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Compare the Seismic Performance of Post-tensioned Concrete Frames to Traditional Moment-resisting Frames with and without Friction Dampers

Yash Tole[1], Manoj Deosarkar[2], Vishwajeet Kadlag[3]
[1]ME Student in Structural engineering, [2]Assistant Professor, [3]PG Co-ordinator, Ajeenkya DY Patil School of Engineering, Pune

Abstract: Conventional reinforced concrete frameworks frequently suffer considerable damage and large residual deformations (drifts) following major seismic occurrences due to the yielding of steel reinforcement and the cracking of concrete. Conversely, post-tensioned (PT) precast concrete frames often employing press technology provide enhanced seismic resilience via a self-centring mechanism, enabling the structure to revert to its initial position following an earthquake. Nonetheless, PT frames by themselves might possess a lower energy dissipation ability when compared to ductile RC frames. This study discusses the effectiveness of a tall structure fitted with various kinds of link dampers to manage seismic vibrations. Owing to their secure, efficient, and economical design, dampers have become increasingly popular in recent years for managing vibrations in structures. They are often used in structural vibration management to mitigate seismic hazards and, by incorporating passive energy dissipation devices, can improve the dynamic performance of both new towers and existing tall buildings. The structure's safety and functionality are enhanced, and the control systems prevent the building from failing in an earthquake, significantly minimizing damage. This paper will examine tall PT + RCC buildings (G+25) incorporating various locations of link dampers for seismic vibration mitigation and investigate the impact of these dampers using ETABS software.
Keywords: PT frames, moment resisting frames, friction dampers, seismic vibration mitigation, ETABs, Seismic analysis

I. INTRODUCTION

Reinforced Cement Concrete (RCC) is the most commonly used building material for urban infrastructure because of its adaptability, fire resistance, and cost-effectiveness. RCC structures can withstand intricate load combinations by merging the high compressive strength of concrete with the tensile durability of steel. In seismically active areas, traditional RCC Moment Resisting Frames (MRFs) are created to dissipate energy via intentional structural damage. This intrinsic 'design for damage' mindset has resulted in an increased need for more sophisticated systems, like Post-Tensioned frames and additional damping devices, intended to improve the seismic resilience of conventional RCC. Post-Tensioned (PT) concrete signifies an advanced development in structural reinforcement, moving from the inert resistance of conventional reinforced concrete to an active internal stress mechanism. In the field of seismic engineering, PT frames are being more widely utilized as a superior option compared to conventional Moment Resisting Frames (MRFs). Through the use of high-strength, unbound tendons, these structures enable a 'jointed' or 'rocking' reaction when subjected to seismic activity. This system enables the beam-column connection to temporarily separate to allow for lateral movement without causing lasting material harm. The main structural benefit of PT systems lies in their natural self-centring ability, which guarantees that the structure reverts to its original vertical alignment after an earthquake, greatly improving the building's resilience and functionality after the event. From a Structural Mechanism and Energy Dissipation viewpoint, Conventional RC frames are constructed as "passive" systems that depend on ductility via material deterioration. In an earthquake, these frames absorb energy by permitting steel reinforcement to yield and concrete to fracture, mainly at "plastic hinge" areas at the ends of beams. In comparison, PT frames function as "active" systems by utilizing high-strength tendons to maintain compression in the concrete. These frames lose minimal energy due to material damage; rather, they employ a "jointed" or "rocking" mechanism that allows the beam-column interfaces to open briefly. This results in a notable performance disparity: although conventional frames are proficient in energy absorption via structural degradation, PT frames do not possess natural damping, frequently necessitating additional devices such as friction dampers to function as "brakes" for the system. From a construction standpoint, conventional RC frames demand significant labour due to the extensive reinforcement detailing (stirrups and ties) necessary for ensuring ductility. PT frames provide a distinct range of efficiencies; utilizing high-strength tendons enables thinner floor slabs, extended spans, and reduced internal columns. This decrease in material volume leads to a reduced seismic mass overall, which naturally diminishes the lateral forces the structure experiences during an earthquake. Structural engineering has arrived at a critical juncture where we need to consider more than merely ensuring a building remains upright during an earthquake. Conventional Moment Resisting Frames (MRFs) are very effective in saving lives as they are engineered to be "ductile"—allowing them to bend and sway considerably without failing. They attain this safety by deliberately permitting certain sections of the structure to fracture and the steel reinforcement to elongate permanently. This intentional damage functions like a "crumple zone" in a vehicle; it safeguards the occupants, but typically the structure is left with a lasting tilt, referred to as residual drift. In numerous instances, even with the structure standing, the expense of correcting this lasting lean and the internal structural harm is so substantial that the building has to be torn down. This paper investigates ways to shift from the "design for damage" strategy to creating more resilient systems that remain upright and can be repaired after the shaking.

