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Preliminary Investigations into Behavior of Load Bearing Structure Using Non-Autoclave Aerated Concrete

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ABSTRACT :*Since the time immemorial, load bearing structures are constructed using burnt / unburnt bricks having compressive strength ranging from 1.5 to 3.5 MPa and above. An attempt have been made in this paper to present preliminary analytical & experimental investigations into behavior of load bearing structure using Non Autoclave Aerated Concrete using the reinforced foam concrete walls. Reinforced foam concrete walls are cast monolithically to receive the load transmitted from roof slab and transfer it to strata. The Foam concrete being light weight, dead load is expected to be reduced. As the casting of walls is carried out monolithically with the slabs, the construction time may be reduced drastically up to in 7 days depending upon the size & extent of construction with nominal workforce. It will also facilitate the repeated use of shuttering & formwork. For making foam concrete sand is eliminated upto 75% and replaced by 10 mm metals. This will help us to counter the problem of shortage of sand. Foam concrete walls can act as good thermal insulator and can be used for extreme weather conditions. For preparation of foam concrete aluminum and liquid foaming agent are used.*

KEYWORDS *- coarse aggregate, foaming agent, Foam concrete, NAAC(Non Autoclaved Aerated Concrete), sand*

I. INTRODUCTION

Traditionally, aerated concrete is autoclaved in order to achieve the high compressive strength necessary for structural use. While the high temperatures and pressures from the autoclaving process give rise to crystallization and thus high compressive strength, the process is extremely energy intensive. Eliminating autoclaving would save significant energy and will also solve the problem of autoclaving at work site, but other methods would need to be employed to maintain good compressive strength. Thus, the primary aim of this project is to develop a form of concrete with a high strength to density ratio: low density for high materials efficiency and high compressive strength with the elimination of autoclaving.

- Our prototype is a non autoclaved aerated concrete (NAAC) with two main benefits: Efficient material usage due to a porous structure and less embodied energy due to the elimination of autoclaving.
- Since aerated concrete is less dense than traditional concrete, it uses less material. The use of aerated concrete would cut down on emissions and energy associated with the primary materials used in concrete.

The demand of natural sand is quite high in developing countries to satisfy the rapid infrastructure growth due to extensive use of concrete; causing very high global consumption of natural sand. Now-a-days large amount of depletion of natural sand is causing a serious threat to the environment as well as society. Increasing extraction of natural sand from river beds causes many problems like retaining sand strata, deepening of the river courses and causing bank slides, loss of vegetation on the banks of rivers, exposing the intake well of water supply schemes, disturbs the aquatic life and also affecting agriculture due to lowering the underground water table etc are few examples. Now a day's sand is becoming a very scarce material, in this situation research began for inexpensive and easily available alternative material of natural sand. Some alternative materials have already been used as a part of natural sand e.g. fly-ash, slag lime-stone and siliceous stone powder are used in concrete mixtures as a partial replacement of natural sand. In this paper we are worked on replacing sand by fly ash and 10mm metal. Traditionally the Frame structures are usually constructed with components like slabs, columns and beams. The load is shared and transmitted by all and hence components only so the grade of the concrete required is moderately high M20 (density $24KN/m^3$), however if equal load is shared by all the components (i.e. monolithic construction of walls, slabs and columns of same grade) then the grade of concrete required is significantly low M5 (density $12KN/m^3$)for one or two storey building. The purpose can be fulfilled by using light weight concrete. So we aimed at preparation of **non autoclave aerated concrete**. Since we are using light weight concrete, the dead load transferred from floor to floor is reduced considerably. So load coming on substructure is also reduced. We are also aiming at comparing Frame structure design with NAAC structure. **Since no Indian standard code is available** for foam concrete, extensive laboratory research programme has to be carried out in addition to previous research work is referred for the design of foam concrete.

