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Seismic Analysis Trends in Elevated Metro and Flyover Structures: A Bibliometric Review

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Abstract

Seismic analysis studies involving elevated metro and flyover constructions are the subject of this bibliometric evaluation, which focusses on research that has used SAP 2000 software. The study examines a wide variety of literature from different databases, drawing attention to trends in publishing, the effects of citations, and the networks of scholars that work together. The number of publications has increased significantly over the last several years, with a growing focus on performance-based design processes and creative modelling techniques, according to key results. The use of sophisticated computational techniques, soil-structure interaction, and dynamic interaction analysis are among the key study topics identified in the review. In addition, we address the limitations in the existing literature and suggest avenues for future study to strengthen elevated transportation systems' ability to withstand seismic occurrences. By shedding light on the dynamic nature of seismic analysis, this study is an excellent tool for civil engineering academics and professionals.

Keywords: Seismic analysis, Elevated metro structures, Flyover structures, Dynamic interaction, Soil-structure interaction, Performance-based design

Introduction

The Metro bridges are examined, and the displacement, bending moment, and shear force distribution are computed as a result of the loads that are applied. In order to do this, the finite element approach is being used, and the structural analysis program staad pro v8i is being utilised to conduct seismic analysis on the bridge structure. The pier and the box girder are the two primary components that make up an elevated metro system. Figure 1.1 (a) depicts a model of an elevated metro bridge that is typical in appearance. The viaduct or box girder of a metro bridge necessitates the use of a pier in order to provide support for the station buildings and each span of the bridge. Piers may be built in a variety of cross-sectional designs, including elliptical, square, rectangular, and cylindrical shapes, amongst others. In the current investigation, the piers that were taken into consideration have a cross section that is rectangular, and they are situated underneath the station construction. When it comes to the building of an elevated metro rail bridge, box girders are used very extensively. It is because of the closed section of the box girder that the tensional and warping stiffness of the box girder is present. Additionally, the box section has a high bending stiffness, and there is an effective utilisation of the whole cross section. At times, the cross sections of box girders might be in the shape of a single cell. Based on both the strength-based technique and the performance-based method, a seismic study was performed on a double-decker pier. The force-based design and displacement analysis for a structure with a single degree of freedom in accordance with IRS 5,16,24, 78, IS 1893 part1:2002, and RDSO guideline-13 Performance studies of various configurations are being conducted for each of them. seen in figure 1.1 is a model of an elevated double-decker pier that is common.

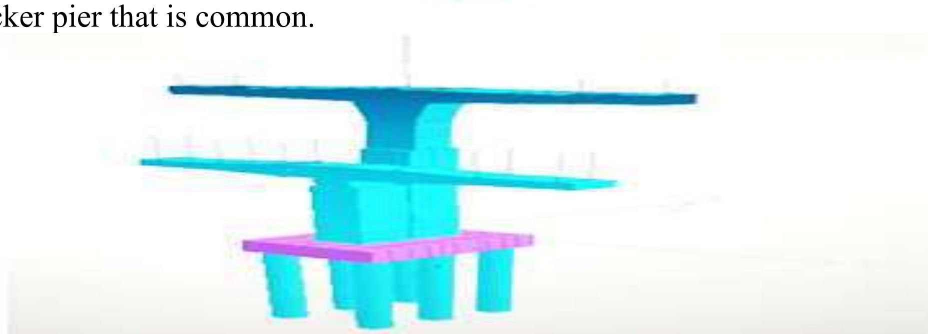

Figure 1: Bridge Pier in staadpro [4]

Background of Seismic Analysis in Civil Engineering

Particularly in earthquake-prone areas, seismic analysis is an important tool for civil engineers. Analysing how buildings react to the shaking and tremors caused by earthquakes is called seismic analysis. Structures, particularly those essential to urban transport networks, must be able to endure seismic shocks if urban populations and infrastructure needs are to remain high. In order to transfer people and commodities throughout cities and reduce traffic on the ground, urban transport networks rely on elevated metro systems and flyover constructions. But because of their height, these buildings face distinct seismic problems that call for new approaches to study and design (Duncan et al., 2019).

Seismic activity has been on the rise in recent decades, drawing more attention from academics and engineers to the weak points in city infrastructure. The destruction and death brought about by earthquakes highlight the importance of using strong design ideas and efficient analytical instruments (Verma & Setia, 2019; Verma & Setia, 2020). Because of their height and intricacy of design, elevated structures move dynamically differently than ground-level buildings. According to Kruwinkler and Miranda (2004), these properties have to be acknowledged and included into seismic study if performance and safety standards are to be satisfied.

New computing methods, especially finite element programs like SAP 2000, have let engineers more precisely forecast how buildings will react to seismic loads. These tools help complex modelling techniques to now account for material properties, geometric configurations, and environmental interactions (Huang et al., 2020; Verma & Setia, 2019; Verma & Setia, 2020). Performance-based design approaches have lately been somewhat popular as a tool to reach specific performance targets, instead than concentrating only on fulfilling traditional code requirements. (Mazzolani & Piluso, 2018).

