

EFFECT OF ALKALINE ACTIVATORS ON FLY ASH BASED BAMBOO REINFORCED FERROCEMENT

P.B. KADAM¹, Dr. S.L. HAKE²

¹P.G. Student, Department of Civil Engineering, Dr. V.V. Patil College of Engineering, Ahemednagar, Pin- 414111, Maharashtra, India.

²Guide- Associate Professor, Department of Civil Engineering, Dr. V.V. Patil College of Engineering, Ahemednagar, Pin-414111, Maharashtra, India.

Abstract - This paper reports a detail study of the effect of alkaline activators (sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3)) & Fly Ash on flexural & bending behaviour of bamboo reinforced ferrocement panels. The NaOH concentration used ranged from 10 M to 19 M. The flexural strength showed the optimum value when NaOH concentration is 16 M. The flexural strength showed the optimum value when Fly Ash is 50 %. The flexural strength showed the optimum value when (Na_2SiO_3) concentration is 13 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 find out the optimum value of fly ash, Sodium Silicate, Sodium Hydroxide in 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. 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 load have been investigated. The experimental programme consists of testing ferrocement panels of size 500 mm X 500 mm with the thickness of 50 mm. In which the some slabs panels laid in chicken mesh with 0%-100%, replacement of cement as fly ash with adopting grids of bamboo strips as skeletal reinforcement, were cast, cured under water tank for 28 days and then tested under loading Also some panels with 10M, 13M, 16M, 19M, concentration of NaoH & Na_2SiO_3 were cast, cured under oven then tested under UTM and the test results obtained.

Key Words: Bamboo reinforcement¹, Ferrocement², Bamboo strips³, Chicken wire mesh³, Cement⁴, Fly Ash⁵, sodium hydroxide (NaOH)⁶ and sodium silicate (Na_2SiO_3)⁷.

1. INTRODUCTION

1.1 General

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. 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.

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.

Fly ash is less expensive as compared to cement.

1.2 Objectives

1. Study the effect of NaOH & Na₂SiO₃ concentration on bamboo mesh ferrocement panel.
2. To study the bending & Flexural behaviour of bamboo 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.

2. 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] 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.

They said that –

1. The bamboo mesh and steel mesh can be used in the modern engineering constructions for improving the properties of ferrocement panels.
2. The tensile strength of bamboo is relatively high hence it can be provided at bottom of the specimen due to its tensile loading applications.
3. The bamboo and steel mesh ferrocement slab (57KN) has less more withstanding capacity than the steel mesh ferrocement slab (54KN) and bamboo mesh ferrocement slab (38KN).

Jeeva Chithambaram, et.al [Dec. 2016] 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.

They concluded that-

1. The system of ferrocement slab panels involving the use of bamboo as replacement of steel and flyash as partial replacement of cement can be used as roofing slab panels particularly for inaccessible roofing for low cost housing. This type of system will be useful for low cost housing in rural and sub urban areas. The benefits of this system are the utilization of flyash waste and bamboo, thus conserving the environment without hindering the structural integrity of the system. Also, Ferrocement and bamboo strips can be considered as one among the building materials that are less capital intensive and can be categorized under low cost roofing materials.
2. The first crack loads and the ultimate loads for both slabs are found to be similar and are in good agreement with the observed values of the loads. The ultimate load is approximately twice than that of the first crack load.

Subramani, et.al [May 2016], 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 x 15mm (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.

They concluded that-

1. The flexural loads at first crack and ultimate loads depend on number of reinforcing mesh layers used in ferrocement. Increase in number of mesh layers also improves the ductile behaviour of ferrocement slabs.

2. The deflection of slabs at first crack using PVC-coated weld mesh is showing about 25% more ductile behaviour than slabs with steel coated weld mesh.

Kamarudin Hussin, et.al[Jan 2016] main objective is the effect of NaOH concentration on flexural strength, phase formation and microstructural development of kaolin geopolymer ceramic.

They concluded that-

1. It can be concluded that the concentration of NaOH has significant effect on flexural strength, phase formation and microstructural development.

T. Ahmad, et.al[March 2014] 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.

They Concluded That-

1. The investigations undertaken clearly highlight the suit-ability of using roof slab system comprising of ferrocement panels with 0 and 20 % fly ash resting over RC beams for low cost housing as it has lower crack width, compared to other alternatives. The aforesaid system is ductile and economically viable as compared to the other prevalent floor systems. The technology can be used not only for greater cost reduction benefits but also for effective utilization of fly ash waste there by conserving the environment as well without any compromise on the structural integrity of the resulting system. The approach will be especially useful for low cost row housing schemes and emergency shelter housing projects for disaster affected areas.

