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Interlocking Brick Design-Paradigm for Sustainable Construction

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***Abstract* – Recent change in mode of construction industry can be make out with the increasing demand of cement , cement mix product like concrete and clay bricks. All this increased demands for material is result of growth in world population .However, this growth and urbanisation is unstoppable but the demand for such resource consumptions needs to be balance so as to balance ecosystem and environment. This can only be achieved with the concept and implementation of sustainability. The study done and shown in this paper is one such paradigm towards sustainability. The study is done on the concept, modelling of interlocking brick and its strength parameters are checked by laboratory testing and computations method. When the comparison is done for the model made up of conventional clay wall and interlocking brick wall, the strength, durability of later one proved to be much more as compared to initial one. Further study reflected that the application of interlocking brick specified below not only increases strength but also decreases the quantity of mortar required for bonding of wall units. Application of such bricks leads to reduction in material consumption, reduction in environmental pollution, increase in strength and durability of structure, creating an example for sustainable approach towards construction methodology.**
***Keywords* – interlocking bricks, sustainable, paradigm, strength parameters, ecosystem.**

I. INTRODUCTION

K. R. Thakre (1) studies the population rate of India, according to which the census records of 2001 reflects that almost 27% population of India lived in urban areas and this is projected to be 40% till 2021 which seems to be unavoidable, the author highlighted that it contributes approximately 60 % of nations economy and the major problems associated with urban growth is water demand and supply, sanitation, electricity, resource scarcity etc of urban areas. Some of the researcher has done resource scarcity studies like S.K.Agrawal ,et.al ,(2) studies the urban growth ratio of India and suggested the sustainable mass housing technology for India. According to census 2001 urban population in India was 286.1 million which was 377 million as per 2011 census and demand was for 22.44 million dwelling units out of which shortage was of 8.8 million units. This huge demand supply gap for urban housing units increased with time and this needs to be developed with appropriate technology which is highlighted in their research work .Unit with speedy construction, sanitation, and green concept, durable, resistive against fire, blast etc should be considered while incorporating these houses. Utilization of Ferro cementing for walls, hollow slabs and precast panels were adopted for case designed. This high need for housing units indirectly demanded for construction materials like cement, concrete, water, brick etc. Dr. N.Subramanian (3) presented the statistical data of high resource consumption stating that cement is being used for at least 12 million years. Concrete is used widely than any other substance except water, approximately 10km3 every year. The 10.5 billion tons a year concrete industry is thus the largest user of natural resources in the world. It is estimated that the demand for concrete is expected to grow to 16 billion tons a year by 2050. Ordinary concrete typically contains about 12 percent cement, 8% of water and 80% aggregate by mass. This means that, in addition to 1.5 billion tons of cement, the concrete industry is consuming annually nine billion tones of aggregates together with one billion tones of mixing water. T.Noguchi (4) studied on the present pollution effect of cement in use and stated that for manufacturing 1m of concrete generates approximately 0.25 ton of CO2 from the cement production and additionally 0.1 to 0.2 ton of CO2 from the aggregate production, the transportation of materials and the concrete production . 20 billion ton of concrete is produced annually worldwide and consequently concrete-related industries emit approximately 7 to 10% of global manmade CO2 according to a White Paper on the Environment published by the Ministry of the Environment. Similar scarcity and pollution of other such precise resource is matter of high concern that is water. Dr. M. Arif Shaikh , S.B.Kolhe (5) has shown that 4000 billion cubic meter of water is gained from sky out of which only about one fourth of this is actually usable, the rest runs off into the river. The average availability of usable water has corresponding decreased from approx. 6000 cubic meter per capita to 1500 cubic meter. Water crises are major issue which may lead to water war as in Africa stated in United States development report. Water prevention against wastage household or due to runoff should be done with provision of water shed management. D.M.Patil (6) stated that with change in human life style the demand for fresh water is also increasing. However only one sector is accessing water and more than a billion people currently lack access of clean drinking water and almost 3 billion lack basic sanitation services. The urban sector enjoying water availability pollutes water and same water is dissipated in rivers causing threat to 20% of freshwater fish spices. This diversion and equal distribution of water resources is must for facing the challenges of changing world. The projected use of water and its effect was studied (7) on the basis of present water demand for various construction activities and manufacturing. The environmental effect due to water pollution is also forecasted for 2050 in this research work. Water demand will be 50% more as if now. Nitrogen effluent was 6 million tons /year in 2000 which is projected to be 18 million tons till 2050.Population lacking to improved water source was maximum in 1990 however in 2050 still 200 millions of people will be lacking from clear water availability. Charges on wastage of water, water retaining structures, and water re treatment plants should be bought into practice. Not only construction is leading scarcity of resources but it is also making sever effect on land mass. Increasing construction is causing serious land problems like degradation, loss in fertility, land pollution and exploitation. In India about 175 million ha of land area is subjected to various processes of degradation and leading to formation of wasteland in different agro –ecological regions of country. In order to achieve the goal for fulfilment of food fuel, fodder and timber requirement deforestation is adding up the degradation ratio of land. Out of various reasons for degradation of land one major factor is rapid construction and need for land and timber. All this is leading to reduction in loss in fertility of soil and crop yield finally affecting natives of country. This problem needs to be overcome by plantation of specific soil retaining tress, plants and shrubs as studies by M.N. Naugraiya et.al, (8). With these huge challenges there is rapid change in potential research work for construction technology and material utilization in last few decades. This rapid change in research work is leading to new inventions of material and technology and thus responsible for change in construction methodology too. This changing scenario of construction methodology is demanding for new generation, rationalized codes for concrete structures as mentioned by S.G.Joglekar (9). Various nations are adopting and amending their code of practice with change in there construction practices however India is lacking back in comparison with other countries. BIS, IR & IRC should realize that the future generations would be demanding the design and analysis concepts for new inventions of bridge, concrete or sustainable structures and thus such provisions should be adopted and amended as soon as possible.

