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Experimental Study on the Ferrocement Panels

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Abstract: An improved qualitative arrangement of wire mesh which is thought to reflect more realistically the behavior of ferro-cement in flexure is arranged.
The presence of wire mesh reinforcement in ferrocement improves bending strength and crack resistance. The objective of the study is to investigate the behavior of material reinforced with varying mesh layers and orientations and to evelove its material properties.
Tension tests were also carried out on meshes. Bending tests is to be conducted for specimen under two point loading. The effects of the varying reinforcement arrangements would replicates its response on strength and bending characteristics of ferrocement characteristics under tension and simple bending which to be studied experimentally, and those results also will be discussed in the paper.
Keywords: Ferrocement, Compressive Strength, Tensile Strength.

I. INTRODUCTION

Ferrocement is the composite of Ferro (Iron) and cement (cement mortar). Ferrocement can be considered as a type of thin walled reinforced concrete construction in which small-diameter wire meshes are used uniformly throughout the cross section instead of discretely placed reinforcing bars and in which Portland cement mortar is used instead of concrete. In ferrocement, wire-meshes are filled in with cement mortar. It is a composite, formed with closely knit wire mesh; tightly wound round skeletal steel and impregnated with rich cement mortar

With Ferrocement it is possible to fabricate a variety of structural elements, may be used in foundations, walls, floors, roofs, shells etc. They are thin walled, lightweight, durable and have high degree of impermeability. It combines the properties of thin sections and high strength of steel.

In addition it needs no formwork or shuttering for casting. Ferrocement have applications in all fields of civil construction, including water and soil retaining structures, building components, space structures of large size, bridges, domes, dams, boats, conduits, bunkers, silos, treatment plants for water and sewage.

II. LITERATURE REVIEW

A. Dr.T.S.Thandavamoorty and S.Durairaj Professor at Adhiparasakti Engineering college Melmaaruvathur

A hollow cored ferrocement floor panel of size 900 mm X 600 mm was precast with cement mortar 1:2 and cured for 7 days. Then it was arranged in a loading frame and tested under gradually increasing static loading till failure. The ultimate load sustained by the panel was 85 kN.

B. Mohamad Mahmood Civil Engineering department Mosul University Iraq

The paper describes the results of testing folded and flat ferrocement panels reinforced with different number of wire mesh layers. The main objective of these experimental tests is to study the effect of using different numbers of wire mesh layers on the flexural strength of folded and flat ferrocement panels and to compare the effect of varying the number of wire mesh layers on the ductility and the ultimate strength of these types of ferrocement structure. Seven ferrocement elements were constructed and tested each having (600x380mm) horizontal projection and 20mm thick, consisting of four flat panels and three folded panels. The used number of wire mesh layers is one, two and three layers. The experimental results show that flexural strength of the folded panels increased by 37% and 90% for panels having 2 and 3 wire mesh layers respectively, compared with that having single layer, while for flat panel the increase in flexural strength compared with panel of plan mortar is 4.5%, 65% and 68% for panels having 1, 2 and 3 wire mesh layers respectively. The strength capacity of the folded panels, having the particular geometry used in the present study, is in the order of 3.5 to 5 times that of the corresponding flat panels having the same number of wire mesh layers.

C. STRUCTURAL BEHAVIOR OF FERROCEMENT SYSTEM FOR ROOFING By Wail N. Al-Rifaie and Muyasser M. Joma'ah (1) University of Nottingham, U.K. and Professor Emeritus, University of Tikrit (2) Civil Engineering Dept, Eng. College, University of Tikrit

Experimental work: - Slab specimens S1 to S4, are square having overall dimensions of 500x500 mm. Specimens S1 and S2 are 20 mm thick, whereas S3 and S4 are 30 mm thick. Specimens S1 and S3 have two mesh layers while specimens S2 and S4 have four mesh layers. Hexagonal wire mesh with diameter of 0.7mm is used for both slab specimens and beam models. The moulds of slab specimens consists of a flat steel plate of which angle iron pieces having out-standing leg of 20 mm or 30 mm have been bolted to get square inside dimensions of 500x500 mm. Ink markings have been made all-round the inside periphery of the mould to indicate location of the mesh layers. The top surface has been leveled off by a trowel.