Different Earthquake resistant systems are given below:

- Lateral load resisting systems: shear walls, braced frames, concentric beams, eccentric braces, steel plates
- Seismic base isolation: rubber bearings, friction pendulum, air cushion isolation.
- Energy dissipation damping: viscous dampers, friction dampers, yielding dampers, viscoelastic dampers, tuned mass dampers.

Behaviour of structure under earthquake:

Structures experience dynamic forces during earthquakes. In the design of earthquake-resistant buildings, the base is subjected to random movements, which generate inertial forces and subsequently induce stresses. These stresses lead to displacements within the structure. The fundamental parameters that influence seismic design are the mass and stiffness of a building. Since creating a completely elastic structure that remains undamaged is not feasible, we design buildings that can absorb energy while minimizing significant damage during minor, medium, and severe earthquakes. Ductility has been one of the methods utilized for many years. The seismic principles outlined in the Indian code are rooted in the concept of ductility in design. Ductility refers to the ability of a structure to deform beyond its elastic limit while still maintaining control over the deformation.

II. LITERATURE REVIEW

John et al [1] The research detailed in this article delved into examining the influence of design parameter variations on the behaviour of precast, assembled columns using a fibre beam element model. A pivotal discovery of the study was that augmenting the proportion of unbonded post-tensioned tendons (UPT) emerged as a noteworthy factor in enhancing the energy-dissipating capacity of the precast columns. Furthermore, the application of high-strength concrete was determined to be efficacious in mitigating damage and residual deformation post-seismic events. It was underscored that the ratio of unbonded post-tensioned tendons and energy-dissipating bars holds a pivotal role in the overall efficacy of the columns. These findings underscore the critical importance of meticulously considering design parameters to bolster the seismic resilience of precast structures.

Changkal et al [2] In this scholarly article, the primary focus was on utilizing an incremental dynamic analysis (IDA) method to comprehensively model the complete mechanical behaviour history of short columns. The IDA curves were scrutinized, along with the distribution of inter floor displacement angles and the limit state of vertex displacement in frames, in order to delve into the seismic responses of structures. The research revealed that reinforced concrete (RC) frames with short columns constitute a vulnerable layer, ultimately compromising seismic performance. Conversely, the incorporation of ECC short columns was demonstrated to improve seismic performance, albeit still falling short when compared to standard frames. This study illuminates the significance of considering various column types in the design and analysis of structures to ensure their resilience against seismic events.

V. G. Kiran Kumar [3] Explained through their paper that the use of ETABS for a High Rise Building. Load calculation, wind load calculation, seismic load calculation and the design of a post-tensioned frames can be studied. With the use of post-tensioning method, thickness of the slab is reduced. If thickness of slab is reduced, this creates a chain reaction i.e. number of columns and beams is reducing which leads to the structure being more economic and ecofriendly.

Bing et al [4] This paper presents an innovative precast concrete frame beam-column joint that integrates high strength reinforcement. The research conducted simulated reversed cyclic loading tests on two precast connections and one cast-in-place connection to assess the seismic performance of the new precast joint.

The outcomes revealed that YZ1 showcased superior ultimate displacement and ductility in contrast to the cast-in-place connection. Conversely, YZ2 displayed insufficient ductility and energy dissipation capabilities when compared to the other connections. These results emphasize the advantages of implementing the proposed precast connection in earthquake-resistant structures.

Majd Armaly, Hala Damerji, Jaafar Hallal, Mahmoud Fakih [5] This paper represents the seismic response of this dissipative structural method is compared with the response of the conventional method (shear wall system) for the high rise building. To accomplish this objective, a nonlinear modal time history analysis using the El Centro earthquake record for a 40-storey RC high rise building, is performed with four different damper type formats using ETABS software. To illustrate the response improvement by dampers, storey accelerations, storey displacements, base shear forces, and storey drifts are compared with a conventional fixed base system (shear wall system) for the same building. Results show that using an optimum position and number of dampers, a tall building can remain operational during a seism.

