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Various Alternatives in Flexible Pavement Design and their Suitability

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Abstract: The road network of about 63.3 lakh Km in India is the second largest in the world. Mostly Flexible pavement construction had been adopted but over last decade, emphasis is made to build long lasting pavement and hence Concrete Pavements have got more adoptability. All pavements are designed in accordance with the relevant codes. However, in order to make road infrastructure more economical by virtue of utilization of various recycled materials, greater flexibility is available in terms of design. However, this requires a thorough understanding of the genesis of various design types, their suitability under various site conditions and also availability of construction materials and technologies. This paper is intended to make an overview of such attempts and studies that may act as an extended guide for pavement engineers and designers. An attempt will be made to study the life cycle cost of different pavements.
Keywords: Flexible Pavement; IRC 37-2018.

I. INTRODUCTION

The road network of about 63.3 lakh km is the second largest in the world and consists of the following categories:Table 1: Road length of different categories:

	Type of Road	Length in km
1	Expressways	47132
2	National Highways	1452403
3	State Highways	1869084
4	Major District Roads	6321545
5	Rural and Other Roads	6331791

Though conventional types are Rigid and Flexible; the semi-rigid type category has recently found higher degree of applicability due to various reasons.

The design of flexible pavements having design traffic volume > 5 msa is done in accordance with the guidelines mentioned in IRC: 37-2018.The empirical design charts can be used as a guide to select the thickness of various layers. Subsequently then analysis is done for checking various strains that are developed at different critical locations of the pavement section. In case the developed strains exceed the permissible values, the proposed section of pavement needs to be modified suitably. The pavement design is checked by using software IITPAVE.

II. VARIOUS TYPES OF PAVEMENT SECTIONS

A conventional flexible pavement section comprises of four layers above the compacted sub-grade. These are: Sub base, Base course, Binder course and Wearing or Surface course. The Sub base and Base courses are usually granular material and Binder course and Wearing course are made of aggregate of suitable grading and bituminous binder. However various other materials that are obtained from older pavements, can be suitably used.

This provides the following major benefits:

1) Sustainable use of materials leading to reduction in load on requirements of fresh or virgin aggregate
2) Economy in construction
3) Permit the designer to make choices based on their need and also availability of materials.
4) Make creative use of technology

As per IRC: 37-2018; the following 6 types of sections may be adopted for Flexible pavement:

1) *Case-1: Conventional section*

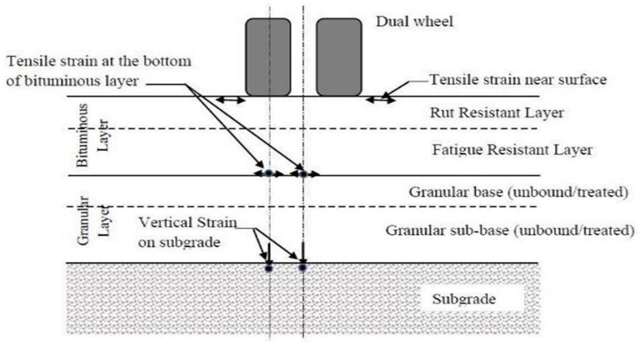


Figure 3.1 A pavement section with bituminous layer(s), granular base and GSB showing the locations of critical strains

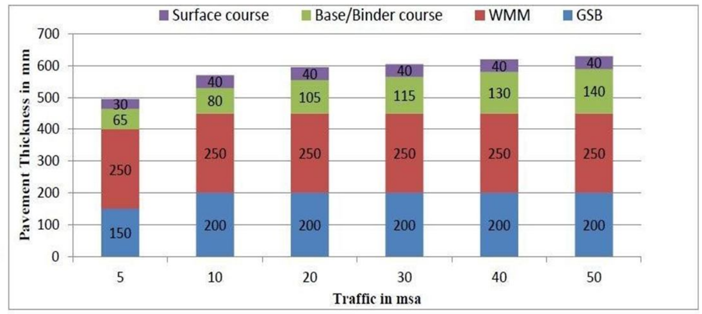


Figure 12.1 Catalogue for pavement with bituminous surface course with granular base and sub-base - Effective CBR 5% (Plate-1)

