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Structure Modeling of Underground Structure for Fault and Failure Detection Using Seismic Condition

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Abstract: In the scope of this study, an effort was made to determine the impact of the rectangular construction plan columns' size, shape, and orientation on the overall stiffness and seismic response of the shaking building. Using ETABS software, a multistory RC building is modelled with various column sizes, forms (square and rectangular), and orientations (varying cross-sectional area at building height) to see how each affects the stiffness and seismic response of the structure. In terms of base movement, overburden displacement, layer deflection, and time period, the analytical results of each model were contrasted.
Keywords: Tunnels; Underground structures; Performance; Soil-structure interaction; Risk; Seismic design; Seismic earth pressures; Shear stresses etc.

I. INTRODUCTION

The smooth movement of people, products, and services is made possible by tunnels, which have become crucial components of both national and metropolitan transportation and utility systems. Megacities and urban areas with high population expansion have forced the hastened building of tunnels to keep up with the growing demand for space. These tunnels provide a practical way to reduce traffic, improve connection, and make the best use of the city's limited space. Authorities and urban planners can successfully handle the problems caused by population increase and urbanisation by integrating tunnels into the municipal infrastructure. This research seeks to expand our understanding of the seismic response of tunnels under seismic loading by building upon the groundwork established by two significant government reviews [1]. A thorough understanding of tunnel behaviour during seismic occurrences can be formed by combining the most recent information and insights discovered through these reviews. Shaking table tests offer a significant platform for investigating the intricate interactions between complex structural systems exposed to seismic stresses because they can simulate seismic conditions in a controlled setting. The importance of mitigating structural weaknesses and the effects of malformed tunnel segments are particularly highlighted by a collapse occurrence that occurred during the construction of a tunnel section [2]. The aforementioned investigations have effectively monitored and analysed the enhanced acceleration felt by the surrounding soil as well as the reaction of tunnel models to ground shaking by utilising accelerometers. Such findings have enormous potential for influencing future tunnel design procedures and for developing efficient mitigation techniques for the seismic risks connected with these vital assets[3].

II. PROBLEM STATEMENTS

1) Create a structure model for underground structures to use seismic conditions to identify faults and failures.
2) Gather and examine seismic information related to the underground structure.
3) Use algorithms based on seismic data analysis to find probable flaws or failures.
4) Make it possible to track seismic activity in the subsurface structure in real time.
5) Produce reports and notifications when potential flaws or failures are found.
6) Utilise predictive maintenance methods to foresee potential problems based on past data.
7) Create a user-friendly interface for seismic data visualisation and interpretation.
8) Improve subsurface infrastructure performance and safety through proactive fault and failure detection.

III. OBJECTIVES

The objectives of proposed work are as follows:

1) In order to assess the effectiveness of the ego wave energy converter in small- and FM radio circumstances, consistent results were obtained using linear, mildly nonlinear, and totally nonlinear systems.
2) The results show that the ego wave energy converter outperforms non-adjustable webs in terms of energy harvesting while exhibiting resilience in withstanding rough ocean wave conditions.

IV. LITERATURE REVIEW

An new method for assessing seismic damage in single-layer steel latticed shells was developed by Zhang et al. [6]. This approach takes into account the impact of various vibration modes that happen during seismic events. To evaluate the structural reaction and degree of damage to these shells, the authors propose a thorough methodology that combines numerical simulations, experimental data, and statistical analysis. By using this strategy, the research makes a significant contribution to our understanding of how single-layer steel latticed shells behave under seismic loading. The results provide useful information for designing and evaluating these structures in earthquake-prone regions.

The seismic analysis of a tunnel orthogonal underpass landslip utilising information from a shaking table test is the main topic of the study carried out by Pai et al. [7]. The authors analyse the tunnel's dynamic reaction and assess its susceptibility to seismic events using a multi-attribute spectrum analysis methodology. The study provides important insights into the behaviour and performance of the tunnel under simulated earthquake circumstances by analysing several seismic data properties, such as frequency content and amplitude. The research presented in this paper advances our understanding of tunnel engineering and offers useful data for designing and evaluating tunnels in landslide-prone areas.