D. FERROCEMENT BOX SECTIONS-VIABLE OPTION FOR FLOORS AND ROOF OF MULTI-STOREYED BUILDINGS By A. Kumar Structural Engineering Division, Central Building Research Institute, Roorkee

A 5m x 9m size interior panel of a framed structure has been designed as beam-slab construction, flat slab construction and using ferrocement box sections for 5 kN/m2 live load. The self-weight, floor/ roof height and cost of these options have been compared. It is found that the flat slab option is comparable in weight to the beam-slab option, about 58.2% less in floor height and 17.7% costlier than the conventional beam and slab construction. The ferrocement box section alternative is found to be 56.2% less in weight, comparable in floor height and 15.6% cheaper than the beam - slab construction. The ferrocement box sections being light in weight need less strong supporting structures.

E. PERFORMANCE OF PRECAST FERROCEMENT PANEL FOR COMPOSITE MASONRY SLAB SYSTEM BY Y. Yardim, Universiti Putra Malaysia

This study investigates the performance of inverted two-way ribs precast ferrocement thin panel. The two-way inverted ribs in the ferrocement panel enhanced its flexural stiffness, as well as providing link between the precast layer and the in situ elements. Flexural behaviors of two precast panels and two composite slabs are investigated under two line load and distributed load. Test results indicate that the thin panel with suitable ribs layout and support distance can be used as permanent formwork. Typical load from construction worker and in situ elements could be sustained by the panel. The panel also acts as good composite component with in situ brick and concrete. Composite full slab can sustain typical design loads for residential buildings and until ultimate load and no separation or any horizontal cracks between the layers were observed.

III. MATERIAL AND PROPERTIES

A. Materials use Dinferrocement Structures

Skeletal steel in the form of angles, steel bars, welded wire fabrics or pipes. b) Steel wire meshes for forming cages. c) Rich cement mortar, as matrix in form of micro-concrete. All these three raw materials are those which are commonly used in practice in construction of conventional buildings.

B. Skeletal Steel

In the form of steel bars: Skeletal steel as the name implies is generally used to give basic shape and size to the structure. If used only to give the form to the structure, the steel rods may be spaced wide apart, say even up to 500 mm. When they are not treated as structural reinforcement, they also act as spacers to the layers of meshes. In highly stressed structures, where the skeletal steel acts also as reinforcement, their spacing will be as per the structural design of the structure. Steel bars of 4 to 10 mm dia. are generally used. Sometimes angle framework may be used to support the structure.

C. In Form of Welded bar Fabric

Welded bar fabric may be used as skeletal steel for Ferrocement panels of large size. A wide range of permutations of bar sizes and spacings is available, from which the required design can be chosen. Welded bar fabric is available for bar diameters from 4 to 10mm, with spacing of bars from 50 X 50 to 300 X 300 mm square or rectangular in shape.

D. Specifications

Steel bars to be used should be according to I. S. Specifications as follows: i.Mild steel bars confirming to IS-432(Part I) 1982, ii.Hard drawn steel wires confirming to IS-432 (Part II) 1982 and iii.Hard drawn steel wire mesh fabric IS 1566-1982.

E. Practical Hints in Selecting the Skeletal Steel

i.The steel area particularly at the location of welding of cross bars should not be more than 50% of the cross-sectional area of ferro-cement. It is observed that when large diameter steel bars are used or angles are used, temperature cracks are formed along the line of steel bars. ii.Bars of 6 or 8 mm diameter could be used for small structures, to maintain the rigidity of framework, the edge-bars may be 8mm dia. tor-steel, while the other bars may be 6mm dia. mild steel. iii.The following table 3.1 and table 3.2 will be useful in placing an order in the market for steel bars:

F. Steel Wire Meshes

Fine wire mesh reinforcement is the basic element of ferrocement, it controls the specific surface, which is an important factor in design. The number of layers of meshes, decide the thickness of the composite. Four basic types of meshes are in use. a. Weldmesh b. Fine wire mesh (woven square mesh/interlocked hexagonal wire mesh/Chicken wire mesh) c. Expanded metal. d. Crimped wire mesh

G. Weldmesh

Welded wire mesh of rectangular pattern as shown in fig. 3.1 is formed by aligning wires perpendicularly and welding them at their intersections. Weldmesh is tied on skeletal steel framework and it provides a base for tying fine wire meshes on it. Its surface area is considered in calculating the specific surface of the composite. Weldmesh is designated by the spacing of wires or the size of openings, followed by the gauge of the wire in longitudinal and transverse directions. Thus a 100 mm x 100 mm x 12 g x12 g means a weldmesh of opening size of 100 mm x 100 mm and wire gauge used in longitudinal and transverse directions are 12 gauge. Weld meshes generally used in ferrocement structures are having opening sizes in mm as 25 x 25, 50 x 50,75 x 75, 100 x 100, and 150 x 150. The wire gauges may vary from 10 to 16. Rolls of weld meshes are available in widths of 900, 1200 and 1500 mm and in lengths of 15 m or 30 m