II. CONCRETE FORMATION

2.1 Aluminum Powder as foaming agent

The reactions that drive the concrete formation process are essential to understanding the optimization process of NAAC. The ingredients that comprise NAAC and their descriptions are presented

Table No. 1 Constituents of the foam concrete

Raw material	Description
Aluminum Flake	Reacts with water and Quicklime to form hydrogen gas, aerating the concrete
Type I/II Portland Cement	Provides most of the compressive strength in its hydrated form and acts as a binding agent
Quicklime	Facilitates aluminum aeration reaction and acts as a binding agent
Water	Hydrates the portland cement to increase compressive strength, and reacts with Quicklime to form calcium hydroxide
Fine Sand	Acts as a filler/aggregate
Fly ash	Acts as a filler
TiO_2	To enhance strength

The aeration of NAAC is fundamentally the result of the chemical reaction of aluminum with water to produce hydrogen gas, which becomes entrapped in the concrete slurry and forms voids, creating the cellular structure required for NAAC. Although the reaction between aluminum and water is thermodynamically favorable, the aluminum oxide layer on the surface of the aluminum inhibits the reaction, requiring the presence of Ca(OH)2 to aid in the removal of the oxide layer.2 Quicklime, otherwise known as calcium oxide, exothermically reacts with water to form calcium hydroxide, which then facilitates the aluminum reaction:

CaO + H2O = Ca(OH)2 (1)

Portland cement, sand, lime, and water form the hardened concrete matrix. Many types of cement are available in the market, but the most commonly used is Portland cement, which contains ~75% various forms of calcium silicates, as well as a combination of aluminates and metal oxides. The two calcium silicates most commonly found in Portland cement are (CaO)3*SiO2 (alite) and (CaO)2*SiO2 (belite), and the main oxides in Portland cement are CaO,SiO2, Al2O3, Fe2O3, MgO, and SO3.5 The curing reactions in concrete involve the hydration ofthe Portland cement to form calcium silicate hydrates (CSH).Allite, for example, is formed inthe following stoichiometric reaction, with calcium hydroxide also formed as a byproduct:

2(CaO)3*SiO2 + 6H2O = (CaO)3*(SiO2)2*(H2O)3 + 3Ca(OH)2 (2)

In AAC, all components of the concrete slurry are exposed to temperatures of ~180oC and pressures of ~800 kPa; consequently, chemical reactions which may not occur at STP go to completion and all the processes occur much more quickly. Principally, the CSH formed in the hydration reactions are crystalline, providing AAC with high strength. The most prevalent crystalline mineral formed is tobermorite; however, other mineral phases are present. Conversely, in NAAC, the hydration of Portland cement results in various amorphous CSH products, displaying poor crystallinity and resembling a porous solid/rigid gel referred to as tobermorite gel, due to its chemical resemblance to the sought after product from autoclaving. However, tobermorite gel is inherently weaker than crystalline tobermorite. Additionally, while autoclaving reduces the curing process to a matter of hours, NAAC requires at least several months of curing to reach full compressive strength

III. SAMPLE PREPARATION

The samples of foam concrete are prepared initially for checking the strength and the desired density of foam concrete. So the samples are prepared without addition of $TiO_2$and lime(TYPE 1) initially but as the strength given by these sample is not meeting the requirement the $TiO_2$and lime is added to increase the strength(TYPE 2). The dose of $TiO_2$is referred from the previous research of various authors. The procedure of sample preparation is same for the both(i.e. TYPE 1 and TYPE 2).

Initially all the dry constituents sand, cement, 10 mm metals, lime and TiO_2(added only for TYPE 2) are mixed until a homogeneous mix is formed . Then water with some plasticizer(to increase the workability) is added and a slurry mix is obtained. Before half to one minute of the pouring the mixture into the cubes aluminium powder is added and mixed thoroughly. Because as the aluminium comes in the contact of the cement constituents in the presence of water the reaction is get started and hydrogen gas evolves which is mainly responsible for the aeration. The cubes are of dimension 150mm.

IV. SAMPLE PROPORTION

As the investigation is totally based on the NAAC (Non Autoclaved Aerated Concrete) the proportions of the different constituents are referred from the previous research for autoclave aerated concrete. However, as there is no IS code is provided the investigation is based on previous researches.

