"LITERATURE REVIEW FOR GENERATION OF PUNCHING SHEAR STRENGTH STATISTICS OF FERROCEMENT SLABS"

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Abstract:
Ferrocement slabs have emerged as an efficient alternative to conventional reinforced concrete elements due to their superior tensile strength, enhanced ductility, lightweight configuration, and ease of fabrication. Despite these advantages, the punching shear behavior of ferrocement slabs remains a critical structural concern, particularly in applications involving concentrated loads and column–slab interactions where sudden brittle failure may occur. Existing studies have explored parameters influencing shear capacity such as mesh type, mortar strength, reinforcement volume fraction, layer orientation, slab thickness, and boundary conditions; however, the quantification and statistical characterization of punching shear strength remain limited. This review consolidates and evaluates experimental investigations, analytical models, and numerical simulations related to punching shear resistance in ferrocement slabs. Emphasis is placed on generating statistical correlations, variability measures, probabilistic strength estimation, and reliability-based design approaches for improved accuracy in structural performance prediction. The analysis identifies key research gaps, including insufficient large-scale database development, lack of unified design models, and limited integration of statistical methods with nonlinear finite element modelling. The study concludes that establishing comprehensive statistical frameworks is essential for standardizing design procedures, improving predictive accuracy, and enhancing structural safety of ferrocement slab systems under punching shear loading.

Keywords:
Ferrocement slabs; Punching shear strength; Statistical analysis; Mechanical properties; Reinforcement mesh; Mortar matrix.

I- INTRODUCTION:
Ferrocement is a highly versatile composite material consisting of a cement-sand mortar reinforced with one or more layers of closely spaced steel mesh, providing improved tensile strength, crack resistance, and ductility compared to traditional reinforced concrete. Due to its lightweight nature, ease of construction, and superior structural efficiency, ferrocement slabs are increasingly utilized in applications such as roofing systems, hydraulic structures, prefabricated housing units, shell elements, and marine structures. Despite these advantages, ferrocement structures are susceptible to punching shear failure when subjected to concentrated or localized loads, especially in slab–column interactions. Punching failure is brittle, sudden, and often catastrophic, making the accurate prediction of punching shear strength critical for ensuring structural safety and serviceability.

While extensive research has been conducted on punching shear behavior in conventional reinforced concrete slabs, the unique reinforcement mechanism of ferrocement characterized by thin sections, multiple mesh layers, and distributed reinforcement results in distinct load transfer behavior and failure modes. Parameters such as mesh type, volume fraction, mortar strength, slab thickness, curing method, and loading configuration significantly influence punching shear capacity and associated crack patterns. However, existing studies primarily focus on experimental observation and deterministic strength prediction, with limited emphasis on statistical characterization of strength variability.

In practical design scenarios, structural resistance is not deterministic but inherently variable due to uncertainties in material properties, fabrication quality, reinforcement distribution, and environmental effects. Hence, generating statistical models and probabilistic strength estimates is essential for establishing reliability-based design formulations and safe load-bearing capacities for ferrocement slabs. A comprehensive statistical evaluation further supports the development of performance-based standards and codified design guidelines, which are currently lacking for ferrocement structures.

This review consolidates published experimental results, analytical models, finite element simulations, and probabilistic evaluation techniques related to punching shear behavior in ferrocement slabs. The study aims to identify governing parameters, quantify statistical trends, highlight research gaps, and establish a structured basis for developing reliable design models. The review ultimately contributes toward enhancing structural safety, improving predictive accuracy, and enabling standardized design procedures for ferrocement slabs subjected to punching shear.

2.1 Advantages of Ferrocement:
Ferrocement is a suitable technology for developing countries for the following reasons:
(a) Its basic raw materials are readily available in most countries.
(b) It can be fabricated into any desired shape.
(c) The skills for ferrocement construction can be acquired easily.
(d) Heavy plants and machinery are not involved in ferrocement construction.
(e) In case of damage, it can be repaired easily. Being labor intensive, it is relatively.

2.2 Properties of ferrocement:
Numbers of Research workers have made an attempt to study the various properties of ferrocement.

2.2.1 Tensile Behaviour:
Unlike reinforced concrete, tensile behaviour of ferrocement is considerably different. This is mainly because the reinforcement is spaced closer and uniformly than in reinforced concrete and smaller diameter results in a larger specific surface area. This in turn affects cracking behaviour (finer and number of cracks) in ferrocement.

Naaman and Shah's[15] (1974) work indicated that the stress level at which the first crack appeared and the crack spacing were a function of the specific surface of reinforcement. The ultimate load of the ferrocement specimen was the same as the load carrying capacity of the reinforcement in that direction. This should be expected since the load is carried by the reinforcement itself after the mortar is cracked.

2.2.2 Compression Strength:
The high compressive strength of mortar contributes primarily to the compressive strength of the ferrocement composite. Although the reinforcement may have some influence on the compressive strength, but this is limited to certain types of reinforcement. For example, the use of welded wire mesh would increase compressive strength due to the lateral restraint provided by the welded transverse wires, while the hexagonal mesh or expanded metal may weaken the composite due to longitudinal splitting.