III. OBJECTIVES

1) Comparison of the seismic performance of post-tensioned concrete frames to traditional moment-resisting frames with and without friction dampers by software.
2) Evaluate the effectiveness of friction dampers in reducing seismic displacements and damage by software.
3) Evaluation of shear forces, story drift of a critical areas by a post-tensioned concrete frames and moment resisting frames by software.
4) Evaluation of deflection, bending moment of a critical areas by a post-tensioned concrete frames and moment resisting frames by software.
5) Evaluation of results with different positions of friction damper.

IV. METHODOLOGY

A. Modelling

This study is carrying out to investigate the behavioural effect on structure using dampers to structure having post tensioned concrete frames and moment resting frames in it, and at seismic zone IV to determine the effective position of seismic damper. The modelling and analysis is done using ETABS software.

Methodology adopted:

1. Analysis of the model of post tensioned concrete frames and moment resisting frames using soft computing tool.

2. Development of model with and without dampers and bracing considering earthquake zone and soil type.

3. Confirmation of obtained software results referring to the results available in the literature for the similar type of buildings.

4. Developing the models of combine structure (post tensioned and moment resisting) with dampers providing at different positions considering earthquake zone and soil type.

5. Developing the different models of structure with friction dampers providing at different positions in building.

Fig.1 Flow chart of methodology

Model specification are given below:

In this study, a seismic analysis is performed on G+25 high rise structure including PT and moment resisting frames in the structure. A 60m x 35m rectangular floor plan including 3 refuge floors. The floor to floor height is 4m. The total height of building considered is 104m. In the structure at periphery there are 12 columns of 1.5m x1.5m and 0.3m thick shear wall is provided. The core portion of structure has lift wall and some shear walls are provided. The long span beams in Post tensioned frames in 1.2m x 0.6m in size. The core area beams in RCC having size 0.3m x 0.6m in size. Slabs are modelled which are in RCC as well as in PT having size 0.15m and 0.25m respectively.

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In model shear walls and columns considered M40, Beams and slabs considered M30. Concrete cover for shear walls and columns is 40mm, for beams 30mm, for slabs 25mm is considered in model. Reinforcement is considered 500 & 415 for main bar and confinement respectively.

Modelling of Friction dampers:

Friction brake is widely used to extract kinetic energy from a moving body as it is the most effective, reliable and economical mean to dissipate energy. For centuries, mechanical engineers have successfully used this concept to control motion of machinery and automobiles. This principle of friction brake inspired the development of friction dampers. The friction dampers are modelled using link elements (Damper exponential). Damper is considered as friction damper and their properties are given below:

Link (friction damper) properties	
Link type – Damper exponential	
Mass	2200 Kg.
Weight	0.225 KN
Effective Stiffness	20,000 KN/M
Effective Damping	4,000 KN-S/M

Fig. 2 Damper Properties

There are 5 types models has been carried out for analysis having 1 model for without FDs and 4 models for with FDs with changes in locations of dampers are given below:

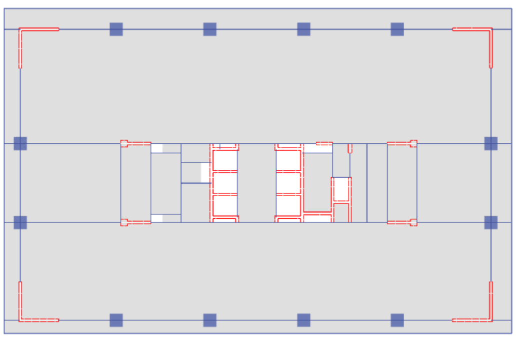


Fig.3 Model View Plan

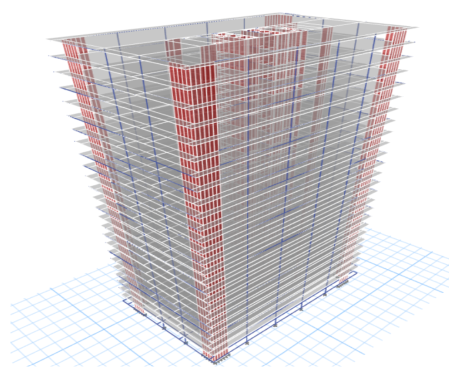


Fig.4 Model without FD

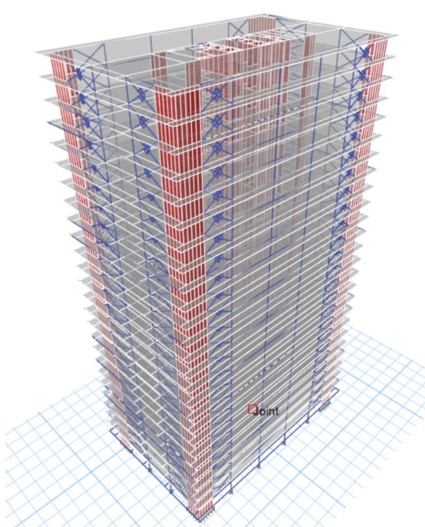


Fig.5 FD at corner grid

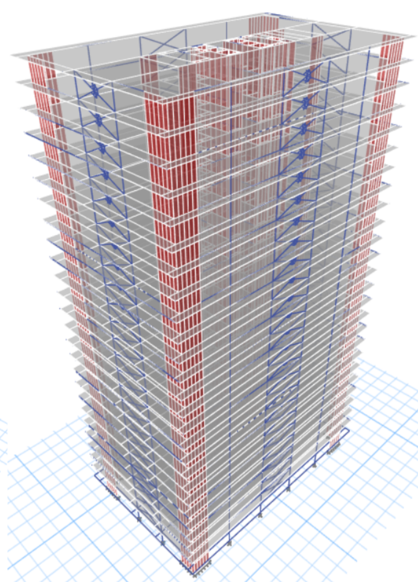


Fig.6 FD at central grid

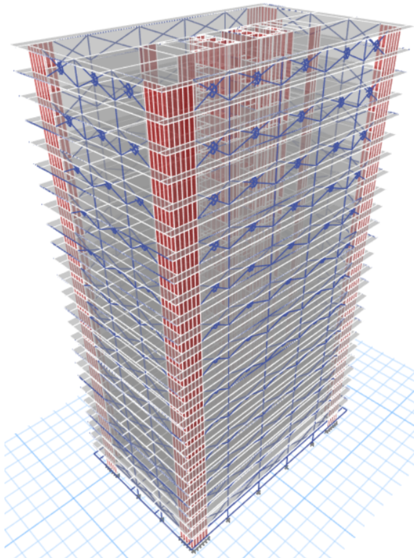


Fig.7 FD at alternate levels

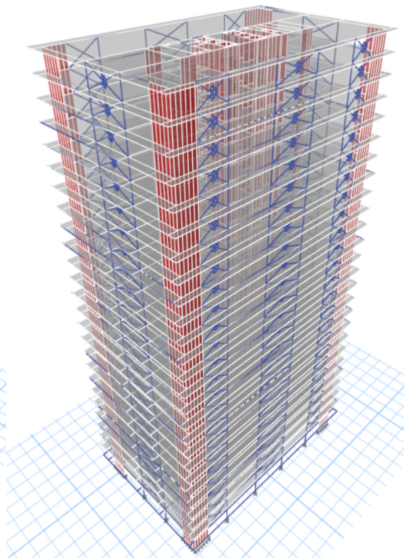


Fig.8 FD at alternate grids

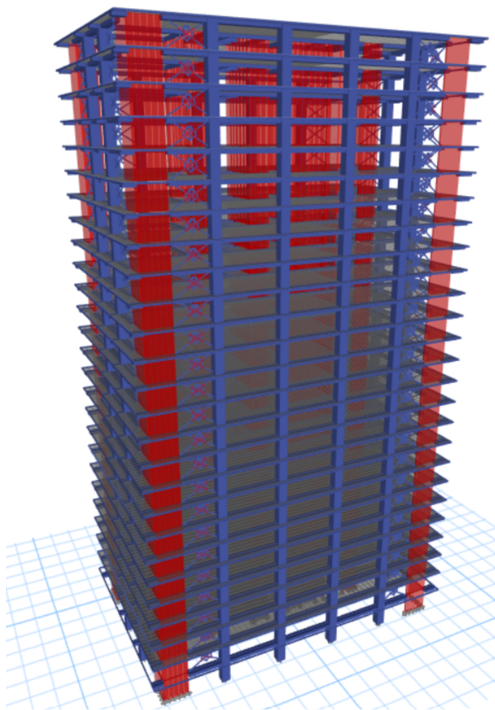


Fig. 9 The 3D rendered view of ETABs model

Above figures shows the different types of models in which position of damper is changed to perform analysis with effective position of friction damper in model.

