iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 6 **Issue:** VII **Month of publication:** July 2018

DOI: http://doi.org/10.22214/ijraset.2018.7006

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 6 Issue VII, July 2018- Available at www.ijraset.com

Base Isolation for Earthquake Resistance: A Review

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***Abstract:** Researches in past reviewed for base isolation analysis using response spectrum it is found that the design in ancient time are not sure and safe due to lake of technology and lesser software analysis availabilities. Some countries applied base isolation these days and the building response constructed with base isolation performed better at practical ground. The response of base isolated building is lesser in terms of amplitude and the cost of the building can also be optimized. Many researchers studied for this subject and they concluded that base isolation must be applied in critical seismic zones and the isolators must be used to save lives and properties. It is seen that Indian construction practices are lacking to apply use of base isolation in building design. It is suggested in the end that it must be motivated to study and research base isolation in Indian constrains and conditions.*
***Keywords:** Base isolation, LRB, Friction base, fixed base, Drift, Displacement, SAP 2000.*

I. INTRODUCTION

Base isolation is a tool in the hands of engineers practicing construction under earthquake boundary conditions. The principle of bake isolation works like, when building is subjected under seismic vibrations and is provided with fixed base the vibration coming from ground are transferred to building and hence building may fails while providing base isolation disconnects the building from ground and reduces earthquake impact and effects.

II. BASE ISOLATION

Experiments and observations of base-isolated buildings in earthquakes indicate that building acceleration can be reduced to as little as one-quarter of the ground acceleration.

A. Lead-rubber bearings are frequently used for base isolation. A lead rubber bearing is made from layers of rubber sandwiched together with layers of steel. The bearing is very stiff and strong in the vertical direction, but flexible in the horizontal direction.

B. Friction sliding isolation uses bearing pads that have a curved surface and low-friction materials similar to Teflon. During an earthquake the building is free to slide both horizontally and vertically on the curved surfaces and will return to its original position after the ground shaking stops. The forces needed to move the building upwards limit the horizontal or lateral forces that would otherwise cause building deformations.

III. LITERATURE REVIEW

The researchers are studying and performing research in the field of base isolation to innovate some improved base isolation technique. Both analytical and simulation research is performed to find best type of isolation system on the basis of application and field zone.

J. C. Ramallo et al., (2002) A ‘‘smart’’ base isolation strategy is proposed and shown to effectively protect structures against extreme earthquakes without sacrificing performance during the more frequent, moderate seismic events. The limited performance of passive systems is revealed and the potential advantages of smart dampers are demonstrated. Two- and six-degree-of-freedom models of a base-isolated building are used as a test bed in this study. Smart isolation is shown to achieve notable decreases in base drifts over comparable passive systems with no accompanying increase in base shears or in accelerations imparted to the superstructure.

Fabio Mazza And Alfonso Vulcano (2004), The main objective of this work is to compare different base-isolation techniques, in order to evaluate their effects on the structural response and applicability limits under near-fault earthquakes. A numerical investigation is carried out. The seismic analysis of the test structures, subjected to strong ground motions recorded near faults, is carried out by using a step-by-step procedure.

Sajal Kanti Deb, (2004), 3D nonlinear analysis procedure of base isolated building is discussed here. Important issues related to design of base isolated building are presented. Shear test for obtaining force-displacement hysteresis loop of isolation bearings is outlined.

Satish Nagarajaiah and Sanjay Sahasrabudhe (2005) Electiveness of a new semi active independently variable stiffness (SAIVS) device in reducing seismic response of sliding base isolated buildings is evaluated analytically and experimentally. This study investigates the performance of a 1:5 scaled smart sliding base isolated building model equipped with the SAIVS device analytically and experimentally, under near fault earthquakes, by developing a new moving average non-linear tangential stiffness control algorithm for control of the SAIVS device.

