EFFECT OF ALKALINE ACTIVATORS ON FLY ASH BASED BAMBOO REINFORCED FERROCEMENT

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ABSTRACT

This paper reports a detail study of the effect of alkaline activators (sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3)) concentration on flexural strength of bamboo reinforced ferrocement GPC. The NaOH concentration used ranged from 6 M to 14 M. The flexural strength showed the optimum value when NaOH concentration is 12 M. Ferrocement is composite material of cement matrix and reinforcement having multiple layers of mesh. Ferrocement technologies are mostly used these days in many countries. These are associated with the features such as mechanical properties, advantages, design parameters, research and development, applications, and safety and economy factors. The work presents the results of an experimental investigation carried out to assess the strength of bamboo mesh ferrocement panel. There is a need to develop low cost building elements with the help of locally available materials to fulfil the demand of low cost houses. In rural areas the bamboo, available in abundance, may be utilized as replacement of common M.S or HYSD bars (a costly building material). Fly ash, a by-product from thermal power plants can replace cement in normal mortar or concrete. The objective is to investigate behaviour of bamboo reinforced geo-polymeric ferrocement paste, investigate combine effect of chicken mesh and bamboo reinforcement for geo-polymeric ferrocement paste. Experimental investigations on simply supported ferrocement slab panels subjected to monotonically increasing uniformly distributed load have been investigated. The experimental programme consists of testing ferrocement panels of size 450 mm X 230 mm with the thickness of 50 mm. Out of these slabs, some panels laid in chicken wire mesh with conventional mortar 1:3 and some after 15% cement replacement by fly ash with adopting grids of bamboo strips as skeletal reinforcement, were cast, cured under wet gunny bags for 28 days and then tested under loading and the test results obtained were compared with the theoretical results.

Keywords: Bamboo reinforcement, Ferrocement, Bamboo strips, Chicken wire mesh, Cement, Coarse Aggregate, sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3).

I. INTRODUCTIO

Ferrocement has a history of more than 170 years. The idea of impregnating closely spaced wire meshes with rich cement mortar is similar to the Kood type of age-old method of walling. In Kood system, bamboo and reeds are tied closely together and filled in with a mix of mud and cow dung as a matrix. It is used in rural areas of India. Hence Ferrocement may be called as a modified form of Kood with standardized raw materials, systematic method of construction and reliable structural properties. Here the mesh is used in place of bamboo and reeds, and cement mortar instead of mud. In the early Ferrocement is introduced by P L Nervi an Italian architect and engineer in 1940 and used ferrocement for shipbuilding to overcome the shortage of steel plates in the world war-II. Ferrocement has increased applications due to its properties such as strength, toughness, water tightness, lightness, ductility and environmental stability. Ferrocement can be constructed to any desired shape or structural configuration that is generally not possible with standard masonry, reinforced concrete or steel. Ferrocement can be cast in various shapes and forms even without the use of formwork. The thickness of ferrocement generally varies from 10 mm to 50 mm. Ferrocement repairs and rehabilitation can be done in reinforced concrete structures to increase its strength. Ferrocement which can be made from non – formwork construction process is an advantage over other type of repairs and strengthening techniques. It imposes small additional weight on the structures. This material proves to be a cost effective solution for rehabilitation and general applications. Ferrocement can be used to increase the ductility of masonry columns and walls. In geo-polymerization, activator such as alkaline solutions aids in the dissolution process of raw material. The most common alkaline activator used is a mixture of hydroxide (NaOH or KOH) and liquid silicates (Na_2SiO_3 or K_2SiO_3). The type of activator used depends on the cost and availability; sodium based chemicals are typically less expensive and readily available than potassium based chemicals. Several research have been done synthesizing geo-polymers from sodium based solutions, potassium based solutions and cesium based solutions.

1.1.Future Study

Green building and sustainable development are the two main parameters which need to focus as per environment point of view.

1.2. Objectives-

1. Main objective is to study the effect of NaoH concentration on flexural strength of bamboo mesh ferrocement panel.
2. To assess the strength of bamboo mesh ferrocement panel & steel wire mesh (chicken wire mesh) ferrocement panel.
3. To investigate behaviour of bamboo reinforced geo-polymeric ferrocement paste.
4. To investigate combine effect of chicken mesh and bamboo reinforcement for geo-polymeric ferrocement paste.
5. It is also a part of objective to innovatively produce bamboo mesh panels with more corrosion resistance and higher strength.
6.To fulfill demand of low cost houses by replacing cement as fly ash & steel as bamboo.

II. LITERATURE REVIEW

Brief information of the research work done by researchers about topic which will help us to decide about the subject is as given below.