All this reasons justify to find alternative methods so that resource consumption, pollution reduction can be achieved. Construction industry contributes highly for all such problems and thus remedy should be find out for making construction sustainable. Keeping this need in mind the concept of interlocking brick is initiated , designed , tested , analysed and reviewed in this research work done.

II. CONCEPT & IMPLICATIONS FROM IT

The conventional brick which is being used at mass level are having bonding provision in the vertical direction in the form of frog. However, these bricks prove to be weak when acted upon by lateral forces as no lateral interlocking is present. Along with that to make bonding between bricks, mortar is use as binding material. Thus, if geometrical design of brick is changed such that its interlocking property in vertical and horizontal direction increases, integrity between units, the wall will become more durable and resistive. With proper interlocking it may further reduce the need of binding material ‘mortar’ and just cement slurry can serve bonding properly.

This will lead to achieve four purposes towards sustainable construction:-

A. Increase resistive property of wall against vertical and lateral forces.
B. Reduce amount of recourse consumption as mortar will be replaced by cement slurry.
C. Reduce cost of construction.
D. Increase durability of structure.

III.DESIGN AND SPECIMEN CASTING

A. Design trial 1

The design is made according to the concept and it is shown in the figure below. As it can seen that brick has trapezoidal notches at sides for lateral interlocking and square notches at top and bottom for longitudinal interlocking. It has bore at centre for provision of bar for greater strength. It has a rectangular dimension of 19*9*9 cm and notches dimensions are shown in fig. This design will be made from same conventional procedure of brick. The raw mixture of clay with 30% fly-ash is made. It is poured in the mould and a raw brick is casted. It is kept for drying after that, it is burnt in brick. For this a new mould of this design is obtained.

