POURED EARTH CONCRETE (PEC)
RESEARCH

POURED EARTH CONCRETE (PEC) WITH RECYCLED CONSTRUCTION WASTE AGGREGATES (CWA)

PRELIMINARY REPORT

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1. INTRODUCTION

1.1 BRIEF BACKGROUND OF RESEARCH

Construction waste is one of the major unaddressed problem areas, globally. Responsible management of waste should be an essential aspect of sustainable constructions and infrastructure development. In this context, managing waste means eliminating waste where possible minimizing waste where feasible and reusing materials which otherwise may become waste. Waste management practices have identified reduction, recycling, and reuse of wastes, essential for sustainable management of resources.

1.1.1 Scenario: Construction industry India

The construction industry in India is at its boom. It is growing at an annual rate of 10 per cent over the last decade as compared to a world average of 5.5 per cent. Yet 70 per cent of the building stocks are yet to be constructed. Buildings, construction and infrastructure are not just the core, but also an outcome of our demands. The core essence of infrastructural development is demand for water, energy and material resource. However one of the major outcomes of the construction industry is the 'construction and demolition' waste.

A new construction generates about 40-60 kg of construction and demolition waste per sq. meter, with an average of 50 kg per sq. meter. There is no systematic database for this waste. Not just are options of reusing the waste absent, but the various laws existing are manipulated, such that, it helps individuals excuse themselves from using reused or recycled materials.

1.1.2 Schmidt MacArthur Fellowship

The Schmidt-MacArthur Fellowship is an international postgraduate fellowship on the circular economy for design, engineering and business students. The Fellowship programme is delivered by the Ellen MacArthur Foundation with expert input from Cranfield University, Imperial College London and London Business School.

As a fellow for the year 2014-15, I took it up to develop a 'circular economy' model in the construction sector, relevant in the Indian context and to regions with similar setups. The areas of concern, while developing such a system were sources of construction waste, social groups that can get involved, technological feasibility and the socio-economic impact of the entire chain.

1.1.3 Aim of project

Hypothesis
'Poured earth concrete with construction waste aggregates can be used in wall construction applications.'

Aim of the experiment
a) Determine the differences of behaviours and properties using different CWA as an inclusion in PEC, at a given and fixed mix ratio.
b) Test a full CWA gradation according to the sizes of CWA available (Soil + cumulative CWA)

Auroville Earth Institute gave me the opportunity to work with their 'poured earth concrete' (PEC) technology as the start point of my project. The technique of PEC is a new field of research which was begun in 2011, by Auroville Earth Institute[1].

This report documents experiments of integrating various construction waste aggregates in the poured earth concrete. This mix was made to cast test samples for wall application. The idea behind this experiment is to see the viability of using construction waste as an inclusion, in the earth body, for poured earth concrete applications.

1.2 HISTORY & PREVIOUS RESEARCH

Earth is a potential building resource. Use of PEC is relevant in today's scenario as it helps in building forms relatively faster. PEC also opens the possibility to experiment with various shapes and forms.

It became a significant field of investigation at the Auroville Earth Institute since five students spent about six months on the subject one after another. A series of tests and sample casting were done to optimize the properties of the concrete. Various studies of aggregates using soils from Auroville, Mangalam and Thiruvakkarai have been carried out in the past. These aggregates were mixed with a broad range of binders, additives, stabilizers and plasticizer to reach the best properties at best cost and sustainability[4].

For the purpose of this experiment, the 'Théo wall Report' and 'Léo and Théo Final Synthesis Report' have been used as references to begin this experimentation. They carried out a detailed study of soil analysis, mix proportions, concrete behaviour, casting samples and casting their final prototype for wall application.

They used the following definitions to elaborate on their study[3]:

a) *Aggregates* are soils and different size of gravels and pebbles added in the mix which make the main composition of earth concrete.
b) *Additives* are cement, lime and other components added in small quantities.
c) *Dry mix* is the mix without water i.e. aggregates and additives.