Kameshwara Rao and Kamasundra (1986)[18] investigated the stress-strain curve and poisson's ratio of ferrocement in axial compression. It was found that the specific surface is the only factor, which controls the behaviour of ferrocement in axial compression. Equations developed for predicting the increase in strength, strain and modulus of elasticity by regression analysis were used to generate the stress-strain curve of ferrocement under axial compression. They have found that ferrocement behaves linearly up to 50 – 60% of the ultimate strength in compression; beyond this limit the behaviour becomes non-linear. The value of ultimate strength and Young's modulus increase with increasing of specific surface area.

2.2.3 Flexural strength:

In some application, ferrocement may be subjected to flexural stress. In such cases, one must consider the method and manner in which its behaviour in flexure may be predicted. Needless to say that compared an average reinforced concrete beam (which is generally under-reinforced), the ferrocement beams due to several layers of wire mesh ten to be over reinforced concrete beam.

Mansur and Paramasivam (1986)[14] proposed a method to predict the ultimate strength of ferrocement in flexure based on the concept of plastic analysis where ferrocement is considered as a homogenous perfectly elastic-plastic material. Simple equations are derived for direct design of a cross-section. An experimental investigation was also conducted to study the behaviour and strength of ferrocement in flexure. It was found that the ultimate moment increase with increasing matrix grade (decreasing water cement ratio) and increasing volume fraction of reinforcement.

2.2.4   Shear:

Venkata Krishna and Basa Gouda[20] (1988) performed testing on ferrocement beams with different volume fraction of reinforcement in transverse shear. It was found that the shear strength depends upon mortar, strength of wire mesh, volume fraction and shear span. Theoretical expressions were development for predicting the shear strength at first crack and collapse of ferrocement beams with different type of wire meshes namely hexagonal, woven and welded.

2.2.5   Fatigue Resistance:

Fatigue strength plays an important role in restricting the use of ferrocement in structures subjected to such a loading as in bridges. The fatigue strength of the wire, as tested in air, is the primary factor affecting fatigue of the composite. Balaguru et al[9] (1977) investigated the flexural fatigue properties of ferrocement beams reinforced with square woven and welded meshes. Their finding is the relationship between the stress range in the outermost layer of steel mesh and the number of cycles to failure.

2.2.6   Impact Resistance:

Impact strength is a useful parameter in applications related to offshore structures and boasts. Reports attesting the favourable characteristics of ferrocement in collisions involving boats with each other or with rocks are numerous. The main attributes include resistance to disintegration, localization of damage, and ease of repair. However, due to experimental complexity associated with measurement of impact resistance, little quantitative or comparative data exist.

Impact strength was defined as the energy absorbed by the specimens when struck by a swinging pendulum dropped from a constant height. The damage was measured by the relative flow of water through the specimen surface for a fixed energy absorbed which in 6001b-in (66.7kN-mm).

Shah and Key (1972)[19] tested 9in² (5625mm²) and ½in (12mm) thick ferrocement slabs using an impact tester. From the test, it indicated that the higher the specific surface of the meshes and the higher the strength of the mesh, the lower the damage due to impact loading.

2.2.7   Durability:

When ferrocement is exposed to aggressive environment, its successful performance depends to a great extent on its durability against the environment than on its strength properties. The external causes may be physical, chemical or mechanical. They may be due to weathering, occurrence of extreme temperatures, abrasion, electrolytic action, and attack by natural and industrial liquids and gases. The extent of damage produced by these agents depends largely on the quality of the mortar, although under extreme conditions any unprotected mortar will deteriorate. The internal causes are alkali-aggregate reaction, volume changes due to the differences in thermal properties of aggregate and cement paste, and above all the permeability of mortar. The permeability of mortar largely determines the vulnerability of the mortar to external agencies, so that in order to be durable the mortar must be relatively impervious.

Although the measures required to insure durability in reinforced concrete also apply to ferrocement, three other factors which affect durability are unique to fenocement. First, the cover is small and consequently it is relatively easy for corrosive liquids to reach the reinforcement. Second, the surface area of the reinforcement is unusually high, so the area of contact over which corrosion

reactions can take place, and the resulting rate of corrosion, are potentially high. Third, although many forms of reinforcement used in ferrocement are galvanized to Prevent corrosion, the zinc coating can have certain adverse effects bubble generation. All three factors have varying importance depending on the nature of the exposure condition. However, in spite of these unique effects, there is no report of serious corrosion of ferrocement not associated with poor plastering or poor matrix compaction. To insure adequate durability in most applications, a fully compacted matrix is necessary. A protective coating may also be desirable.