Alberto Parducci et al., (2005) this paper illustrates the design criteria that guided the architectural and structural designs of the base isolated buildings of the new Emergency Management Centre of Foligno (Umbria). A special attention was paid to the architectural shapes and structural configurations. They have been selected in order to maximize the effectiveness of the seismic protection that can be achieved through the Base Isolation approach. The high potentiality of the Base Isolation option is also illustrated showing its capacity to solve the design problems.

Koji Tsuchimoto et al., (2005) this paper introduces an example of the use of a semi-active base isolation system combining variable oil dampers with the conventional passive base isolation system. The results of a time history response analysis in the event of an earthquake will be presented, and the effectiveness of the system in reducing acceleration will be indicated. Finally, the monitoring system, which serves as a fail-safe system will be explained.

Satish Nagarajaiah and Sanjay Sahasrabudhe (2006) Effectiveness of a new semi active independently variable stiffness (SAIVS) device in reducing seismic response of sliding base isolated buildings is evaluated analytically and experimentally. The analytical and experimental study presented clearly indicates that the semi active stiffness variation using the SAIVS device reduces the base displacements.

Xiaoyu Gu et al., 2007, In this paper, an innovative smart base isolation system employing such MRE isolator is proposed and a novel frequency control algorithm is developed to shift the fundamental frequency of the structure away from the dominant frequency range of earthquakes. Extensive simulation has been conducted using a 5-storey benchmark model with the isolation system. The simulation results demonstrate that compared to bare building and passive base-isolated building models, the smart base-isolated building with the proposed control method demonstrates remarkable performance in minimizing acceleration, inter-storey drift and base shear at the same time under different types of earthquake attacks.

Di Sarno, L. et al., (2007) the present paper focuses on the application of base isolation (BI) to a complex multi-storey irregular structure for hospital building that is under construction in the North-East of Naples, in South of Italy. The case study demonstrates that BI is an effective strategy to improve the seismic performance also for relatively flexible framed structures both at serviceability and ultimate limit states. The design of the sample BI structure was based on the application of the rules implemented in the Eurocode 8, which are similar to those included in the recent Italian seismic code. Architectural and engineering aspects, including both civil and mechanical works, are also discussed.

M. De Iuliis et al., (2008) the non-linear response of isolation devices is considered and defined. This paper aims to investigate non-linear behaviour of isolated structure. In this paper, the seismic response of structure in which the non-linear response of isolation devices is considered. Results highlighted that the seismic performance in reducing the seismic displacement demand is lower than in the case of linear behaviour: a 10% maximum reduction for the peak isolator displacement and a 15% maximum reduction for the RMS base displacement has been observed.

N. Torunbalci and G. Ozpalanlar (2008) Researchers in this research studied analysis methods for most suitable and realistic approaches, where the isolators are provided for the foundations of low-rise and medium-rise buildings. The methods are static equivalent earthquake force analysis, linear response spectrum analysis, linear time history analysis and nonlinear time history analysis. The results are compared for total base shear forces, story shear forces at columns and absolute and relative story drifts. It can be concluded that it is more reasonable to perform first static and then linear response spectrum analysis prior linear time history analysis.

Pan Wen and Sun Baifeng (2008) two step design method for base isolation structure was put forward based on Code [Seismic Code, 2001]. Paper aimed on detail design, the step-by-step time history analysis was adopted for determination of superstructure, foundation and base isolation device. The computation result shows that two step design method is simple and practical, and its concept is clear and easy for further expansion and application. The method is advantageous to enhance design quality and reduce design period.

Silviu Nastac and Adrian Leopa (2008) Summary of existing study for isolation performances improvement of the vibration isolation devices is presented in this paper. Main study is provided with passive isolation, using different structural configurations, based on the compressing and torsion rubber elements. The major conclusion of this study is that the proposed elastic systems with special configurations, have a decisive contribution to increasing the isolation degree of the base structure - isolator - super structure ensemble, up to the 85 to 95%, these values being provided by actual laws.

