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Finite element analysis of ferrocement barges: A Review

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Abstract - To accommodate the growing population's economic and developmental needs, there is a significant demand for usable space in many large urban centres. In this regard, using the available coastal sea space is a workable solution to the land scarcity problem. Floating structures have been built along coastlines in many different nations for this purpose. High-density polyethylene and steel are frequently used to construct floating structures, particularly pontoons. However, research into alternate raw materials for modular floating pontoon construction as multipurpose floating structure is required. Ferrocement is a material that can be mass produced, is adaptable, and is simple to customise. Its mechanical strength is equivalent to that of steel and other materials. The improved resistance to cracking that characterises ferrocement. In water retention structures and other comparable buildings, ferrocement could therefore be used more frequently. There is little research on the structural behaviour of ferrocement floating structures because most studies are concentrated on the structural behaviour of ferrocement slabs, composite beams, and channels. The use of ferrocement technology as a viable material for building thin bulkheads for barges is examined in this paper.

Keywords- ferrocement, barge, finite element analysis

I. INTRODUCTION

To address the economic and developmental needs of a growing population, there is a significant demand for usable space in many large urban centres. In this regard, using the available coastal sea space is a workable answer to the problem of land shortage. The traditional method of land reclamation, which involves dumping sands and boulders into the sea, is where floating systems are most frequently used. Environmentally friendly floating systems require substantially less time to produce **(Dongqi Jiang et al.) [17].** Steel and high-density polyethylene are typically used to construct floating constructions, particularly pontoons. In terms of cost, strength, and capacity, steel and HDPE each have their own advantages and disadvantages. However, research into alternative raw materials is required to build modular floating pontoons that can serve several purposes. Ferrocement is an adaptable material that can be mass produced, is simple to customise, and has a mechanical strength that rivals that of steel and other materials. Increased resistance to cracking is a defining feature of ferrocement **(G. J. Xiong & G. Singh) [3].** Thus, ferrocement could be utilised more in water retention structures and other similar structures. There is little research on the structural behaviour of ferrocement floating structures because most studies are concentrated on the structural behaviour of ferrocement slabs, composite beams, and channels. The use of ferrocement technology as a viable material for thin bulkheads for barges is studied in this work, and the applicability of finite element (FE) calculations to evaluate the structural performance of ferrocement barges under different forces is also examined.

II. FERROCEMENT

According to ACI Committee 549 (ACI, 1988), ferrocement is a type of thin wall reinforced concrete that is typically made of hydraulic cement mortar and reinforced with thin, continuously layered wire mesh that is positioned tightly together. Ferrocement, often known as reinforced concrete, is made by combining cement with sand mortar and spreading it over several layers of small-diameter welded or woven steel mesh, as described by **G. Singh and G. J. Xiong [1]**. Iron or steel is the most popular metal, and wire with a diameter of between 0.5 mm and 1 mm is utilised to create the mesh. Sand and cement are combined in a rich mortar mixture at a 3:1 ratio. The thickness of ferrocement members typically ranges from 10 to 25 mm. It is frequently used in shipbuilding, water and food storage tanks, silos, roofs, structure maintenance, and for homes in both urban and rural locations. It is also utilised in water transport tubing. Due of the accessibility of its basic resources, cement is particularly well-liked. There aren't many skilled people needed for it. Additionally, it is simple to prepare and fireproof **(V. Greepala, P & Nimityongskul) [23]**. The characteristics of ferrocement have been researched by numerous academics. According to **Shopana K. et al. [25]**,