Shaikh Anas R, et.al [March 2017][1] investigation aim the "comparative study of bamboo reinforcement, steel reinforcement and combination of bamboo mesh and steel mesh in ferrocement slab panels". The main objective of the study is to maximize the strength to weight ratio of ferrocement slab panels. Here the bamboo mesh plate is reinforced on bottom side to resist tensile forces and the steel mesh plate provided at the top for resisting compressive forces.

S. Jeeva Chithambaram, et.al [December 2016][2] study "flexural behaviour of bamboo based ferrocement slab panel with fly ash". this research work mainly focused on develop low cost building elements with the help of locally available materials to fulfil the demand of low cost houses. experimental investigations on simply supported ferrocement slab panels subjected to monotonically increasing uniformly distributed load have been investigated. the experimental programme consists of testing 12 ferrocement slab panels of size 470 mm 940 mm with the thickness of 40 mm and 50 mm each having 6 slabs. out of these slabs, 6 numbers with conventional mortar 1:3 and 6 after 15% cement replacement by fly ash, with adopting grids of bamboo strips as skeletal reinforcement, were cast, cured under wet gunny bags for 28 days and then tested under uniformly distributed loading and the test results obtained were compared with the theoretical results.

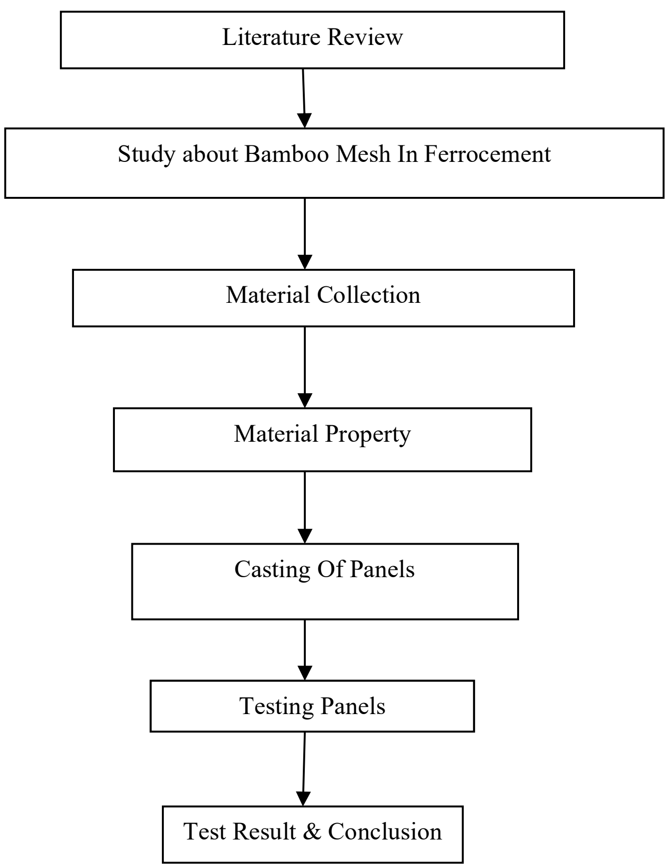
T. Subramani, et.al [May 2016][3], "Experimental study on Flexural And Impact Behaviour of Ferrocement Slabs". They studied particular behavior such as mechanical properties, and impact strength. The main aim of this work was to investigate the behavior of fibrocement reinforced with waste plastic fibers addition of 5% and 15% usage in ferrocement panels under impact loading. A total of 8 ferrocement panels with dimensions of 600mm x 600mm x 25mm (thickness) and 600mm x 400mm x15mm (thickness) were constructed and tested, 8 panels tested under low velocity impact. For impact test, the results showed that the addition of waste plastic fibers increased the number of blows which were required to make the first crack and ultimate failure, with the increase of number of pvc coated wire mesh layers.

T. Ahmad, et.al [March 2014][4] This paper focuses on “Experimental investigation on ferrocement roof slab system for low cost housing”. They Investigated the strength of pre-cast roof slab system comprising of ferrocement slab panels resting over RC beams. In the ferrocement panels, the cement was replaced by 0 and 20 % fly ash. This roof slab system proves out to be a cost effective and structurally safe and viable alternative for low cost housing, much better than the conventional roofing system comprising of steel girder and brittle sand stone panels commonly used in regions where sand stone panels are easily available. The testing includes three sets of roof system comprising of 12 ferrocement panels placed on two pre-cast RC beams, and an enclosure of brick walls on four sides. A similar set of roof slab system comprising of 12 sand stone panels in place of ferrocement panels were also tested for comparison. The testing was continued till the cracks were pronounced. It was observed that load carrying capacity of RC beam and ferrocement panel system with same thickness is higher as compared to similar arrangement of RC beam and sand stone panels. The crack propagation phenomenon was also studied. The ferrocement roof slab system exhibited ductile failure whereas brittle failure was observed in case of sand stone roof slab system. Cost analysis reveals that two pre-cast systems of RC beams and ferrocement panels with and without fly ash are economical as compared to red sand stone panels or RC slab system. The theoretical calculations have also been carried out to establish the adequacy of the sections to sustain the flexural loading applied in the present investigation.