Sakthivel P.B, et.al[Jan 2015] "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.

They concluded that

1. Ferrocement elements undergo high deformations before collapse. It has high level of impact and cracking resistance, toughness and ductility.
2. The ferrocement structures are thin and light-weight compared to conventional reinforced concrete. Hence there is considerable reduction in self-weight of the structure and saving in foundation cost. Transportation cost is also less.
3. Ferrocement is most suitable for water-retaining structures due to water-tightness and impermeability.
4. Ferrocement structures can be easily maintained, and also repaired in the event of structural damage without any major problems.

S. R. Suryawanshi, et.al[April 2018] Experimental Studies On Ferrocement". they Said That 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.

They Concluded That-

1. An experimental study has been carried out in ferro cement slabs by using self-compacting mortar to avoid the requirement of skilled mason and speedy in construction. The study indicates that the ferro cement 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.

3. EXPERIMENTAL PROGRAM

3.1 Material used

1. Cement – The cement used is fresh and without any lumps. Cement is the most important ingredient used. One of the important criteria for the selection of cement is its ability to produce improved microstructure. The cement should be fresh of uniform consistency and free of swellings and external matter and of the nature or grade depending on the application. Cement is a Binding Material . Using Ordinary Portland cement(OPC) of Grade 53 conforming to IS: 8112



Fig 3. 1. 90 micron sieve for fineness test.

100g of OPC of grade 53 is taken and it is sieved on 90 micron sieve for 15 minutes by giving circular and vertical motion. And the residue on sieve is weighed and checked so that it is not more than 10% of the original weight taken (i.e. 10g).



Fig 3 .2 Vicat Apparatus for Consistency, IST, FST.

Table1. Physical Properties of (OPC) Cement

| | |
|-----------------------------|-------------|
| <i>Specific gravity</i> | 3.12 |
| <i>Consistency</i> | 33 % |
| <i>Initial Setting Time</i> | 34 minutes |
| <i>Final Setting time</i> | 455 minutes |
| <i>Fineness Modulus</i> | 3.5% |

2. Fly ash –

Fly Ash is a by product from pulverised coal-fired electricity generating power plants. Using P-60 grade of Fly Ash .

Table No. 2Physical Properties of Fly Ash

| | |
|--------------------------------------|-------|
| <i>specific gravity</i> | 2.12 |
| <i>Unit weight(KN/M)²</i> | 14.39 |
| <i>Liquid limit(%)</i> | 24 |
| <i>Loss on ignition (% by mass)</i> | 0.40 |

3. Fine aggregate -

Those fractions from 2.36 mm to 75 microns are termed as fine aggregate. Locally available sand from Pravara River, passing through the IS 2.36 mm sieve.

Specific Gravity test(Pycnometer)-

Specific gravity G is defined as the ratio of the weight of a given volume of soil solids at a given temperature to the weight of an equal volume of distilled water at that temperature, both weights being taken in air.

Pycnometer of 900ml capacity, with a conical brass cap screwed at its top was taken. It was cleaned and weighed with the brass cap (M1). 200 to 400g of oven-dried soil was taken and it was placed in the Pycnometer. Then the weight of Pycnometer plus soil was taken (M2). After that Pycnometer was filled with distilled water to its half of the height. It is mixed thoroughly with glass rod. Then more water is added and it is stirred. Screw top is replaced and Pycnometer flush is filled with hole in conical cap. Then it is weighed (M3). After that the Pycnometer is emptied and it is cleaned thoroughly. Then the distilled water is filled to the hole of the conical cap and it is weighed (M4).



Fig 3.3 . Pycnometer to find out specific gravity

Particle size distribution (Sieve analysis)-

Particle size distribution is the fundamental property to consider as for as sand is concerned. The percentage of various sizes of particles in a given dry soil sample is found by particle analysis (i.e) the separation of a soil into its different size fractions.

1kg of fine grained soil passing through 2.36mm sieve was taken. And a set of sieves ranging from 1.18, 0.6, 0.3, 0.15, 0.075mm, pan were arranged. The Soil sample was placed in top sieve, then the entire set up was placed in a sieve shaking machine and it was allowed to shake for 10minutes. The portion of soil retained on each sieve was weighed. The percentage of soil retained on each sieve was calculated on the basis of the total mass of the soil sample taken.