Importance of Elevated Metro and Flyover Structures

As urban locations are experiencing the phenomenon of the world's high increases of people and size, above-ground how to light rail and roadways are also be told. These types of structures from the mass and velocity that have been assigned to them, thus they are of essential importance when it comes to the infrastructure growth of all urban areas. The height of the skyscrapers that make the city a decent space is the reason why people can be mobile without walking on the ground already occupied by other facilities. In a research project, seismic analysis has to be done with knowledge of their height and mass as these structures are more susceptible to ground shaking (Zhang et al., 2019).

There are a number of challenges that come with higher altitude buildings that are caused by the seismic shocks. Among them is the height of such structures that can lead to higher horizontal loads on them; in addition, the response of the dynamic might be radically different from the one that grounding type of architecture has. The buildings react to various elements such as the dissimilarity of the structure, the connection it is used as well as the materials used in the construction (Liao et al., 2018). Elevated interaction of structures to settlement and ground can induce complex behaviour with careers of different vibrations across the foundation or even differential settlements (Bozorgmehrnia et al. 2013). In order to guarantee the dependability and the safety of elevated metro systems and flyovers, the knowledge about their seismic behaviour should be obtained.

Trends in Seismic Analysis Research

The last few decades have observed tremendous progress in the discipline of Seismic analysis. Earlier, the focus was on predicting the behavior of a structure subjected to seismic loads using empirical methods and linear elastic models. Nevertheless, the two approaches emphasized here could not fully capture the nature of seismic stress. However, as researchers have been more conscious of the fact that seismic loads are not static, there has been enormous progress in the development and utilization of advanced analytical techniques which can be used to determine the response of buildings during an earthquake (Chopra, 2017).

Therefore, there has been noticeable progress on the level of use of nonlinear dynamic analysis methods. These methods treat geometrical and material nonlinearities thereby estimating better

a structures' response to an earthquake. One other method that has shown promise in this regard is Incremental Dynamic Analysis (IDA) which tends to offer an understanding of the earthquake performance of structures through time step effects (Vamvatsikos & Cornell, 2002). Performance based design is becoming more common in seismic analysis. This approach allows you to define specific performance objectives for structures to meet during seismic events. Unlike force based design methods which mainly focus on strength and stability under predefined load combinations, performance based design looks at how the structure will perform under seismic forces. This shows a more detailed approach to design, analysing at overall behaviour and performance under seismic loads (Hosseini et al., 2021).
Recent research in analysis tools have changed the seismic analysis area. By the use of software to analyse and simulate complex systems like elevated metro lines and flyovers under various seismic conditions. software SAP2000 allow you to investigate nonlinear responses, dynamic behaviours and soil-structure behaviours and get a more detailed seismic performance (Huang et al., 2020).

Challenges in Seismic Analysis of Elevated Structures

Despite all the advanced seismic analysis tools available, analyse the seismic performance of elevated metro and flyover structures is a with task. One of the major problem is the differences in ground motion with parameters due to regional sesmic effect, soil properties and geographical context. The non-stationary and unpredictable nature of seismic motion makes it difficult to predict how structures will behave during an earthquake (Zhang et al., 2019).
Moreover, the interaction between high structures and those at having lower levelsadds more complexity. Elevated systems are more prone to soil-structure interaction effects which can change sustain the forces transmitted based on the behavior of the load transfer to soil (Li et al., 2018). Lack of research on these process may lead to ineffective assessment and potentially unsafe designs.
Seismic analysis also depends on the models used in the research. Many times studies are made in the research methodology which can lead to control that does not reflect the real world scenario. Empirical confirmation data is fundamental to ensure that the analytical models are built properly. To improve the seismic assessment, there is a necessary for better data group methods such as implementing advanced monitoring systems and field tests (Nishida & Matsuoka, 2019).
The significance of this bibliometric review lies in the synthesis of the current seismic analysis research related to elevated metro and flyover structures. By combining the findings of various studies, this review aims to provide academics, practitioners and policymakers with a clear understanding of the current state of the art and future directions in seismic analysis. Moreover, the insights from this study will support the ongoing urban infrastructure development and inform future research.

Research Methodologies in Seismic Analysis

Seismic analysis as a discipline has undergone considerable change for the better and is now supported with the development of better approaches. In the beginning, however, the studies were based on linear elastic models which were used in predicting the seismic loads of structural elements and buildings. It was realized, however, that such simplifications are more revolution than evolution as they underestimating the forces developed within the structures especially in the case of extreme seismic events. Therefore, more sophisticated, and indeed more realistic approaches developed that included nonlinear static and dynamic analysis to appropriate structural response configuration (Chopra, 2017).
Most often referred to as pushover analysis, nonlinear static analysis enables the estimation of the potential seismic capacity of a building more realistically. This method includes the production of capacity curves explaining the relationship between base shear and lateral displacement, which enables engineers to understand the different responses of structures subjected to different seismic levels (Krawinkler & Miranda, 2004). Contrarily, nonlinear

dynamic analysis provides a greater insight on the impact of particular seismic occurrences as this type of analysis calculates the response of a structure to ground motion data.
The increasing use of performance-based design techniques signifies the growing need to specify the performance objectives for structures subjected to a different level of seismic events. Contemporary evaluation methods take into account not only the safety provisions present but also how effectively the structural components perform their functions (Mazzolani & Piluso, 2018). Such a change of view enables the evaluation of a building's resilience in more global terms rather than just safety.
Advanced software packages like SAP2000, which are essential in computational modeling of the components and their interactions, are employed to a great extent in the modern seismic analysis and designing. These tools allow the engineers to conduct dynamic analysis on various loading and response spectrum types which assists in understanding the behavior of the structure more effectively. (Huang et al., 2020).