2) *Case -2: Section with stabilized Sub base and Base course (with AIL)*

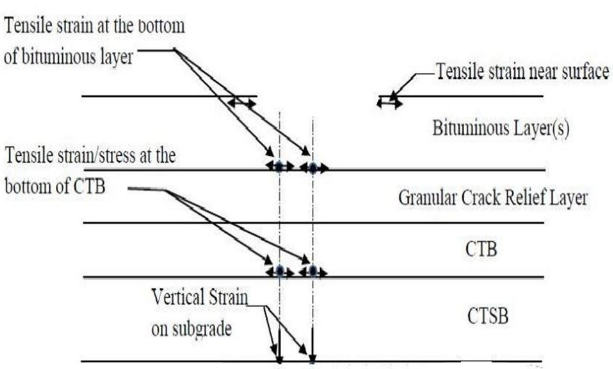
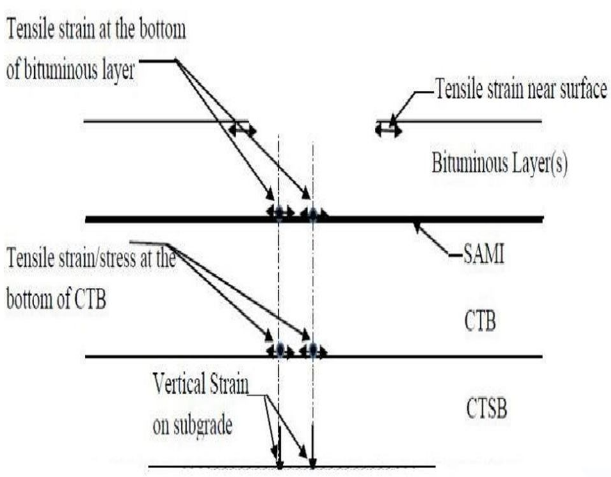


Figure 12.9 Catalogue for pavement with bituminous surface course with CTSB, CTB and granular crack relief layer - Effective CBR 5% (Plate-9)

3) *Case-3: Section with Stabilized Sub base and Base course (with SAMI layer)*



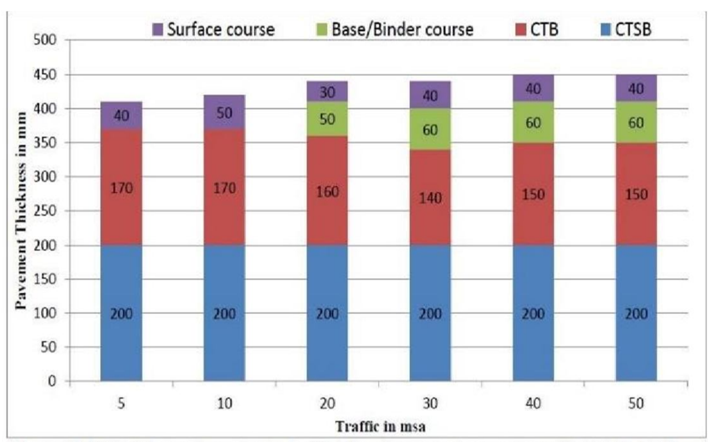


Figure 12.17 Catalogue for pavement with bituminous surface course with CTSB, CTB and SAMI - Effective CBR 5% (Plate-17)

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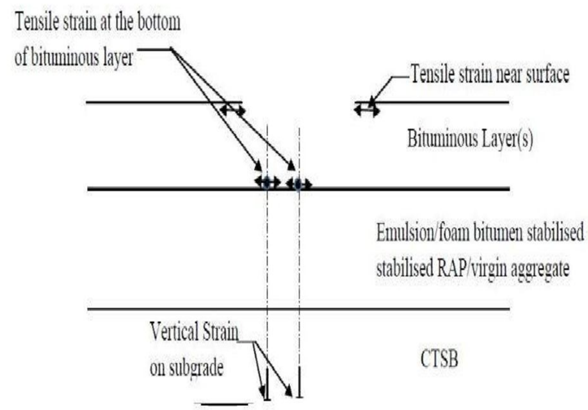
4) *Case -4: Section with Stabilized Sub base and foam bitumen stabilized RAP*