In their study [8], Wang et al. concentrated on the settlement analysis of an immersed tube tunnel, specifically looking at the effects of a nonuniform foundation and tidal stresses. To explore the various settlement mechanisms and patterns under varied tidal conditions, the authors use analytical and numerical methodologies. The study contributes to the design and construction of immersed tube tunnels by providing useful insights into the complex settling behaviour of immersed tube tunnels by accounting for the impact of a nonuniform foundation. This study improves our knowledge of settlement analysis in immersed tube tunnels and offers helpful advice for engineering practitioners working in this area, despite the lack of precise journal information and page numbers.

The focus of Li, Xin, and colleagues' study [9] is on the examination of seismic reaction in subterranean pipes. To evaluate the performance and behaviour of pipelines under seismic conditions, the author suggested using a non-linear soil model. The research offers a more precise picture of the pipeline's reactivity and vulnerability to seismic loading by taking into account the non-linear properties of the surrounding soil. This study makes a substantial contribution to the understanding of seismic analysis techniques designed expressly for subterranean pipelines, providing insightful information for their design and evaluation.

Lai, Yao, et al. [10] discuss the use of dynamic analytic techniques in performance-based seismic design for underground structures. The authors examine the application of cutting-edge analytical methods to assess the seismic performance of underground structures and to guide design choices. Consideration of numerous aspects, including as ground motion, structural reaction, and performance standards, promotes a more robust and thorough approach to seismic design for underground structures. The essay makes a contribution to the subject of performance-based earthquake design and offers guidance to engineers and scientists studying subsurface structures.

The seismic behaviour of tunnels is the main topic of the study by Tsinidis et al. [11]. The authors go over the experimental studies and analysis methods used to understand and predict the behaviour of tunnels under seismic loads. The understanding of tunnel behaviour is improved by integrating laboratory tests, field observations, and numerical modelling, and helpful insights for seismic design and risk assessment of underground structures are supplied.

Xiangbo Bu et al. [12] propose a case study that focuses on the seismic design solution for an underground subway station. The authors suggest an innovative design strategy to improve the structure's seismic performance. Through a mix of computational analysis and laboratory testing, insights into the behaviour and response of the underground station under seismic circumstances are revealed. The essay offers helpful advice for boosting underground buildings' durability and advances the area of earthquake design.

The study by Wuqiang Cai et al. [13] focuses on the real-time design and forward analysis of deep tunnelling. The authors offer a system for assessing the behaviour and stability of deep tunnels during construction that combines three-dimensional numerical modelling and digital in-situ testing. The study offers insights into the tunnel's performance as well as a framework for real-time design process optimisation.

The seismic design and analysis of rectangular underground structures is the main topic of Huo and Hongbin's study [14]. The author looks into how these structures behave and react when subjected to seismic loading conditions. Through a combination of numerical modelling, analysis methods, and design considerations, the study seeks to offer insights and suggestions for the seismic design of rectangular underground buildings.

Kampas et al. [15] study the effect of volume loss on the seismic response of tunnels in coarse-grained soils. The authors look into how tunnels react to ground settlement brought on by volume loss in the soil around them. Through numerical analysis and laboratory testing, the effects of volume loss on tunnel performance are evaluated, revealing the mitigation strategies that can be used to improve their seismic resilience.

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V. RESEARCH METHODOLOGY

A thorough process that considers numerous elements is needed when designing tunnels to withstand seismic activity in seismically active areas. The procedure starts with a detailed evaluation of the seismic risk in the area, which entails studying seismological research, geological investigations, and historical earthquake data [16]. Important details about possible ground motions and peak accelerations that the tunnel might encounter during an earthquake are provided by this assessment. The qualities of the soil and rock strata along the tunnel path are then investigated in depth using geotechnical methods. This entails determining the likelihood of soil liquefaction, estimating soil toughness, and locating any active faults or unstable slopes [17]. Appropriate seismic design parameters are established in accordance with the seismic hazard assessment and geotechnical investigations. The following design procedure is guided by these characteristics, which include peak ground acceleration, ground reaction spectra, and design earthquake magnitude. Advanced computer modelling techniques are used in dynamic analysis to assess how the tunnel-soil system will react to earthquake loading. The tunnel may undergo excessive displacements, strains, or stresses during seismic occurrences, which might be identified by this research as potential areas of concern.