Fig 3.4 . Sieve shaker

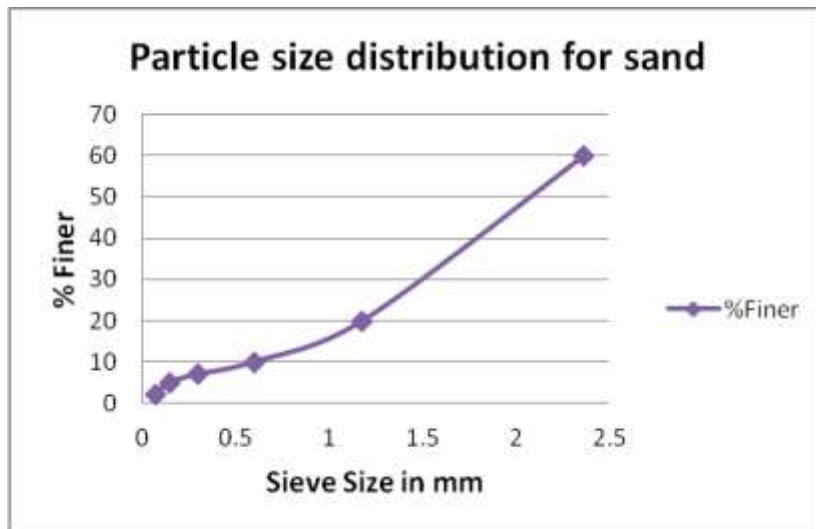


Chart 1- Particle size distribution curve for sand

Table.3 .Physical Properties Of Fine Aggregate

| | |
|----------------------------------|------------------------------------|
| <i>Particle Shape & Size</i> | <i>Rounded & 2.36 mm Below</i> |
| <i>Specific Gravity</i> | <i>2.53</i> |
| <i>Fineness Modulus</i> | <i>2.7 %</i> |
| <i>Water Absorption</i> | <i>1%</i> |
| <i>Bulk Density</i> | <i>1460M³</i> |

4. Bamboo strip and wire mesh-

Locally available bamboo strip of size 8 mm, 470mm length ,Hexagonal chicken wire mesh of 0.64 mm(28 Gauge) diameter.

5. Alkaline activator-

The alkaline activator used was of sodium hydroxide (NaOH) and sodium silicate (Na₂SiO₃).

6. Water-

A tap water available in the concrete laboratory is using in casting process. Water Should be potable. The pH of water should be less than 7, and it is colourless, odourless and free from salts.



FLY ASH



CEMENT



BAMBOO STRIPS



CHICKEN MESH

Fig 3.5. Materials used

3.2 Mix Design -

As the plan dimensions of the slabs were 500 mm x 500 mm x 50mm the size of the reinforcement were kept as 470 mm to ensure a minimum cover of 15mm, when placed inside the mould. Bamboo 470 mm was cut and was and made the mesh.

Based on the limited research on ferrocement mortar system, new mortar mixes were decided. In the existing ferrocement system the ingredients of the mortar are cement and sand in the ratio 1: 2. In this project we are incorporating two additional ingredients to partially replace the earlier with fly ash.

The different mixes are

Mix A(1) – C : S = 1:2 Tor steel (water/cement ratio of 0.5) (Refer S. Jeeva Chithambaram, et.al)

Mix A(2) – C : S = 1:2 For Bamboo

Mix B – C : F : S = 0.90 : 0.10 : 2(10% Fly ash)

Mix C – C : F : S = 0.80 : 0.20 : 2(20% Fly ash)

Mix D – C : F : S = 0.70 : 0.30 : 2(30% Fly ash)

Mix E – C : F : S = 0.60 : 0.40 : 2(40% Fly ash)

Mix F – C : F : S = 0.50 : 0.50 : 2(50% Fly ash)

Mix G – C : F : S = 0.40 : 0.60 : 2(60% Fly ash)

Mix H – C : F : S = 0.30 : 0.70 : 2(70% Fly ash)

Mix I – C : F : S = 0.20 : 0.80 : 2(80% Fly ash)

Mix J – C : F : S = 0.10 : 0.90 : 2(90% Fly ash)

Mix K – C : F : S = 0.00 : 0.100 : 2(100% Fly ash)

Mix L – C : F : S = 0.50 : 0.50 : 2(10M NaoH)

Mix M – C : F : S = 0.50 : 0.50 : 2(13M NaoH)

Mix N – C : F : S = 0.50 : 0.50 : 2(16M NaoH)