Sakthivel P.B, et.al[5] Presented Paper on “Ferrocement Construction Technology and its Application”. Ferrocement construction technology is quite popular throughout the world. Ferrocement, a thin element, is used as a building construction as well as a repair material. This paper attempts to review the literature on ferrocement and bring out the salient features of construction, material properties and the special techniques of applying cement mortar on to the reinforcing mesh. This study brings out the importance of using ferrocement in swimming pools and water tanks, silos, corrugated roofs, shell and dome structures, and also in the repair of old/ deteriorated RCC structures. The study concludes that ferrocement will certainly be one of the best structural alternatives for RCC in the future

III. METHODOLOGY

Figure.1. shows the methodology adopted in this study.



3.1 Material used

1) Cement –

The Ordinary Portland Cement of 53 grades conforming to IS: 8112 is used. The cement used is fresh and without any lumps. Physical property of cement is as per Table 1.

Specific gravity	3.12
Consistency	33 %
Initial Setting Time	34 minutes
Final Setting time	455 minutes

Table 3. 1. 1. Physical Properties Of (OPC) Cement Characteristic Value.

2) Fine Aggregate –

Those fractions from 4.75 mm to 150 microns are termed as fine aggregate. Locally available sand from Pravara river, passing through the IS 4.75 mm sieve, and free from Tap water was used for both mixing of mortar and curing of test specimens
.

Particle Shape & Size	Rounded & 2.36 mm Below
Specific Gravity	2.53
Fineness Modulus	2.7 %
Bulk Density	1460 Kg/M^3

Table 3.1.2.Physical Properties Of Fine Aggrgate

3) Bamboo strip and wire mesh-

Locally available bamboo strip of size 10 mm, 990 mm length coated with anti-termite and then protective coating to preserve it against the action of insects, fungus and water.
Hexagonal chicken wire mesh of 0.64 mm (22 Gauge) diameter.

Fig. 3.1.1 chicken wire mesh and Bamboo strips

4) Alkaline activator
The alkaline activator used was of sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3).

3.2 Mix Design -

As the plan dimensions of the slabs were 450 mm x 230 mm, the size of the reinforcement were kept as 440 x 220 mm to ensure a minimum cover of 5mm, when placed inside the mould. Bamboo 480 mm was cut and was and made the mesh.

Based on the limited research on ferrocement mortar system, two new mortar mixes were decided. In the existing ferrocement system the ingredients of the mortar are cement and sand in the ratio 1: 3. In this project we are incorporating two additional ingredients to partially replace the earlier with fly ash .

The different mixes are
Mix A – C : S = 1:3 ...... (Refer S. Jeeva Chithambaram, et.al)
Mix B – C : F : S = 0.85 : 0.15 : 3(15% Fly ash)
Water /cement ratio of 0.40 And NaoH-14M

Sr. No.	Slab	Size in mm			Mix Ratio C:F:S	W/C Ratio
		L	B	D		
1	S	450	230	50	0.85:0.15:3	0.40

Table no.3 Mix Design

3.3 Mixing, Compaction, Preparation of specimen And Curing –

The specimens cast, were left in the moulds for 24 hours. After that identification was marked on the exposed face of the specimens, the specimens were de-moulded and immediately placed under water in a curing tank. The specimens were allowed to cure under water for a period of 28 days. The Ferro cement slabs along with the cubes cast from the same mortar were taken out of the curing tank at the age of 28 days and their surfaces were cleaned, for removing any salt de-posits.

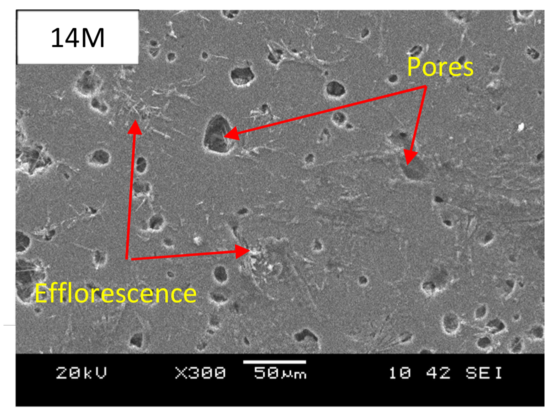


Fig 3.3.1 SEM images with different NaOH concentration.