The predicted seismic forces are taken into account in the tunnel's structural design [18]. To increase the tunnel's resilience to seismic loads, factors like tunnel shape, reinforcement details, and the potential usage of seismic isolation or energy dissipation devices are taken into account. Addressing seismically caused ground collapses is essential in seismically active places. To lessen the effects of liquefaction, landslides, and fault rupture, ground improvement procedures such soil densification, grouting, and slope stabilisation may be used. The proper methods and strategies are used to minimise ground disturbances and control groundwater throughout the construction phase [19]. The installation of monitoring devices enables constant evaluation of the ground's stability and the tunnel's performance during seismic occurrences. To prevent further harm or degradation, routine inspections and maintenance procedures are carried out, maintaining the tunnel's long-term robustness. Engineers are able to create tunnels that can withstand the seismic risks posed by seismically active places [20]. To maintain the continuous safety and dependability of tunnel infrastructure, regular modifications and improvements that take into account new findings and lessons discovered from previous earthquake disasters are essential [21].

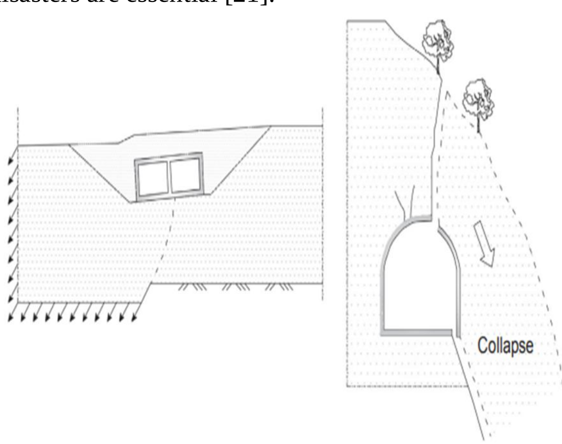


Fig. 1. Examples of the effects of seismically-induced ground failures on tunnel.

A. Design

1) *Requirement Analysis:* Understanding project requirements, user demands, and limitations completely is the first step in the design process. In order to establish the system's scope, functionality, and performance goals, information must be gathered and analysed.
2) *Conceptual Design:* Designers produce a high-level conceptual design during this stage that describes the system's general structure, constituent parts, and interactions. It entails determining the essential attributes, features, and interfaces needed to achieve the project's goals.
3) *Detailed Design:* Specific components, modules, and interfaces are defined at the detailed design stage, which also involves the refinement of the conceptual design. To give a roadmap for the implementation stage, detailed design involves producing architecture diagrams, flowcharts, data models, and user interface designs.
4) *Design Review:* Design reviews involve evaluating the design against the project requirements and constraints. It ensures that the design meets the desired functionality, performance, scalability, and maintainability goals. Feedback and revisions may be made based on the review outcomes.

B. Implementation

1) *Coding and Programming:* The implementation phase involves translating the design into executable code or programming language. Programmers write the necessary code based on the design specifications, following coding standards and best practices.
2) *Testing and Debugging:* Throughout the implementation phase, rigorous testing is conducted to identify and resolve any errors or bugs in the code. This includes unit testing, integration testing, system testing, and acceptance testing to ensure the system functions as intended.
3) *Integration:* Integration involves combining individual components or modules into a cohesive system. It ensures that all elements work together seamlessly, with interfaces and dependencies properly addressed. Integration testing is performed to validate the interoperability of the integrated components.
4) *Deployment:* Once the system has been thoroughly tested and validated, it is ready for deployment. This involves installing and configuring the system in the production environment or making it accessible to end-users. Deployment may include data migration, user training, and establishing necessary support mechanisms.
5) *Maintenance and Iteration:* After deployment, the system enters the maintenance phase, where updates, bug fixes, and enhancements are implemented based on user feedback and evolving requirements. Iterative cycles of design and implementation may be undertaken to continuously improve and refine the system.

