International Journal of Disaster Recovery and Business Continuity
Vol.12, No. 1, (2021), pp. 1387–1395

Technological Advancements in Earthquake Resistant Construction

Maheshkumar Anant Kakade,
Ph.D. student, Kalinga University, Raipur.
Dr. P.S. Charpe,
Ph.D. Guide, Kalinga University, Raipur.

Abstract

This paper reviews recent trends in modern construction which employ techniques for protection of buildings from collapsing due to earthquakes. The construction technologies have seen rapid changes since last century and tend to improve the quality of material used in them. Also, design aspects of the construction have improved owing to simulations and analysis of the structure which is carried out before construction. This paper discusses these key components of material, design and methods of analysis used for seismic design of buildings. A summary of recent established methods is thus presented.

Keywords—Earthquake resistant, seismic design, design criteria, material advancements, analysis methods

I. Introduction

Earthquakes and their destructive consequences have influenced historical culture, and gaining intelligence to predict or prevent earthquake hazards has been a significant component of human quest for awareness since the dawn of time [1]. Since the dawn of new building methods, earthquake-resistant construction has been on the minds of engineers. Buildings have been built to be shock and vibration resistant since ancient times. However, the majority of the innovation has been focused on preventing the loss of human life rather than the technological or economic implications of these systems. These modern buildings are allowed to undergo plastic deformation during the occurrence of earthquake wherein a building is just prevented from getting collapsed by building supporting structures and steel in the joints. This cause major economic damage due to cost of repairs and the time it requires for complete renovation. Hence, it is need of the day to design structures so that the buildings can resume operation quickly even in case of major earthquakes [2-3].

Without major collapse, all conventional earthquake-resistant construction technology offers the structure the potential to withstand large seismic forces. These innovations can be classified into the following general groups focused on the consideration of systemic behaviour:

1. Construction methods that utilize ductile construction materials, such as timber and bamboo houses.

2. Construction innovations, such as structures with symmetric plan and elevation, utilize robust design styles.

3. Construction technologies, such as buildings with bands and braces, that use robust structural configuration.

4. Construction technologies reducing seismic forces – such as through use of light-weight non-structural members [4].

Comparison of various methods for their seismic response is highly demanded for various different types of building constructions to maximize their safety. This will not only prevent human loss but also economic loss that the buildings have to undergo during an event of earthquake. Both numerical and simulation methods have to be used to identify basic response of a structure for its implementation for better understanding of its tensile capacity [5].

With the use of distributed multiple tuned mass dampers in the base of the buildings, they can be isolated for the effect of seismic forces. This technology can be expanded even in low rise buildings so as to give maximum protection to those buildings. Schools, hospitals, power plants and gas/fire stations may get huge benefit from this technology [6].

There is a strong demand for new thinking in the construction field for suppression of seismic forces which require formation of new structures, more robust evaluation of response of new designs and materials used in buildings, retrofitting ideas for old schools and masonry buildings and provide seismic isolation to the foundation of non-engineered construction. New methods of structural integrity evaluation are thus needed for this purpose [7-10].

This paper presents a rigorous review of construction material, structural designs and analysis methods for building earthquake resistant buildings. The paper is organized as follows: Section II covers basic literature review

ISSN: 2005-4289IJDRBC

followed by review of construction materials in Section III. Section IV and V cover the design aspects and analysis methods for earthquake proof construction while Section VI concludes the paper.

II. Literature Review

In [1] the authors discuss the need for new thinking for creating building infrastructure to accommodate the requirements of not just life-saving approach but for economic and business development as well. The structure of the buildings should be such that they should get easily and quickly restored even after a major earthquake. Today's designs allow plastic deformations so that they dissipate the energy from the earthquake while disallowing the structural collapse and loss of human life. However, it takes long time for full recovery of the building which results in huge financial loss. Hence, there is a need to design structure which follow seismic isolation mechanism using superstructure technology. In [2] the authors review the most commonly used traditional methods for seismic forces resistant structures developed by people over the years. They present a case study of Portugal culture of erecting earthquake resistant buildings. However, this concept is losing its hold as construction business is more and more focused on erecting the structures quickly and at lowest cost which compromises on their safety. Hence, it is necessary to readopt the earlier proven construction technology. In [3] and [4] authors discuss the fundamentals of earthquake resistant structures and their design. They work on various aspects of earthquake modelling, response of different structures for that modelling, methods to represent the demand that it infers and its evaluation. They also discuss few alternate approaches to reduce the impact of seismic waves on the structures.