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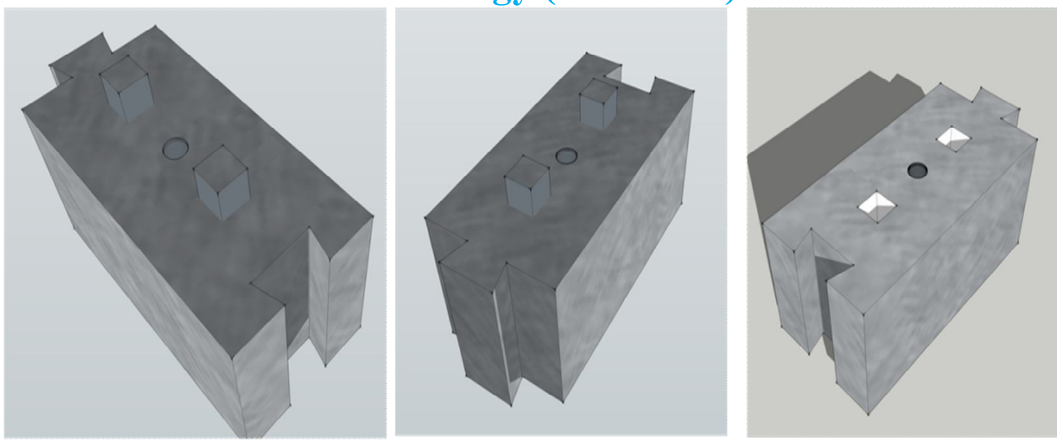

Fig. 1: Interlocking bricks 3D design

For the above interlocking design discussed above and shown in fig. a mould is prepared , made of steel sheet as shown in fig below. The mixture of clay and 30%fly ash is poured in mould and it has top side open, which is impressed on the poured material. Then the top side is removed and mould is kept in inverted position and material is allowed to fall on flat surface. From this a raw sample is made.

Failures with model 1:

1) The brick is not getting release when the mould is kept in inverted position. This is due to the small dimension that specimen get jammed in the mould
2) The clay also sticks to the mould and specimen obtained is partial with edges sheared.
3) Notches failure: Shearing occurs at the notches and it is not obtained.

B. Design Trial

With the failure of model no.1, a revised model with some changes is designed. For this model a new mould made of wood is designed. As the conventional manufacturing process uses wooden mould we tried the same. The same manufacturing process is used to cast the brick in which the mould is wetted and layer is filled at the sides of the mould which will be helpful for release of brick. The sample cased is shown in figure. It requires too much time for casting a single brick.

Figure2: Specimen of ILB model no 2

Failures with model:

1) The similar problem of release of brick occurs with the mould. The material gets fixed in the notch which does allow it to release. With some efforts we succeed in casting some sample.
2) The specimen obtained is not in proper shape due to releasing problem of brick.
3) The inner bottom square notches get cracked due to inversion of mould
4) Due to side opening of the mould it is very hard to handle and cast a brick
5) The inclination of the trapezoidal notches is creating a weak shear zone, which another issue with the notches

C. Design Trial 3

Another revised model is designed keeping all previous problems in mind by changing the dimensions. New model has a dimension of rectangular block 20*10*10 cm. The square notches and bore is of same size. The angle of inclination of trapezoidal notches is changed. The new mould is made of wood with side wall open and tied with the help of iron coupling as shown

.

Fig 3: Mould and specimen ILB of model no. 3

The material is poured in the mould as same as the previous procedure with application fly ash and all. The model is kept as it is and impression of top side made. After that the sides are remove and specimen in released. The specimen casted is shown below

Failures with model:

1) Friction occurs due to the provision of iron rod for bore.
2) Due the bore at the centre, shearing occurs in the centre.
3) The fresh specimen remains good, after some time due to bore the bottom notches also get cracked.

D. Design trial 4

The bore is reason for failure in the design. It is cancelled and keeping all designs features same as of model no. 3. The specimen is casted as shown in the figure

Fig.4 : Raw specimen of ILB Model no. 4

Properties of interlocking brick:

1) Dimension: 20*10*10
2) Density: 1252 Kg/m³
3) Moulding material: Clay with 30% fly-ash
4) Burnt at temperature: approx. 400°C
5) Weight : 2.50 Kg

E. Various test conducted and results:

1) Nail test: This test is performed by making a scratch on the lateral surface of brick with finger nail. No impression is left on the brick, hence the specimen is sufficiently hard
2) Structure Test: The specimen is broken into two pieces and is examined, it was found homogeneous, compact, and free

from defects e.g. lumps and holes, etc.