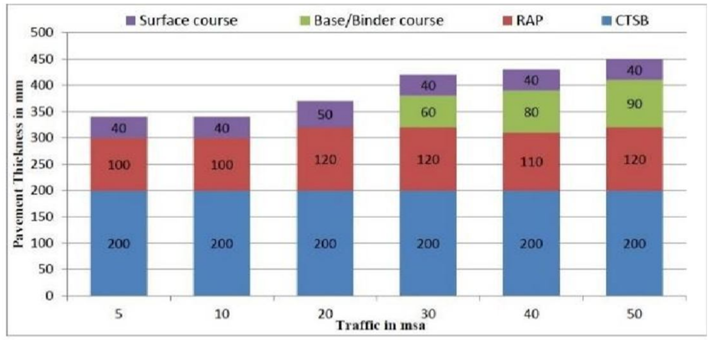
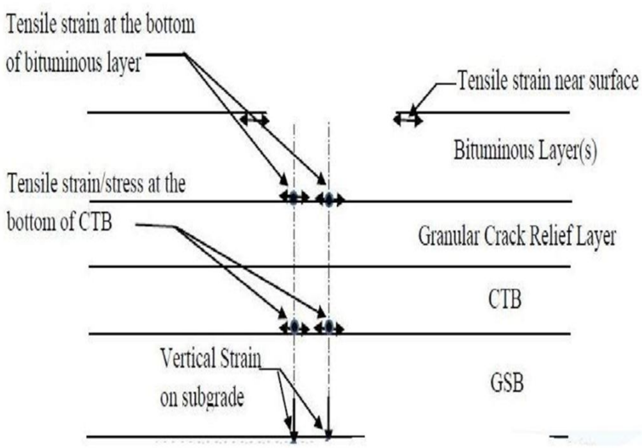


Figure 12.25 Catalogue for pavement with bituminous surface course with CTSB and emulsion/foam bitumen stabilised RAP/virgin aggregate - Effective CBR 5% (Plate-25)

5) *Case-5: Section with stabilized Base (along-with Granular crack relief layer)*



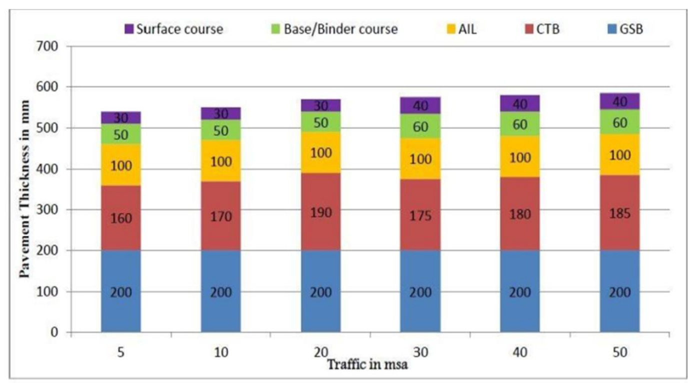
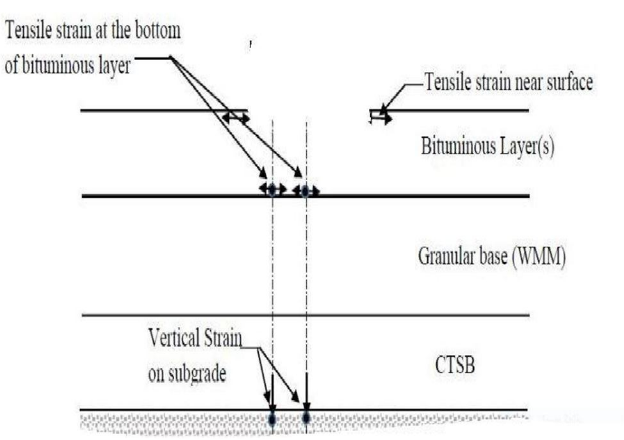