The use of glass curtain partitions is rapidly growing in modern-day architecture. They have one day illustrated destruction after witnessing earthquake movements. The behaviour of such systems under seismic loads is studied in these paintings. The authors in [5] aim to make a commitment to enhancing the functionality of designers and suppliers. Buildings may have excellent durability against residual force applying structural load, but inadequate capacity against compression and tension involving earthquake forces. To secure their structural protection and to extend their useful life, it is important to seismically reinforce their constructs. The study presented in [6] takes the approach of reinforcing a historic system of masonry that's been constructed in the late nineteenth century but deserted for several years.

About 74 percent of residential properties were constructed in Italy before 1980, while 25 percent of the region was labelled as seismic. Almost 86 percent were installed before 1991, while the primary restrictive electricity output law was passed. Many households want any seismic and electricity safety movement to increase their degree of sustainability. For reinforced concrete framed houses, the suggested mixed retrofit approach is mainly based solely on the removal of the outer layer of double-leaf infill walls [7].

Modular steel construction (MSC) includes volumetric components and on-site fabrication assembled off-site. When the ceiling height rises, the effect of the earthquakes is important. An analysis of mid-to-high MSC seismic output is described in [8]. The goal is to facilitate the further widespread application of MSC in earthquake zones. Masonry constructs usually occur in practice and are still common all over the world. These homes are responsible for high external loadings levied with the aid of earthquakes, strong winds, explosions, etc. Specific seismic retrofitting and reinforcing procedures for masonry structures have been advanced and applied in the last few decades [9]. Even in India, almost 80 percent of Delhi's houses, the capital of India, are not earthquake prone. Lateral strain resisting devices such as chevron braces, knee braces are located in aggregate with aluminium shear hyperlinks to minimize the impact of the earthquake on the drift systems [10].

Multi-story houses are responsible for wind or earthquake lateral masses. Buildings may be constructed by means of several strategies to lower these lateral masses. The behaviour of structural diaphragms for the length of the earthquake on their overall output is being observed [11]. Due to more than one known characteristics, timber systems historically produced high-quality seismic overall performance. The results of the final global earthquakes have practically shown that the seismic wooden layout can be changed in a similar way [12]. Today, wooden structures target higher heights and face a number of severe seismic criteria. As a hotspot in wood engineering science, seismic protection technologies (SPTs) have arisen. Precast concrete facilitates a construction method using durable and rapidly erectable prefabricated members to create cost effective and high-quality structures. The connections between the precast members as well as between the members and the foundation require special attention to ensure good seismic performance [13]. In [14] authors show extreme strategies to increase the seismic efficiency of homes and bridges. In particular, the look at illustrates the effect of various insulators and dampers on the damage prevention of building. A static control system to decrease seismic activity is the multi-level pipe damper (MPD) is proposed by

ISSN: 2005-4289IJDRBC

the authors in [15]. The seismic performance of MPD-equipped structural steel is presented. For buildings in severe earthquake zones, MPD may be used as a maintenance and repair strategy.

It has been observed that there is no integration between the pier and the base during the building process for the cord bridge with tilt construction. Once an earthquake happens, the upending of the structure or the collapse of the bottom turntable can easily be triggered. Under the 6-degree and 7-degree earthquake amplitude, the identifying pin at the middle of the ball-end pivot has severe shearing power. In the analysis [16], the seismic steps for assembling anchor rods at the edges of the turntable are proposed. The development of cross-laminated wood (CLT) is becoming part of standard routine in wood engineering. Consequently, planning and installing CLT systems in earthquake-inclined regions is not for early adopters. The latest seismic architecture of CLT buildings is shown in [17]. In [18] authors present few recent methods used for analysis for earthquake resistant design which include equivalent lateral force method and response spectrum analysis. They also provide comparative analysis of both these methods. It is observed that if R factor is less than 6 then it is suggested to perform nonlinear response history analysis. In [19] authors propose a design for earthquake resistant masonry buildings. These buildings have tremendous weight with no appreciable tensile strength and improper construction of its walls. They propose vertical steel reinforcement of building walls so as to give them enough plasticity to overcome seismic forces acting on them.