H. Cement Mortar

The matrix used in ferrocement primarily consists of mortar or micro concrete with hydraulic cement as binder, sand as fine aggregate and water. Normally the aggregate consists of well graded fine sand passing IS 2.36 mm sieve. If permitted by the size of the mesh and the distance between the mesh layers, small size coarse aggregate may be added to the sand. The mortar matrix usually comprises of more than, 90 percent of the ferrocement volume, and hence has a great influence on the behavior of the final product. Hence a great care should be exercised in choosing the constituent materials and in mixing and placing them.

I. Cement

The cement should be fresh, of uniform consistency and free from lumps and foreign matter. It should be stored under dry conditions for as short duration as possible. Types of cement are ordinary Portland cement of various grades, rapid hardening cement, sulphate-resisting cement, white and coloured cement and pozzolana cement. The choice of any particular cement depends upon the site conditions.

Generally Ordinary Portland Cement of 43 or 53 grades is used in ferrocement. In coastal areas or for structures exposed to sea water or acidic industrial wastes sulphate resisting cements are recommended. If sulphate-resisting cements or admixtures are not available, rich cement mortar should be used and later the structure should be coated. Cement content in ferrocement is higher than in conventional reinforced concrete. For Ordinary Portland cement IS 8112: 2015 and IS 12269: 2015 should be referred.

J. Aggregates: Sand

Natural Sand

Well graded and washed river sand passing 2.36mm IS sieve is most commonly used as fine aggregate in ferrocement. The maximum size of aggregate depends upon the size of mesh openings and the spacing between the layers of mesh. For 13mm mesh openings, 1/4th its opening size, that is less than 3.25 mm, should be the maximum size of the fine aggregate. For proper gradation fineness modulus of sand should be between 2.4 to 2.5 for maximum grain size of 1.18mm and it should be 2.9 to 3.0 for maximum grain size of 2.36 mm. As shown in fig 3.5, proper control over the grain size and fineness modulus will result in the least water requirement, with better workability and higher strength. Grading of sand, with cement of 43 grade and aggregate as crushed sand confirming to IS 383-1970

K. Grading of sand for Grading zone II

TABLE :01

Sieve Size		Grading limit
ASTM	Particle size	% passing
4	4.75 mm	90 to 100
8	2.36 mm	75 to 100
16	1.18 mm	55 to 90
30	600microns	35 to 59
50	300microns	8 to 30
100	150microns	0 to 10

The fine aggregate should be clean, free from organic matter and relatively free from clay and silt. Hard, strong and sharp silica will give strong mortar, while rounded grains of river sand will result in smooth mortar finishes. IS 383-1970 for coarse and fine aggregates from natural sources should be referred to for specifications of natural sands.

L. Crushed Sand or Manufactured Sand

Crushed sand is a good substitute for natural sands. It is manufactured from quarried rock, by bringing down its particle size in the range of 4.75mm to 150 microns. Crushed sand is quite different than stone dust, which is a waste from stone crushers. Crushed sand has two important features; one is its gradation and the second is its particle size. Crushed sands are successfully used for various grades of concrete from M15 to M40.

M. Water

The mixing water should be fresh, clean and potable. It should be free from organic matter, silt, oil, sugar, chlorides and acidic materials. The value of pH should be close to 7.0. The salt water is not acceptable but chlorinated drinking water will do.

N. Admixtures

Chemical admixtures in ferrocement serve four purposes:

1) Water reduction which increases the strength and reduces the permeability. It can be achieved by using super plasticizers.
2) Waterproofing compounds may be used to get watertight structures.
3) Air entraining agents increase the resistance to freezing and thawing.
4) Suppression of galvanic action between galvanized steel and cement is achieved by using Chromium trioxide approximately 300 parts per million, in mixing water.

O. Proportioning of Cement Mortar

Normally rich cement mortars of mix proportions of (1:1.5) to (1:4) by volume are used in ferrocement. When sand content is increased, its water requirement goes up to maintain the same workability. To obtain strong, dense and mortars of such a consistency, which can easily penetrate the layers of meshes, trial mixes should be taken. Fineness modulus of the sand, water cement ratio and the sand cement ratio for the mix should be determined and used. Due to dispersion of wires throughout the body of ferrocement, problem of shrinkage is not there. Depending upon the method of application of mortar, its plasticity plays an important role. Normally the slump of cement mortars should not exceed 50 mm to provide stiff mortar mix, which can penetrate meshes. For most applications, the 28 days compressive strength of moist cured cement mortars should not be less than 35 MPa. Generally the mix proportions are specified by their weight but on small jobs mixes are made on volume basis. The bulging effects of moist sands must be allowed for, when the mixes are based on volume basis.