Figure 12.33 Catalogue for pavement with bituminous surface course with GSB, CTB and granular crack relief layer - Effective CBR 5% (Plate-33)

6) *Case-6: Section with Stabilized Sub base*



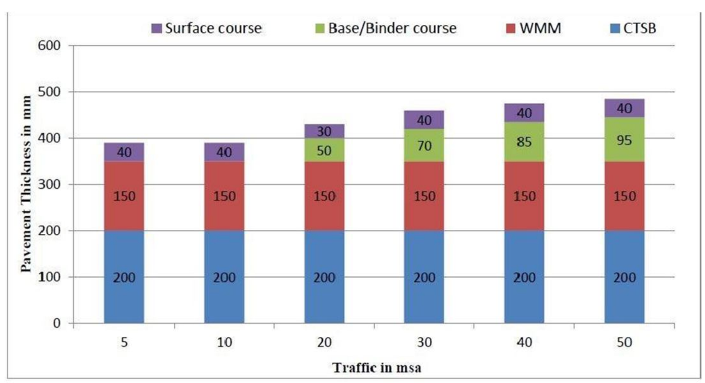


Figure 12.41 Catalogue for pavement with bituminous surface course with CTSB and granular base course - Effective CBR 5% (Plate-41)

An Overview of above 6 options can be summarized as below:

Layer Material	Case -1	Case -2	Case – 3	Case - 4	Case - 5	Case - 6
Sub Base	GSB	CTSB	CTSB	CTSB	GSB	CTSB
Base	WBM/ WMM	CTB	CTB	Foam stabilized RAP/Virgin Agg.	CTB	WMM
Binder Course	DBM	-	-	-	-	DBM
Granular Crack Relief Layer	-	Y	-	-	Y	-
SAMI layer	-	-	Y	-	-	-
Surface Course	Bituminous (BC /SMA etc.)					

A. Selection of Pavement Composition

With so many options available, selecting a most appropriate type shall be guided by various factors such as:

1) Type of materials available e.g. virgin, recycled etc.
2) Technology available
3) As whether the construction is new or is it case of strengthening.
4) Scarcity of virgin materials
5) Time available

However, given an option that any of these can be chosen, the issue zeroes down to determining the most economical optionwhich is technically viable as well. Thus, the study to determine most economical section is required to be done.

III. REVIEW OF LITERATURE

1) Narayan KC[1], Rajendra Aryal[2] (October 2022): CTB is practically impervious due to its hard, rigid nature. It is resistant to cyclic freezing, rain, and spring-time damage. The unconfined compressive strength, flexural strength (modulus of rupture) and modulus of elasticity tests were used to evaluate the performance of CTB. Even when subjected to traffic, a cement-treated base gains strength with age.
2) Patil V. P.[1] & Karvekar A. V.[2] (2019) “A Study of Cement Treated Base and Sub Base in Flexible Pavement”: The initial cost of construction and maintenance cost is less for CTB and CTSB method due to minimum use of material, less transportation charges, less machinery and fuel consumption. It is seen that the pavement with conventional crust fails for the distresses such as cracking, and rutting. But, the pavement with CTB and CTSB provides better fatigue and rutting resistant. Further, the pavement thickness is reduced up to 100 mm after usingthis.
3) Sharma H.[1], Bhardwaj H.[2], & Nagar, D.[3] (2019) “Economic Analysis of use of Cement Treated Base & Sub- Base in Flexible Pavement”: Cement treated flexible pavement layer require less thickness as compared to conventional pavement because the loads are distributed over a large area. CBR values of the cement treated layers are increased as we increase the % of cement content. It is designed to resist damage caused by cycles of wettingand drying and freezing and thawing. The overall saving is up to 9% by using optimum amount of cement contentin granular layers of flexible pavement.
4) Dewalegama U. A.[1], Sharma S.[2], & Sachdeva S. N.[3] (2018) in their study “Thickness Reduction in Flexible Pavement Using Cement Treated Base and Sub-Base” observed that use of CTB and CTSB saves the material cost, transportation cost, maintenance cost. It is seen that the pavement with conventional crust fails for the distresses such as cracking, and rutting. But the CTB and CTSB gives resistance to fatigue and rutting. The pavement thickness is also reduced.
5) Patil Yadnesh, Rayate Rahul (et.al)(2018) “ Cement Treated Sub-Base For Bituminous Pavement “It aims to develop a pavement design chart for rural and urban roads with light to medium traffic using cement and lime stabilized sub-base to save costs and increase road life. The study highlights that stabilizing agents such as cement, bitumen, lime, or non-traditional agents can improve soil properties, with cement-bound materials showing high stiffness, strength, and good performance for pavement serviceability and durability. Cement Treated Base (CTB) is recognized for improving engineering properties, construction speed, structural capacity, and pavement life. The findings emphasize that CTB reduces base thickness and increases bearing strength compared to unbound granular bases. The study concludes that using cement-treated sub-base results in longer pavement life, accelerated project completion, reduced aggregate consumption, cost savings, and improved resistance against cracking and fatigue. It provides cost-effective and durable solution for road construction, especially in low-lying water-clogged areas.