Mix O – C : F : S = 0.50 : 0.50 : 2(19M NaoH)

Mix P – C : F : S = 0.50 : 0.50 : 2(10M Na₂SiO₃)

Mix Q – C : F : S = 0.50 : 0.50 : 2(13M Na₂SiO₃)

Mix R- C : F : S = 0.50 : 0.50 : 2(16M Na₂SiO₃)

Mix S - C : F : S = 0.50 : 0.50 : 2(19M Na₂SiO₃)



Fig 3.6. Placing of bamboo chicken mesh





Fig 3.7. Casted Panels

3.3 Test Method -

Flexural Strength-

All the elements were tested with their two edges simply supported over a span of 450mm under two points loading. The distance between the two loading points is 150mm with moment arms of 150mm at both sides of the loading points. The test was performed in universal testing machine and the corresponding deflections were noted. The ultimate load and the corresponding deflection are noted.

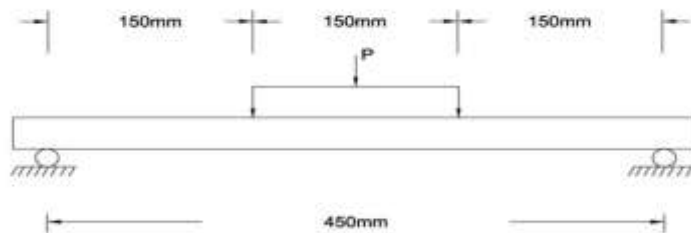


Fig 3.8 Test setup For Flexural Strength (Two point loading)



Fig 3.9. Testing of panels for flexure

Bending-All the panels tested under point loading.

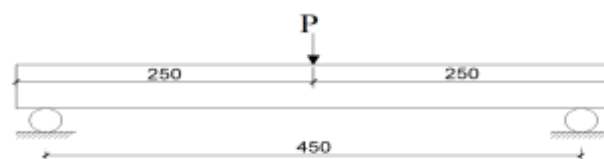


Fig. 3.11 Test setup for bending



Fig 3.11. Testing of panels for bending

4. RESULT AND DISCUSSION

4.1 Flexural & Bending-

The results of the tested specimens in flexure and bending are listed in the table 4 as follows.

| FLEXURE | | | | | | | | | | |
|-------------|------|------|------|------|------|-------|------|-------|------|------|
| Type of mix | A(1) | A(2) | B | C | D | E | F | G | H | I |
| Load(KN) | 7.64 | 6.10 | 1.90 | 1.85 | 2.11 | 5.49 | 7.10 | 6.18 | 4.81 | 3.50 |
| Disp.(MM) | 1.98 | 1.12 | 0.64 | 0.89 | 1.01 | 1.09 | 2.01 | 1.35 | 1.06 | 1.42 |
| Type of mix | J | K | L | M | N | O | P | Q | R | S |
| Load(KN) | 1.88 | 00 | 2.90 | 3.12 | 6.90 | 4.90 | 1.90 | 6.51 | 5.4 | 4.20 |
| Disp.(MM) | 0.69 | 00 | 0.95 | 1.02 | 1.85 | 1.32 | 1.25 | 1.56 | 1.22 | 0.95 |
| BENDING | | | | | | | | | | |
| Type of mix | A(1) | A(2) | B | C | D | E | F | G | H | I |
| Load(KN) | 3.56 | 2.9 | 0.5 | 0.7 | 1.5 | 2.56 | 3.4 | 3.125 | 2 | 2.2 |
| Disp.(MM) | 4.25 | 3.69 | 2.51 | 3 | 3.2 | 4.035 | 5.25 | 5.1 | 4.9 | 3.89 |
| Type of mix | J | K | L | M | N | O | P | Q | R | S |
| Load(KN) | 1.8 | 00 | 0.5 | 1.9 | 3.01 | 2.22 | 1.9 | 2.5 | 2.1 | 1.32 |
| Disp.(MM) | 2.99 | 00 | 2.52 | 3.27 | 4.69 | 3.025 | 1.79 | 3.69 | 2.75 | 2.56 |