1.2.1 Mix Design by Léo Boulicot and Théo Vinceslas

The standard mix composition used for this experiment has been taken from the 'Théo walls report' considering it as their composition to give the best results.

The table of composition is as follows[2]:

Aggregates + soil % in volume					
Red Soil (%)	½" (%)	1" (%)	2" (%)	Cement (%)	Lime (%)
40	10	30	20	9	0 – 1?

Note:
However, 1% lime has been used to cast samples for this experiment. It is so because on referring to the 'Léo and Théo Final Synthesis Report' it was noted that, they had used lime in order to obain their results, cast samples and cast walls.

2. TESTING PROTOCOL

2.1 MATERIALS REQUIRED FOR PREPARING DRY MIX

The constituents of the dry mix are as follows:
(a.) Soil
(b.) Cement
(c.) Lime
(d.) Gravel
(e.) Construction waste aggregates(CWA)
(f.) Water

2.1.1 Soil
The aim of this experiment is to design a PEC for wall applications with 40% soil. The soil for this experiment has been procured from Thiruvakkarai, a village 20km from Auroville.

2.1.2 Cement
The cement is added to the mix as it acts as a binder. In case of earth concrete, it acts as a component that enables the clay to get stabilized against water.

2.1.3 Lime
Lime is an additive in the mix. It protects the skeleton compound of aggregates and helps to gain resistance against humidity, erosion and degradation caused due to any kind of climatic conditions. Addition of lime also has an effect on the water absorption[3].

Léo & Théo in their final synthesis report', have recorded the effect of the quantity of lime, on the water absorption[3]. The same is represented in graph 8 of the Léo & Théo Final Synthesis Report[3].

2.1.4 Gravel
The gravel added in the mix is a form of Basalt. It is also referred to as 'blue metal'. Gravel of sizes ½", 1" & 1 ½" have been added to the mix. The proportion of gravel added to a mix depends upon the quantity of soil in any mix. The size of the gravel added also has an impact on the water absorption.

2.1.5 Construction waste aggregates (CWA)

There is a vast range of construction waste that exists. The following post-industrial CWA have been taken into consideration to be integrated with PEC, for wall application.

(a.) CSEB Waste
(b.) Fired brick waste
(c.) Concrete debris

(a.) CSEB Waste:
Auroville Earth Institute deals with manufacturing CSEBs intensively. It was observed that there was a considerable stock of reject and CSEB waste. It comes from various reasons such a damaged blocks, demolition, experimentation and prototyping. Having been based out of the institute, it was a good opportunity to consider CSEB waste as an aggregate to be considered for this experiment. It would also prove to be highly

efficient if this experiment could lead to successful reuse of the material. The CSEB waste was procured from the Auroville Earth Institute and was considered as a local source of the CWA, with respect to the experiment location.

(b.) Fired brick waste:
Fired brick waste is the most common waste output where red brick construction is carried out. A drawback in the waste is that most of the bricks are unevenly broken into different sizes and hence are difficult to be used in new construction. Another source of red brick waste is demolition sites. The wastes are neither dumped in landfills nor considered for recycle of reuse.

The red brick waste has been procured from various sites in and around Auroville. The idea was to look for a source of raw materials locally and find solutions to address the issue of littered construction waste.

(c.) Concrete debris:
The concrete debris were procured from a firm m/s Rock Crystals Pvt. Limited, based out of Bangalore, Karnataka. The firm deals with collecting concrete waste from various construction sites and legalized landfills. They have a plant on the outskirts of Bangalore, where they use high end industrial techniques to crush the debris into different sizes, including powder.

The purpose of sourcing the material from Bangalore was to encourage various firms dealing with, processing concrete waste. They prepare recycled aggregates but have limited outlet or market to source the same. This experiment aims to provide new range applications so as to enable the use of recycled aggregates.