VI. RESULTS AND ANALYSIS

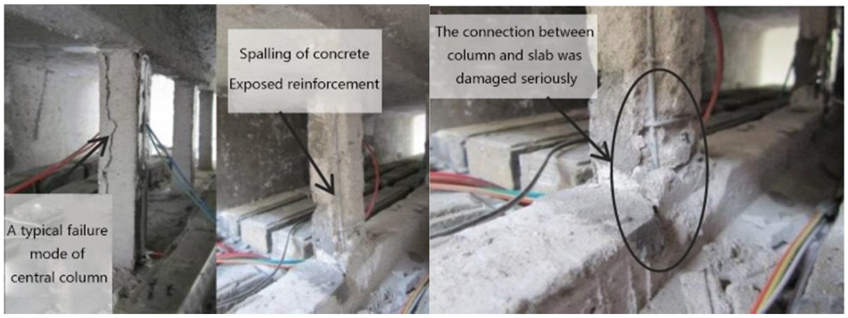
Significant results have been obtained through the use of structure modelling in the fault and failure identification of underground structures utilising seismic circumstances. It is now possible to precisely analyse and evaluate the structural integrity of subsurface structures in seismically active areas by using cutting-edge modelling techniques. Potential faults and failures can be recognised by the integration of seismic data and sophisticated modelling algorithms, enabling proactive interventions to reduce hazards and improve safety.

The behaviour and response of subsurface structures during seismic events have been better understood thanks to the application of seismic conditions in structure modelling. It has made it possible for engineers and researchers to comprehend the dynamic forces—such as ground tremors, wave propagation, and long-term ground deformations—that are applied to these structures. By including this understanding in the design and construction phases, underground structures can be better equipped to withstand seismic hazards and reduce the potential for damage.

The overall performance and durability of subsurface structures have increased thanks to the adoption of fault and failure detection systems based on seismic conditions. Monitoring and analysing seismic data in real-time enables quick detection of any structural anomalies or departures from normal behaviour. As a result, there is less chance of catastrophic failures and early intervention, maintenance, and essential repairs are made possible. Assuring the security and dependability of underground structures in seismically active areas has shown to be a successful strategy when using structural modelling in conjunction with seismic conditions in fault and failure detection. The accuracy and efficacy of these detection techniques can be further improved with future research and developments in the field, which will ultimately increase structural performance and seismic hazard protection.

A. Earthquake Damage

The earthquake's structural damage was discovered via the shaking-table test. The part of the tube station model with the most significant damage is the column. Significant spalling on the lower middle column reveals the longitudinal reinforcement, and vertical cracks on the upper middle column (a typical shear-compression failure) are present. The seismic damage to the side wall and centre column at the joint with the top and bottom plates has resulted in the ripping out of the armpit angle reinforcement and significant concrete spalling. The roof and floor are still in good condition after the earthquake. The largest crack measures 15 mm in width, and the largest vertical differential settlement is 32 mm.



(a) (b)

Figure 2. In the shaking table test, there were three types of earthquake damage that occurred: (a) failure of the joint between the central column and the slab; (b) failure of the joint between the side wall and the slab.

B. Reliability Analysis of FDTHA

When the maximum shear deformation occurs on the surface and bottom of the model foundation, the comparison illustrates the horizontal relative displacement of each measuring point relative to the bottom of the model foundation under the influence of seismic waves with varied peak accelerations. The horizontal relative displacement of the model foundation along the soil depth is distributed uniformly in both the numerical simulation and the shaking-table test. Acceleration sensors were positioned along the side wall of the model building from bottom to top at the appropriate areas. Comparisons between numerical simulation and shaking-table test of each measuring point in the model structure under the effect of seismic wave are shown for the acceleration response time history and associated Fourier spectrum. In terms of time-history waveform, amplitude, and Fourier spectrum, the acceleration response in the model structure given by the numerical simulation and shaking-table test is identical. Therefore, it can be said that the numerical simulation and numerical model of the dynamic interaction between the loess and a subway station produced in this work accurately approximated the acceleration response of a subway station structure.