Contributions of Computational Tools

The emergence of sophisticated computing resources has greatly enhanced the seismic analysis techniques, enabling the engineers to model complex behavior of structures. In this regard, the software SAP2000 has found great acceptance in the engineering field as it is easy to operate and provides impressive analytical features. The application allows users to create computer models of, for example, elevated metro systems and bridges, under various loading conditions (Li et al., 2018).
SAP2000's unique feature is that it can perform dynamic analyses such as time-history and response spectrum analyses necessary for the assessment of the seismic performance of a high-rise structure. As noted by Zhang et al. (2019), SAP2000 offers the possibility to model the effects of soil-structure interaction, thus allowing for greater insight into the effects of ground conditions on the structural response during an earthquake.
In addition, the construction of real-time monitoring systems provides the capability for modification of designs and engineering analysis through the use of computational techniques. Performance-based designs can be achieved since the models are improved through the use of real performance data of the structure.

Collaborative Efforts and Research Gaps

Seismic computation has constantly changed over the years and thus necessitates teamwork in carrying out research. Civil engineers, geotechnical specialists, and seismologists could work together and devise new techniques of seismic analysis. This teamwork can be useful in solving the problems relating to seismic design and assessment (Krawinkler & Miranda, 2004).
However, as much as that has been done, there is minimal or no seismic research done on uplift systems such as elevated metro and flyover structures. More often than not, the research looks at the subsystems of complex systems rather than the systems as a whole. There is a clear and present need for further advancement in the generation of real data to validate numerical models, especially models with different soil types, and soil seismicity (Li et al., 2018).
With this, future studies should not only focus on investigating new procedures but also extend to improving data gathering and encouraging teamwork so as to close the gaps that have been identified. This will promote the reliability of the seismic analysis which in turn will help build more earthquake-proof cities.

Literature Review

This bibliometric review aims to systematically analyze the existing literature on seismic analysis trends in elevated metro and flyover structures. By compiling and synthesizing relevant research articles, conference papers, and technical reports, this study seeks to:

- Identify key trends and developments in seismic analysis methodologies specifically for elevated structures.
- Highlight influential studies and authors in the field of seismic analysis.
- Assess the collaborative networks and publication patterns among researchers, identifying key institutions and their contributions.

- Identify gaps in the existing literature and propose areas for future research based on emerging trends.

1. **Ghosh et al. (2008)**: While performance-based design (PBD) methods for buildings have received much attention, research on bridges, particularly those made of reinforced concrete, is noticeably lacking. The use of PBD to continuous bridges is the primary subject of this study. The authors demonstrate the evolution of PBD methodology by comparing and contrasting contemporary PBD approaches with more traditional force-based design (FBD) methodologies. With PBD, they argue, a more precise evaluation of overstrength and ductility is feasible, leading to a more accurate prediction of a structure's performance during seismic events. The paper highlights the need of further research into the topic of integrating building and bridge design in order to enhance the safety and resilience of transportation infrastructure in seismic events.
2. **Monsees & Merritt (1991)**: The writers zeroed in on the unique concerns of earthquake design for the Los Angeles Metro system. They suggest a fresh approach to design wherein structures include deformations caused by earthquakes rather of depending only on pseudo-loads. This method reflects a more realistic projection of how constructions would respond in actual earthquake events. We discuss the results of thorough computer modelling, which indicate that this creative approach generates conservative design answers. The paper suggests using comparable methods in next seismic evaluations of urban transport systems to increase infrastructure safety and lifetime.
3. **Kairui et al. (2020)**: This paper explores agent-based modelling in the context of transport networks after earthquakes. The writers underline how vulnerable surface transport systems are to earthquake damage even if they are absolutely important for urban development. They handle the challenges these sorts of events bring, particularly the ambiguity that makes response and preparation more difficult. By focussing on the modelling of transport networks after seismic events, this study aims to provide some insight on effective management and restoration methods. Based on the findings, integrated approaches help urban transport systems to be more robust against natural disasters.
4. **Rossetto & Duffour (2013)**: With an eye towards allowing structures to withstand seismic events with specified frequency intervals, this paper outlines the fundamental principles for earthquake-resistant architecture. The authors explore the complex interactions among the ductility, stiffness, strength, and damping of a structure with regard to its response to ground motion. The foundations of their systematic approach to earthquake-resistant building are consistent structural form, effective linkages, and capacity design concepts. The paper also discusses isolation devices as a way to reduce the effect of earthquakes and fairly evaluates design strategies and modern technologies in seismic resilience.
5. **Konakli (2011)**: The stochastic dynamic analysis of this work focusses on bridges subjected to ground vibrations varying in space. The author underlines that traditional analytical methods sometimes overlook the difficulties resulting from the fact that seismic waves have different characteristics as they pass through different types of ground. By including aspects like incoherence and wave-passage effects, this study offers a more thorough view of the complicated link between ground motion variability and bridge response. Particularly in regions with different underlying conditions, the findings are rather crucial for improved seismic assessment and bridge construction.
6. **Meng (2010)**: The author examined how underground structures—particularly tube systems—reaction to seismic waves using finite element analysis. The main inquiry is how these subsurface systems respond to plane S waves. By means of stress distribution across the construction, this analysis identifies the most stressed sections of the building, including the connections of floor and walls. Based on the results, it is advised that these high-stress areas be given particular attention when planning and constructing underground infrastructure to increase their seismic catastrophe resistance.

