Experimental Study on Performance of Ferrocement Pipe with A Sustainable Material, Basalt Textile Reinforcement

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***Abstract*—This project presents an experimental investigation into the structural performance of ferrocement water pipes reinforced with basalt textile mesh as a sustainable alternative to conventional steel reinforcements. Ferrocement, known for its thin section, high tensile strength, and excellent crack resistance, becomes even more environmentally friendly and durable when combined with non-corrosive basalt textiles. The study involved the casting and testing of cylindrical pipe specimens with an internal diameter of 200 mm, external diameter of 300mm, wall thickness of 50 mm, 1000 mm length and with reinforcement configurations including basalt textile mesh and, for comparison, traditional chicken mesh. The mortar mix used had a cement-to-sand ratio of 1:4. The pipes were tested statistically under line loading in universal testing machine to assess parameters such as first crack load, ultimate load, failure pattern, ductility, and crack propagation. The results indicated that basalt textile-reinforced pipes exhibited improved crack distribution, enhanced ductility, and comparable or superior load-carrying capacity relative to chicken mesh reinforced specimens.**

***Index Terms*—— Basalt fiber mesh, Chicken mesh, Ductility, Ferrocement pipe, Load- Deflection, Ultimate load**

I. INTRODUCTION

Ferrocement is a composite construction material widely used and is made of cement mortar reinforced with closely spaced layers of wire mesh, steel mesh or steel rods. This technology was first used in the 1840s by Joseph- Louis Lambot to build boats which demonstrated better waterproof and durability properties of the material. However, it was not recognized until mid-20th century when Pier Luigi Nervi, an Italian architect and engineer began using it in modern construction especially in thin shell structures and boat construction. Nervis innovation showed ferrocement durability, flexibility, and economic use of materials. This gained global recognition and led to increased use of this technology in civil and marine applications.

Ferrocement consists of cement mortar, which is (a mixture of cement and sand) reinforced with different layers of metallic mesh or synthetic mesh or other natural fiber mesh. Typically, rich mix with water cement ratio of 0.35 to 0.45 is used for better strength and workability. One of the primary advantages of ferrocement is its high tensile strength. The fine reinforcement arrangement in it gives excellent crack resistance which minimizes crack propagation. Ferrocement is mainly used in seismic zones as it can absorb shocks and vibrations better than traditional concrete. Ferrocement offers multiple benefits for engineers and architects. One of its foremost advantages is cost effectiveness due to its locally available materials and minimal equipment usage. It is labor intensive which is advantageous in areas where labor availability is less. Its thin section and lightweight nature reduce dead load and material usage. Additionally, maintenance cost of ferrocement structures is less and process great lifespan If the specimen is not provided with adequate cover to mesh and exposure the water may inhibit corrosion which is major concern when exposed to wet environment. Since it is labor intensive, it is time consuming in large projects compared to precast structural elements and skilled supervision is needed to maintain quality standards.

II. MATERIALS AND METHODS

A. Materials used

Ferrocement pipes were cast using ordinary Portland cement (OPC 53 grade), M-sand as fine aggregates, potable water, and two types of mesh reinforcement (Chicken mesh and basalt textile mesh).

- Cement: OPC 53 grade cement was used in the entire project.
- Fine aggregates: The fine aggregates used to mix were Manufactured sand (M sand) with maximum particle size of 4.75 mm.
- Water: Clean portable water was utilized throughout the experiment with chlorine and acidic free for mixing and curing.

Mesh reinforcement

1. Chicken Mesh: In this project it was used as reinforcing material within the mortar to improve tensile strength.

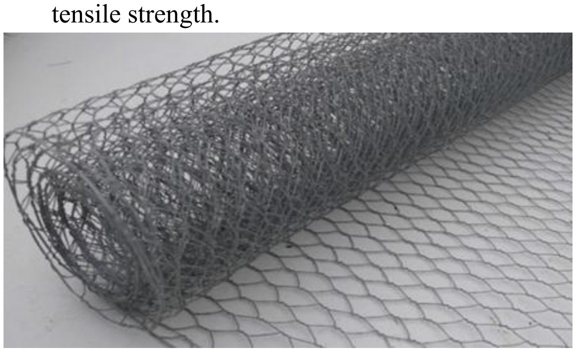


Fig 1. Chicken mesh

2. Basalt fiber mesh: Basalt fiber mesh was used as a reinforcing material since it has excellent resistance to crack corrosion and ductile nature