2.2   PREPARATION

The testing procedure includes casting of cylindrical samples of PEC integrated with CWA. In order to carry out the relevant tests on the samples, 6 cylinders of each mix were casted. The cylinders are of the following dimensions:

Height = 300mm
Diameter = 306mm
Volume = 21.20L

No. of cylinders to be casted/mix = 6
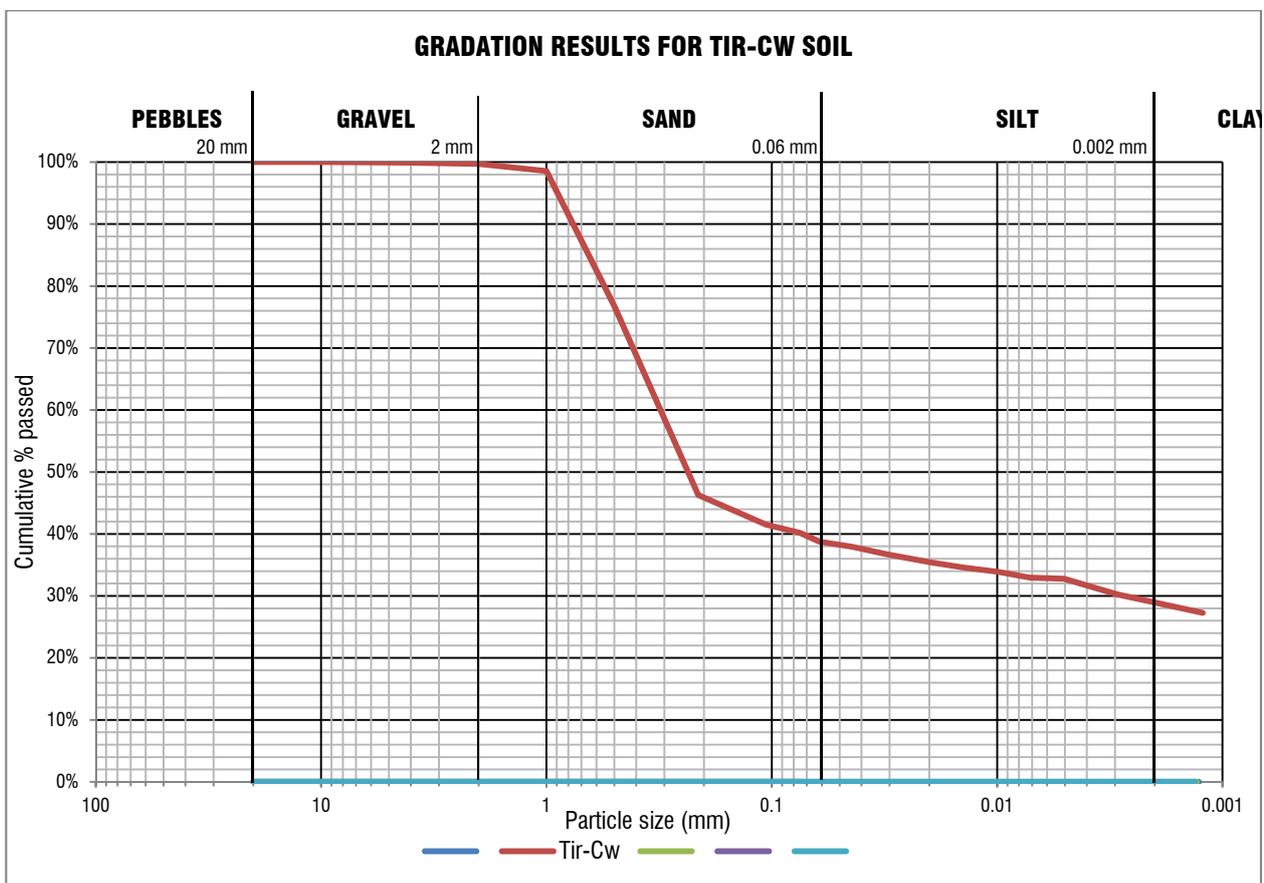Total number of cylinders casted = 7x6 = 42

The tests to be carried out on the samples are as follows:

(a.) Slump Test
(b.) Water absorption
(c.) Compressive strength

2.2.1   Soil Characteristics

Tir- Cw		
S.No	Particle Diameter (mm)	%
1	20	100.00%
2	10	100.00%
3	4	99.91%
4	2	99.69%
5	1	98.55%

6	0.5	76.77%
7	0.212	46.28%
8	0.106	41.52%
9	0.075	40.18%
10	0.06133	37.50%
11	0.04363	36.70%
12	0.03111	35.57%
13	0.01986	34.28%
14	0.01412	33.48%
15	0.01002	32.83%
16	0.00711	31.86%
17	0.00503	31.70%
18	0.00294	29.28%
19	0.00123	26.39%

GRADATION RESULTS FOR TIR-CW SOIL

2.2.2 Densities

The two densities calculated to understand the physical description of the soil are specific and bulk densities.

(a.) Specific Density
It is the mass of a material by volume unit. In a homogeneous material, it is an intrinsic property[3].

(b.) Bulk density
It is used to characterize a fractioned sample. The visible volume (included matter, porosity and spaces between grains) is used instead of the real volume (corresponding to the volume of full matter).

<u>Bulk densities of different materials</u>

(a.) Soil - Thiruvakkarai

Tir-Cw	ρ_{bulk} (kg/L)
Full Distribution	1.4978

(b.) Gravel

Size	ρ_{bulk} (kg/L)
½"	1.426
1"	1.5102
1 ½"	1.4603

(c.) CSEB

Size	ρ_{bulk} (kg/L)
½"	1.0014
1"	0.99
1 ½"	0.94
Full distribution >10mm & <50mm	1.09

(d.) Red Brick

Size	ρ_{bulk} (kg/L)
½"	1.001
1"	1.05
1 ½"	0.95

(e.) Concrete Debris

Size	ρ_{bulk} (kg/L)
½"	1.27
¾ "	1.32
2"	1.20

2.2.3 Mix compositions

The construction waste aggregates used to cast PEC samples are:

(a.) CSEB Waste

    i. CSEB 1 – a sample with ½", 1" and 1 ½" CSEB aggregates.
    ii. Full CSEB – a sample of CSEB waste containing an average distribution of aggregates <50mm and >10mm

(b.) Fired brick waste
(c.) Concrete debris

The control sample had a standard composition which was used as reference to design the mixes with the other CWA. The compositions of each mix are as follows:

I. Calculations for Control Sample(bulk density 1.3)

DATA		THEORETICAL CALCULATIONS			CALCULATIONS FOR SAMPLE		
Components	Bulk densities	Desired %	Theo. weight per bag of cement (Kg)	Theo. Vol. per cement bag (L)	Actual % by approx. Volume	Exact bulk Vol. required (L)	Exact bulk weights required (Kg)
Cement	1.2083	9.00%	50	41.380	8.26%	16.153	19.517
Lime	0.6462	1%	5.556	8.597	0.99%	3.356	2.169
Soil	1.4978	40%	223.860	149.459	40.00%	58.341	87.383
Gravel chips	1.4495	0%	0.000	0.000	0.00%	0.000	0.000
Gravel 1/2"	1.4260	10%	53.282	37.365	10.00%	14.585	20.798
Gravel 1"	1.5102	30%	169.285	112.095	30.00%	43.755	66.079
Gravel 1.5"	1.4603	20%	109.128	74.730	20.00%	29.170	42.597
	Total	100%	611.111	423.626		165.360	238.544

I(a.) Repeat: Calculations for control sample (bulk density 1.5)