B. Loading:

Loading are considered as a SDL 4.3Kn/m^2 and 3.6 Kn/m^2 for water proofing in it. Live load is taken 5Kn/m^2.

Seismic load:

- Seismic zone = IV
- Zone factor (Z) = 0.24
- Importance factor (I) = 1.2
- Response reduction factor (R) = 4

- Damping ratio = 5%
- Type of soil = II
- Fundamental translation of natural time period = 0.09xh/(√dy)

Wind load:

- Basic wind speed (Vb) = 39 m/sec
- Risk coefficient (K1) = 1.02
- Terrain factor (K2) = 1
- Topography factor (K3) = 1
- Importance factor for cyclonic region (K4) = 1

Loading combinations: As per building geometry considered orthogonal loading combinations given by IS.

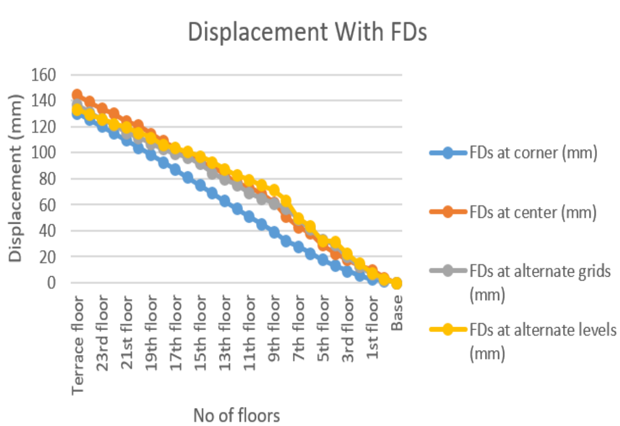
C. *Analysis:*

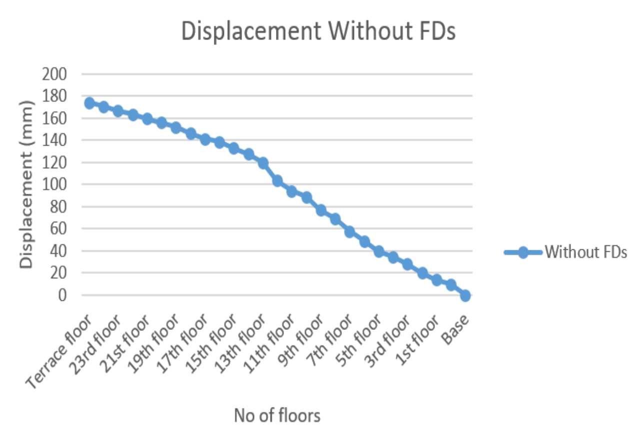
- Linear Static Analysis
- Dynamic Analysis: Response spectrum analysis, Time history analysis, Nonlinear Analysis

Response spectrum method is used for the analysis. Functions are defined in etabs model