P. Practical Hints for Proportioning and Mixing of Cement Mortars.

1) A simple field test to find out stiff consistency of mortar is to form a ball of the mortar in hand and when it is tossed up, it should retain its shape.
2) Another practical test is, when the trowel is inserted in the heap of the mix, it should stand erect.
3) To check silt content in sand, mix it with water, put it in a glass jar, shake it and allow it to settle. The thickness of the layer of the silt collected over sand will show percentage silt content in sand approximately.
4) Another simple test to check silt content, is to rub the wet sand on the palms of hand, the hands will get spoiled if the silt content is high.
5) One medium sized ghamela when filled in to its brim, with level surface, contains about 6 to 8 liters of sand.
6) A good homogeneous cement mortar mix has uniform gray cement-colour and smooth texture. All sand particles are fully covered with cement paste.
7) Compressive strength of ferrocement is the compressive strength of matrix. Hence extreme care should be taken while proportioning and mixing of mortar. If higher strengths are desired, steel fibers may be added or polymer mortars may be used.

Q. Guidance of Proportion of Mortar

A quick guide for various mortar mixes by volume measure and by weight

R. Cement Mortar mix by Volume

Dry mix of mortar = 1.33 x (wet mortar mix)

(Quantities per m3 of wet mortar)

TABLE :02

Mix by volume	Cement (Liters)	Dry sand (Liters)
1:1.0	666	666
1:1.5	533	800
1:2.0	444	888
1:2.5	380	952
1:3.0	333	1000
1:4.0	267	1066

IV. ADVANTAGES OF FERROCEMENT

Ferrocement has following basic advantages over RCC

1) *Increase in Bond Strength:* The transfer of load from steel to concrete and vice versa takes place through bond between the two materials. The bond depends upon the bond-stress of concrete and the area of contact between the steel and concrete. Bond stress of concrete depends upon the grade of concrete. It is hardly 6 kg/cm2 for M15 concrete. The bond can be substantially increased if the contact area between steel and mortar is increased. For Ferrocement, it is achieved by use of small diameter wires and mortar.
2) *Bond area Increase:* Increase in bond area will result in more adhesion between steel and mortar, making it behave more like a homogeneous material and which has become very strong in tension due to increase in bond.
3) *Dispersion of Steel Wires:* Ferrocement is formed by tying together a number of layers of continuous wire meshes. Volume of steel percentage is very large, may be up to 8 percent. Also the mortar cover over the meshes is hardly 3 to 5 mm. Hence, throughout the body of the composite, the wire reinforcement is fully dispersed. This leads Ferrocement to become more homogeneous. It results in improving the properties of Ferrocement in tension, flexure, impact resistance and crack resistance.
4) *Crack Control:* Meshes are fully bonded to mortar and spaced very near to the surface of Ferrocement. Such closely spaced fine wires, very near to the surface of Ferrocement, act as crack arrestors.
5) *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.

6) *Containment of Mortar Matrix in Mesh Layers:* In Ferrocement, layers of wire meshes tightly tied together are impregnated with cement mortar. The matrix is held by the meshes in between and is contained by them.
7) *Formless Construction:* Tightly tied meshes in ferrocement can hold wet cement mortar when it is pressfilled 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 pressfilling, as the mortaring is done in front of your eyes. If the mesh is tied loosely or water cement ratio is not maintained to thick consistency or over-sanding is done, the mortar will flow down and will not be held by the meshes.
8) *Strength Through Shape:* Ferrocrete structures are thin walled and may be hardly 25 to 50 mm in thickness. Hence, to take care of slenderness and buckling, Ferrocement is shaped in different forms to achieve its strength.
9) *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.
10) *High Strength to Weight Ratio:* Being a thin walled structure of high strength, strength to weight ratios in tension and compression of ferrocement are very high. Hence thin sections can take higher loads.