DATA		THEORETICAL CALCULATIONS			CALCULATIONS FOR SAMPLE		
Components	Bulk densities	Desired %	Theo. weight per bag of cement (Kg)	Theo. Vol. per cement bag (L)	Actual % by approx. Volume	Exact bulk Vol. required (L)	Exact bulk weights required (Kg)
Cement	1.2083	9.00%	50	41.380	10.18%	19.008	22.967
Lime	0.6462	1%	5.556	8.597	2.41%	4.134	2.671
Soil	1.4978	40%	223.860	149.459	41.10%	68.901	103.199
Gravel chips	1.4495	0%	0.000	0.000	0.00%	0.000	0.000
Gravel 1/2"	1.4260	10%	53.282	37.365	10.96%	18.374	26.201
Gravel 1"	1.5102	30%	169.285	112.095	27.40%	45.934	69.369
Gravel 1.5"	1.4603	20%	109.128	74.730	20.55%	34.450	50.308
	Total	100%	611.111	423.626		190.800	274.715

Note:

Casting No.	Bulk Density	Water added	Slump result	Issues
1	1.3	10.5+17+0.5= 28L	20mm	• The control sample was casted using gravel of sizes, ½", 1" and 1 ½". • The slump was insufficient as per the recommendation. This happened as the largest size aggregates were larger than 40mm, which made the process of compaction, in the slump test difficult, giving an incorrect result.
2 (Repeat Casting)	1.5	2x10.5+2x5+2x1 = 33L	45mm	• The first mix was prepared considering a bulk density of 1.3. However, this mix was not sufficient to cast 6 sample cylinders. In order to prepare a mix sufficient to cast 6 cylinders, the calculation was revised, with a bulk density of 1.5.

II. Ca lculations for CSEB 1 (a sample with ½", 1" and 1 ½" CSEB aggregates)

DATA		THEORETICAL CALCULATIONS			CALCULATIONS FOR SAMPLE		
Components	Bulk densities	Desired %	Theo. weight per bag of cement (Kg)	Theo. Vol. per cement bag (L)	Actual % by approx. Volume	Exact bulk Vol. required (L)	Exact bulk weights required (Kg)
Cement	1.2083	9.00%	50	41.380	8.49	16.631	20.096
Lime	0.6462	1%	5.556	8.597	1.07	3.617	2.337
Soil	1.4978	40%	281.011	187.616	39.47	72.344	108.357
CSEB Distribution	1.09	0%	0.000	0.000	0.00	0.000	0.000
CSEB 1/2"	1.0014	10%	46.970	46.904	10.09	18.488	18.514
CSEB 1"	0.99	30%	139.286	140.712	30.70	56.268	55.697
CSEB 1.5"	0.94	20%	88.288	93.808	30.70	36.172	34.043
	Total	100%	611.111	519.018		203.520	239.045

Note:

Casting No.	Bulk Density	Water added	Slump result	Issues
1	1.6	4x10.5+9x1=51L	35mm	• The vibrating machine broke down before the casting could be completed and the entire process took 1hr 15 minutes instead of 30 minutes. • The casting had to be carried out again due to the same. • The process of mixing creates a lot of CSEB powder, which leads to greater water absorption than calculated.
2 (Repeat Casting)	1.6	4x10.5+0.5= 42.50L	36mm	• The mix was not sufficient to cast 6 cylinders. Only 5 cylinders could be casted. • The mix was prepared carefully not to create CSEB powder. • This lead to a lesser amount of water addition to the mix than calculated.

III. Calculations for Full CSEB Sample(a sample of CSEB waste containing an average distribution of aggregates <50mm and >10mm)

DATA		THEORETICAL CALCULATIONS			CALCULATIONS FOR SAMPLE		
Components	Bulk densities	Desired %	Theo. weight per bag of cement (Kg)	Theo. Vol. per cement bag (L)	Actual % by approx. Volume	Exact bulk Vol. required (L)	Exact bulk weights required (Kg)
Cement	1.2083	9.00%	50	8.597	16.436	16.436	19.859
Lime	0.6462	1%	5.556	8.597	2.11%	3.575	2.310
Soil	1.4978	40%	265.910	177.533	41.86%	71.493	107.083
CSEB Distribution	1.09	60%	289.646	266.300	58.14%	99.296	108.001
Gravel 1/2"	1.4260	0%	0.00	0.00	0.00	0.00	0.00
Gravel 1"	1.5102	0%	0.00	0.00	0.00	0.00	0.00