7. **Xia et al. (2009)**: This work analyses an elevated bridge-operational linear induction motor (LIM) train utilising a three-dimensional dynamic interaction model. Part of a coupled system model of the LIM-driven vehicle and the bridge, the authors describe the difficulties of reproducing electromagnetic forces between the train and the bridge. Modal superposition techniques allow one to obtain the equations of motion, therefore enabling a comprehensive modelling of dynamic events. The findings of the research provide some insight into the stability and security of higher transportation networks under dynamic loading conditions.
8. **Ouchi et al. (2000)**: The authors examine the approach of elevated bridge infrastructure design, with a focus on subway stations. Their findings highlight a substantial gap in our knowledge of how column-free and large-span structures perform during seismic events. The study emphasises the difficulty of seismic analysis, notably due to interactions between earth and buildings. To provide the framework for future design methods that take varied soil conditions into account, the authors call for more rigorous experimental testing and computer research to understand the seismic behaviour of these distinct structures.
9. **Li et al. (2021)**: This paper proposes an efficient modelling approach to examine the coupled train-track-bridge system under seismic excitation. With the authors' closed-loop model of a simply supported railway bridge, anticipating dynamic responses may be done with less processing power without compromising accuracy. The study's comparison of simulation results demonstrates that this model runs in a tenth of the time needed by conventional methods. The findings suggest that by enabling real-time analysis and decision-making, this efficient approach has the potential to enhance the design and maintenance of railway infrastructure in the face of seismic dangers.
10. **Kumar & Debnath (2021)**: The authors assess the seismic performance of a railway bridge located in a seismically active region of Northeast India. Utilising simulated ground movements tailored to the local geological conditions, the study investigates how the bridge responds to multi-support seismic excitation. The results suggest that homogeneous seismic stimulation models may be underestimating the vulnerability of the bridge. This research emphasises the need of incorporating localised seismic data in design codes to increase the seismic resistance of transportation infrastructure.
11. **Ding et al. (2014)**: This research evaluates the seismic performance of metro stations based on large-scale shaking table tests, with a focus on their dynamic response characteristics. To get a comprehensive understanding of how underground multi-story structures behave during seismic events, the authors analyse a number of characteristics, including acceleration response and earth pressure over time. The paper emphasises the need of stringent seismic design criteria that enhance metro systems in metropolitan regions, where infrastructure is important for daily operations.
12. **Dalal et al. (2012)**: This study examines how structures' inelastic behaviour in the event of significant seismic events is ignored by typical elastic design approaches. The Performance Based Plastic Design (PBPD) method, which the authors strongly encourage, aims to provide predictable and desirable structural responses under seismic stresses. A framework known as PBPD allows engineers to specify goal drifts and yield mechanisms in order to improve building performance during earthquakes. The findings suggest that, if used, this design method would significantly lower the risk of earthquakes.
13. **Hu et al. (2010)**: The authors develop Bridge Information Modelling (BrIM) to make bridge design and construction easier, particularly in seismic situations. They highlight the advantages of automated processes, which reduce the need for human data entry and expedite project delivery schedules. This study emphasises the significance of incorporating seismic considerations into building information modelling (BrIM) and shows how BrIM may enhance design processes and decision-making to create more robust bridge infrastructure.