Shunsuke Otani et al., (2008) This paper reports the response of 10-story reinforced concrete base-isolated buildings to ground motions simulated for large-magnitude earthquakes. If columns are assumed to lose vertical load carrying capacity after the design shear force is developed, the structure collapses in the upper stories after large response deformation is developed in the seismic isolation layer. It is essential even in the design of base isolated buildings to provide ductility on the basis of the weak-beam strong-column concept against unexpected disturbances.

Simon Petrovčič et al., (2009) this article briefly presents the applicability of base isolation made of elastomeric isolators for the protection of heritage architecture. The influence of the slenderness of the structure is analyzed in detail. The analysis is based on the corresponding rocking prevention criterion, upon the condition that the isolators cannot bear any tensile forces. The article concludes with a presentation of the maximum height-to-width ratios for objects that can be mounted on isolators, fulfilling the given rocking prevention criterion for different soil conditions.

Christophe Collette et al., (2011) this paper reviews researches and innovations in the field of active vibration isolation. Limitations of passive vibration isolations are discussed and different active strategies are presented using simple systems and are compared. Finally, several specific issues are listed and briefly discussed. This paper has presented recent patented developments in the field of active vibration isolation. The main active strategies have been presented and compared using single d.o.f. models. Finally, specific issues in the design of active suspensions have been highlighted, like tilt-to-horizontal coupling and cross-talks.

A. B. M. Saiful Islam et al., (2011) Researcher highlights that regarding seismic isolation, there is a lack of proper research. Review of various articles on base isolation incorporation in building structure. Lead rubber bearing (LRB), high damping rubber bearing (HDRB), friction pendulum system (FPS) have been critically explored. It was concluded that the obligations for practical isolation system to be incorporated in building structures are flexibility, Damping and resistance to service loads.

Hyung-Jo Jung et al., 2011, this article investigates a smart base-isolation system using magnetorheological (MR) elastomers. The primary goals of this study are to develop a smart base-isolation model that represents the field-dependent dynamic behaviors of MR elastomers, to design and construct a scaled smart isolation system and a scaled building structure for a proof of concept study and to investigate the dynamic performance of the smart base-isolation in mitigating excessive vibrations of the scaled building structure under earthquake loadings. The results show that the proposed MR elastomer base-isolation system with the fuzzy logic control algorithm outperforms the conventional passive-type base isolation system in reducing the responses of the building structure for the seismic excitations considered in this study.

Shirule Pravin Ashok et al., (2012) the paper deals with the response spectrum to the earthquake resistant structure. An example is presented with fourteen storey structure analyzed with three alternatives which are fixed base, rubber bearing and friction *pendulum* bearing. The results are compared to find best optimal solution with the results such as base and storey shear forces, storey and relative storey drifts, isolator's reasonable displacements. The aim of the paper is to compare between the seismic isolation and fixed based building but not to compare isolation alternatives within themselves.

Yunbyeong Chae and James M. Ricles, 2012, The use of semi-active devices can be a viable solution to decrease the acceleration demand in base-isolated structures under short-period ground motions while it can maximize the damping force under long-period ground motions by adaptively activating/deactivating the damper according to a control law based on structural response. The statistical results from a series of numerical simulations are provided and discussed to validate the performance improvement and robustness of the newly developed semi-active controller.

Donato Cancellara et al., (2012) in this paper a new seismic base isolator, called High Damping Hybrid Seismic Isolator (HDHSI), is proposed. It is obtained by the assembly in series of a Lead Rubber Bearing (LRB) and a Friction Slider (FS) with a high friction coefficient. The HDHSI device is in contrast with the Resilient-Friction Base Isolator (R-FBI) with the aim of optimizing the Electricité De France (EDF) system. The mathematical model of a structure base isolated by a HDHSI system is analyzed with a two Degree of Freedom System (2-DOF) in which the superstructure is assimilated to a rigid body. Nonlinear finite elements are adopted for modeling the HDHSI device. A dynamic nonlinear analysis is performed and the hysteretic cycles are derived and evaluated for the single components and for the innovative HDHSI device.