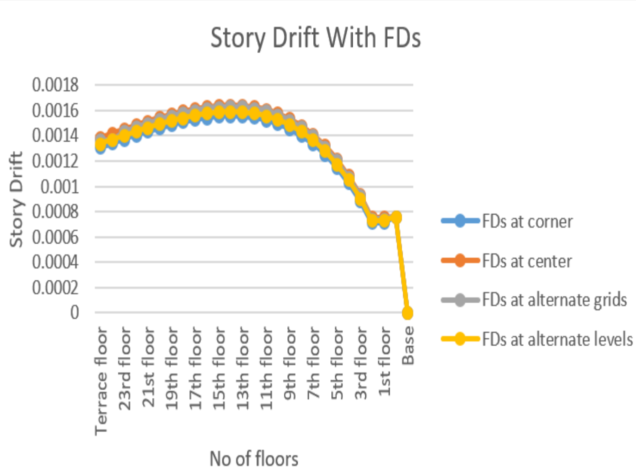
V. RESULTS

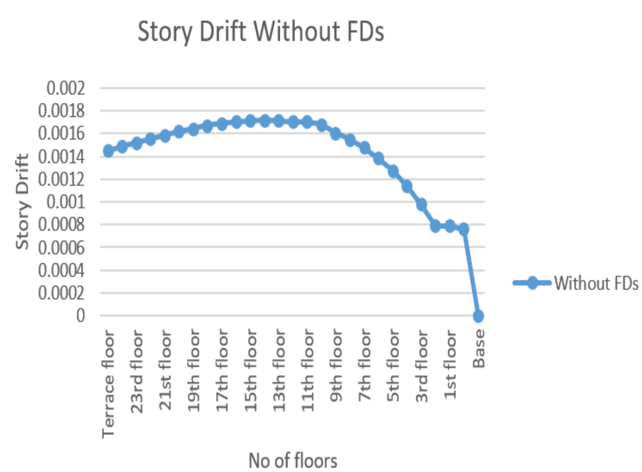
The results are calculated by ETABs software and Response spectrum method. The results are shown in the format of graph.



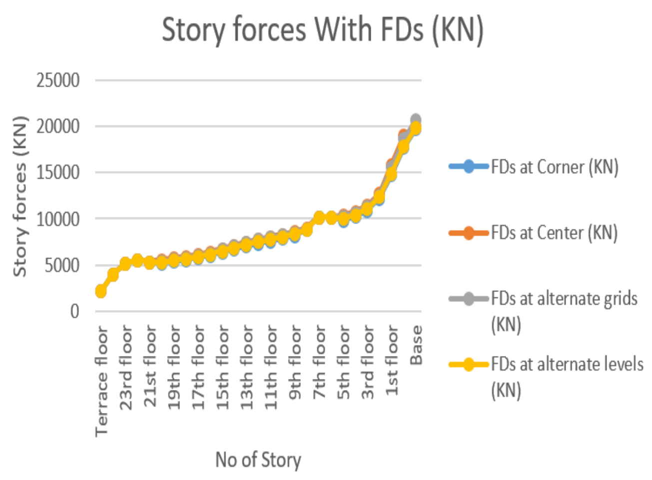


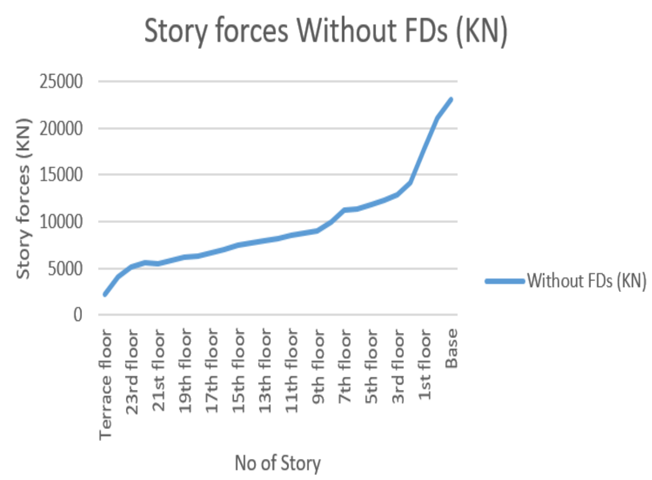
As per the results shown by software, Displacement for without FDs are more than with FDs. As per IS-1893, the permissible displacement is based on the height of building.





As per the results shown by the software, Story drift with friction damper improves without friction dampers.





As per the results shown by software, story shear forces with friction dampers are less than without friction dampers.

VI. CONCLUSION

1) After analysing of different models we can say seismic performance improves by using friction damper.
2) As per the results story drift, displacement and story forces are effective if we provides X type friction damper to the frames.
3) As per results shown by software, the effective position of friction damper is at corner of building.
4) The cross position of friction damper is effective because it workable to carry lateral forces.
5) The friction dampers provide at corner are more effective than other positions carried out in model.