14. **Khade (2018)**: Using G+20 reinforced concrete frames, the seismic response of structures with and without shear walls is compared in this article. Applying Non-linear Static Pushover Analysis in SAP2000 software to shear walls significantly reduces lateral displacement and increases structural stiffness was shown to be beneficial. The results emphasise how crucial it is to include shear walls into high-rise building designs in order to improve seismic safety since they greatly enhance the structures' overall seismic performance.
15. **Zhang & Xu (2008)**: This research looks at the shear-flexural interaction of columns in relation to the seismic response of reinforced concrete bridges under seismic pressure. The authors develop a hysteretic model to account for the nonlinear behaviour of bridge components during earthquakes. Using finite element modelling, the research investigates the effects of soil-structure interactions and provides insightful information on the intricate behaviour of bridge columns during seismic events. Therefore, it aids in the creation of design methods that are more successful.
16. **Khan & Parker (2013)**: The authors of this paper look at a large-scale nuclear reactor building model and compare the results of utilising SASSI2010 and SAP2000 to study soil-structure interactions. Despite using different methodologies, they demonstrate that the two software systems provide comparable results by analysing metrics like as transfer functions, fundamental frequencies, and base shear forces in detail. Both approaches have been verified, confirming their reliability for seismic analysis of complex structures and providing significant information for their possible future usage.
17. **Zhou et al. (2012)**: This study investigated the behaviour of a tube station during an earthquake by performing seismic response analysis using large-scale shaking table testing. According to the study, upper levels of multi-story underground structures are more likely to experience damage during seismic tests. Because of the special problems of developing underground in seismic zones, the findings underscore the need for higher design standards.
18. **Agrawal & Khedikar (2018)**: The scientists examined both conventional and unusually shaped high-rise reinforced concrete structures to assess how well they performed during seismic occurrences. Their findings suggest that ductile frames outperform less ductile structures during seismic shocks. The research stresses the relevance of ductility concerns in high-rise construction by providing a detailed examination of how different design methodologies impact structural behaviour during seismic events.
19. **Tao et al. (2011)**: The response displacement method (RDM) and pushover analysis technique (PAM) are two of the seismic design approaches investigated in this work for underground projects. The authors discuss the benefits and drawbacks of each technique, with a particular emphasis on how well it relates to the real geological conditions in Beijing. According to the study, if we want more accurate and trustworthy seismic assessments for tube design, we must carefully pick and employ these approaches.
20. **Wang (2013)**: This paper introduces the elasto-plastic response spectrum analysis (EPRSA) technique for viaducts supporting urban rail traffic in order to improve performance-based seismic design. The author outlines a comprehensive design process that incorporates EPRSA and performance metrics such as member strength and deformation. In terms of efficiency and accuracy, the study found that the technique outperformed traditional nonlinear time-history analysis. This provides helpful insights on urban infrastructure design.
21. **Ding et al. (2012)**: This research investigates the challenges posed by seismic loading and evaluates the seismic performance of structures utilised in underground metro stations. To study how these structures respond to earthquakes, the authors conduct extensive shaking table tests; their results provide insight on the effects of many seismic elements. Their study demonstrates that metro systems in cities need strong earthquake design principles to be more robust.

22. **Li (2005)**: The author uses time-history analytic methods to analyse the seismic response of two-story subway stations. While seismic deformations are often lower in underground structures than in above-ground buildings, research suggests that these structures may be subjected to greater internal stresses. The study's findings highlight the need of adopting appropriate design criteria to ensure structural integrity throughout underground building projects, emphasising the need for a thorough understanding of seismic effects.
23. **Shobha (2021)**: This study emphasises the need of monitoring dynamic forces, namely seismic stresses, that buildings face during their lifespan. The author goes into the complexities of dynamic force analysis, emphasising the need of conducting detailed assessments of the impacts of diverse ground motions on reinforced concrete structures with several stories. The project's aims are to improve design methodologies and ensure structures are ready for seismic occurrences. It also promises to generate new measurements and insights.
24. **Quansah et al. (2017)**: To predict the seismic behaviour of multi-story frame structures, the authors emphasise the need of understanding structural properties, particularly the beam-to-column stiffness ratio. The research investigates the need to improve the seismic resilience of ordinary buildings via the application of simple and cost-effective design approaches. The paper presents the automated structural analysis techniques in SAP2000 utilising the CSI Application Programming Interface (API), demonstrating their efficacy in varied engineering applications.
25. **Kumar & Debnath (2021)**: The authors investigate the seismic behaviour of a railway bridge under the effect of localised synthetic ground vibrations", highlighting the inadequacies of traditional uniform seismic excitation models. Recommendations for improved design codes that account for regional seismic characteristics are based on their findings, which reveal that localised seismic data significantly effects structural responses.
26. **Zhou et al. (2012)**: This study emphasises the importance of soil-structure interaction in assessing the seismic performance of structures utilised for underground metro stations. The authors' experimental results demonstrate that surrounding soil conditions have a substantial influence on earthquake responses. The study stresses the need of employing advanced analytical techniques to include these interactions into approaching designs.
27. **Nam et al. (2003)**: This paper investigates the seismic behaviour of subsurface reinforced concrete structures and advocates the development of path-dependent soil models in order to better predict how buildings will respond during seismic events. The study's focus on the need for full models that account for the interfacial behaviour of structures and soil enables more accurate seismic assessments.
28. **Besednjak (2012)**: This thesis evaluates the SAP2000 algorithm's suitability for building reinforced concrete frames using Eurocode 8 criteria. The author points out that the approach does not operate well, particularly when estimating bending capacities and shear forces, and that it does not adhere to capacity design guidelines. The findings emphasise the need for improved design algorithms that adhere more rigorously to seismic design guidelines.
29. **Nikolić & Herak Marović (2006)**: Mechanical resistance and overall stability are the key subjects addressed in this paper as they relate to seismic bridge design. The authors point out that Eurocode 8's seismic analysis procedures are more sophisticated than those in previous versions of the code, resulting in larger seismic forces and capabilities. To mitigate the consequences of seismic stresses on bridges, they advocate utilising seismic isolation measures, such as elastomeric bearings.
30. **Gowardhan et al. (2008)**: The authors dive into the various methods to seismic design for buildings and bridges, emphasising the disparities in research goals. They point out that, although much work has been done on PBD for buildings, bridges have yet to be properly explored. To make bridges more resistant to seismic occurrences, the paper proposes doing more research and creating PBD methodologies that are particular to bridges.