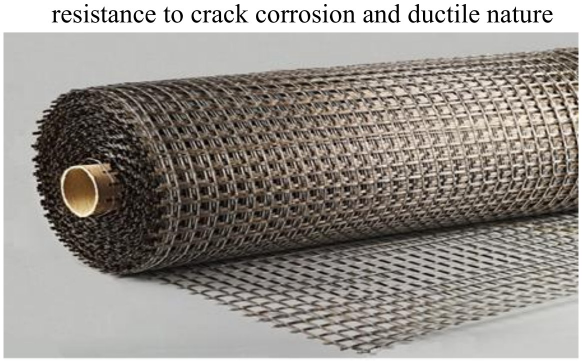


Fig 2. Basalt fiber mesh

Fig 1 and Fig 2 represent the Chicken mesh and Basalt fiber mesh used in the experiment.

B. Mortar mix

A cement-to-sand ratio of 1:4 was adopted for all mixes, with a water-cement ratio of 0.45. Mixing was done using a mechanical mixer to ensure uniform consistency.

Table I. Mix proportion for ferrocement pipes

Materials	Mix
Cement	450 Kg/ m ^{3}
Fine aggregate	1200 Kg/ m^3
Water	180 Kg/m^3

C. Specimen details

A total of seven ferrocement pipe specimens were cast and tested to evaluate the effect of mesh type and number of reinforcement layers on structural performance. All pipes were fabricated with an internal diameter of 200 mm, external diameter of 300 mm, uniform wall thickness of 50 mm, and a length of 1000 mm. The specimens were divided into three groups based on the mesh type and number of layers.

Table II gives the properties of Chicken Mesh and Basalt fiber Mesh provided by the supplier

Table II. Properties of Chicken Mesh and Basalt Fiber Mesh

	Basalt fibre mesh	Chicken mesh
Tensile strength	800-1600MPa	300-600MPa
Density	2.6 g/cm^3	7.6 g/cm^3
Youngs modulus	86-112GPa	190-210GPa
Thermal resistance	Up to 800˚ C	Strength decreases after 400˚ C
Corrosion resistance	Very high	Low to moderate (if not protected)
Water absorption	<0.1% (negligible)	Absorbs moisture and may rust

(Note: Properties as per the supplier)

Table III provides the details of the test specimens along with the naming convention adopted

Table III. Details of test specimens

Pipe ID	Pipe type	Layer numbers
P1CM-1	Chicken mesh	1
P1CM-2	Chicken mesh	1
P1CM-3	Chicken mesh	1
P1BM-1	Basalt fibre mesh	1
P1BM-2	Basalt fibre mesh	1
P2BM-1	Basalt fibre mesh	2
P2BM-2	Basalt fibre mesh	2

The nomenclature follows the pattern

P{Layer} {Mesh type}- {Specimen Number}, where "P1CM-1" denotes Pipe with 1 layer Chicken Mesh Specimen 1
"P2BM-2" denotes Pipe with 2 layers of Basalt Mesh Specimen 2

D. Test setup
The pipes were tested under line loading using a Universal Testing Machine (UTM). Load was applied gradually until failure. Dial gauges were used to record deflection at four points along the pipe length. Specimen dimensions were 1000 mm length 200 mm internal Dia 300 mm external Dia 50 mm uniform thickness. The loading gradually increased, and deflections were noted using dial gauges.