In low seismic areas [20], Accelerated Bridge Construction (ABC) has been tested. The implementation of ABC has been confined to excessive seismic zones. The links seek to imitate the traditional creation of plastic hinges by an earthquake within the side of the bridge columns. To minimize the shocks from an earthquake, seismic isolation gadgets are used [21]. They minimize the bottom shear and displacement, but the ground acceleration and inter-storey drift rise. In earthquake-inclined countries, owing to intrinsic properties, metallic structures are considered to be one of the reasonable choices. The restoration and regeneration of fractured structures is a daunting job and a time-ingesting process in addition. In [22] authors offer a critical description of the current architectures dealing with metallic lateral load resistance with replaceable fuses that help repair metallic systems smoothly.

Statistical analysis is carried in [23] out by using mathematical tools of five, 10 and 15 storied building. In terms of top floor velocity and bearing movement, it is inferred that mounting a tuned mass damper for each floor level decreases the seismic behaviour. As compared to the STMD and MTMDs, the d-MTMDs are more useful as otherwise enormous controller mass can now be separated and spread on different locations. Seismic architecture, complex nonlinear structure analysis, and reaction simulation (kinematic and dynamic) of steel moment resistance frames are automated by the platform suggested in [24]. To improve the adaptability of the system, a modular architecture is implemented. To improve analytical-driven modelling approaches, the model can be used to construct a comprehensive prototype steel moment model construction database. Owing to non-conformance to modern-day layout standards, current homes could be at an additional seismic risk. A retrofit option system that is largely focused solely on the seismic stability of weak dwellings is presented in [25] which also suggests that seismic resistance can be used as an overall output metric to assess the impact of a hazard on perseverance.

III. Construction Material

Construction material used for buildings play an important role in absorbing the impact of seismic forces and aiding the earthquake resistant construction. Following are few of the commonly used materials for seismic resistant construction.

A. Autoclaved Aerated Concrete (AAC)

A large number of structures were constructed all over the world prior to the implementation of strict earthquake and energy conservation standards. As a result, most buildings would need both seismic and energy renovations in order to increase their long-term viability. The suggested combined retrofit approach for reinforced concrete framed buildings focuses on replacing the exterior layer of hollow brick double-leaf infill walls with high-performance AAC blocks: this method can be applied primarily from the outside of the structure, minimizing occupant disturbance throughout retrofitting [7]. ACC blocks are made up of pulverized fly ash, gypsum, lime, cement, water and aluminium powder which are processed in a mould. Figure 1 shows the ACC based construction.

ISSN: 2005-4289IJDRBC

Fig. 1. ACC blocks-based construction

The advantages of ACC based construction are that the construction is lightweight as it weighs 50% less than standard concrete block, it can be easily cut or drilled or milled to fit in desired dimensions according to requirement and they are easy to install with minimum wastages as the ACC blocks seldom break. Moreover, they are thermal, fire and seismic resistant and cost less as they require minimum cement and steel. However, they are brittle and have less load bearing capacity and can only be used as partition walls. They are suitable for low to medium storey construction and cannot be used for high rise towers due to these limitations.

B. Modular steel construction (MSC)

Fig. 2. ACC blocks-based construction

MSC consists of off-site assembled volumetric components and on-site installation, resulting in shorter construction times, higher efficiency, and less pollution. As an alternative to conventional on-site design, this environmentally sustainable approach has been widely used for low-rise buildings as shown in Fig. 2. Because of its major technological advantages, MSC is now being used in mid-to-high-rise applications in seismic regions to satisfy the growing urban development need [8]. These structures are flexible and have high resistance to seismic forces. They can dissipate the seismic energy very fast. However, they are not suitable for high rise construction and require super-elastic SMA bolts for interconnection. This increases the cost of such structures.

C. Precast concrete

Precast concrete allows for the creation of cost-effective and high-quality buildings by allowing for the use of sturdy and quickly erectable prefabricated members. To ensure good seismic results, the relationships between the precast members, as well as the members and the structure, need special attention in this process. Since the 1980s, extensive development has resulted in new precast concrete structural structures, designs, details, and techniques that are particularly suitable for use in high seismic hazard areas [13].

IV. Design Improvements

Structural design is the most important aspect of modern buildings. It's important to prepare for earthquake damage and incorporate appropriate earthquake-resistant strategies to protect lives. Newer methods are

ISSN: 2005-4289IJDRBC

being used to make structures earthquake resistant. Performance-based architecture is one such technique, in which the structure's performance is prioritised over current norms. Lateral load resisting mechanisms such as chevron braces and knee braces, when used in conjunction with aluminium shear chains, have been found to reduce the effect of earthquakes on buildings in terms of drift.