31. **Kairui et al. (2020)**: An agent-based model for evaluating the reconstruction of transport networks after earthquakes is presented in this paper. The authors emphasise the need of considering the connections between various components of the network in light of the challenges faced during restoration. The findings suggest that the implementation of a comprehensive recovery strategy may significantly increase the resilience of urban transport networks.
32. **Rossetto & Duffour (2013)**: The authors stress the significance of including a broad variety of factors that impact a structure's performance during earthquakes into earthquake-resistant design concepts. To enhance the security and resilience of buildings and infrastructures, they advocate for methods that blend conventional design, efficient connectivity, and inventive damping technology.
33. **Konakli (2011)**: The effects of spatially varying ground motions are the major focus of this study's comprehensive stochastic dynamic analysis of bridges. Inadequate assessments of bridge performance are a typical outcome of traditional methodologies, which, as the author points out, often neglect the complexities of seismic wave propagation. The findings emphasise the necessity for developing approaches that account the special aspects of seismic ground vibrations and the interactions between soil and structures.
34. **Meng (2010)**: Using state-of-the-art finite element modelling methods, the author finds out how subterranean buildings, especially subway stations, react to earthquakes. The research highlights the importance of knowing how these buildings distribute stress during earthquakes and finds key areas that need improvement in building methods.
35. **Xia et al. (2009)**: This paper develops a dynamic interaction model to evaluate a LIM train's and an elevated bridge system's performance. The authors determine the train's equations of motion by focussing on the electromagnetic forces operating between the bridge and the train using modal superposition techniques. The findings provide crucial data on the performance of elevated transit systems under dynamic loads, including structural integrity and safety.
36. **Ouchi et al. (2000)**: The study of design methods by the authors centres on elevated bridge construction—more especially, tube systems. They underline that little is known about column-free and large-span structures and need for further experimental and computational investigations to clarify their behaviour during earthquakes.
37. **Li et al. (2021)**: This paper investigates, using an efficient model, the coupled dynamics of train-track-bridge systems under seismic stimulation. The researcher explained that how to apply this method to build a perfect strong structure by reducing the changes of low accuracy so that study optimize the real time assessment and decision making.
38. **Ding et al. (2014)**: This study optimized the solution of seismic performance variations and its affect on the structure of constructiong metro bridge the under go the different types of loadfing conditions, the author make simplification of the research to sesmic design guldelines for increasing the strength of the structure under the dynamic loading conditions**.** This research explaining the better design to sustain the high load on the structure without failure to enhance the urban transport system and operational effect during earthquakes and emphasises the requirement of the study to analyse the sesmic to affect on which structural member
39. **Dalal et al. (2012)**: The authors argue that conventional elastic design techniques are flawed as they rely too heavily on linear evaluations, which cannot represent the inelastic behaviour of buildings during major earthquakes. Their fervent belief is in the Performance-Based Plastic Design (PBPD) approach. Forecasting structural reactions in many earthquake scenarios is the main goal. Through the choice of target drifts and yield mechanisms, this approach improves building seismic performance and lowers the possibility of collapse during an earthquake.
40. **The researcher performed the study on the about the design specification of the structural member that undergo with different loading conditions** which cannot

represent the inelastic behaviour of buildings during major earthquakes. This phenomenon is in the Performance-Based Plastic Design (PBPD) approach shows the Forecasting structural reactions in many earthquake.

41. **Hu et al. (2010)**: Especially in seismic situations, this paper presents Bridging Information Modelling (Brim) as a fresh technique to improve bridge design and construction. The authors address how by lowering manual data input and including seismic risks into design processes building information modelling (BIM) might improve project delivery timeframes. The paper explores how Brim may strengthen bridge construction to resist seismic shocks and improve stakeholder communication.
42. **Khade (2018)**: Using SAP2000's Non-linear Static Pushover Analysis, this study evaluates the seismic response of G+20 RC frame designs both with and without shear walls. The results show that shear wall buildings have much less lateral displacements and more stiffness than simple frames. This studies show that, especially in seismically sensitive places, shear walls are essential for improving the seismic performance and general stability of tall buildings.
43. **Zhang & Xu (2008)**: Focussing on hysteretic modelling of bridge columns, the authors study the seismic response of three reinforced concrete bridge prototypes under many earthquake scenarios. By analysing the shear-flexural interaction of columns using a particular hysteretic model, their work shows that soil-structure interaction significantly affects seismic demand. Including these interactions into design and evaluation processes is very essential as the study provides understanding of the complex behaviour of bridge constructions during seismic events.
44. **Khan & Parker (2013)**: The consequences of soil-structure interaction (SSI) on the seismic design of a nuclear power plant reactor building are investigated in this work using SASSI2010 and SAP2000. The authors show that for important criteria like base shear forces and in-structure response spectra, both software tools provide identical answers independent of their different approaches. The research demonstrates the effectiveness of these approaches in evaluating complicated structures under seismic loads, therefore enhancing design criteria for vital infrastructure.
45. **Zhou et al. (2012)**: This work addresses the relevance of soil-structure interaction on the seismic performance of subterensive metro stations. The authors show via experimental testing how different soil conditions affect the structural response to seismic occurrences. The study supports the use of advanced analytical methods that may include these interactions in order to improve the design and safety of subterranean structures in seismically active sites.
46. **Nam et al. (2003)**: The authors study the seismic behaviour of subsurface reinforced concrete constructions and support the creation of path-dependent soil models in order to better forecast how buildings will react during seismic occurrences. The research underlines the requirement of thorough models that include the behaviour of the interface between structures and the soil around them. This is required to provide consistent seismic evaluations.
47. **Besednjak (2012)**: The use of the SAP2000 method in creating reinforced concrete frame designs meeting Eurocode 8 criteria is investigated in this thesis. The author notes many problems with the method's shear force and bending capacity evaluation and suggests that it should be corrected so as to be more in line with seismic design ideas. The results underline the necessity of more efficient design methods to guarantee structural seismic safety.
48. **Nikolić & Herak Marović (2006)**: With an eye on mechanical resistance and general stability, the study investigates important aspects of seismic bridge design. The authors underline these developments as new seismic analysis techniques based on Eurocode 8 provide higher seismic forces and capabilities than prior codes. To lessen the impact of

