Locally available river sand was utilized as a part of the present examination. Specific gravity test and sieve analysis were carried on and completed as per IS:2386-1963 and the requirements as per IS 383-1970 is satisfied and is as exhibited in the Table 6

III. EFFECT OF SLUDGE ON THE PROPERTIES OF CEMENT AFTER PARTIAL REPLACEMENT BY CETP SLUDGE

It is important to check its effect on the basic properties of cement with replacement of CETP sludge. Industrial by-products should not have considerable effects on the properties of cement, otherwise they can have a deteriorating effect on the mix. This effect was studied by conducting suitable tests and concluded that the CETP sludge does not have any undesirable effect on the setting time of cement, while the consistency of cement varied to a certain extent with the addition of sludge Table 7 indicates the effect of CETP sludge on the properties of cement

IV. MIX DESIGN

The mix design proportion was designed by fixing a few parameters such as flyash content and water content. The testing program was performed on 12 CLSM mixtures by partially replacing CETP sludge with cement. Mix proportioning is a progression of selecting appropriate ingredients and determining their proportions which would create, as inexpensively as probable, a mix that satisfy the job requirements. The proportioning of the ingredients of concrete is an important phase of concrete technology as it ensures quality and economy. Since self compactibility is largely affected by the description of materials and the mix proportions, it becomes necessary to evolve a procedure for mix design of CLSM. ACI 229R-99 have proposed a mix proportioning system based on trial and error Cement was partially replaced by CETP sludge (5 % and 10 %.. Mixing of the various constituents was performed with Hobart Manufacturing's Model A120 mechanical mixer. The mix formulation in the investigation was carried out by trail and error method, where proportions are not specified, trial mixtures are evaluated to determine how well they meet certain goals for strength, flow-ability, and density. Adjustments are then made to achieve the desired properties. ACI 229R, describes the proportions for the CLSM mixtures were designed for cement contents ranging from 30 to 90 kg/m3 with an increase in 20 kg/m3 of cement content. Fly ash content was kept constant at 600 kg/m^3. Water content is kept constant for all the mixtures at 300 kg/m3. The mix proportioning is given in the Table 8.

V. FLOWABILITY

Flowability is the property that distinguishes CLSM from other fill materials. It enables the materials to be self leveling, to flow into and readily fill a void and be self-compacting without the need for conventional placing and compacting equipment. This property represents a major advantage of CLSM compared with conventional fill materials that must be mechanically placed and compacted. Because plastic CLSM is like plastic concrete and grout, its flowability is best viewed in terms of concrete and grout technology. Methods of expressing flowability include the use of a 75 x 150 mm (3 x 6 in.) open-ended cylinder modified flow table test (ASTM D 6103). Flowability ranges can be expressed as follows:

1) Low flowability: less than 150 mm (6 in.),
2) Normal flowability: 150 to 200 mm (6 to 8 in.)
3) High flowability: greater than 200 mm (8 in.)

In the present investigation, the flowability was tested and flow of the mixes showed values greater than 15 cm as shown in the fig. This indicates the proportioned CLSM mixtures have a good flowability. Comparing the flowability of different mixes, it is observed that flowabilty reduces with the increase in sludge, fly ash and cement contents

VI. UNCONFINED COMPRESSIVE STRENGTH OF CLSM

In the present investigation, the compressive strength for all the specimens was tested for 7 days and 28 days respectively. These mixes were selected since they satisfied the spread, hardening times less than 24 h, and stability requirements The data was collected and plotted as shown in Fig.4 and Fig.5.Unconfined Compressive Strength is the parameter that determines the load-carrying ability of CLSM. From the figures, it can be concluded that the higher quantity of cement used will produce CLSM with higher compressive strength as it has lower water/cement ratio.

This is very rational as cement is the major source of cementitious materials within the mixture that is used to bond the aggregates and particles. It is also observed that that the compressive strength at 7 and 28 days for the mixes of same series reduced to a certain extent with reduction in the cement content. For test samples containing 10% of CETP sludge the unconfined compressive strength increased from 2.53MPa at 7 days to 5.5 MPa at 28days.