3.4 Test Method –

All the panels of size 450mm X 230mm. All the panel were tested with their two edges simply supported over a span of 450mm under two points loading

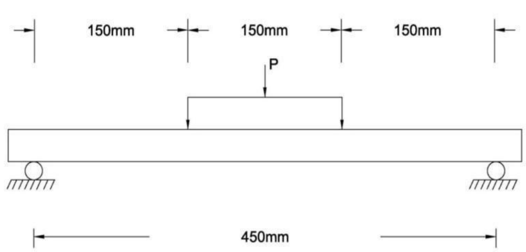


Fig 3.4.1 Test setup

Fig 3.4.2 Testing of panel

IV RESULT AND DISCUSSION

Flexural strength

The NaOH concentration investigated were 6 M-14 M. The samples were sintered at the same sintering temperature of 900 °C to ensure uniform measurements taken to assess the properties. Figure 4.1 shows the effect of NaOH concentration on the flexural strength. From the figure, it can be observed that NaOH concentration has a significant effect on the flexural strength of geopolymer ceramics. The flexural strength showed steady increment as the NaOH concentration increase from 6 M to 14 M. The dissolution of Si^{4+} and Al^{3+} from kaolin was increased upon increasing NaOH concentration and enhanced the formation of sodium alumina- silicate leads to increase in strength. Further increment in NaOH concentration up to 14 M degrades the strength significantly. The maximum flexural strength of 36.50 MPa were recorded at 12 M NaOH concentration. This inferred that there is an optimum alkalinity (Na concentration) for activating the kaolin. Concentration of NaOH solution affects the dissolution ability of the kaolinite particulates as higher concentration provides better dissolving ability and accelerate the condensation of the monomer, hence increase the bonding strength of the geopolymer. Guo et al. also reported that the compressive strength increase as the alkali concentration increase due to the increasing solubility of aluminosilicate. The strength at 6M is expected to be lowest among the other NaOH concentration due to lower alkalinity. The lowest NaOH concentration of 6 M is chose based on the previous work done by Further increment to 14 M caused strength degradation of 25.98 MPa. This might be attributed by the excess of Na^{+} cations at high NaOH concentration. It can be concluded that NaOH concentration has important effect on strength of the samples.

Figure 4.1: Effect of NaOH concentration on the flexural strength.

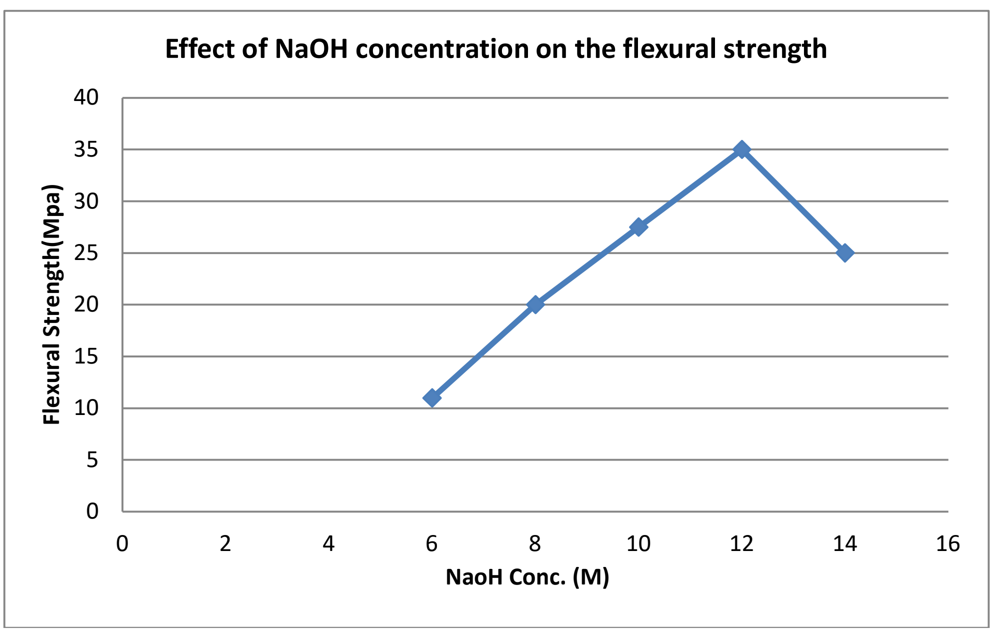


Figure 4.1: Effect of NaOH concentration on the flexural strength

Table 4.1 Hardened properties of geopolymer mortar.