Chandak N. R. (2013) Seismic base isolation reduces inertia forces in the structure, it is because isolators shifts the fundamental period of the structure out of dangerous resonance range. A parametric study on Reinforced Concrete building with fixed and isolated base with rubber bearing and friction isolator are carried out using response spectrum method. The researcher in this paper investigates the differences caused by the use of different codes in the dynamic analysis of multistoried RC building along with fixed and isolated base condition. SAP2000 is used to perform the study. It was concluded that the building response with isolated base is very less to that of building with fixed base in all the cases.

Katsumi Kurita et al., (2013) a new device of reduction for seismic response using friction force was developed. In this paper, vibration analysis of a small base isolation system using the device was investigated by excitation experiment using artificial seismic waves. Peak acceleration amplitude on the base isolation system has decreased to 43 - 90% compared to input waves. And root mean square (RMS) amplitude has decreased to 76 - 94%. Although a spectral peak around 0.5 Hz that is equal to natural frequency of the system was identified when the input waves with low frequency band component were used, it was decreased using friction bearings that generate high friction force. Comparing the response waveforms of the excitation experiment and of the numerical analysis using a linear 2DOF model, it was good agreement. This system is useful for reduction of seismic response.

Hyun-Su Kim (2014) in this study, the adaptability of a semi-active top-story isolation system with an MR damper for reduction of seismic responses of tall buildings has been investigated. A fuzzy logic controller (FLC) was used to control an MR damper and the FLC was optimized by multi-objective genetic algorithms (MOGA). In this study, a smart top-story isolation system consisting of an MR damper and low damping elastomeric bearings was proposed to reduce the seismic responses of a building structure. Both the isolator drift and acceleration response of the example structure were used as objective functions for the multi-objective optimization problem.

Anusha R Reddy, V Ramesh (2015) the aim here is to study the mode period of structures under fixed condition and base isolated condition. Considering structure G+13 storey building and G+5 storey buildings design is performed using ETABS software. Lead rubber isolator are provided linear response spectrum and time history analysis are performed for both fixed base and base isolated buildings under zone v and medium soil. It is investigated that the mode period is increased after providing rubber isolator due to the flexible property of the isolator. When compared with fixed base structure, the base shear is reduced in base isolated structures, thus the response of building is good in base isolated structures than fixed base structures.

S.Keerthana et al. (2015) Response of structures and its components to earthquake vibrations is the major cause of damages and loss to lives. It can be reduced if the responses are controlled to a tolerable limit. The base isolation system is control system that discontinue structure from the horizontal components of the ground motion. This paper deals with the effect of base isolation on a structure comparing the responses of the base isolated structure and fixed base structure. The influence of isolation characteristics on the seismic response of the structure has been investigated. The effect of using bilinear hysteretic isolation model on the response of the structure has been studied and compared with the linear models.

Minal Ashok Somwanshi and Rina N. Pantawane (2015) a new type of base-isolation system is developed here for a multi-storey reinforced concrete building First case is fixed base and second case is base isolated. Modeling and analysis is done using E-TABS software for Bhuj earthquake ground motion records. Maximum vertical reaction is obtained from analysis in E-TABS software. This paper intends to demonstrate how an isolation system can be efficient, evaluating its effectiveness for the building in terms of maximum shear force, maximum bending moment, base shear, storey drift and storey displacement reductions. From analytical results, it is observed that base isolation technique is very significant in order to reduce the seismic response of both symmetric as well as asymmetric models as compared to fixed base building and control the damages in building during strong ground shaking. Finally it is concluded that base isolation system is significantly effective to protect the structures against moderate as well as strong earthquake ground motion.

M. Mohebbi and H. Dadkhah, K. Shakeri (2015) in this paper, optimal design of hybrid low damping base isolation and magnetorheological (MR) damper has been studied. Optimal hybrid base isolation system has been designed to minimize the maximum base drift of low damping base isolation system where for solving the optimization problem, genetic algorithm (GA) has been used. The main objective of this research has been designing optimal hybrid base isolation which has the capability of controlling the maximum base drift of low damping base isolation. Results of numerical simulations has shown that hybrid base isolation has been more effective than high damping base isolation system in controlling the maximum base drift of the structure so that in this case study about 75% more reduction in maximum base drift has been obtained by using the hybrid base isolation.