6) Rasha. Abd Al-Redha Ghani, Dr. Mohammed A. Al-Jummaily and Dr. Ahlam K. R. Al-Zerjawi (2018) The research paper investigates the mechanical behavior of cement-treated aggregate mixtures in construction applications, particularly for road bases and pavement. Based on laboratory tests such as proctor compaction test, CBR, plate loading test, unconfined compressive test, and tensile strength it was found that cement-treated aggregate bases provide additional strength and support without increasing the total thickness of pavement layers, thereby enhancing the structural capacity, reducing construction time, and extending pavement life. There are also potential economic benefits of using cement-treated aggregate bases. Additionally, it presents recommendations for future studies, such as evaluating CTAB materials' performance by resilient modulus, flexural strength, and permanent deformation, and analyzing stresses and strains within pavement structures containing CTAB. The findings suggest that a 10% cement proportion by weight of dry aggregate is the best for providing strength and durability.
7) Prasad S.1 (2016) “Feasibility Study on Cement Treated Base and Sub Base layers of Service Roads”: CTB & CTSB layer reduces cost of the project and also increase life of pavement. It is also found suitable for low lying water clogged area.
8) Chaudhary P.M1 et.al (2016): In many rural areas, most of the roads suffer from premature failure in terms of heavy deformation, cracking, rutting & stripping. For this study, six rural road sections were selected for sub- grade and sub-base stabilization with the use of lime, lime & fly-ash and lime & sand. Tests such as index property, Free Swell Index and CBR were conducted in the lab. Tests showed increase in CBR and overall reduction in construction cost.
9) Mamun Md. Mahmud Hasan1 et.al (2016): In this paper, author reviewed that the strength development in stabilized base or sub-base mixtures is due to matrix that binds the aggregate particles together. The quantity of cementations material in a stabilized base or sub-base mix usually ranges from 5 to 10 percent by weight of the mix.
10) Prasad Saket1 et.al (2016): The research work include development a pavement design chart using cement and lime stabilized base for rural roads with light to medium traffic (traffic volume upto 5 million standard axles). Cement stabilized layers was used in service roads of NH50. Service road of 22.6 km was constructed using cement treated base and sub-base layers. This process was very economical and also helped in increasing life of road.
11) Mojtaba Shojaei Baghini1 et.al (2015): This study investigated effect of freeze-thaw (FT) cycles and moisture susceptibility on the behaviour of cement-bitumen emulsion-treated base (CBETB). The moisture damage was evaluated by performing FT, Marshall conditioning, and AASHTO T-283 tests. Evaluation results of both the Marshall Stability ratio and the tensile strength ratio show that the additives increase the resistance of the mixtures to moisture damage.
12) Satander kumar1, Parveen2, Sachin Dass3, Ankit Sharma4 (March, 2013) “Guidelines on Composite Pavement- Design and Evaluation of Composite Pavements”: This paper evaluates the behaviour of PC mixtures by employing different dosages using the PCD methodology. The main variables were studied (s/c ratio, w/c ratio, AG, compaction level and cement amount) and the main functions were characterized (hydraulic, mechanical and safety properties). It was found out that AG and cement proportion are the main factors that influence the results of PC mixtures.
13) Katman H.Y. et. al. (2013) study the indirect tensile strength of the dry foamed asphalt mix evaluated on the reclaimed asphalt pavement. The strength of the foamed asphalt mixes containing reclaimed asphalt pavement was examined using an indirect tensile strength (ITS) test. The sample was prepared according to the Marshall process in accordance with ASTM D6926 and evaluated in accordance with ASTM D6926-07. Following a 72- hour cure in an oven set at 40°C, samples were examined for ITS. Dry condition or unconditioned refers to this testing circumstance. Reclaimed asphalt pavement (RAP) ingredients don't significantly influence the ITS outcomes, according to laboratory studies. Foamed bitumen contents had a substantial impact on ITS performance.
14) Mantri Anjan Kumar1 et.al (2012): The use of lime stabilized fly-ash sub-base course in model field pavement stretches was made in this study. Cyclic plate load tests were conducted on fly- ash sub-base and on lime stabilized fly-ash sub-base stretches. But instead of fly-ash, lime stabilized fly-ash is used as sub-base material.
15) Mantri Anjan Kumar et.al1 (2009): In this study fly-ash, lime stabilized fly-ash, cement stabilized fly-ash and lime-cement stabilized fly-ash was used as subbase course. Off-lane test tracks were constructed in the JNTU Engineering college campus, Kakinada. It was found that load carrying capacity increases and heave values decreases for lime-cement stabilized fly-ash subbase stretch with respect to the fly-ash subbase stretch on expansive soil subgrade.
16) Marandi S.M1 et.al (2009): Cement and bitumen emulsion together were used in base course stabilization. For optimization of cement and bitumen emulsion ITS, UCS and Marshall Tests were carried out. FWD used to examine the pavement strength. It was found that, the optimum values to eliminate the creation of shrinkage cracks in the whole project and minimize the execution period and construction costs were 3% for both binders in stabilization and its replacement with conventional pavement method.