V. SCOPE OF FUTURE STUDY

1) After experimental as well as empirical solution the shear strength of ferrocement depends upon the volumatric fraction ow wire mesh and the shear span to depth ratio.
2) The ductility and load carrying capacity of ferrocement element can be improved by applying different layer of wire mesh.
3) The number of mesh increases the shear load carrying capacity of the ferrocement element.
4) Shear behaviour of ferrocement element is equal to that of reinforced concrete element.
5) The equation used for calculating the shear strength of reinforced concrete thus can be implimented for the case of ferrocement member.
6) Based on the simple mechanism of R.C.C the proposed equation can be used to predict the shear force at cracking and failurefor different cases of ferrocement reinforcement.
7) The critical shear force is normally found to be governed by flexure-shear.
8) The given expression [10 & 11] can be used for calculating the shear strength of ferrocement element .
9) The partial safety factor can probably used for designing the ferrocement element against shear.

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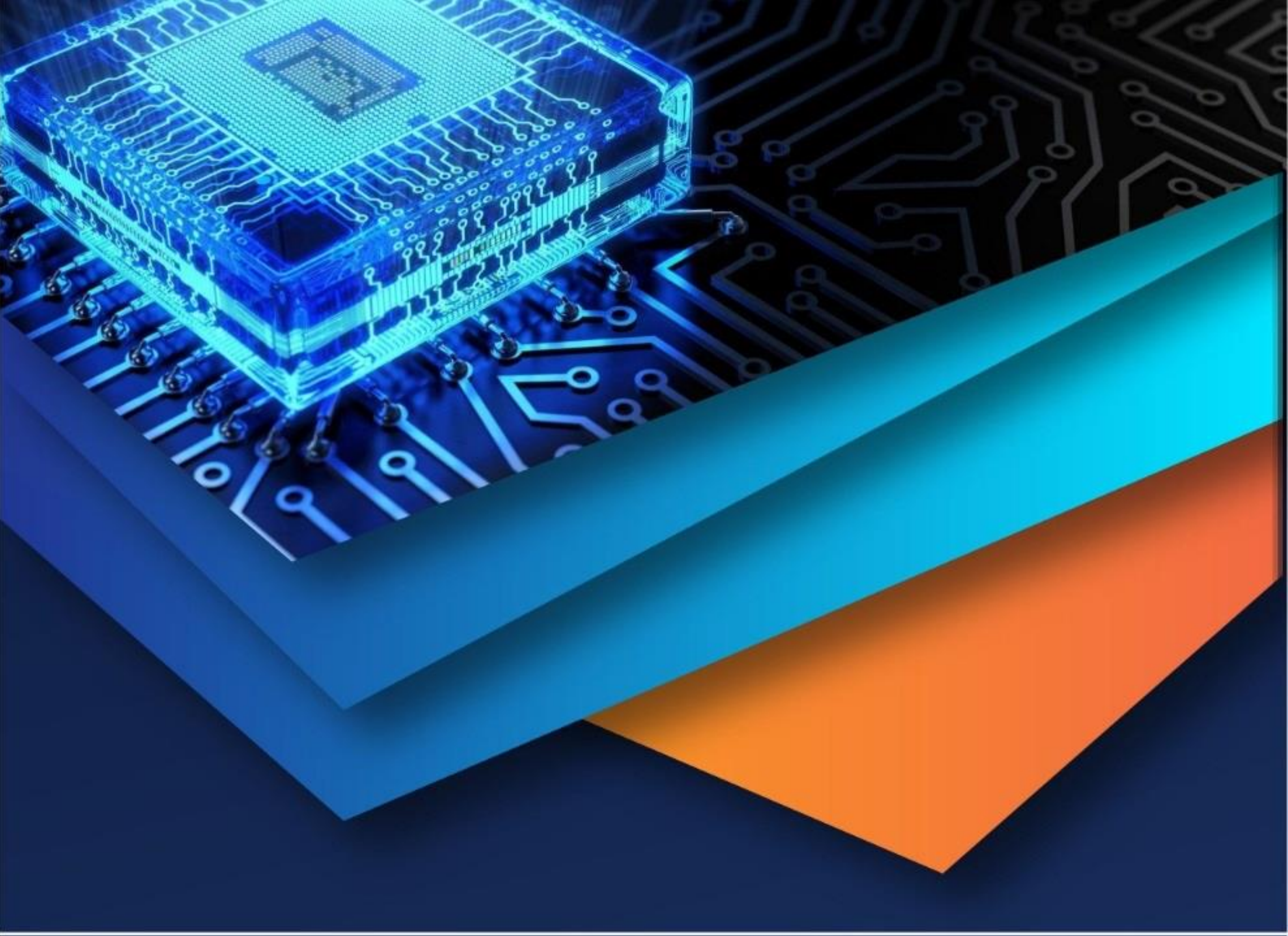

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