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adding more wire mesh layers significantly increases the ductility of the ferrocement panel. It is known to improve the seismic resistance of masonry structures **(S. Shang, K. Liu, and F. Yao) [24]** and ferrocement panels can be used as an ultra-thin overlay inside rigid pavements. The curvature, diameter, and geometry of the mesh wire, in addition to the elastic qualities of the mesh wire, all affect the ferrocement's elastic properties **(A. A. Skudra). Basunbul et al. [4]** conducted an experimental analysis of the flexural behaviour of ferrocement sandwich panels and discovered that increasing the number of wire mesh layers and employing skeleton steel in the tension plate enhances the ductility in the working range as well as the ultimate strength. The stiffness and rigidity of the wire mesh are not significantly affected by the number of wire mesh layers in the uncracked stage, but they are improved in the cracked stage. In their study of the impact of cyclic stress on fracture width and crack space ferrocement, **G. J. Xiong et al.** [3] discovered that one of the most crucial elements affecting crack width is crack spacing. Additionally, experimental research has raised the possibility of using ferrocement as a substitute roofing material **(Hago et.al). [5]** The research conducted an experimental study to determine the maximum load carrying capability of slab panels and ferrocement slabs. According to research, silica fume, fibres, fly ash, and some kind of resin may be used as additives to strengthen mortar in ferrocement. The effects of adding steel and glass fibres to ferrocement plates were examined by **M. Jamal Shannag et al. [7]** They discovered that adding discontinuous fibres can effectively stop the mortar cover from spalling at maximum load. To investigate how silica fume affects the flow properties and compressive strength of the ferrocement, an experimental programme was run **(P. Rathish Kumar) [9]**. Ferrocement can be used to reinforce existing reinforced concrete structures or as a material for repairs. The flexural fracture width is influenced by the concrete covering on the reinforcement. At the surface, thicker cover causes broader fissures. Therefore, it is necessary to reduce cover thickness as much as feasible in order to manage cracking. However, many standards of practise for establishing a minimum limit for the concrete cover have been influenced by environmental considerations. The use of ferrocement as a covering for the reinforcement in concrete slabs is the subject of another investigation. Concrete slabs with reinforcement can be made from ferrocement cover **(Kubaisy et al.) [11].**

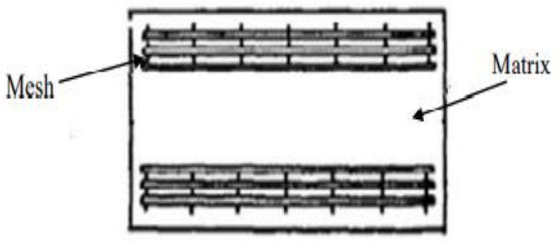

Fig. 1: Typical meshes used in ferrocement

III. FINITE ELEMENT ANALYSIS FOR FERROCEMENT

Many researchers-initiated investigation to determine the mechanical properties of ferrocement as well as its potential use in construction applications. But the need for use of FEM in ferrocement to provide the basis for design continues. By applying the FEM, the time and cost for studies gets reduced as compared to the expenses of experimental tests. Also, FEM represents the loading and support conditions of the actual structure. FEM is used to investigate the flexural behavior and shear transfer of ferrocement composite beams under a two-point loading system **(Nassif et al)**. [6] They used a smeared crack model, that is used to determine failure in concrete and as a result they found that the ferrocement composite beams have better ductility, cracking strength, and ultimate capacity compared to reinforced concrete beam. Ferrocement Slabs was investigated using finite element model to examine the composite action between the ferrocement slabs and steel sheeting **(Boshra et al.)**. [8] This was done as an initial step towards using the ferrocement slabs to improve the behavior of compression member in spaced trusses. The finite element technique was used to model the behaviour of these slabs. Hamid et al. Provided an experimental sample to assess deflection in a standard ferrocement channel **(Hamid Eskandari & Amirhossein Madadi et al.) [10]**.

IV. BARGES

A barge is a long shipping vessel are flat-bottomed boats. Barges do not have a self-propelling mechanism and needs to be pulled by tow or a tug boat. They are mainly built for transport of bulk goods. Barges have changed throughout time. Nowadays self-propelled barges are available. Barges are used for low-value bulk items, and for very heavy items. Normally very large objects are assembled onsite, in order to reduced costs assembled units are shipped using barges.

There are different types of barges which include,

Barracks Barge: A houseboat, often referred as barracks barge, is highly prevalent in places like Laos, Cambodia, Kashmir, Australia, and Canada. These kinds of barges are mostly utilised for residential purposes, and they make for quite striking immobile floating objects in rivers and lakes.