This continual increase in strength, as shown in Fig. 4 and Fig. 5, can be explained by the FA/cement/CETP sludge interaction. The sludge acts as an accelerator using the readily available unreacted calcium to increase pozzolanic reactions, also the compressive strength of CLSM is depending on the bond formed between these particles. Thus, it is reasonable that more cement used can generate more strength as particles are more effectively bonded together. Besides cement, fly ash CETP sludge content also causes minor effects to the compressive strength of CLSM specimens. All CLSM mixtures developed were within the ACI recommended limits 28-day unconfined compressive strength specification of 8.3MPa to qualify as low strength material. However, the 28-day strength for the mix with 10% CETP sludge satisfies the criteria for excavatability and should only be used for permanent fill structures. Walkability limits of 450 kPa was also achieved based, as indicated, on the unconfined compressive strength shown in Table 9.

VII. CONCLUSIONS

The focus of the present investigation was to develop a green CLSM mix by utilizing industrial by-product and satisfying workability and performance requirements. Results of this investigation demonstrated that CLSM composed of high contents of waste by-products, specifically Class-F FlyAsh and Common Effluent Treatment Plant sludge, can be utilized as structural fill. Based on the results obtained in this research, the following specific conclusions can be made.

1) All the CLSM mixes developed satisfied the requirements specified by the ASTM standards.
2) CLSM mixtures showed increase in 28 days' strength for different mixtures with increasing cement content which indicates that, with increase in cement content, the strength of CLSM mixture increases.
3) CLSM mixtures showed an increase in 28 days' strength with increasing fly ash content. Comparing CLSM mixtures with increasing fly ash content and constant cement content, a considerable increase in 28 days' strength of the mixtures was observed. This shows that fly ash contributes to the 28 days' strength of CLSM.
4) CLSM mixtures with cement content of 90 kg/m^3 achieved strength up to 5.5 MPa with high water content of 300kg/m^3. This shows that CLSM mixtures with high strength can be achieved with high flow-ability.
5) CLSM mixtures having strength ranging from 2MPa to 5MPa can be used for backfilling, pavement bases and other suitable applications.
6) CLSM mixtures showed increase in both 7 and 28 days' strength when cement was replaced with sludge for a constant fly ash content. This shows that CETP sludge possess the required Pozzolonic properties and hence can be utilized for development of CLSM.
7) Recommended mix ratio for flowable fill is 10% CETP sludge, replaced with 90 Kg/m^3 of cement, 600 Kg/m^3 Class-F Flyash, water content on the order of 300 Kg/m^3. This mix ratio satisfies the excavatability and walkability requirements as well as the hardening time and stability criteria.

VIII. ACKNOWLEDGEMENTS

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REFERENCES

[1] ACI 229R-94 Report, Controlled Low-Strength Materials _CLSM., American Concrete Institute, Detroit, MI, 1994, 10 pp.
[2] Tarun R. Naik, Bruce W. Ramme and Henry J. Kolbeck International Conference on the Utilization of Fly Ash and Other Coal Combustion By-Products Shanghai, China September 18-20, 1991
[3] M.A. Gabr , John J. Bowders Controlled low-strength material using fly ash and AMD sludge, Journal of Hazardous Materials 76 _2000. 251–263 2000 Elsevier Science
[4] Brian H. Green, Innovations for Navigation Technical Report INP-SL-2 Projects Research Program October 1999
[5] David Trejo, Kevin J. Folliard, and Lianxiang Du A comprehensive investigation of CLSM, funded by the National Cooperative Highway Research Program (NCHRP) under Project 24-12 and 24-12(1) ("Controlled Low-Strength Material for Backfill, Utility Bedding, Void Fill, and Bridge Approaches") 1998.
[6] Amnon Katz, Konstantin Kovler Utilization of industrial by-products for the production of controlled low strength materials (CLSM); Waste Management 24 (2003) 501–512.
[7] Suresh Kumar, Dinesh Kumar and Nancy Mittal Use of fly ash in Making Controlled Low Strength Material (CLSM) for use as self-compacted structure backfill, National council for cement and Building Materials, Ballabgarh, Haryana, India
[8] Yinan Weng, and C. Vipulanandan Study on Controlled Low Strength Material (CLSM); Department of Civil and Environmental Engineering University of Houston (2013), TX 77004
[9] V. R. Marjive, V. N. Badwaik, and B. Ram Rathan Lal Experimental studies on Controlled Low Strength Material using stone dust and EPS beads; IACSIT International Journal of Engineering and Technology, Vol. 8, No. 4, August 2016