Fig 3. Test setup for Pipe Specimen in UTM machine
Fig 3. Schematic representation of the test setup showing line load application and positions of dial gauges on the ferrocement pipe specimen

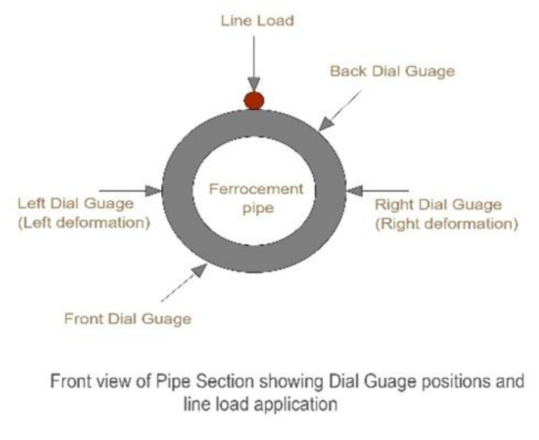


Fig 4. Schematic representation of test setup
Front view of ferrocement pipe showing line load at the crown and positions of four dial gauges (Front, Back, Right and Left) used to measure deformation where line load was applied at the top of pipe.

III. RESULTS AND DISCUSSION

A. Experimental Results and Failure Mechanism
In this experimental investigation seven pipe specimens were tested under axial line loading to evaluate the structural behavior with different reinforcement types. All pipes were cast with geometry 1000 mm length 200 mm internal diameter 300 mm external diameter and 50 mm uniform thickness The specimens were divided into 3 categories based on reinforcement configurations. Chicken mesh (P1CM-1 to P1CM-3), Basalt fiber mesh single layer (P1BM-1 & P1BM-2), Basalt fiber mesh two layers (P2BM-1 & P2BM-2). Line loading was applied through a steel rod placed horizontally along the top of the pipe to record the crack behavior. It was observed that initial crack load (P_{cr}) and the ultimate load (P_u) were nearly equal in all cases. In the chicken mesh group, the pipe reached the ultimate load of 45kN, 42kN and 39kN for P1CM-1 P1CM-2 & P1CM-3 respectively with corresponding peak elongation between 3.95mm and 4.86mm. The average load carrying capacity in this group was 41kN. And pipes reinforced with single layer basalt mesh recorded an ultimate load of 42kN & 45kN (P1BM-1 & P1BM-2). With elongations at peaks of 4.20mm and 4.78mm. The specimens with two-layer basalt mesh exhibited higher load carrying capacity with ultimate load of 39Kn and 48Kn(P2BM-1&P2BM-2).

Table IV. Experimental results of Pipe specimen

Pipe ID	Load		Deformation								Ductility Δ u / Δ cr			
	1st crack load P_{cr} (kN)	Ultimate load P_u (kN)	Deformation at first crack Δ cr (mm) Dial Guage readings (mm)				Deformation at Ultimate Load Δ u Dial gauge readings (mm)							
	P_{cr}	P_u	FGD	BDG	RDG	LDG	FDG	BDG	RDG	LDG	FDG	BDG	RDG	LDG
P1CM1	45	45	0.50	1.20	0.31	1.61	0.55	1.29	0.37	2.03	1.10	1.08	1.19	1.26
P1CM2	39	42	0.72	0.62	1.35	0.86	0.86	0.71	1.40	0.89	1.19	1.14	0.84	1.03
P1CM3	35	39	0.5	2.07	1.96	0.56	0.75	2.1	2.1	0.59	1.5	1.01	1.07	1.05
P1BM1	43	45	0.54	0.3	1.28	2.28	0.55	0.34	1.28	2.30	1.01	1.13	1.0	1.0
P1BM2	40	42	0.4	0.74	1.65	1.78	0.45	0.78	0.68	1.96	1.25	1.05	0.41	1.10
P2BM1	39	42	1.06	0.27	0.85	1.03	1.15	0.28	0.97	1.47	1.08	1.03	1.14	1.42
P2BM2	46	48	0.64	0.88	0.77	0.98	0.68	0.90	0.77	1.00	1.06	1.02	1.00	1.05

B. Failure mechanism

After the test, the pipe showed a single long vertical crack running from top to bottom. The crack appeared suddenly and continued throughout the pipe, showing the pipe failed in a brittle manner. There were no signs of multiple cracks or signs of gradual failure. As the axial load increased, the pipe section experienced flexural tension on the outer surface while compression dominated the interior, leading to sudden rupture once the tensile capacity of the pipe was exceeded.