17) Saltan Mehmetet.al1 (2007): in his study, reviewed the usability of the pumice of the Isparta-Karakaya those categorized in the light aggregate class, have been examined in terms of stabilization material in the sub-base considering volumetric unit weight. Experiments such as stability to freeze, solidity, strength, Atterberg limits and California Bearing Ratio (CBR) have been carried out. It has been observed that pumice can be used as subbase material in pavement construction.

III. FINDINGS DRAWN FROM LITERATURE REVIEW

1) Use of Stabilized Bases and Sub-bases can reduce the overall thickness requirements of pavement.
2) Pavements with Stabilized Bases and Sub-bases results in improved performance against Fatigue and Rutting
3) Use of Stabilized Bases and Sub-bases results in savings of virgin materials .
4) Use of foamed bitumen stabilized base results in savings of virgin material and may enable achievement ofeconomy in construction.
5) The study on dry foamed asphalt mix with reclaimed asphalt pavement found that the foamed bitumen contentsignificantly affects the indirect tensile strength (ITS) performance.

IV. GAPS IN LITERATURE REVIEW

1) The comprehensive studies on design with different sub-grade strength and design traffic need to be carried out to enable designers help select appropriate design options.
2) More studies on evaluation of pavement performance need to be done for different designs.
3) The type of stabilizers may also affect the pavement performance and hence these aspects also need to be analysedover.
4) The economy in construction may dependent upon availability of materials and technology available.

V. PROPOSED STUDY

Further research in this field involves the preparation of various designs involving use of conventional as well as othermaterials. Based on layer thickness obtained from this analysis, cost comparison shall be done for a particular region. This shall be done for a particular set of Soil subgrade CBR value and number of msa's.

VI. CONCLUSION

In order to utilize RAP and to reduce the load on virgin aggregate requirements, provisions have been made in IRC:37-2018. Many studies indicate that use of stabilized sub bases and bases results in improvement of flexural strength of layers and hence better performance against rutting and fatigue in such pavements could largely be emanating from their use. Further research and studies need to be done for various combinations of major design parameters namely sub-grade strength and traffic volume. The long term field studies on performance of such pavements also is required in building up confidence among stakeholders. The present study shall help in building up such data.