VII. ACKNOLEDGEMENT

It gives me great pleasure to offer my heartfelt gratitude and sincere appreciation to my guide Prof. Manoj Deosarkar and PG Co-ordinator Prof. Vishwajeet Kadlag, Department of Civil Engineering ADYPSOE, Pune for giving me constant encouragement, supervision, scholarly guidance, and prompt advice throughout the research work.

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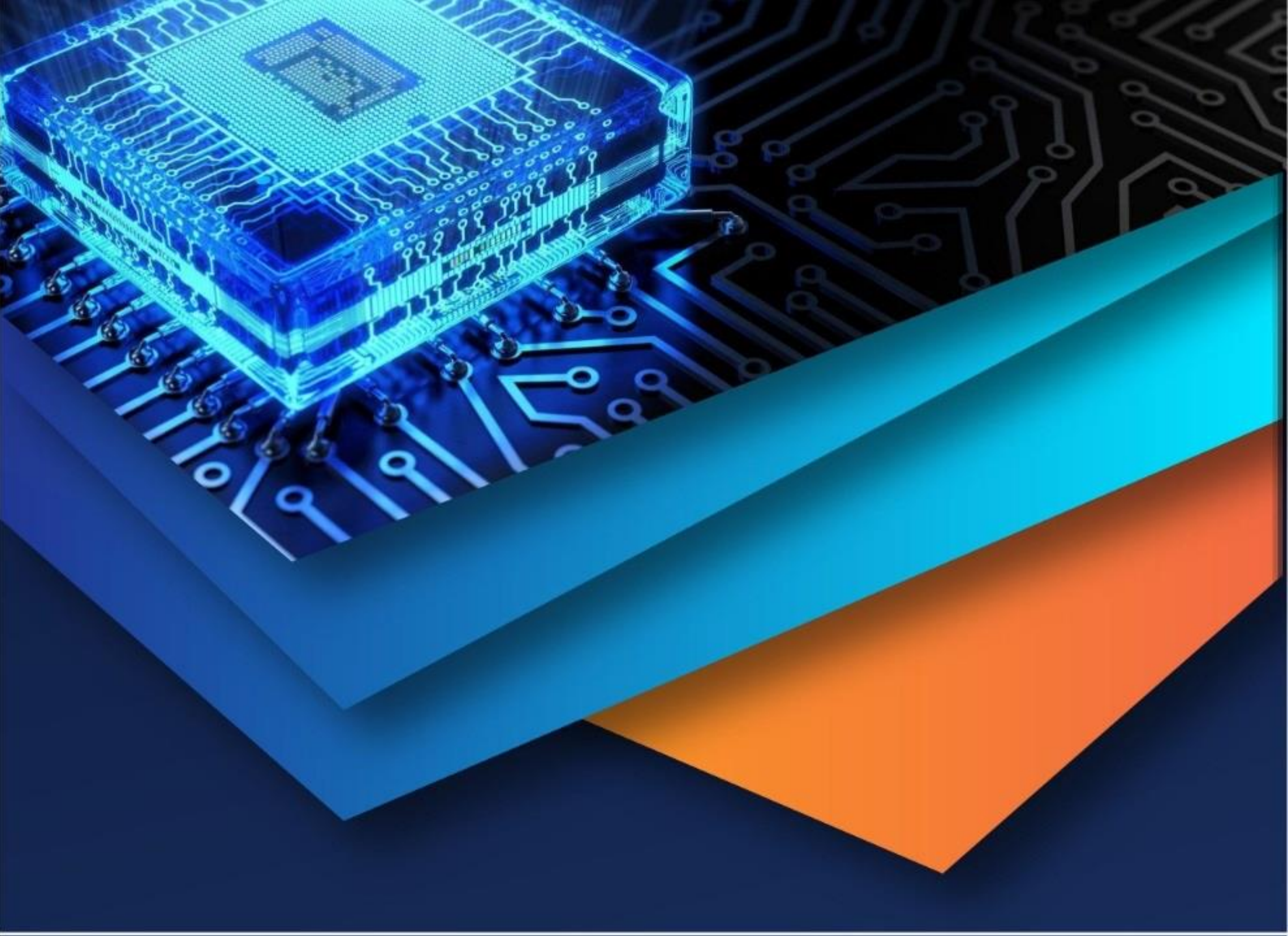

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