#	Temperature (°C)	NaOH:fly ash ratio	Na_2SiO_3:fly ash ratio	Sand: fly ash ratio	7 day hardened density (kg/m^3)
1	32	0.050	0.025	1.0	2,117
2	33	0.050	0.050	1.0	2,113
3	34	0.050	0.075	1.0	2,121
4	37	0.050	0.100	1.0	2,134
5	35	0.075	0.025	1.0	2,161
6	37	0.075	0.050	1.0	2,161
7	39	0.075	0.075	1.0	2,158
8	41	0.075	0.100	1.0	2,138
9	43	0.100	0.025	1.0	2,174
10	42	0.100	0.050	1.0	2,167
11	44	0.100	0.075	1.0	2,187
12	46	0.100	0.100	1.0	2,186
13	53	0.125	0.025	1.0	2,119
14	54	0.125	0.050	1.0	2,136
15	49	0.125	0.075	1.0	2,151
16	52	0.125	0.100	1.0	2,138
17	38	0.100	0.100	1.5	2,041
18	37	0.100	0.100	2.0	2,091
19	37	0.100	0.100	2.5	2,136
20	36	0.100	0.100	3.0	2,220

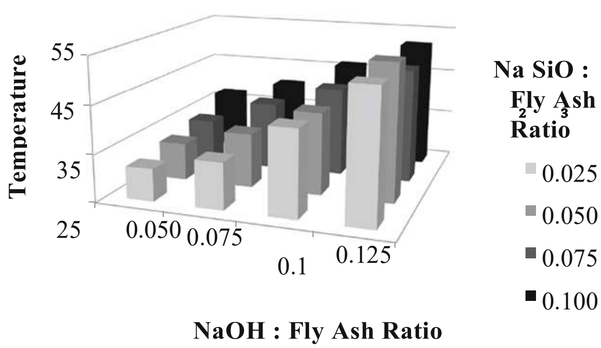


Fig. 4 Effect of sodium silicate and sodium hydroxide on temperature.

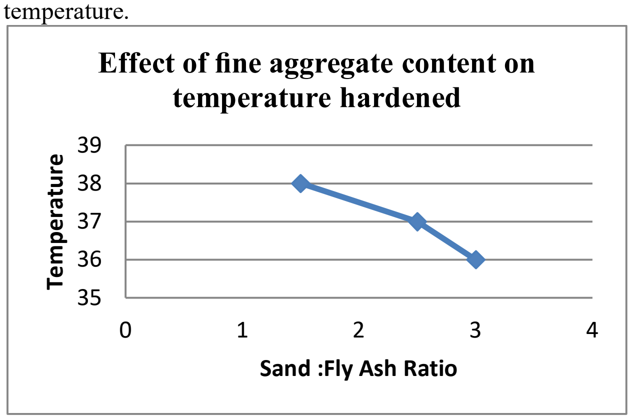


Fig. 5 Effect of fine aggregate content on temperature hardened

V ADVANTAGES

1. Formless construction-

Tightly tied meshes in ferrocement can hold wet cement mortar when it is press-filled in them. The consistency of cement mortar is very thick with very low water cement ratio. It won't come out of the meshes. Thus casting of Ferrocement does not need any formwork or shuttering. The other advantage of this aspect is no honeycombing will occur in press-filling, as the mortaring is done in front of your eyes.

2. Lightweight, homogeneous and versatile material-

Ferrocement structures have high equal strength in both directions. It can be moulded in any shape and size. Ferrocement is homogeneous, easy to work and can be made available in thin sections.

3. Equal strength in both directions-

The continuity and placement of equal mesh reinforcement in both directions make Ferrocement to achieve equal strength in two directions and to become strong in resisting diagonal tensions due to shear.

4. Size-

Thickness is small, between 25 mm to 50 mm.

VI CONCLUSION

It can be concluded that the concentration of NaOH has significant effect on flexural strength. The highest flexural strength value of 36.50 MPa was achieved at an optimum NaOH concentration of 12 M. Higher NaOH concentration of 14 M degrade the strength measured.
An experimental study has been carried out in ferrocement slabs by using self-compacting mortar to avoid the requirement of skilled mason and speedy in construction. The study indicates that the ferrocement slabs by using self-compacting mortar is possible. The structures which are built by ferrocement can give resistance to loading and deflection and has safety and economy to construct.

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