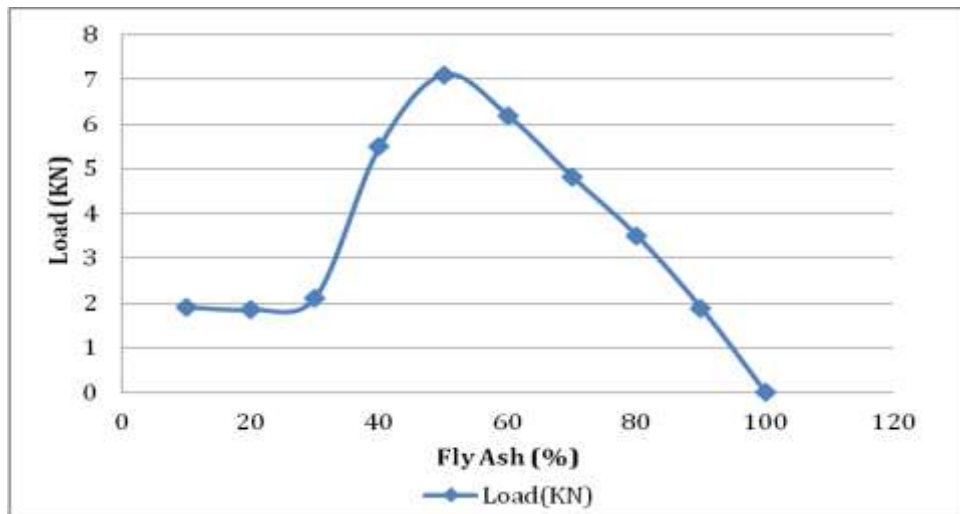


Chart 2-. for % Fly ash V Load

The above graph for flexure shows that load is increase for fly ash 0-50% then load is decreases. For fly ash Content 50% shows the maximum load.

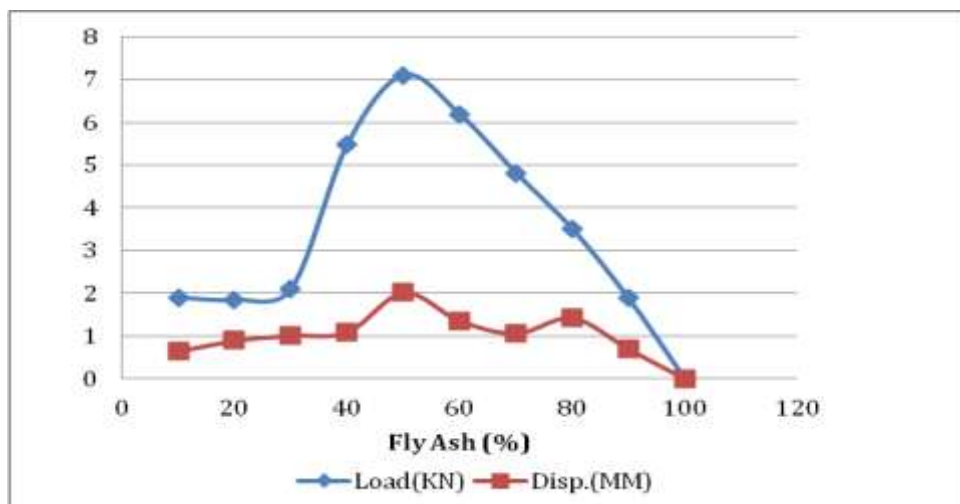


Chart 3. Shows the Load And Displacement for Fly ash

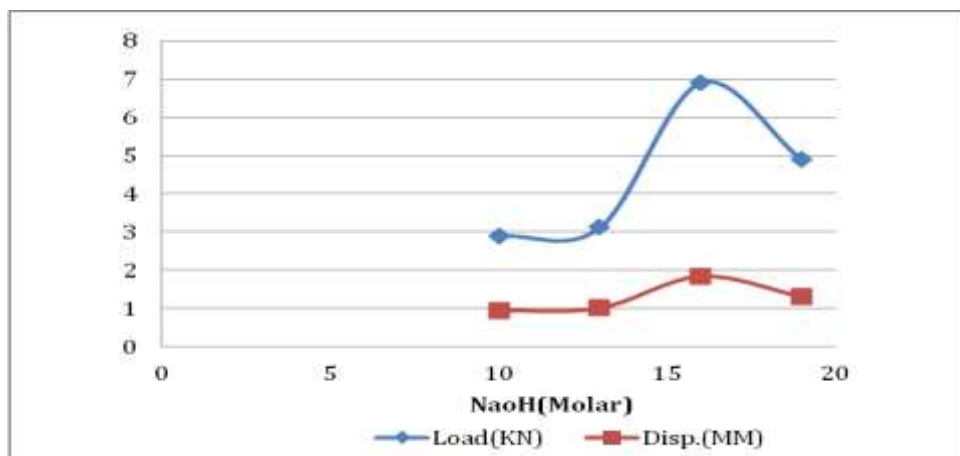


Chart 4. Load & Displacement for NaoH

Fig shows that Maximum load for 16 molar of NaoH.