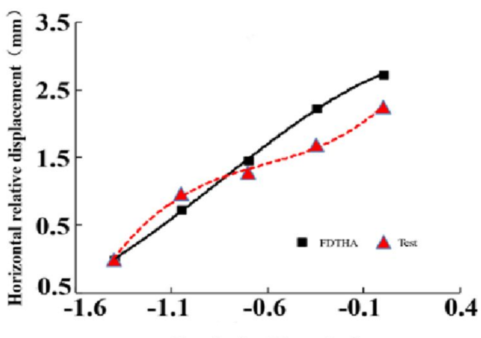


Figure 3. Analysis of the temporal evolution and the horizontal relative displacement of the model's base during shaking-table testing.

C. Seismic Analysis

1) The internal forces on an underground structure as computed by the FBM are modest since the friction and shear stresses caused by soil deformation are not taken into account. The DBM is simple to set up, and its fundamental premise is to produce springs and deliver horizontal displacement to the crucial stratum in order to simulate the interaction between soil and structure.

2) The DBM is a basic model that, by adding springs and applying horizontal displacement to a stratum, duplicates the interaction between soil and structure. When spring stiffness and ground horizontal displacement are approximated with the appropriate values, the output of the structural shear force and bending moment approaches that found using the time-history method of analysis. Accuracy of axial force output is less accurate than DESANM, however shear force and bending moment output accuracy are both better than DESANM.

3) Because the loess stratum is established in the DESANM calculation model, fewer parameters are needed for the computation. When the value of the horizontal relative displacement is accurate, the structural internal force of DESANM generates outcomes that are consistent with those of the time-history approach of analysis. Even yet, the computing is more challenging, and the time-history analyses are more complex than it.

VII. CONCLUSION

In seismically active places, it is crucial to use structure modelling for fault and failure identification in underground structures utilising seismic conditions. Engineers can accurately assess the behaviour and reaction of underground structures to ground motion and seismic hazards by using cutting-edge seismic monitoring and analysis tools. This method is essential for locating and detecting defects and breakdowns in real-time, allowing for quick alerts and preventative measures to reduce potential hazards. To create resilient subsurface structures that can survive the dynamic pressures brought on by earthquakes, structure modelling techniques must be integrated into the design and construction process. Engineers can ensure that the structures are built to resist the projected ground motion and minimise the risk of damage and structural failure by taking seismic conditions into account during the design phase. For the purposes of maintenance and monitoring, the ability to identify faults and failures in subsurface structures using seismic conditions is very helpful. Engineers can spot any changes or abnormalities that can point to possible structural problems by regularly monitoring the structures. This enables prompt upkeep and repairs, ensuring the subsurface infrastructure's long-term integrity and safety.

VIII. FUTURE SCOPE

It is very promising to use structure modelling to detect faults and failures in subsurface structures using seismic conditions. The early detection capabilities and overall resilience of underground structures in seismically active places will be greatly improved by developments in seismic monitoring, machine learning, modelling methodologies, risk assessment, and collaboration. Real-time data gathering and analysis made possible by the integration of sensor networks and Internet of Things (IoT) technologies will allow for preventative maintenance procedures and well-informed decision-making. Additionally, the creation of thorough risk assessment procedures will advance knowledge of susceptibility and potential repercussions related to breakdowns in subsurface infrastructure. This information will make it easier to put good mitigation measures in place. In order to facilitate data sharing, insight exchange, and cooperative research initiatives that will foster innovation and establish best practises, collaboration between researchers, business experts, and government agencies will be essential. With these developments, the possibility of safer and more durable underground constructions in seismic conditions is on the horizon.