Table N0. 2 Proportions for NAAC without TiO_2 and lime

Required Density (Kg/m^3)Design Prop	1200	1400
Target Comp. Strength (N/mm^2)	6.5	12
W/C+F.A Ratio	0.55	0.5
OPC (Kg)	294	336
Fly Ash (Kg)	126	144
Fine Sand (Kg)	549	680
Water(Kg)	231	240
Aluminium (Kg)	1.176	1.344

Table No. 3 Proportions with $TiO_2$and Lime

Required Density (Kg/m^3)Design Prop	1200	1400
Target Comp. Strength (N/mm^2)	6.5	12
W/C+F.A Ratio	0.55	0.5
OPC (Kg)	294	336
Fly Ash (Kg)	126	144
Fine Sand (Kg)	549	680
Water(Kg)	231	240
Lime (Kg)	97	116
TiO_2 (gm)	485	700
Aluminium (Kg)	1.176	1.344

Theoretically the w/c ratio is about 0.5 but practically as the lime and flyash is added to the mix the w/c ratio increases because of the some amount of water is required to wet these material. The above proportions are given for full sand but one of the part of the investigation is to reduce the use of sand and hence only for the proportion weight of the sand. the sand is replaced by 25%, 50%, 75% . Thus in TYPE 1 and TYPE 2samples we again have four variations of **agg:sand**(i.e.0:1 ,1:3, 1:1, 3:1)

V. EXPERIMENTAL RESULTS

In TYPE 1 samples (without TiO_2 and lime) all the cubes are placed for water curing. For the TYPE 2 samples (with $TiO_2$and lime) half of the cubes are placed for water curing and half are kept as it is in the cubes. The strength is checked at 7 days and 28 days respectively.

Table No. 4 Experimental Observations (TYPE 1samples)

Sr. No.	TiO_2, Lime	DENSITY (Kg/m^3)	SAMPLE	PROPORTION Agg:Sand	7 DAYS STRENGTH (MPa)	28 DAYS STRENGTH (MPa)
1	Absent	1200	A	1:0	0.7	1.2
			B	0:1	0.4	1.4
			C	3:1	0.6	1.2
			D	1:1	0.5	1.7
2	Absent	1400	A	1:0	0.9	1.7
			B	3:1	0.8	2.2
			C	1:1	0.7	2.0

The highest strength obtained for TYPE 1 Samples is 2.2 MPa but the strength requirement is about 5MPa

Table No. 5 Experimental Observations(TYPE 2 samples)

Sr. No.	TiO_2, Lime	DENSITY (Kg/m^3)	SAMPLE	PROPORTION Agg:Sand	7 DAYS STRENGTH (MPa)	28 DAYS STRENGTH (MPa)
1	Present	1400	A Curing	**1:0**	**1.4**	**1.7**
			A Dry	**1:0**	**1.3**	**2**
		1200	**B curingg**	**1:0**	**1.2**	**2.2**
			B Dry	**1:0**	**1.2**	**2**
2	**Present**	**1200**	**A Curing**	**3:1**	**1.3**	**2.7**
			A Dry	**3:1**	**1.2**	**2.3**

Due to presence of the TiO_2 and lime, the strength has been increased. And also the cubes placed for the water curing and the cubes kept dry are giving approximately the same value. So it can be inferred that NAAC upto 2.5MPa can be prepared with the help of TiO_2 and lime using aluminium as foaming agent.

VI. MATERIAL COST COMPARISON

Current rate of RMC in India is RS.4500/m^3 while if we calculate per m^3 cost of non-autoclave foam concrete it will cost around Rs.3500-3700/m^3. As the weight of the structure(using foam concrete) will reduced the cost of foundation will automatically decreased. In addition to this we need not required to provide sound and thermal insulation to building.

VII. CONCLUSION

As our aim is to construct the reinforced foam concrete load bearing structure by using NAAC it is necessary to have the foam concrete of desired grade. The use of non autoclaved concrete in place of autoclaved avails us to conserve the energy. Due to use of the foam concrete the Dead load is reduced considerably also it minimizes the time required for the construction. Due to the replacement of the sand by the 10 mm metals we aimed at ceasing the problem related to sand shortage. Thermal and sound insulation is one of the major advantages of foam concrete.

VIII. PROPOSED FUTURE WORK

Initially we targeted the strength of 5MPa but actually we are getting only upto maximum 2.7MPa for NAAC. In order to construct the reinforced foam concrete load bearing structure we require the minimum compressive strength of 5MPa for G+1 or G+2 buildings. But in order to achieve that strength further investigation are carrying out by preparing NAAC using liquid foam agent. Once the strength is achieved then further investigations on the properties of the NAAC foam concrete such as bond strength, shrinkage, soundness, impact resistance, flexural strength etc. Analysis of the structure is being carried out considering the load bearing structure ,all walls casted monolithically with reinforcement without column.

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