earthquakes on bridges, they stress the significance of using elastomeric bearings and other seismic isolation techniques.

49. **Gowardhan et al. (2008)**: The writers go over the differences in research goals between bridge and building seismic design approaches. They point out that whereas performance-based design (PBD) for buildings has progressed greatly, bridges have not gotten the same focus. This paper underlines the need of additional research on PBD techniques designed for bridge construction to increase their seismic shock resistance.
50. **Kairui et al. (2020)**: This study uses an agent-based model to determine how successfully transport networks recover after earthquakes. While discussing the difficulties of restoration, the authors emphasise the interdependence of various sections of the network. Their study provides crucial information for city planners and crisis management by demonstrating that utilising a comprehensive recovery architecture may make urban transport networks substantially more robust.
51. **Rossetto & Duffour (2013)**: When designing earthquake-resistant design ideas, the authors emphasise the need of considering all of the factors that influence a building's performance during an earthquake. To make buildings and infrastructure more secure and robust to earthquakes, they encourage strategies that combine regular design, effective connections, and current dampening technology
52. **Konakli (2011)**: This work uses stochastic dynamic analysis to extensively investigate bridges that are subjected to spatially variable ground motions. The author highlights the need for innovative methods to seismic analysis that take into account soil-structure interactions and the particular aspects of seismic ground movements, since standard methodologies often fall short in capturing the complexities of seismic wave propagation.
53. **Meng (2010)**: The author uses cutting-edge finite element modelling tools to investigate how underground constructions, particularly subway stations, respond to earthquakes. This study emphasises the need of understanding how these structures transfer stress during earthquakes, so that designers and builders may concentrate on the most important challenges.
54. **Xia et al. (2009)**: With a focus on electromagnetic forces, this study develops a dynamic interaction model to investigate the functioning of a LIM train in combination with an elevated bridge system. By enhancing the resilience of urban transit infrastructure, this research advances our knowledge of the safety and structural integrity of elevated transport systems under dynamic loading conditions.
55. **Ouchi et al. (2000)**: The authors' research of design techniques focusses on elevated bridge infrastructure, namely tube systems. They advocate for enhanced experimental and computational evaluations to learn more about the seismic behaviour of large-span and column-free structures, noting that there has been little investigation on these areas.
56. **Li et al. (2021)**: This work examines the coupled dynamics of train-track-bridge systems under seismic stimulation using an efficient model. The authors emphasise how this model aids in railway infrastructure design by reducing processing requirements without losing accuracy, allowing for real-time evaluations and decision-making.
57. **Ding et al. (2014)**: this study based on the sesmic analysis of structural desin in SAP 200, the research assesses the seismic performance of metro systems and highlights the need for stringent design criteria to make these systems more resilient to dynamic stress.
58. **Dalal et al. (2012)**: this analysis bsed on the elastic design methodologies that analyzed inelastic behaviour during earthquakes. The study suggested Performance-Based Plastic Design (PBPD) as a strategy to achieve predictable structural responses.

Results and Discussion

1. Summary of Findings

Extensive bibliometric study has been conducted to significantly enhance seismic examination of elevated metro and flyover structures. Outlined below are the key points from the 59 papers that were considered:

1. **Publication Trends**: The increasing amount of research on seismic safety in tall buildings since 2010 is a clear indication that its importance is becoming increasingly recognised.
2. **Research Themes**: Amidst the complexity of seismic analysis, the most often discussed subjects in literature are performance-based design, soil-structure interaction, and dynamic interaction analysis.
3. **Key Authors**: Scholars who have investigated different aspects of seismic analysis methods have made significant contributions to this field.
4. **Gaps in Literature**: A focus on traditional designs, a lack of varied geographical contexts, and experimental validations of numerical models were all conspicuously lacking.

2. Detailed Findings in Tabular Form

To demonstrate the variety of techniques and insights into seismic analysis, the following table summarises the main methodologies and conclusions from chosen publications within the bibliometric study.