REFERENCES

[1] Qingjun Chen, Luqi Zhang, Ruifu Zhang, Chao Pan, "Seismic Performance of an Underground Structure with an Inerter-Based Isolation System", Structural Control and Health Monitoring, vol. 2023, Article ID 1349363, 19 pages, 2023. https://doi.org/10.1155/2023/1349363

[2] Xin Bao, Jingbo Liu, Dongyang Wang, Shutao Li, Fei Wang, Xiaofeng Wang, "Modification Research of the Internal Substructure Method for Seismic Wave Input in Deep Underground Structure-Soil Systems", Shock and Vibration, vol. 2019, Article ID 5926410, 13 pages, 2019. https://doi.org/10.1155/2019/5926410

[3] Xiaofei Guo, Zhiqiang Zhao, Xu Gao, Zhenkai Ma, Nianjie Ma, "The Criteria of Underground Rock Structure Failure and Its Implication on Rockburst in Roadway: A Numerical Method", Shock and Vibration, vol. 2019, Article ID 7509690, 12 pages, 2019. https://doi.org/10.1155/2019/7509690

[4] Xiaofang Kang, Shuai Li, Guanghui Xia, Qinghu Xu, Dawei Man, Xianzeng Shi, Houxu Huang, Ying Xu, "Overlapping Decentralized Control Strategies of Building Structure Vibration Based on Fault-Tolerant Control under Seismic Excitation", Advances in Civil Engineering, vol. 2022, Article ID 5597410, 13 pages, 2022. https://doi.org/10.1155/2022/5597410

[5] Jinping Yang, Peizhen Li, Hang Jing, Meng Gao, "Near-Fault Ground Motion Influence on the Seismic Responses of a Structure with Viscous Dampers considering SSI Effect", Advances in Civil Engineering, vol. 2021, Article ID 6649124, 20 pages, 2021. https://doi.org/10.1155/2021/6649124

[6] Zhang, Yujian & Luo, Yongfeng & Guo, Xiaonong & Li, Yunsong & Huang, Qinglong. (2021). A new seismic damage assessment method for single-layer steel latticed shells considering multi-modal contribution. Structures. 33. 4670-4689. 10.1016/j.istruc.2021.07.050.

[7] Pai, Lifang & Wu, Honggang. (2021). Multi-attribute seismic data spectrum analysis of tunnel orthogonal underpass landslide shaking table test. Soil Dynamics and Earthquake Engineering. 150. 106889. 10.1016/j.soildyn.2021.106889.

[8] Wang, Yanning & Huan-Zhu, Zhou & Wang, Lechen. (2022). Settlement Mode Analysis for An Immersed Tube Tunnel Considering A Nonuniform Foundation Under Tidal Load.

[9] Li, Xin & Zhou, Jing. (2022). USING NON-LINEAR SOIL MODEL TO ANALYZE SEISMIC RESPONSE OF UNDERGROUND PIPELINES.

[10] Lai, Yi-Chun & Wang, Sheng-Chieh & Chan, Yu-Hsuan & Paramosa, Larissa & Lee, Yi-Ting & Zhang, Chien-Yu & Hsu, Li-Ting & Tsai, Yuan-Yao & Seng, Chia-Ray & Tsai, Jung-Chen & Lin, Chien-Hua. (2022). Application of dynamic analysis method in performance-based seismic design for underground structure.

[11] Tsinidis, G., de Silva, F., Anastasopoulos, I., Bilotta, E., Bobet, A., Hashash, Y. M. A., Fuentes, R. (2020). Seismic behaviour of tunnels: From experiments to analysis. Tunnelling and Underground Space Technology, 99, 103334. doi:10.1016/j.tust.2020.103334

[12] Aderinto, T.; Li, H. Conceptual Design and Simulation of a Self-Adjustable Heaving Point Absorber Based Wave Energy Converter. Energies 2020, 13, 1997. https://doi.org/10.3390/en13081997

[13] Xiangbo Bu, Alberto Ledesma, Francisco López-Almansa, Novel seismic design solution for underground structures. Case study of a 2-story 3-bay subway station,soil Dynamics and Earthquake Engineering, Volume 153,2022,107087,ISSN 0267-7261,https://doi.org/10.1016/j.soildyn.2021.107087.