Gravel 1.5"	1.4603	0%	0.00	0.00	0.00	0.00	0.00
	Total	**100%**	611.111	493.811		190.800	237.253

Note:

Casting No.	Bulk Density	Water added	Slump result	Issues
1	1.5	4x10.5+5+1= 48L	40mm	-

IV. Calculations for Fired Brick Sample

DATA		THEORETICAL CALCULATIONS			CALCULATIONS FOR SAMPLE		
Components	Bulk densities	Desired %	Theo. weight per bag of cement (Kg)	Theo. Vol. per cement bag (L)	Actual % by approx. Volume	Exact bulk Vol. required (L)	Exact bulk weights required (Kg)
Cement	1.2083	9.00%	50	8.597	10.18%	22.809	27.560
Lime	0.6462	1%	5.556	8.597	1.30%	4.961	3.206
Soil	1.4978	40%	265.910	177.533	41.10%	82.681	123.839
CSEB Distribution	1.09	0.00	0.00	0.00	0.00	0.00	0.00
Fired brick 1/2"	1.0010	10%	46.180	46.134	10.96%	22.048	22.070
Fired brick 1"	1.05	30%	145.322	138.402	27.40%	55.121	57.877
Fired brick 1.5"	0.95	20%	87.655	92.268	20.55%	41.340	39.273
	Total	**100%**	**611.111**	**511.318**		**228.96**	**273.826**

Note:

Casting No.	Bulk Density	Water added	Slump result	Issues
1	1.8	2X22 + 10 = 54L	31mm	• A mix containing fired brick aggregates absorbs less water as compared to one with CSEB aggregates.

V. Calculations for Concrete Debris Sample

DATA		THEORETICAL CALCULATIONS			CALCULATIONS FOR SAMPLE		
Components	Bulk densities	Desired %	Theo. weight per bag of cement (Kg)	Theo. Vol. per cement bag (L)	Actual % by approx. Volume	Exact bulk Vol. required (L)	Exact bulk weights required (Kg)
Cement	1.2083	9.00%	50	8.597	10.18%	22.809	27.560
Lime	0.6462	1%	5.556	8.597	1.30%	4.961	3.206
Soil	1.4978	40%	265.910	177.533	41.10%	82.681	123.839
CSEB Distribution	1.09	0.00	0.00	0.00	0.00	0.00	0.00
Concrete debris 1/2"	1.1710	10%	49.793	42.522	10.96%	22.048	25.818
Concrete debris 1"	1.217	30%	155.247	127.565	27.40%	55.121	67.082
Concrete debris 1.5"	1.126	20%	95.759	85.044	20.55%	41.340	46.549
	Total	100%	611.111	475.196		228.960	294.055

Note:

Casting No.	Bulk Density	Water added	Slump result	Issues
1	1.8	1X22+10+4+ 4+3=43L	35mm	• A mix with concrete aggregates absorbs lesser water during the process of mixing, as compared to the mix with CSEB and fired brick aggregates.

2.3   TESTING PROCEDURE

The tests to be carried out on the samples are as follows:

a) Slump Test
b) Water absorption
c) Compressive strength

2.3.1   Slump Test

The slump test is a test done onsite, while casting the structure, applied for usual concrete. It helps to determine the consistency of a mix, before being poured, in order to reach the property of workability set depending on the technique used.

According to previous researches done in the Institute, the mix must have the possibility to be vibrated easily with a vibrating machine. The use of this machine permits to decrease the amount of water in the mix while avoiding air bubbles inside and reorganising as well as possible the aggregates.

The Abraham's cone (with normalised dimensions as in standardised European protocol NFP 18-451) is used to carry out the slump test. It is greased, and then full by layers of around 15cm, each one rammed with a bar of 1.6cm diameter. The top surface is then smoothed and the mould cone is removed and placed close to the concrete cone and the slump is measured. The slump needed for PEC wall application is between 25 and 50mm according to 'IS.10262.2009[5] - Concrete Mix Design'.