S. D. Darshale and N. L. Shelke (2016) this study is concerned with the effects of various vertical irregularities on the seismic response of a structure and controls this response using base isolation. The objective of the study is to carry out response spectrum analysis and time history analysis of fixed base and base isolated vertically irregular RCC structure according to IS 1893:2002 (Part1). The results show that the base isolation reduces the responses lateral displacement, shear forces, bending moments, base shear, storey acceleration, interstorey drift as compared to the conventional fixed base structure drastically. The objective of this study is active seismic vibration isolation. The results show that the base isolation reduces the responses lateral displacement, shear forces, bending moments, base shear, storey acceleration, interstorey drift as compared to the conventional fixed base structure drastically. It can be concluded from the results presented here that base isolation is very effective seismic control measures.

Radomir Folić and Milovan Stanojev, (2016) High seismicity at many locations in the world causes the application of massive structures which induce large inertial forces. This results in severe damage, partial or total demolition of all types of structures. Conventional aseismic design is based on the concept of increasing capacity of resistance of ductile structures using vertical elements and other stiffeners. The paper presents the basic concepts of the base isolation system, a description of the method of designing mentioned system in order to reduce the damage and ensure adequate performance of the structure. In addition it provides a wide review of the literature in the field of base isolation of buildings.

H. Sugihardjo, et al., (2016) A base isolation system is an effective engineering method for reducing seismic impacts by isolating an upper structure from soil vibration due to seismic motion. The primary concept of a base isolation system is the extension of the natural period of a building. However, the production of isolators is very expensive, particularly when an isolator is employed as a residential house's base isolator. To alleviate the issue, a low-cost rubber base isolation system is proposed nonlinear time history analysis (NLTHA) that is based on seven scaled-earthquake records is implemented in one-and two-storey isolated reinforced concrete (RC) residential houses by considering the influence of the isolation ratio. The results indicate that the houses with isolation systems achieved better performance with regard to ductility demand and natural period due to seismic loads. The house with the higher isolation ratio achieved lower ductility demand.

Naveena K and Neeraja Nair (2017) this paper finds that the use of base isolation considerably reduces the response of the structure due to earthquake loading. The significant characteristic of base isolation a system affect the superstructure to have a rigid movement and as a result shows the relative story displacement & story drift of structural element will decrease and consequently the internal forces of beams and columns will be reduced. Due to decrease in lateral loads to stories, the accelerations of the stories are reduced. This results in the reduction of inertia forces. Story overturning moment and story shear are also reduced in base isolated building. From the above points, it is concluded that the performance of isolated structure is efficient in the Earthquake prone areas.

Bhaskar Bhatt, (2017) after much research and development for anti-seismic structures haven't yielded satisfactory results. Studies were being conducted on fixed base structures, but it could be performed on isolated structures. It showed that isolators minimize the lateral load imposed on the structure and reduces size of building components. Base isolation has turned out to be a fruitful design.

Owais Kamran Shaikh and Gitadevi B. Bhaskar, (2018) Modeling and analysis of fixed base and base isolated buildings by using E-TABS software and study the effects of earthquake ground motions on these models and study the effectiveness of lead rubber bearing used as base isolation system and carry out comparison between fixed base and base isolated building on the basis of their dynamic properties like maximum shear force, maximum bending moment, base shear, storey drift and storey acceleration. In this manner it could be possible to decide the effectiveness of this base isolation system, giving advices for future possible applications.

IV. CONCLUSION

It is concluded from review that researchers introduces this new technology of base isolation which protects building to damage under seismic action and the results like drift, displacement and base shear are better with building performance in case of base isolation than fixed base. Further some more concluded points are: cost can be optimized using software simulation applications, high rise buildings can be designed for safety using design software's, column beam design can be optimized for size and hence strength, Quality with cost optimization can be designed for future constructions and effective planning and control can be performed for high rise building using simulation and design software's.