[14] Wuqiang Cai, Hehua Zhu, Wenhao Liang, BaThao Vu, Chenlong Su, Keshen Zhang, Xiaojun Wang, Three-dimensional forward analysis and real-time design of deep tunneling based on digital in-situ testing, International Journal of MechanicalSciences, Volume 226,2022,107385,ISSN 0020 7403, https://doi.org/10.1016/j.ijmecsci.2022.107385.

[15] Huo, Hongbin. (2022). Seismic design and analysis of rectangular underground structures. ETD Collection for Purdue University.

[16] Kampas, Georgios & Knappett, Jonathan & Brown, Michael & Anastasopoulos, Ioannis & Nikitas, Nikolaos & Fuentes, Raul. (2019). Implications of volume loss on the seismic response of tunnels in coarse- grained soils. Tunnelling and Underground Space Technology. 95. 10.1016/j.tust.2019.103127.

[17] Miah Alam, Omar Chaallal, Bertrand Galy, "Soil-Structure Interaction of Flexible Temporary Trench Box: Parametric Studies Using 3D FE Modelling", Modelling and Simulation in Engineering, vol. 2021, Article ID 9949976, 17 pages, 2021. https://doi.org/10.1155/2021/9949976

[18] Kemeng Yu, "Research on Seismic Design Method for Reinforced Concrete Frame Structure", Wireless Communications and Mobile Computing, vol. 2022, Article ID 7851648, 9 pages, 2022. https://doi.org/10.1155/2022/7851648

[19] Yanke Shi, Lin Xu, Rongbin Hou, Dekang Zhang, Duoxin Zhang, "Seismic Response and Damage Analysis of Large Inverted Siphon Structure", Shock and Vibration, vol. 2022, Article ID 5404908, 13 pages, 2022. https://doi.org/10.1155/2022/5404908

[20] Jun Peng, Yufei Li, "Seismic Analysis of Reticulated Shell Structure Based on Sensor Network for Smart Transportation Seismic Isolation Bearings", Journal of Advanced Transportation, vol. 2022, Article ID 5985542, 13 pages, 2022. https://doi.org/10.1155/2022/5985542