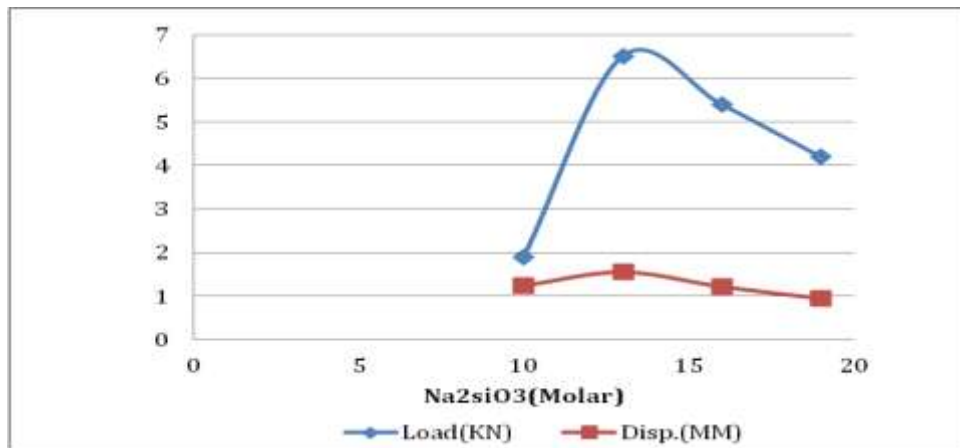


Chart 5. Load & Displacement for Na₂SiO₃

Fig shows that Maximum load for 13 molar of Na₂SiO₃.

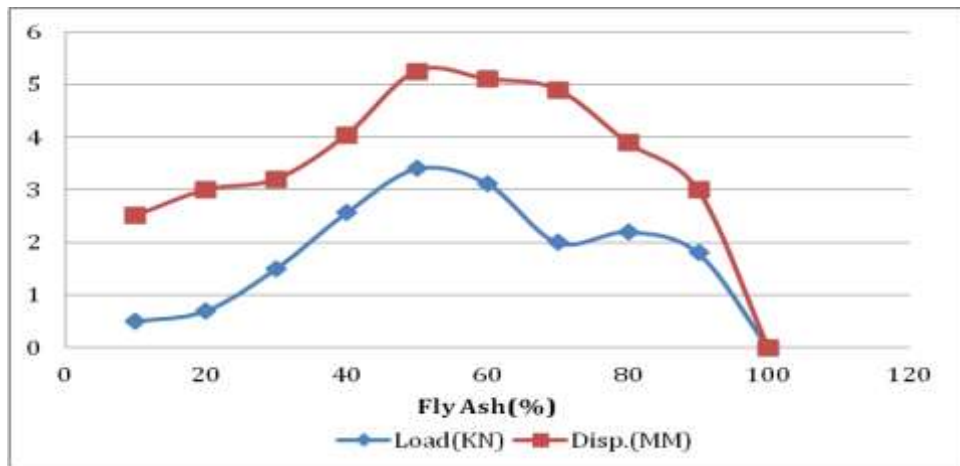


Chart 6. load & displacement for fly ash(Bending)

Fig shows that maximum value of load in fly ash when fly ash is 50 % that is the optimum value of fly ash .