Table 1: Summary of Selected Papers on Seismic Analysis of Elevated Structures

Authors	Year	Methods	Findings
Aakash Kumar, Nirmalendu Debnath	2021	Finite element modeling using synthetic ground motions.	Multi-support seismic excitation leads to greater absolute maximum displacement compared to uniform seismic excitation.
Shobha R.	2021	Dynamic force analysis using various ground motion parameters.	Dynamic forces are critical for building performance during seismic events.
Sejal P. Dalal, Sandeep A. Vasanwala, Atul K. Desai	2012	Comparison of elastic design methods with performance-based plastic design.	Performance-based methods provide more reliable structural responses under seismic loads.
Hanjin Hu, Il-Sang Ahn, Stuart S. Chen, Qiang Gao	2010	Bridge Information Modeling (BrIM) application in design workflows.	BrIM enhances design efficiency and reduces manual errors in bridge construction.
Mohsin Khan, Josh Parker	2013	Comparison of soil-structure interaction effects using SASSI2010 and SAP2000.	Similar results for base shear forces and response spectra indicate effective validation.
Zhou et al.	2012	Large-scale three-dimensional shaking table tests.	Top levels of underground structures experience severe damage during earthquakes.
Nam et al.	2003	Finite element method to analyze seismic behavior of underground structures.	Need for accurate modeling of soil-structure interaction for seismic analysis.
Besednjak, Dani	2012	Assessment of SAP2000 design process against Eurocode 8 requirements.	Identified shortcomings in the SAP2000 algorithm related to shear force assessments.
NikoliÄ‡, Å½eljana, Herak MaroviÄ‡, Vladica	2006	Comparative analysis of seismic design methodologies.	Emphasizes critical aspects in bridge design for seismic safety.
Gowardhan et al.	2008	Comparison of seismic performance of braced vs. unbraced steel frames.	Bracing systems enhance lateral stability and reduce seismic risk.

Kairui et al.	2020	Agent-based modeling for transportation network recovery post-earthquake.	Improves understanding of recovery processes and network robustness.
Rossetto & Duffour	2013	Review of comprehensive earthquake-resistant design principles.	Emphasizes the need for integrated approaches in design.
Konakli, Aikaterini	2011	Stochastic dynamic analysis considering spatial variability.	Addresses limitations of traditional seismic analysis methods.
Meng, Xianchun	2010	Finite element modeling of underground structures under seismic loading.	Identifies significant factors affecting seismic response.
Xia et al.	2009	3D dynamic interaction modeling using finite element analysis.	Analyzes dynamic responses of the train-bridge system.
Ouchi et al.	2000	Exploration of design methodologies for elevated bridges.	Focus on enhancing structural performance under seismic loads.
Li, Z.	2021	Modeling of train-track-bridge systems for seismic analysis.	Presents a computationally efficient method with accurate results.

3. Discussion of Findings

Table 1 shows that seismic analysis of elevated metro and flyover constructions uses a variety of approaches. The growing number of articles highlights the crucial need to address seismic hazards immediately, particularly in metropolitan regions where transportation relies on elevated buildings.

- **Performance-Based Design**: Beyond traditional force-based techniques, performance-based design strategies have been the subject of several research. If we want buildings that can endure earthquake pressures and keep working thereafter, we need to see this development continue.
- **Soil-Structure Interaction**: A recurring theme running across the research is the effect of soil conditions on earthquake reaction. Improving structural resilience requires taking soil-structure interaction effects into account during design and analysis, according to many research.
- **Experimental Validation**: There is still a significant lack of research on the practical verification of computer models. Field research and real-world data are necessary to support and improve these models, as many results are derived from simulations.
- **Interdisciplinary Collaboration**: According to the study, improving seismic analysis methods requires multidisciplinary teams consisting of civil, geotechnical, and structural engineers. By working together, we may find better ways to plan for seismic activity that take into consideration all the elements that affect it.

4. Conclusion

The results of this study shed light on the state of the art in seismic analysis studies pertaining to elevated metro and flyover constructions. One important finding from the bibliometric study was the dramatic uptick in research on seismic safety in urban infrastructure within the last 20 years. This suggests that people have become much more cognisant of the issue and its significance. Consistent with worldwide initiatives to urbanise and the critical need for robust transport networks, this tendency has been more noticeable in the last ten years. A collaborative research environment is emphasised by the identification of important authors and their contributions. It is essential to advance the area via multidisciplinary efforts. Seismic analysis is complicated and requires integrated methods that take environmental and structural elements into account; topics like performance-based design and soil-structure interaction are common. This analysis found a lot of missing information in the literature, especially when it comes to the importance of actually testing computational models. Since many results come from numerical simulations, there is an urgent need for empirical research to back up these theoretical models. To make elevated buildings more resistant to seismic occurrences, future studies should concentrate on investigating novel design methodologies and materials. In order to create more reliable seismic design approaches, the study lays the groundwork for future research that will highlight the significance of cooperation across different branches of engineering. In addition to adding to the scholarly conversation, these findings will have real-world implications, such making sure that elevated metro and flyover structures are strong enough to resist seismic impacts.

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