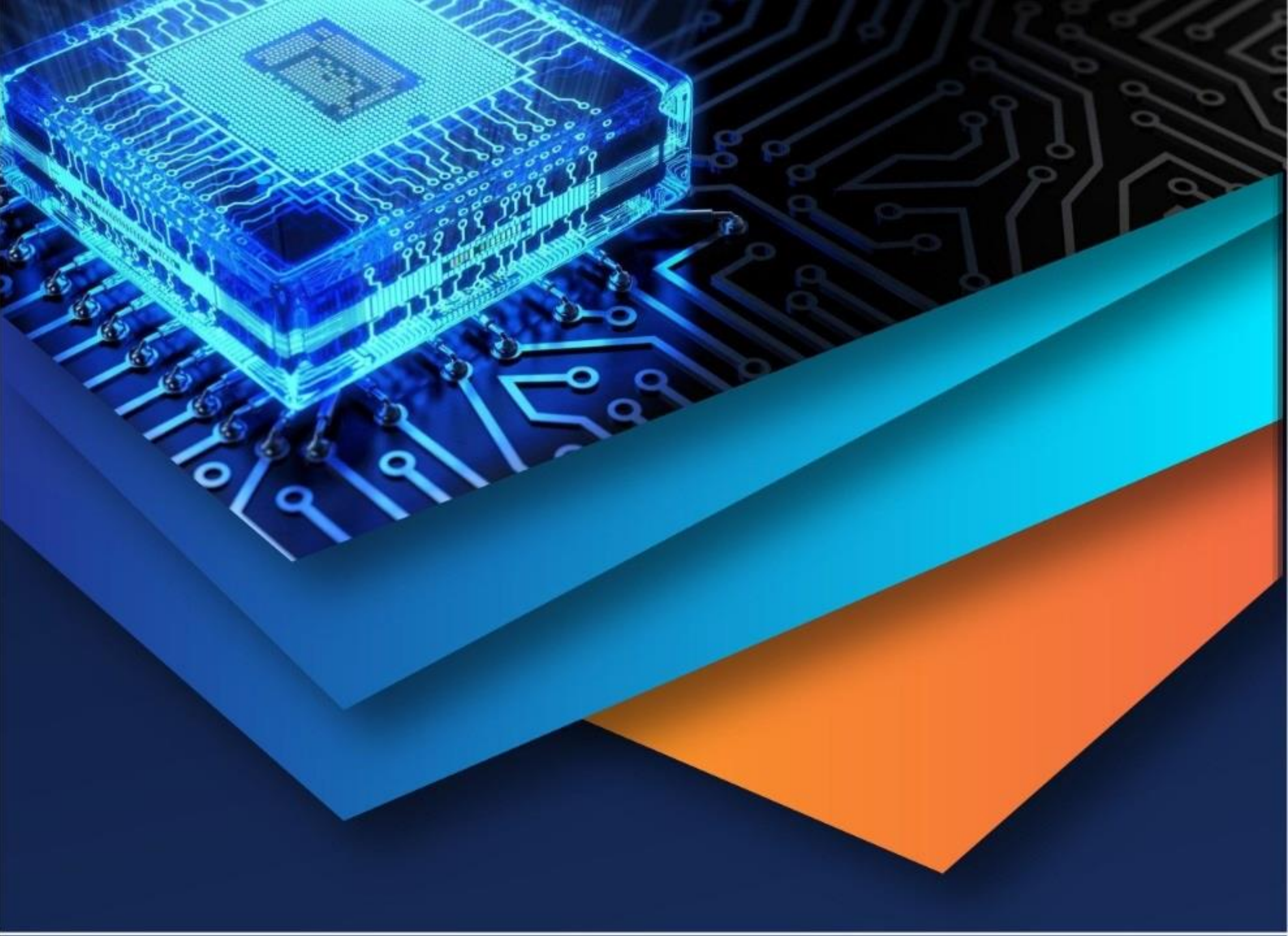
[21] Shuaihua Ye, Zhuangfu Zhao, "Seismic Response of Prestressed Anchors with Frame Structure", Mathematical Problems in Engineering, vol. 2020, Article ID 9029045, 15 pages, 2020. https://doi.org/10.1155/2020/9029045

[22] Rushan Liu, Deyuan Tian, "Study on Analogy Calculation Method for Seismic Vulnerability of Earth-Wood Structure Houses", Mathematical Problems in Engineering, vol. 2020, Article ID 3525896, 10 pages, 2020. https://doi.org/10.1155/2020/3525896

[23] Jesús Morales-Valdez, Luis Alvarez-Icaza, José A. Escobar, "Damage Localization in a Building Structure during Seismic Excitation", Shock and Vibration, vol. 2020, Article ID 8859527, 17 pages, 2020. https://doi.org/10.1155/2020/8859527

[24] Wenhua Cai, Bujun Yu, Fajong Wu, Jianhua Shao, "Seismic Response and Vibration Reduction Analysis of Suspended Structure under Wave Passage Excitation", Advances in Civil Engineering, vol. 2020, Article ID 6468181, 13 pages, 2020. https://doi.org/10.1155/2020/6468181

[25] Ricardo Faria, Sérgio Oliveira, Ana L. Silvestre, "A Fluid-Structure Interaction Model for Dam-Water Systems: Analytical Study and Application to Seismic Behavior", Advances in Mathematical Physics, vol. 2019, Article ID 8083906, 14 pages, 2019. https://doi.org/10.1155/2019/8083906



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