A. Bracing Systems

Two basic structures are used to illustrate the principle of bracings, as seen in Fig. 3. When a normal square structure and a square with diagonal are laterally loaded [shear force], the normal square structure deforms easily, while the square with diagonal absorbs the lateral load better. Or used as a lateral mechanism to withstand wind/seismic loads, a regular square configuration involves rigid joints. In the case of square, axial rigidity is not a factor. The diagonal portion [axially] resists part of the shear load in a square structure with diagonal [10].

The system includes bracing to assist with load transfer and dimensional control, as well as to mitigate the buckling of the major structural components.

Bracing Styles include

1. Bracing for a single diagonal axis
2. Bracing on both sides or cross bracing
3. V-shaped bracing
4. Eccentric Bracing.
5. Bracing (K).

B. Tube System

The tube structure concept is based on a comparison of a building and a vertical cantilever. A frame can be compared to a hollow cantilever beam that can withstand wind and earthquake lateral loads. In the tube framework, the columns are typically close together on the building's perimeter and are kept together by beam elements through moment connections. This arrangement of structural components creates a stiffer frame that reduces the structure's lateral displacements [10].

The following are the key issues that must be discussed in the case of tube systems:

1. Shear Lag, Positive and Negative
2. There isn't enough space for windows and other gaps.
3. Beams that are very deep

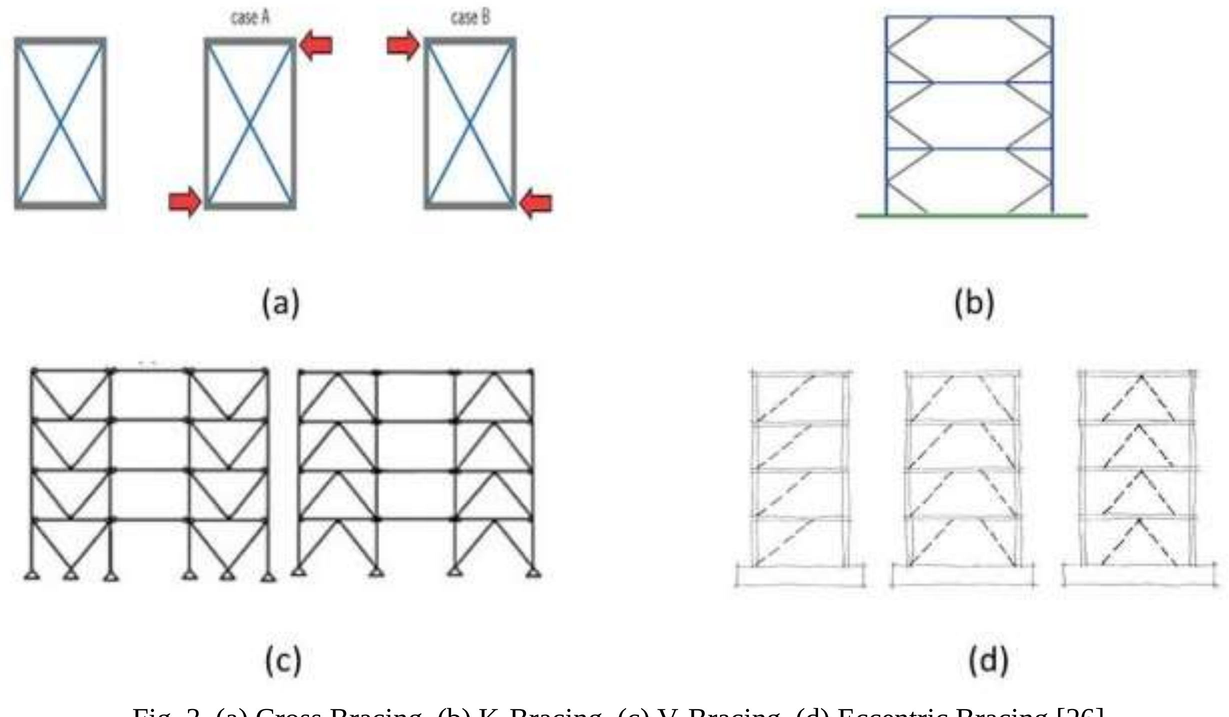

Fig. 3. (a) Cross Bracing, (b) K-Bracing, (c) V-Bracing, (d) Eccentric Bracing [26]

ISSN: 2005-4289IJDRBC

C. Shear Walls

Shear Walls are often classified as structural components (along with slabs, beams and columns). Shear walls normally begin at the base level and extend the entire height of the structure and are shown in Fig. 4. Shear walls can be as thin as 150mm thick or as thick as 400mm thick (in high rise structures). These walls are usually built in both horizontal and vertical directions (along the length and width of a building). Shear walls are vertical deep beams that bear lateral loads caused by wind and earthquakes down to the substructure. Structures with shear walls that are well engineered and comprehensive have shown strong resistance in previous earthquakes [10].