Dry Bulk Cargo Barges: As their name implies, these kinds of barges are employed to transport and convey dry goods. Food grains, sand, minerals like steel and coal, and other dry goods that can be transported through the system of barges are all included in the concept of dry cargo.

Barges Carrying Liquid Cargo: These barges are the exact opposite of dry bulk cargo barges in every way. These barges are particularly helpful for transporting other vital and significant industrial liquid chemicals, as well as petrochemicals and fertilisers that are mostly used in the liquid condition.

Car-float Barges: Early in the 20th century, rail carts were mostly transported using this kind of sea barge. These rail-carts that were attached to the barges can be described simply as portable rail-sets that were transported from one place to another. Car-float barges are still in use in various areas of the United States of America today.

Split Hopper Barge: Due to its special design and appropriate unloading equipment, this barge is utilised to transport dredged material. Due to its ability to discharge the material (soil, sand, dredged material, etc.) on the job site, the split hopper barge is widely utilised in marine construction. The barge has a hydraulic motor and cylinder unit to split apart the hull and can be self-propelled. It can load and unload building materials thanks to a hydraulically actuated split open hull.

Other Barges: Apart from the above cited type of barges, there exist a few different types of barges which include royal barges and strength barges. Power barge these are a moveable power plant. Royal Barges are occasional barges and used as platform for the celebration of royal functions. These are still used in nations like the United Kingdom.

Fig. 2: Barges towed by a tugboat: on the River Thames in London

V. DIFFERENT MATERIALS FOR CONSTRUCTION OF OFFSHORE STRUCTURES

Although steel is frequently used to build offshore structures, other materials can also be employed, including high-density polyethylene, wood, reinforced plastic fibreglass (RPF), and aluminium. But the use of concrete in the construction of floating structures has not gained significant traction. Recently, however, the offshore sector, which is a customer of shipbuilders, has rediscoverd concrete's superior potential over steel. More and more often than steel, concrete is being suggested as an even more suitable material for this purpose for projects like liquefied natural gas (LNG) offshore installations **(Hubbard) [22]**. In the offshore sector, steel and concrete are the two materials that can be used to build any structure's hull. For merchant ships, warships, and other vessels, steel is a material that is frequently utilised in shipbuilding. Small units with lengths less than 100 m and less harsh environmental conditions than in the offshore industry also employ materials like aluminium, glass reinforced plastic (GRP), or wood. Nevertheless, several ships and barges have been constructed from concrete in the past, but these instances were relatively rare and did not alter the standard practise in the sector.

During the First and Second World War concrete was used due to the scarcity of other materials. Concrete was also used to create other floating constructions, but these examples are largely hypothetical. However, these concrete constructions have performed superbly, particularly in terms of maintenance. Concrete will therefore continue to be the material most suited to the offshore industry even though it has not received adequate acceptance in shipbuilding thus far. Concrete ships have previously been determined to be too expensive due to the increased displacement and fuel expenditures. However, because the shipping and offshore industries now have totally different priorities, the reduction in mobility in a concrete hull as compared to a steel hull can be perfectly countered by the benefits afforded by concrete. On the other hand, if a tension load is applied, the concrete progressively begins to crack over time, which could lead to rebar corrosion. Due to the constant tensile loads that are placed on floating marine structures, this behaviour of concrete in tension restricts its use in ship construction. For concrete floating constructions to be used in shallow waters, it is crucial to assess and determine the significance of unique phenomena that only occur in shallow water. Also suggested is a mock test to confirm the concrete floating construction in shallow waters **(D. Jiang et al) [21]**.

In contrast to regular concrete, prestressed concrete has unique steel reinforcing inside that is in tension, producing a higher tensile stress. Despite having similarities to concrete, prestressed concrete needs to be viewed as a distinct substance. Steel supports all loads in prestressed concrete, and the concrete's only purpose is to shield steel from corrosion. Another non-thermal bond for steel is concrete.