3) Soundness Test: This test we performed by striking two specimen bricks with each other. The bricks do not break and a clear ringing sound is produced.
4) Compressive Strength Test: Specimen brick is immersed in water for 24 hrs. Since there is no frog, we remove top notches and bottom notches of brick are filled flush with 1:3 mortar and brick is stored under damp jute bags for 24 hours followed by immersion in clean water for three days. The specimen is then placed between plates of compression testing machine. Load is applied axially at uniform rate till failure. Maximum load at failure divided by average area of bed face gives us compressive strength.

TABLE I
COMPRESSIVE STRENGTH OF BRICK SPECIMEN

Specimen No.	Area of C/S mm^2	Weight of brick Kg	Mean weight Kg	Density Kg/m^3	Water absorption Capacity %	Mean Water absorption	Compressive strength	
							Strength in N/mm^2	Mean strength N/mm^2
1	200	2.55	2.504	1252	9.80	9.942	9.88	9.82
2		2.50			10.10		9.84	
3		2.52			9.96		9.77	
4		2.48			9.82		9.82	
5		2.47			10.03		9.79	

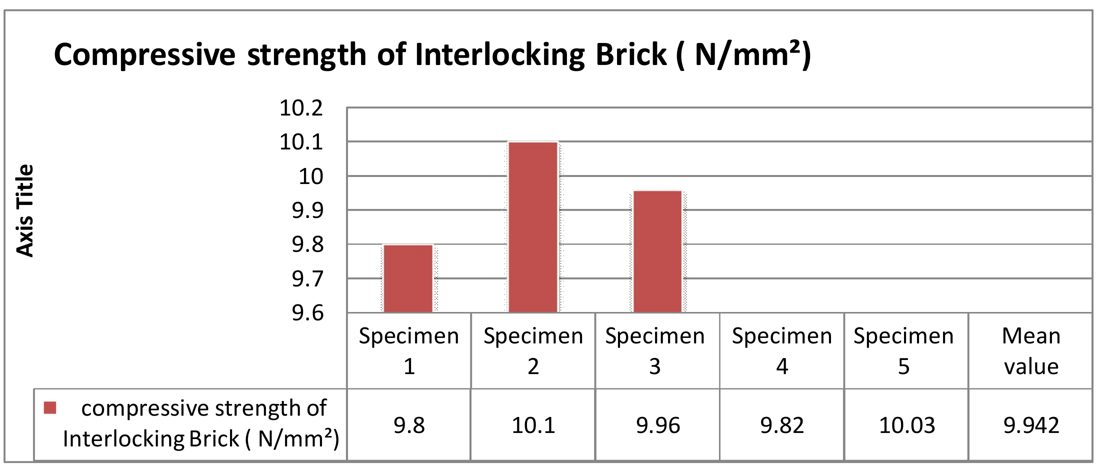

Fig.5 .Compressive strength chart

IV. COMPUTATION MODELLING AND ANALYSIS

To check out feasibilty for application of interlocking brick designed , various case consideration is done . The comparision of normal wall made up of conventional clay brick behaviour for various loading condition is done with the wall made up of this interlocking brick . The dimensions , support condition , material property and loadings for both walls are kept same. Analysis results highlight the merit of interlocking system against normal brick design considered.
The software used to carry out analysis of walls is Staad.PRO .
Basically 6 times analysis is done for following cases:-

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A. Case I :- wall made up of conventional clay brick subjected to vertical / gavity load.
B. Case II:- wall made up of interlocking clay brick subjected to vertical /gavity load.
C. Case III:- wall made up of conventional clay brick subjected to lateral nodal load.
D. Case IV:- wall made up of interlocking clay brick subjected to lateral nodal load.
E. Case V :- wall made up of conventional clay brick subjected to both vertical & Lateral load.
F. Case VI :- wall made up of interlocking clay brick subjected to both vertical & Lateral load.