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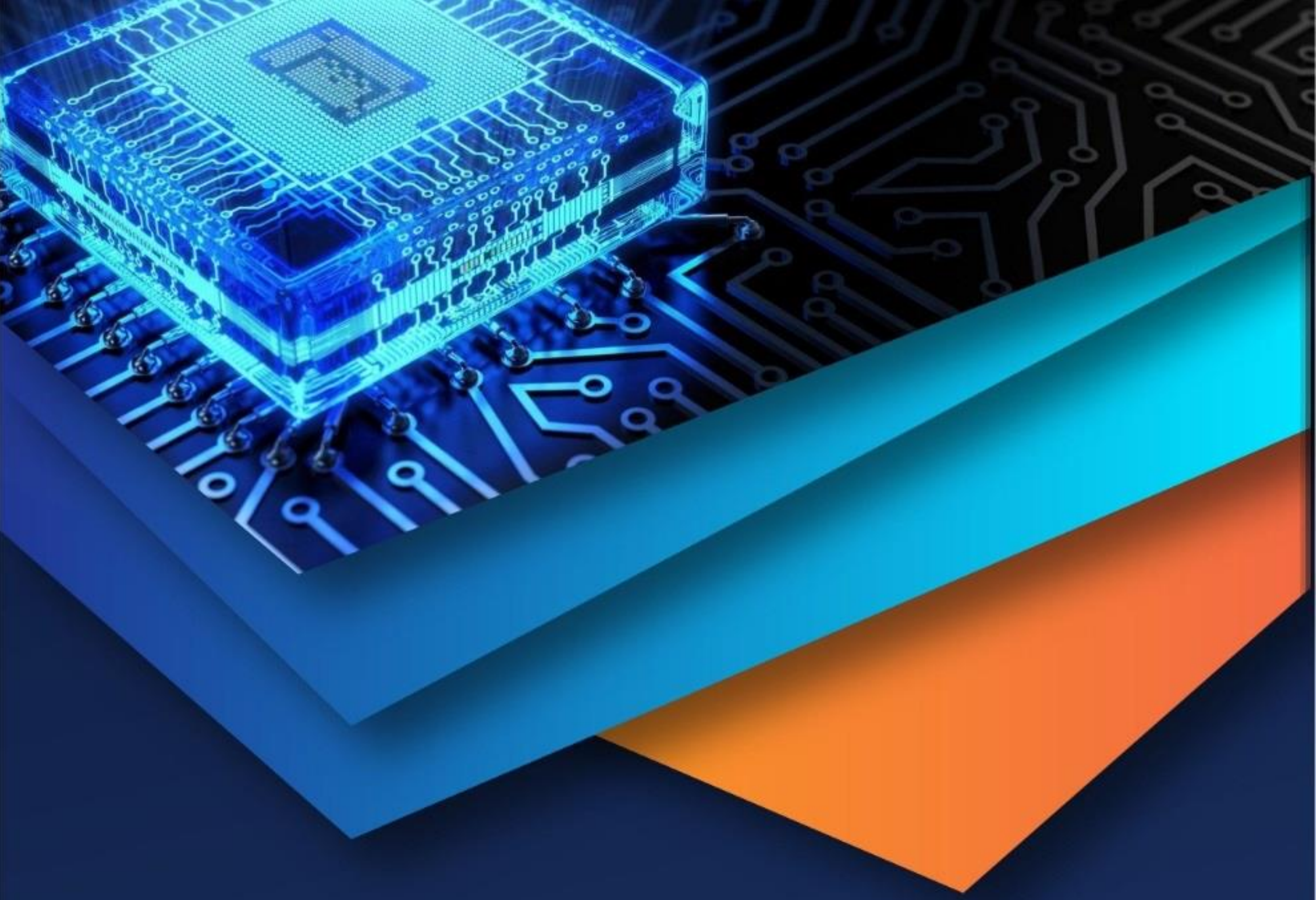

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