Due to their propensity for brittle fracture, ordinary steels are regarded as being unsatisfactory, and special alloy steels come at a premium price. Concrete can get cracked and cause rebar to corrode. It has been demonstrated that concrete may resist brittle fracture when wires of small diameter are used. These factors have led to ferrocement's

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rising use as a boat building material. By enhancing concrete's tensile strength, making it lighter, and enhancing its resistance to dynamic loading, the use of appropriately designed wire meshes can significantly expand the range of applications for concrete used in the construction of submersibles.Ferro-cement is a material that is rising in demand for boat construction. Ferro-use Cement's for offshore buildings was investigated by **(S. P. Shah et al.) [12]**. Since impact loading will be crucial for many applications of ferrocement in offshore constructions, the goal of this research was to examine the impact resistance of ferro-cement plates.

In their article, **Rodrigo et al**. [13] investigated the use of concrete in the offshore sector. Concrete's properties were contrasted with those of steel. In the construction of ships, reinforced and pre-stressed concrete are employed. The properties of both types of concrete were covered in this article, along with the advantages and disadvantages of concrete compared to steel in the offshore business. Due to its high resistance to salt water and low maintenance requirements, concrete.

By taking into account unique elements including a deck crane, pollution department, and a helicopter landing platform, **Nitonye et al**. [14] presented a design for a work barge. Thin-walled reinforced floating structures were the subject of an investigation into the properties of modified expanded clay concrete **(Andrey et al.) [16].** It was discovered that the load carrying capability of a ship is increased when heavy shipbuilding concrete is replaced with lightweight expanded clay concrete.

D. Jiang et al. [21] suggested employing LWAC and low w/c with the addition of silica fume to boost resistance to chloride penetration in their analysis of floating prestressed concrete structures in shallow water based on their examination of the literature. For reinforcing and prestressing steel, the minimum required concrete cover thicknesses are 50 mm and 70 mm, respectively. Along with the hydrodynamic pressure brought on by incoming waves, one must also consider the hydrodynamic pressure brought on by incoming waves' scattering and the radiation wave brought on by body motion. It was found that FRP reinforcement could be used in floating concrete structures to combat corrosion issues. It is possible to think of CFRP as a substitute for the reinforcing and prestressing steel because it has the most favourable behaviour among the different types of polymers in terms of mechanical performance, chloride resistance, and anti-moisture. Serviceability and ultimate limit state should both be considered in the design and analysis of concrete floating structures. It is also necessary to take into account a mix of unintended incidents, like a boat hit, a blast and fire, a tsunami, and others.

Chiorlu et al. [18] He created a Matlab sort code in his study report that can be utilised to foretell the barge's heave and surge motion. Matlab was used to calculate the wave-induced loads on a barge.

VI. FINITE ELEMENT ANALYSIS FOR BARGES AND SHIP

The dependency on effective design tools grows as a result of the rising complexity of loads and improved protocols for various FEA types, which allow for an improved design process and class approval **(Jörg Rörup et al.). [15]** FEA was employed for the analysis in a study on the structural strength of ships with open decks. The model specifies the mesh size, loading, and boundary conditions that should be employed. The proper implementation of boundary conditions on a cargo hold FE model is crucial for accurate results.

Using FEA, characteristics of concrete modular floating structures were examined **(D. Jiang et al.) [21]**. By employing prestressed concrete and subjecting the floating modules to different activities, finite element calculations are carried out to evaluate the structural performance of the structures. The structural performance of concrete floating structures under the influence of self-weight, imposed live load, hydrostatic pressure, and buoyancy force was then evaluated using finite element (FE) studies. Investigations were done into how the structural performance of floating units was affected by geometrical shapes, cell counts, and slab thickness. The findings show that prestressing steels are required to prevent cracking in concrete modules. **Hernández et al. [20]** first presented structural analysis using finite element method (FEM) models. examined the impact of various weights on the midship section of the barge. Cargo was taken into account along with the effects of still water and waves.

VII. CONCLUSIONS

The qualities of ferrocement used for structural members have been the subject of a great deal of research, but more work needs to be done on the subject of ferrocement floating structures.

There is an urgent need for research into the characteristics of ferrocement floating structures, and there is little information in the literature about how these floats behave.

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