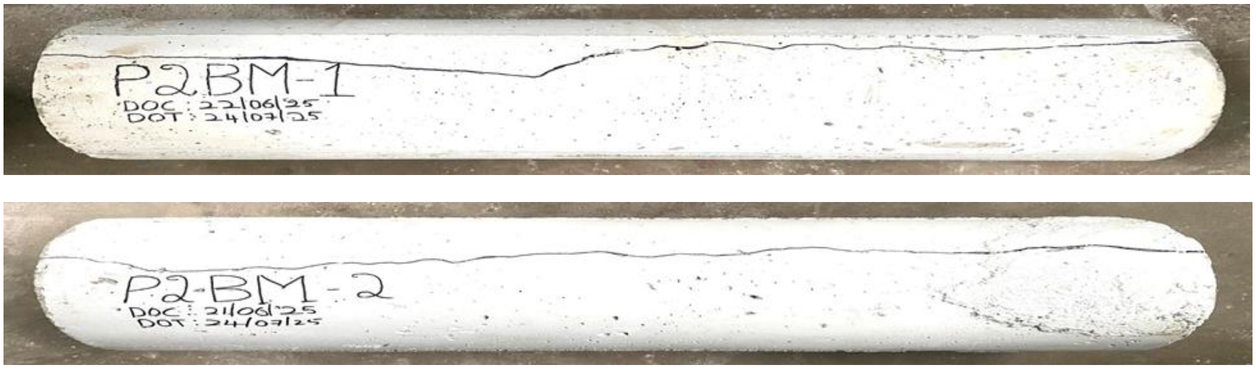
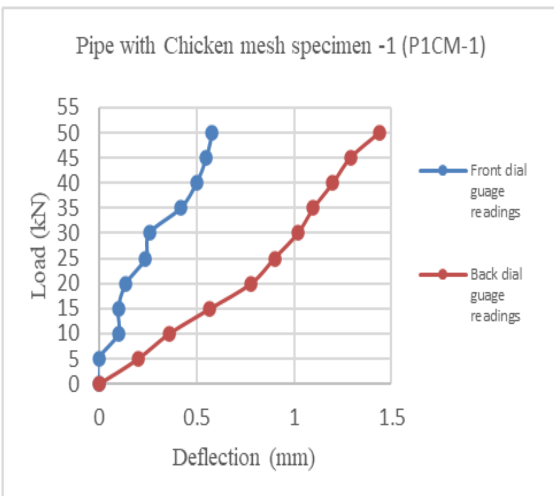
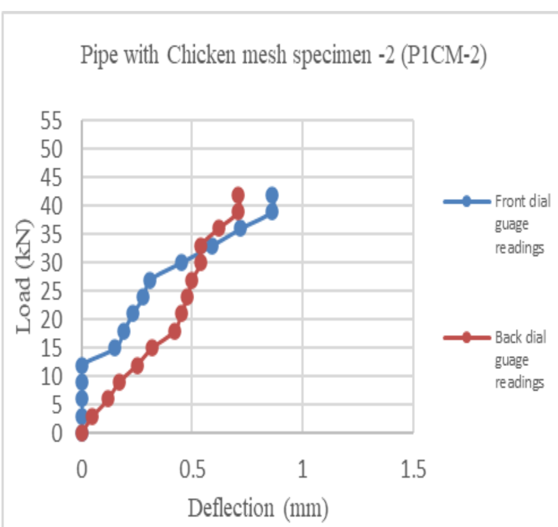
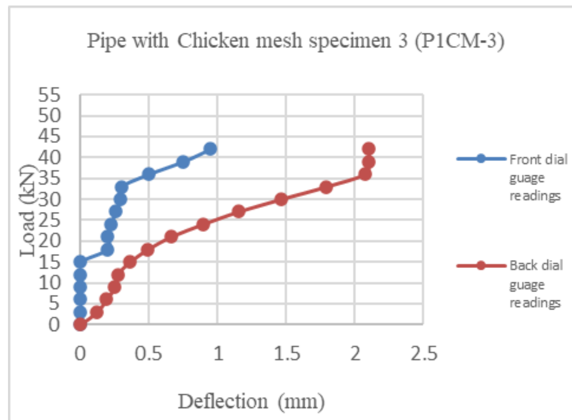