2.3.2   Water Absorption

Water absorption is a consequence of the samples drying. Drying creates porosity and allows water to be absorbed through the pores. It is important to minimize water absorption as it decreases the strength of the material which requires being steady for the monsoon season
.

2.3.3 Compressive Strength

Compressive strength is one of the nominative characteristics of concrete. The compressive strength test is used test to determine the main property of a concrete, the compressive strength. Knowing that for a building material, as earth concrete, strains are mainly put from the top to the bottom, the compressive strength is essential. There are other strengths (traction ore bending strengths due to the buckling for example) but less important, in first approximation, considering dimensions of applied structures.[2]

The compressive strength is measured on cylindrical samples (dimensions: 306mm diameter and 300 mm height), poured into plastic moulds. The dry compressive strength is tested after 10 days of drying under the sun (because of the lack of an adapted oven). The wet compressive strength is tested just after having weighted the wet samples for the water absorption test.[3]

The compressive machine used is a hydraulic machine, not able to measure deformation. The higher value of charge applied on sample's parallel surfaces is recorded and the compressive strength is automatically deduced (after complete dimensions of samples). The speed of loading is 5kN/s, deduced from the flow of the oil pumped. Compressed cardboard sheets are added in order to avoid surface defaults, keeping a good compressive strength's estimation.[3]

$$Compressive\ Strength\ (MPa) = 10 * \frac{Load}{Area}$$

Load: applied on parallel area by the machine, measured with an integrated sensor (kN)
Area: determined with the diameter measure, measured with a calliper (cm²).
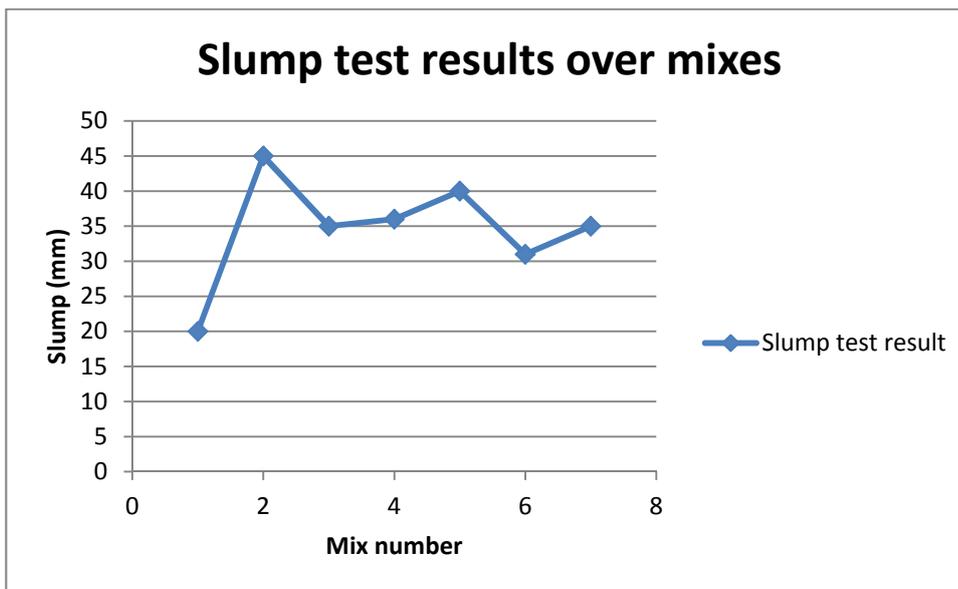
3. TEST RESULTS

3.1 TESTS CONDUCTED UPTIL 19MAR, 2015

S.No	Test	Status
1	Slump Test	Conducted
2	Water Absorption	Pending
3	Compressive Strength	Pending

3.1.1 Slump Test

S.No	Mix Name	Mix Code	Notes	Bulk Density	Water Added (L)	Slump result (mm)