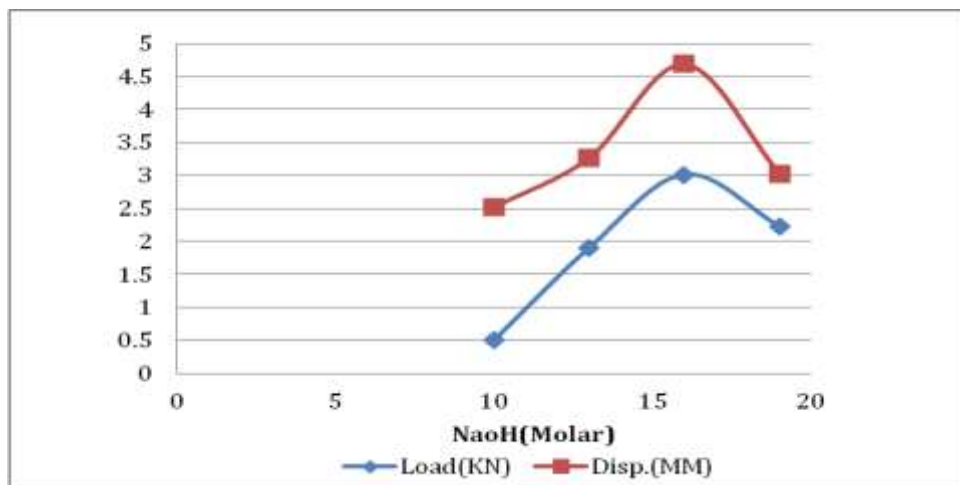


Chart 7. load & displacement for NaOH(Bending)

Fig shows the maximum load for 16 Molar of NaOH.

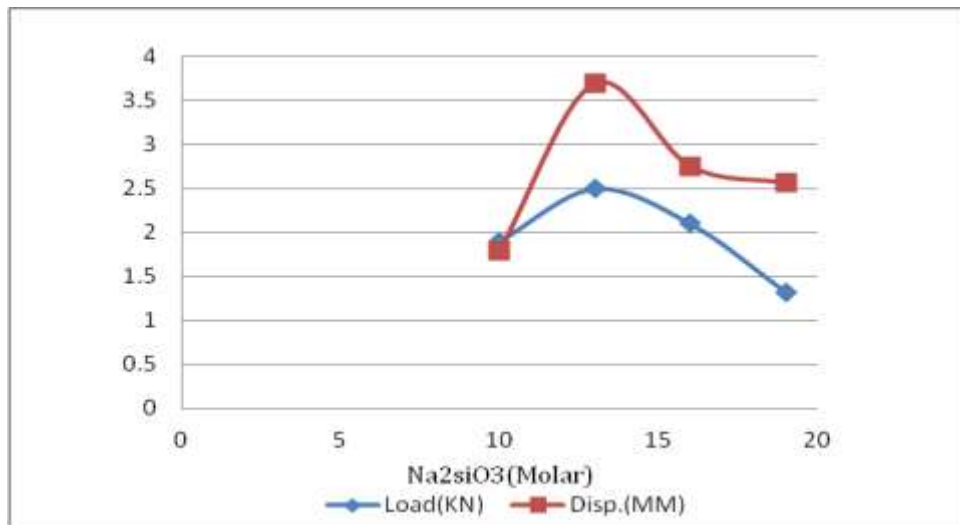


Chart 8. load & displacement for Na₂SiO₃ (Bending)

Fig shows the maximum value of load for 13 molar of Na₂SiO₃.