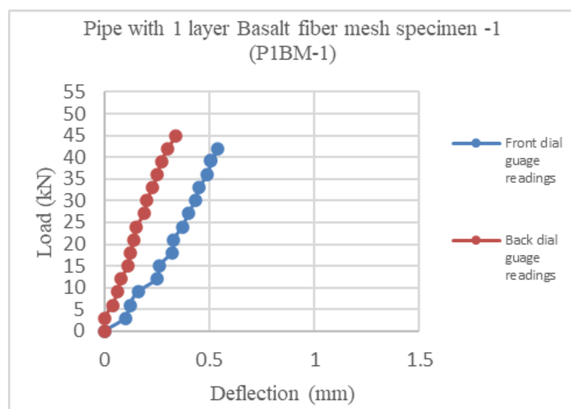
Fig 5. Crack pattern of Tested specimens

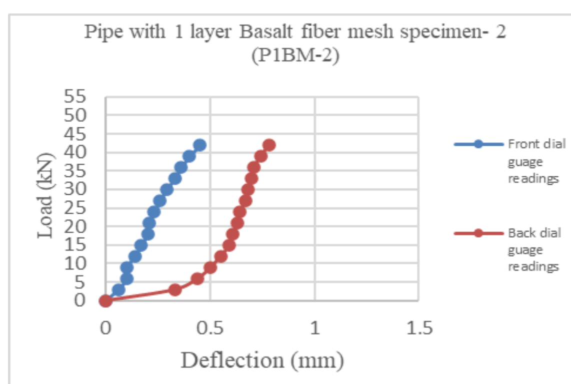
Graphs below represent Load vs Deflection curves for all tested ferrocement pipe specimens (P1CM-1 to P2BM-2) using front and back dial gauge readings)

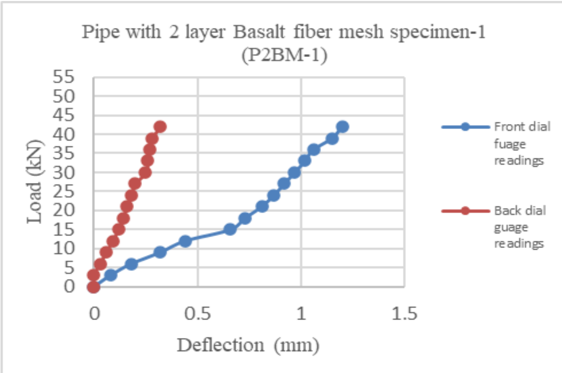












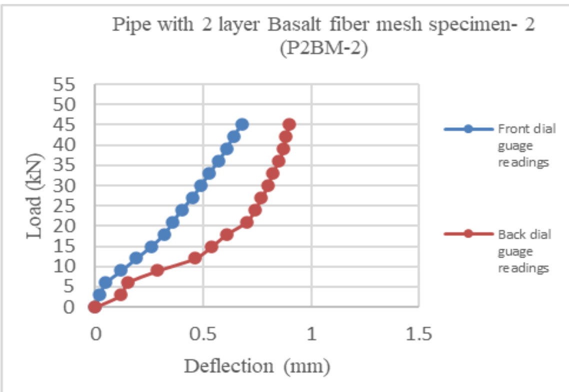


Fig 6. Load vs Deflection Curve of Specimens

IV. CONCLUSION

1. From the experimental investigation, it can be concluded that the incorporation of basalt fiber mesh in ferrocement pipes provides superior performance when compared to conventional steel and chicken mesh reinforcements.
2. The results clearly indicate that basalt mesh reinforcement enhances crack resistance and improves load-carrying capacity.
3. Among the tested specimens, the pipes reinforced with two layers of basalt mesh demonstrated the best structural performance, exhibiting higher first crack load, greater ultimate load, and improved deformation characteristics.

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