V. OBSERVATIONS & REMARK

Table II. Comparision for maximum displacment value of case I (conventionl brick) & Case II (Interlocking brick) wall subjected to vertical load only

Case type	**Sr.no**	**Node. No**	**Location**	**Max. displacement (mm)**		
				X	**Y**	**Z**
CASE I	**1**	-		0	-	-
	2	61	Top corner	-	-1.44E6	0
	3	-		-	-	0
CASE II	**1**	-		0	-	-
	2	805	Top corner	-	-515	0
	3	-		-	-	0

Table III. Comparision for maximum displacment value of case III (conventionl brick) & Case IV (Interlocking brick) wall subjected to lateral load only

Case type	**Sr.no**	**Node. No**	**Max. displacement (mm)**		
			X	**Y**	**Z**
CASE III	**1**	13	4270	-	-
	2		-	0	-
	3	-	-	-	0
CASE IV	**1**	192	2917	-	-
	2		-	0	
	3	-	-	-	-2800

Table IV. Comparision for maximum displacment value of case III (conventionl brick) & Case IV (Interlocking brick) wall subjected to vertical & lateral load .

Case type	**Sr.no**	**Node. No**	**Max. displacement (mm)**	
			X	**Y**
CASE VI	**1**	13	4270	-
	2	61-Top corner	-	-1.44E6
	3	-	-	-
CASE VII	**1**	192	2917	-
	2	805-Top corner	-	-515
	3	-	-	-

Table V.- Comparision for nodal displacment value for top to bottam nodes along one edge of wall for case VI (conventionl brick) & Case VII (Interlocking brick) wall subjected to vertical & lateral load.

Case no	**Node no.**	**Displacment (mm)**	
		X	**Y**
Case VI	61(at top)	4270	-4.52E6
Case VII	**804 (at top)**	**2917**	-1.61E6
Case VI	49	4270	-3.76E6
Case VII	**651**	**2917**	**-1.34E6**
Case VI	37	4270	-3.76E6
Case VII	**498**	**2917**	**-1.34E6**
Case VI	25	4270	-3.76E6
Case VII	**345**	**2917**	**-1.34E6**
Case VI	13	4270	-3.76E6
Case VII	**192**	**2917**	**-1.34E6**
Case VI	1-bottom of wall	0	0
Case VII	**1-bottom of wall**	**0**	**0**

Remark: From all above table , it is obseved that keeping material property and loading same , the resistivity of Interlocking brick is more as compared to normal brick only on basis of geomerty designed.Further more strenght and economy can be achived by repalcement of material .

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VI. CONCLUSIONS

The concept, design and application of interlocking brick design proves to effective example for sustainable approach towards construction. It has been observed that when structure is subjected to gravity load only , the brick wall proves to be stable . But consumes large quantity of binding material, that is mortar. Similarly, when the brick masonry wall is subjected to lateral or horizontal forces , it fails due to shearing or overturning as the bonding is weak in horizontal directions. This further leads to sever human hazard at the time of disasters like earthquake. To overcome all this shortcomings and limitations of conventional clay brick wall , the concept of interlocking brick shown above proves to be very effective. From the laboratory test and analysis done for the design specified interlocking brick wall, the stability and strength of wall is more as compared to conventional walls. The bonding due to notches in vertical as well as horizontal direction leads to high interlocking strength between brick units. Further the material is clay and size is similar to that of normal bricks, no reduction in compressive strength and change in wall thickness is obtained. With the application of this high strength interlocking bricks there are considerable reduction in amount of binding material used for wall that is mortar. And, thus the total material consumption is also reduced. This reduction in material consumption can be increase with application of fly ash based clay mix brick material. Thus the study and research done above, clearly reflects the benefits of using and adopting such brick in construction industry and creates paradigms for sustainability.