4.2 FAILURE PATTERN OF PANELS

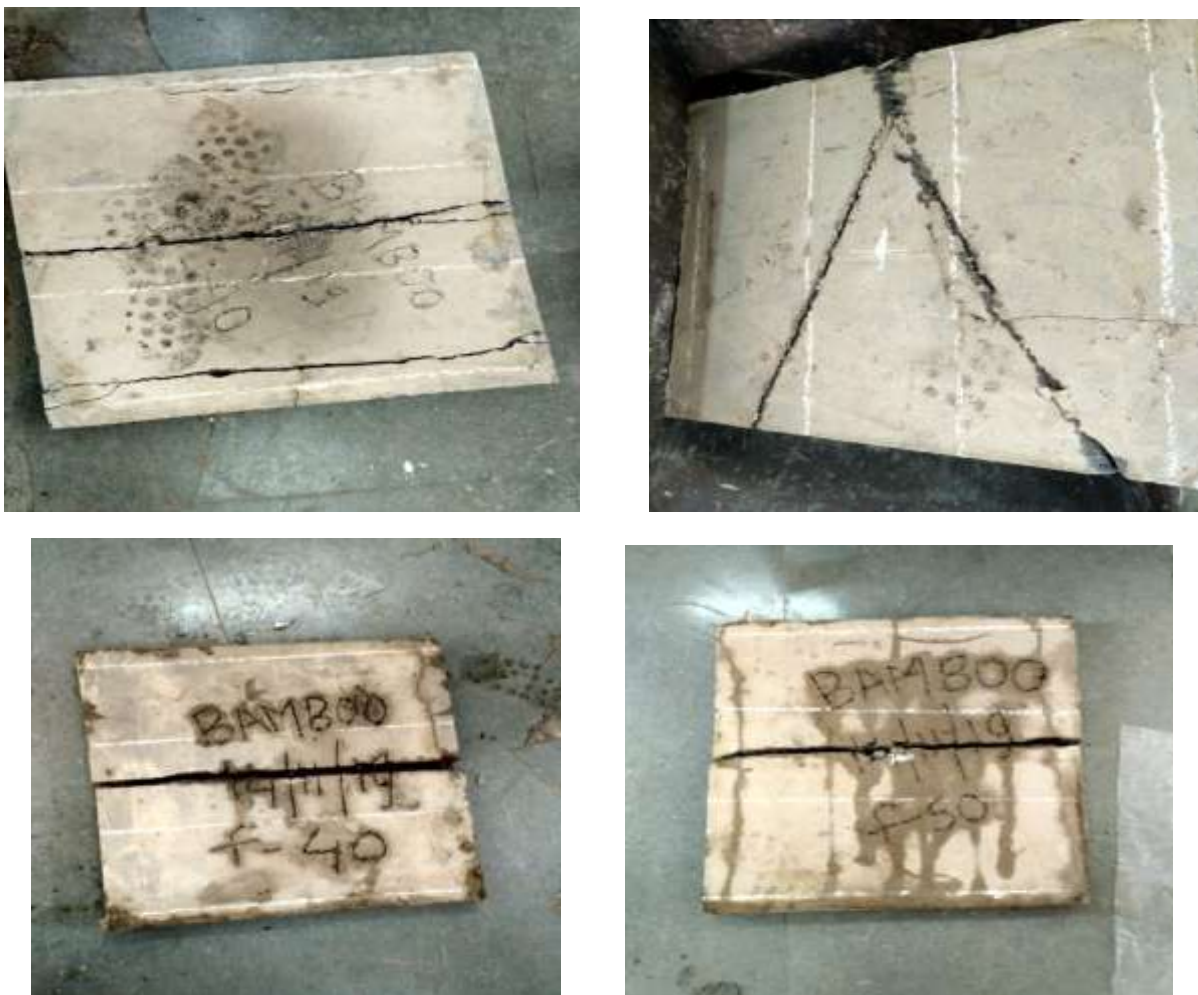


Fig 4.8 . Failure Pattern

4.3 COMPARITIVE STUDY OF PANELS

The ultimate load for flexure and bending with bamboo mesh reinforcement were studied and the details are given below table 5.

| Type of Mix | | Ultimate load(flexure)KN | Ultimate load(bending)KN |
|--|-----------|--------------------------|--------------------------|
| Mix A – C : S = 1:2 For Tor steel | Tor steel | 7.64 | 3.56 |
| Mix F – C : F : S = 0.50 : 0.50 : 2(50% Fly ash) | Bamboo | 7.10 | 3.4 |
| Mix N– C : F : S = 0.50 : 0.50 : 2(16M NaoH) | Bamboo | 6.90 | 3.01 |
| Mix Q – C : F : S = 0.50 : 0.50 : 2(13M Na ₂ SiO ₃) | Bamboo | 6.51 | 2.5 |

From the above table the ultimate load of the panel casted with Mix F – C : F : S = 0.50: 0.5:2(50% fly ash), Mix N– C : F : S = 0.50 : 0.50 : 2(16M NaoH) & Mix Q – C : F : S =0.50: 0.50 :2(13 M Na₂SiO₃) comparatively near to the panel casted with Mix A – C : S = 1:2 for tor steel.

5. Conclusion

1. An efficient and eco-balancing revolution of ferrocement technology has been developed, which overcomes the drawbacks of the traditional methods. The results obtained from the experimental study shows that bamboo mesh strength near the strength of tor steel.

From the experiment

1. Find out the flexure and bending ultimate load for varying fly ash, sodium hydroxide & sodium silicate.
2. From the ultimate load for bending and flexure for 10-100% fly ash, for 50% fly ash replace as cement which gives the maximum load hence optimum value of fly ash for bamboo meshes 50%.
3. Similarly Optimum value of NaoH (sodium hydroxide) which gives maximum load 16 Molar.
4. And For the Na₂SiO₃ (sodium silicate), maximum load obtained for 13 Molar. Hence Optimum value of Na₂SiO₃ (sodium silicate) is 13 molar.

2. Various methods exist for inhibiting corrosion. But yet a permanent solution for corrosion is not prescribed as far as ferrocement technology is concerned.

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BIOGRAPHIES

I post graduate student. I have completed these project under the guidance of Dr. S. L. Hake.



Corresponding Author- Kadam Pranav Balasaheb



Guide- Dr. S. L. Hake