Tables

Table 1
Physical Properties of Cement

Properties	Obtained Value	Requirements As Per Is 8112:1989
Fineness	2 %	Not more than 10%
Normal consistency	30	27 to 33
Initial setting time (minutes)	65	Not less than 30
Final setting time (minutes)	215	Not more than 600
Specific gravity	3.16	--

Table 2
Physical Properties of Flyash

Properties	Value
Specific gravity	2.23
Blaine's Fineness(m2/kg)	523.9
Percent retained on 45µm sieve	12.2
Percent retained on 90 µm sieve	1.6

Table 3
Chemical analysis of FlyAsh

PARAMETERS	TEST METHOD	RESULTS
Silica as SiO2 %	ASTM C114-2011b	47.64
Alumina as Al2O3 %	ASTM C114-2011b	21.08
Calcium as Ca0 %	IS:5949:1990(Reaff.2010)	5.71
Iron as Fe2O3 %	ASTM C114-2011b	11.95
Moisture as MOI %	ASTM C 311-11b	0.23
Sulphates as S03 %	ASTM C 114-2011b	0.850
Loss of Ignition %	ASTM C 114-2011b	4.36

Table 4
Physical Properties of CETP Sludge

Properties	Results
Dry Powder Density (kg/m^3)	
Loose	485
Rodded	571
pH (10% suspension)	9.56
Specific Gravity	2.186

Table 5
Chemical Composition of CETP Sludge by
Energy Dispersive X-ray Spectroscopy

Chemical Composition	C-K	O-K	Al-K	Si-K	S-K	Ca-K	Fe-K
Base(100)_pt	1.30	8.10	0.98	7.73	1.94	76.79	3.16

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Table 6
Physical properties of fine aggregates

Properties	Value
Specific gravity	2.78
Fineness	3.17
Grading	Zone -II

Table 7
Effect on the Properties of Cement by partial replacement of CETP Sludge

Properties	Normal Cement	Cement replaced with 5% CETP sludge	Cement replaced with 10% CETP sludge
Initial Setting time (Mins)	65	64	66
Final Setting time (Mins)	215	210	220
Normal/Standard Consistency	27	28	29

Table 8
Mix ratios of specimens used in the testing program
OPC=Ordinary Portland cement; CETP=common effluent treatment plant sludge; FA=Fly ash; WSR=water-to solids ratio.

Mix	Sample	OPC (Kg/m^3)	CETP Sludge replacement to cement (%)	FA (Kg/m^3)	SAND (Kg/m^3)
A	A1	30	0	600	1129
	A2	28.5	5	600	1130
	A3	27	10	600	1131
B	B1	50	0	600	1112
	B2	47.5	5	600	1111.1
	B3	45	10	600	1110.1
C	C1	70	0	600	1093.2
	C2	66.5	5	600	1092.8
	C3	63	10	600	1091.5
D	D1	90	0	600	1075.5
	D2	85.5	5	600	1074.6
	D3	81	10	600	1072.9

Table 9
7days and 28 days UCS Strength of CLSM Mix in kN/m^2

Mix	7 Days			28 Days		
	0% Sludge	5% Sludge	10% Sludge	0% Sludge	5% Sludge	10% Sludge
MIX A	0.75	0.6	0.52	1	0.75	0.6
MIX B	1	0.75	0.9	3.57	3.2	3.75
MIX C	1.53	1.3	1.75	4.75	4.5	5.2
MIX D	2.25	2.14	2.53	5.3	5.45	5.5