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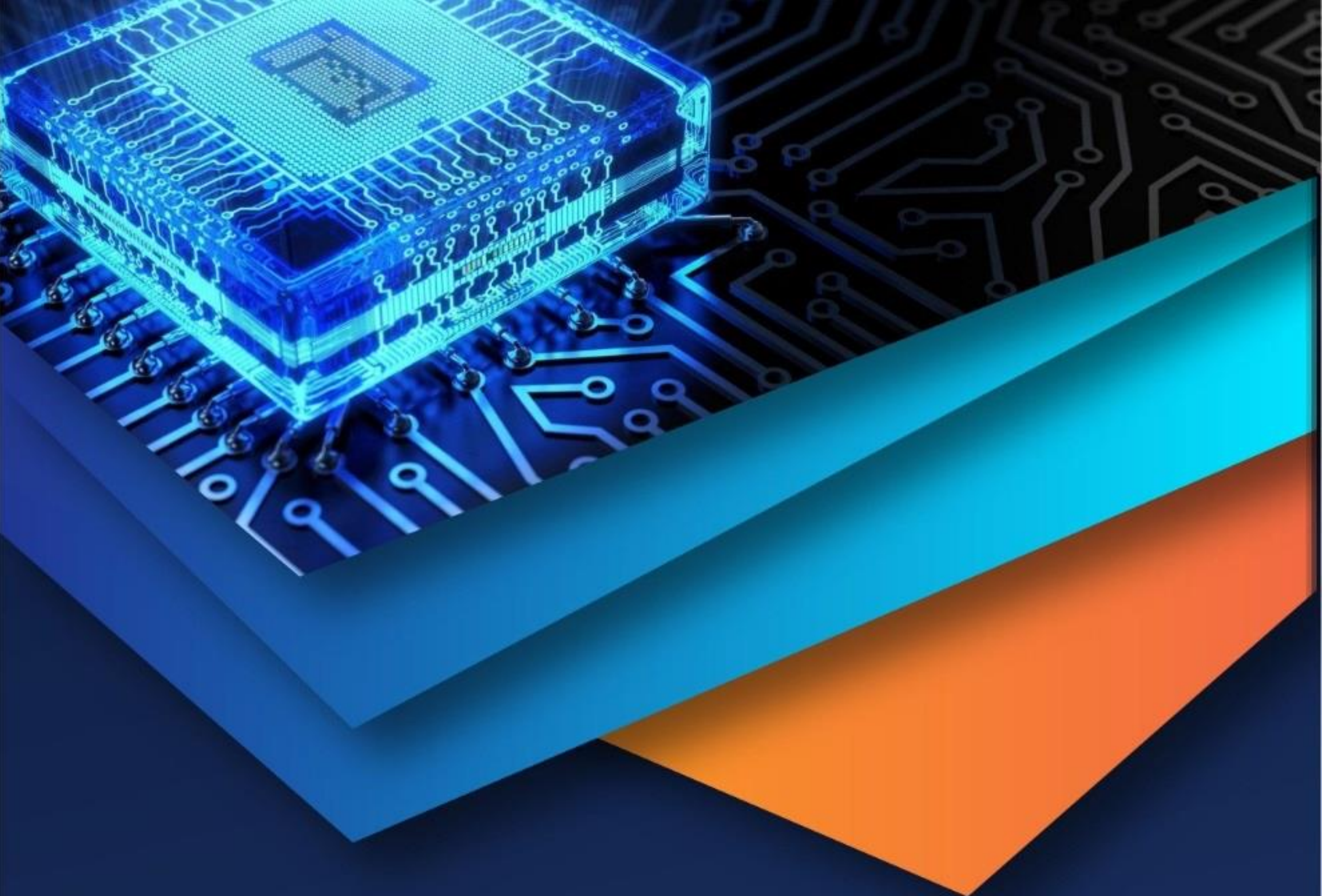

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