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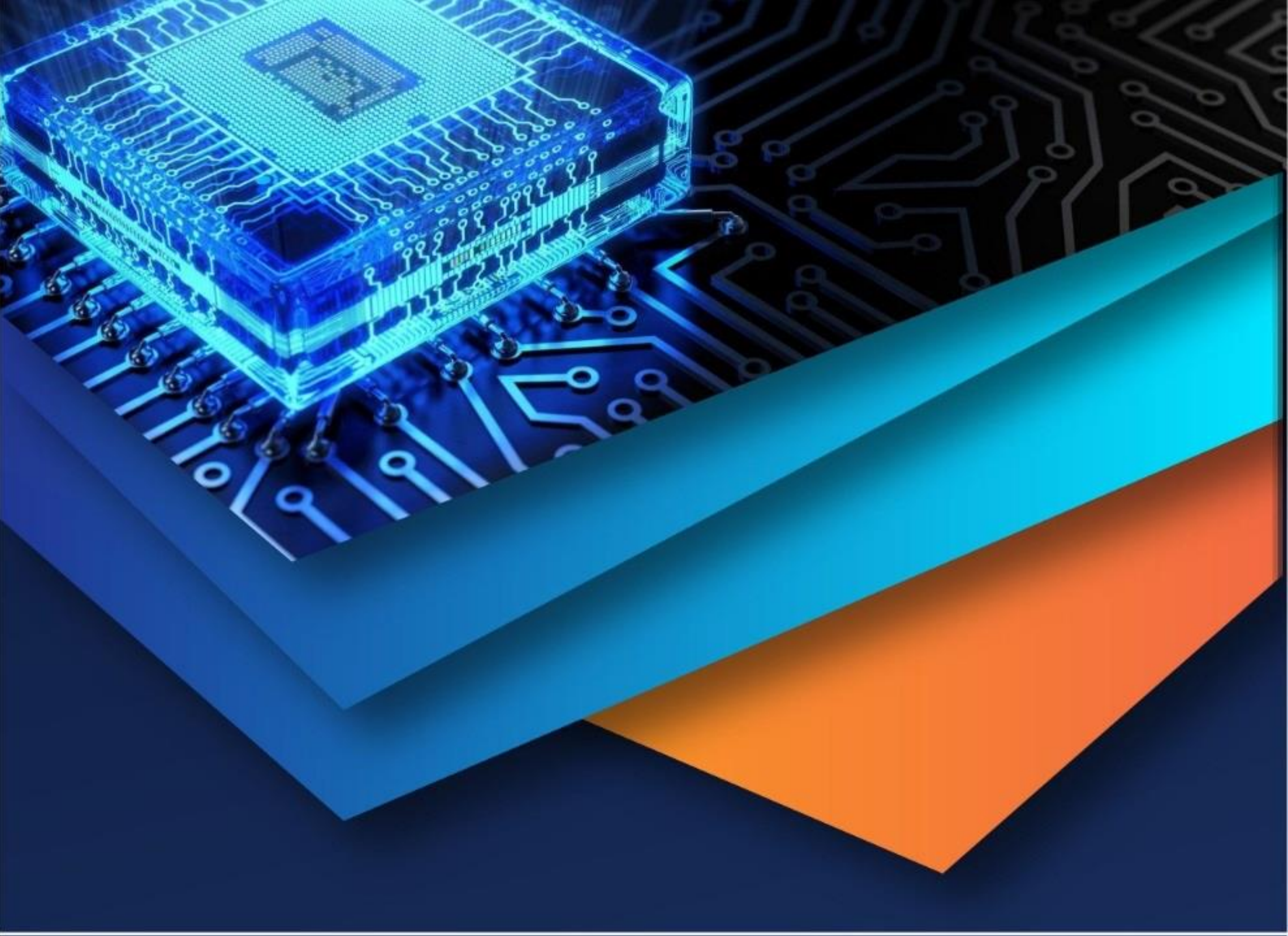

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