1	Control Sample 01	PEC CWA-C	Do not consider for testing: - Largest aggregate was >45mm - This made the compaction process of the slump test difficult.	1.3	28	20
2	Control Sample 02	PEC CWA-C	-	1.5	33	45
3	CSEB 1	PEC CWA CSEB1	Vibrating machine broke down in the middle of the experiment.	1.6	51	35
4	CSEB 2	PEC CWA CSEB 2	-	1.6	42.5	36
5	Full CSEB	PEC CWA CSEB FULL	-	1.5	48	40
6	Fired Bricks	PEC CWA Fired Bricks	-	1.8	54	31
7	Concrete Debris	PEC CWA Concrete Debris	-	1.8	43	35

Slump test results over mixes

3.1.2 Water Absorption

The test will be conducted on the samples 28, days post casting as the period is used to cure the sample.
The results will be recorded post testing.

3.1.3 Compressive Strength

The test will be conducted on the samples, 28 days post casting as the period is used to cure the sample.
The results will be recorded post testing.

4. RECOMMENDATIONS

4.1   MEASURING DENSITY

(a.) In order to calculate the density, the dimensions of the container used for weighing the material must be measured with maximum possible accuracy.

(b.) The weight should be measured 3 times in order to take the average.

(c.) The material should be levelled well, before taking the reading.

(d.) The readings for each material must be taken with and without shaking the container. When the container is filled with the respective material, there are inevitable air traps between the particles. 3 readings must be taken without shaking the container, i.e. leaving it levelled and undisturbed.

However when you shake the container, the air trapped gets released creating some vacant space in the container. More material can be filled into the container, in the newly created vacant space. This should be levelled again before taking the reading. 3 reading must then be taken, after shaking the container.

Hence,

Total number of readings = 6
Without shaking container = 3
Shaking the container = 3

(e.) It must be decided before the calculations as to which set of readings would be considered for the calculation of the bulk density, i.e. the reading with or without shaking the container. This choice must act as the standard for the entire experiment and calculations.

4.2   PREPARATION OF DRY MIX

(a.) The dry mix must be prepared well as it is hand mixed and not machine mixed.

(b.) There must be two labourers/masons who work together to prepare a dry mix, as it not only enables better mixing but is also essential after addition of water, as time is a constraint.

4.3   ADDITION OF WATER

(a.) The amount of water needed for the entire mix must be calculated before the mixing begins. The standard documents must be referred to, for the same.

(b.) The ideal time for the process of casting the samples should be 30 minutes. Timing the process can begin by considering the point of 'addition of water' as the start point and 'vibrating the mix and levelling the top' of the mix in the cylinders as the end.

(c.) This ideally means that adding water and mixing must be finished in about 15 minutes and the casting, levelling and finishing must be done in the next 15 minutes.

(d.) The factor of time is important as the concrete starts setting within 20-30 minutes from the point of addition of water to the dry mix.

(e.) If there is a delay in this process, the concrete starts to set before the right slump result and workability is achieved.

(f.) This condition further compels one to add more water than calculated. In case of additional water added, the right workability might be achieved but, it is eventually harmful for the sample. Larger amounts of water lead to cracking of the sample, hence giving inappropriate results.

4.4   SLUMP TEST

(a.) The standard slump for the particular PEC application must be noted before the experiment commences. This must be calculated or taken from standard documentation available[5].

(b.) The cone must be greased well before the test. Nevertheless, over-greasing must be avoided.

(c.) The mix must be added only three times to almost fill the cone. The mix must be rammed about 20 times by a rod approximately, 1.6cm in diameter, each time the mix is added to the cone.

(d.) The mix must not be rammed after adding the mix for the last time, when the cone is filled completely. It must also not be compressed by hand. It must only be levelled.

(e.) Avoid shaking the cone before removing it to measure the slump.

(f.) Parallax error must be avoided while taking the reading.

REFERENCE

(a.) http://www.earth-auroville.com/

(b.) http://www.cseindia.org/userfiles/Construction-and%20-demolition-waste.pdf

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