Figures

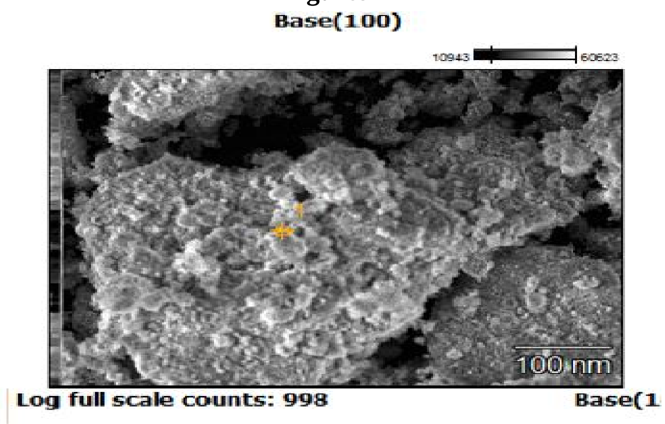

Fig.1 SEM image of CETP Sludge

Fig.2 CETP sludge

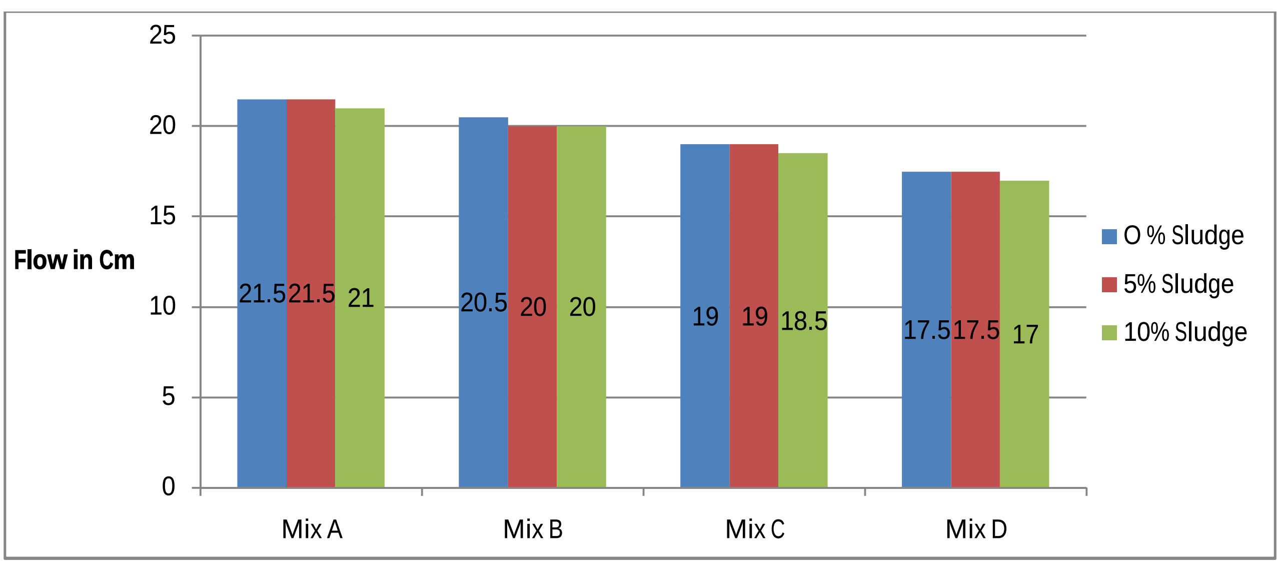

Fig.3 Flowability chart for different proportion of sludge