2.2.8   Corrosion:

Corrosion is the deterioration of metals or alloy due to interaction with its surroundings. The most common example of corrosion is the rusting of steel. Corrosion is normally a fairly slow but complex process; however, due to presence of certain conditions, it may occur very rapidly. Many of these can occur in ferrocement and avoiding them is one of the biggest problems. All ferrocement marine structures, by virtue of their marine environment are liable to corrosion attack. The danger of corrosion is enhanced in ferrocement by the extreme thinness of the cover of mortar over the steel reinforcement. The corrosion process is often difficult to recognise until extensive deterioration has occurred. The severity of the attack on structure will depend basically on how well it has been designed and built, the materials used and what happens to it when in and out of use.

II- LITERATURE REVIEW:

Abdulla and Katsuki Takiguchi[3], have conducted experimental study on wear of concrete by ferrocement boxes. The test results indicate that ferrocement boxes offer significant enhancement in stiffness, strength and ductility.

Ferrocement has proven itself and ideal material for the strengthening and retrofit of a range reinforced concrete as masonry structures. Main advantages are improved crack control, durability, and toughness. As outlined past studies have highlighted the importance of adequate shear connection between the ferrocement coating and underlying structure. When shear connection has proven inadequate the ferrocement coating has failed prematurely before the composite section has attained full capacity. Brickwork is limited by its low shear strength. In conventional reinforced brickwork it is often simply not possible to provide internal shear strengthening. Ferrcemeat might offer a solution a solution to this problem.

Garwood T.G and Tomlison A. 1982[11], has shown that there is some limited success in providing vertical reinforcement. A number of test have been undertaken to study performance of reinforced brick beams in shear. The empirical lower bond shear strength for reinforced brickwork beams is taken as 0.35 N/mm^2 and increased up to 0.7 N/mm^2 when the shear span ration less than two.

Henry A.W 1990[12], has shown the use of steel are in the horizontal mortar bed joints of the masonry walls.

P.J. Walker and M. Damo [16],They had shown the feasibility of using ferrocement coating to provide shear strength for the brickworks.

M. Arif, M. Akhthar, S. Garg, M and basit, F [4], They have shown that the structural units using ferrocement planes can be used with confidence in a variety of wage for low cost housing schemes, agriculture and industrial application.

Abdul Samad, Rashid, Megat Johari, and Abang Abdulla[1], Investigated on the ferrocement box beams subjected two point load tests which induces pure bending moment with shear force. The modes of failures and crack pattern were observed. The lower the a/d ratio (≤1) the more prominent is the diagonal tension failure, for the higher value of a/d (>1) tends to develop flexural failure of the beam. The ferrocement box section beams have very high shear capacity. With very low a/d ratio (0.7).

Al-Kubaisy and Ned Well [2], Studied on the location of the diagonal crack in ferrocement rectangular beams. The variables covered in the study were, a/d volume fraction and compressive strength of the mortar 'f_{cu}'. The results indicated that the location of the critical diagonal crack as measured from the nearest support increases as the a/d ratio is increased and to a lesser extent as 'f_{cu}'

is decreased. The effect of the volume fraction, V_f on the location critical diagonal crack is not well defined. It is also concluded that the ACI –ASCE committee 326 expression for predicting the location of the diagonal crack in conventional reinforced concrete beams under estimates the location for ferrocement beams with a/d = 1.0 and over estimates the location for beams with a/d ≥ 1.5.

Mansur, M.A. and Ong, K.C.G. 1987[13], Conducted shear tests on the ferrocement Channel sections and concluded that, the behaviour of these structural sections is similar to that of structural reinforced concrete sections. It is also mentioned that the ferrocement beams exhibit numerous cracks and sections are serviceable up to 90% of the ultimate load.

Desayi[10], Proposed a semi empirical formula for predicting the shear strength of ferrocement elements. Till today no codal formula is available to assess the shear strength of ferrocement elements. Thus there is a need to verify, where the shear resistance equations given by existing codes of practice for reinforced concrete can be extended to ferrocement also? This is because; ferrocement can be visualized as a variety of concrete having aligned reinforcing mesh in place of coarse aggregates of conventional concrete.

III- CONCLUSION:
1. The ferrocement slabs have undergone punching shear failure instead of flexure.
2. The critical punching shear perimeter may be assumed at a distance equal to 1.8 times the slab thickness from the face of the bearing plate, the shape being an enlarged reflection of the bearing plate.
3. The load-deflection curves for ferrocement slabs under punching shear exhibit
    Ductile behavior. The inclined shear plane usually forms at the periphery of the loaded area on the top surface, with fewer cracks at the top surface than at the bottom.
4. An increase in the slab thickness (h) has resulted in an increase in the punching shear strength.
5. An increase in the Mortar strength (f_{cu}) has resulted in an increase in the punching shear strength.
6. The number and extends of cracks appearing at the compression side are unaffected by the study parameters.
7. Shear behavior of ferrocement elements is almost similar to the shear behavior of reinforced concrete elements.
8. The code equations are not suitable for predicting the punching shear strength of ferrocement slabs.
9. The predicted values are compared with the design codes.
10. The observed, proposed and predicted values are compared with each other.
11. Good agreement is found between observed, proposed and the predicted values.

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