The only issue with putting up Shear walls is that it will lead to a lot of overturning. As a result, extra care must be taken when constructing the structure of shear walls. Shear walls in both directions should be given. If they must be provided in just one direction for whatever purpose, the other structural elements in the vertical plane must be properly oriented in the opposite direction to resist lateral loads in that direction.

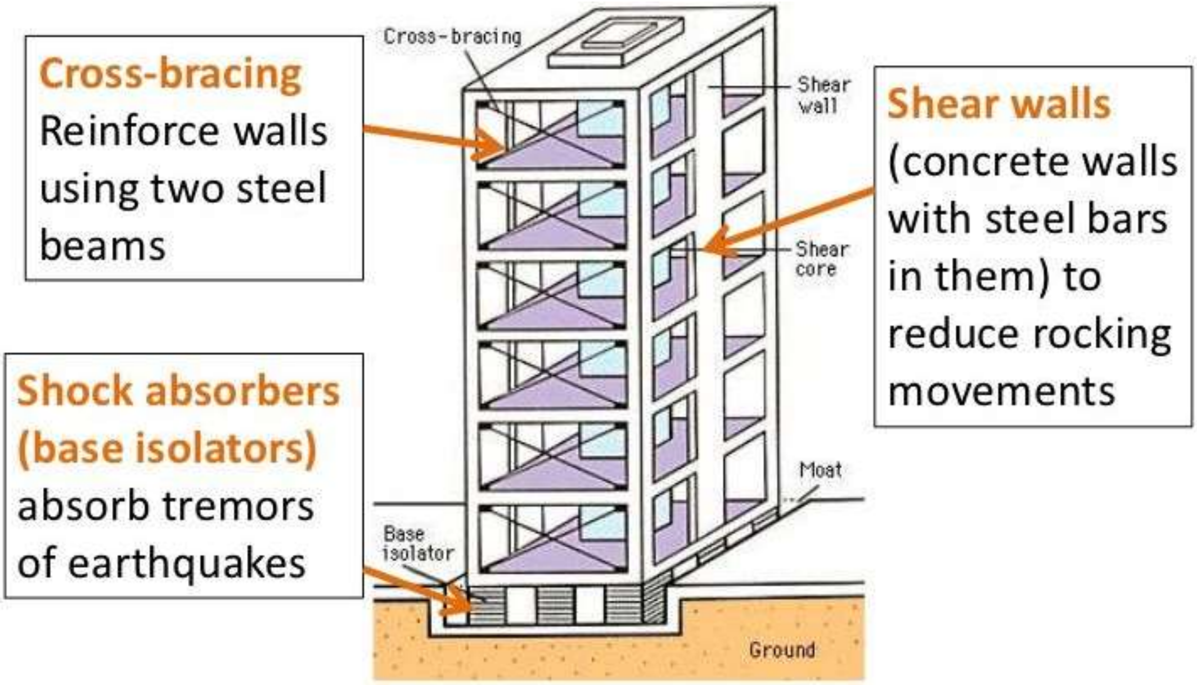

Fig. 4. Earthquake Resistant Building

D. Base Isolation System

Base isolation is a cutting-edge earthquake damage reduction technique in which a foundation is suspended from the ground to reduce the effects of seismic waves. In the field of earthquake engineering, a variety of base isolation systems have been developed and are used in seismic structures for improved vibration management [14].