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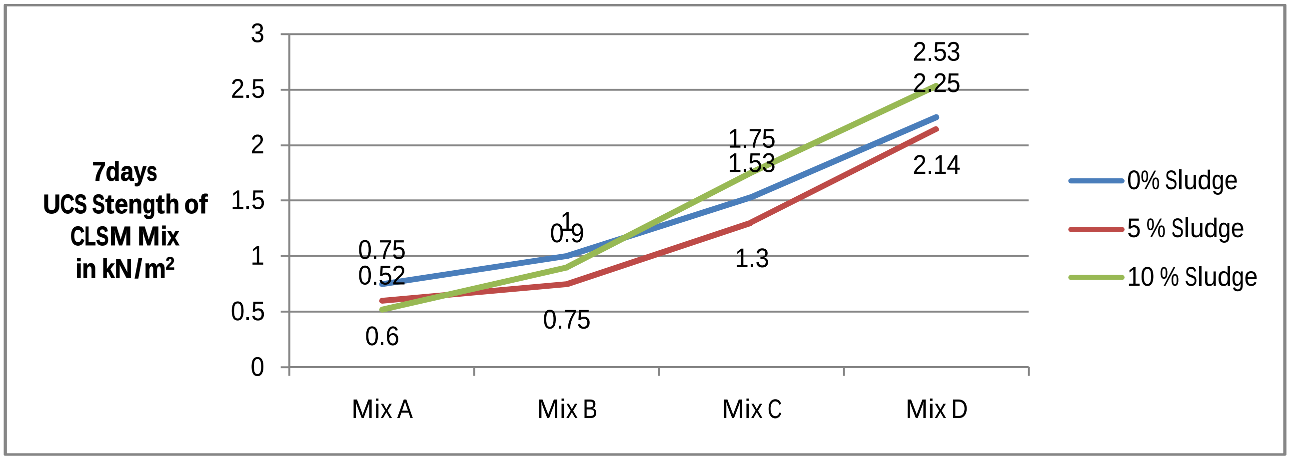

Fig. 4: 7 day's Unconfined compressive strength of CLSM Mix

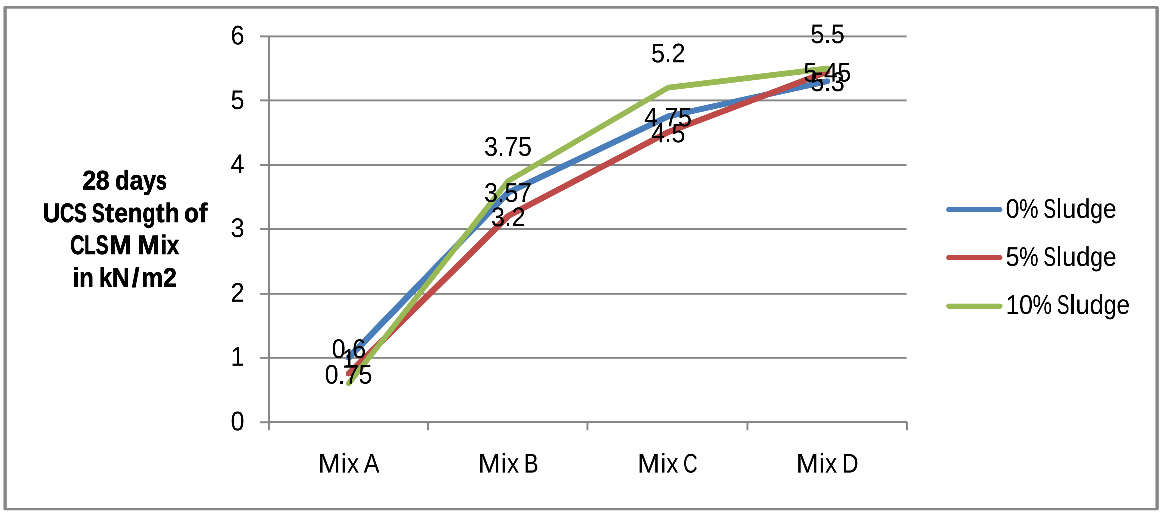

Fig. 5: 28 days Unconfined compressive strength of CLSM Mix