ISSN: 2005-4289IJDRBC

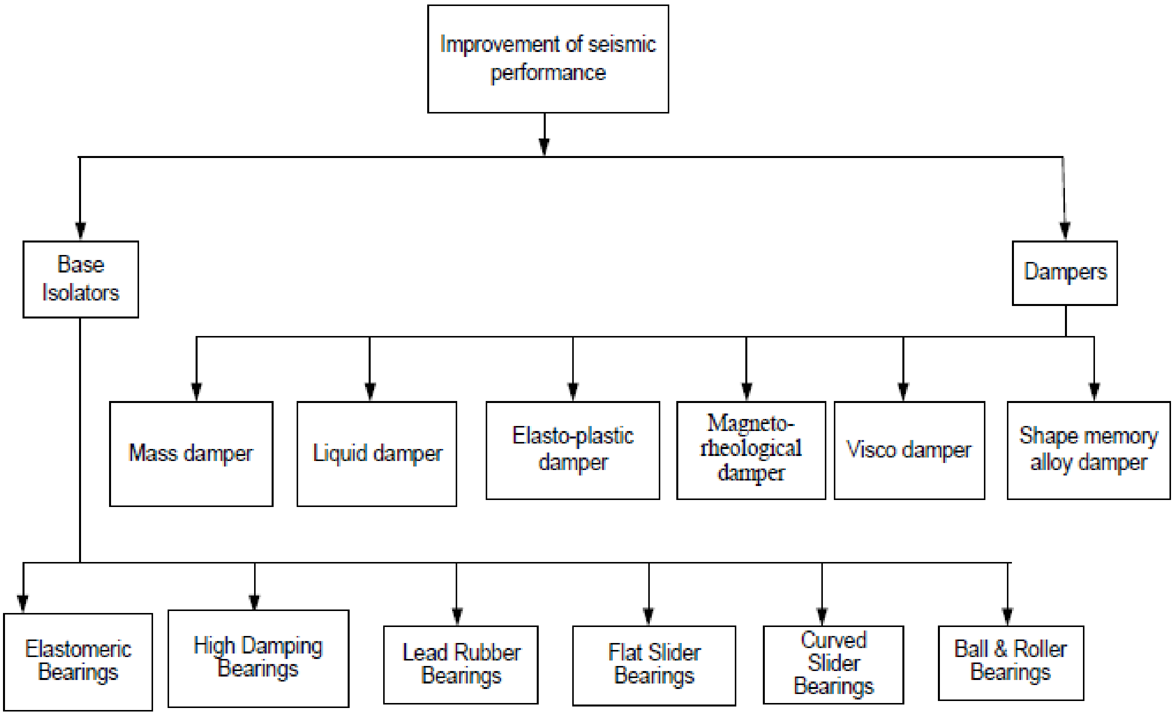

Fig. 5. Different types of base isolators and dampers [14]

Mechanical systems such as foundation isolators and dampers go a long way toward enhancing the seismic efficiency of buildings and civil structures. Elastomeric Bearings, High Damping Bearings, Lead Rubber Bearings, Flat Slider Bearings, Curved Slider Bearings or Pendulum Bearings, Ball & Roller Bearings, and dampers such as Mass Dampers, Liquid Dampers, Elasto-plastic Damper, Visco Damper, Magneto-rheological Damper, and Shape Memory Alloy Dampers have all been discussed extensively in the literature. Different dampers and isolators used to improve seismic stability in buildings as seen in Fig. 5.

V. Structural Analysis

The prediction of a structure's response to arbitrary external loads is known as structural analysis. The future exterior load of a structure is measured during the preliminary structural design stage, and the scale of the structure's interconnected components is determined based on the estimated loads. Structural analysis determines the relationship between the projected external load on a structural component and the structure's established internal stresses and displacements that exist within the member while in action which is required to ensure that the structural members meet the local building code and standards in terms of protection and serviceability. Seismic analysis is done using various software programs developed for structural analysis.

A. GSA Analysis

GSA Analysis provides engineers with a user-friendly nonlinear analysis software platform to help them realise the full value of their designs, no matter where they are. This structural analysis software package is used on a variety of projects all around the world. Engineers can conveniently do 3-D linear, P-delta, non-linear static analysis, and more with this programme. They may also perform Modal and Ritz vibration measurements, including seismic and time-history assessments, with or without the stiffening effects of loads.

B. ELS

Structural engineering may use the Extreme Loading for Structures (ELS) programme to conduct seismic analysis so that structures can withstand seismic events, shielding the structures and their inhabitants. ELS is designed to make it simple for structural engineers to do static or dynamic nonlinear analysis using the Applied Element Method (AEM), which is the only method of analysis that automatically measures crack initiation, propagation, and element separation. Engineers may use ELS to analyse not just homes, but any structure, including bridges, stadiums, cranes, pipelines, and so on.

ISSN: 2005-4289IJDRBC

C. STAAD Pro

STAAD, also known as STAAD.Pro, is a structural analysis and architecture software programme created by Research Engineers International in 1997. STAAD-advantages Pro's include: confirmation with Indian standard codes, the ability to solve any kind of problem, an easy-to-use interface, and the accuracy of the solution. Features include a user interface, visualisation tools, and a powerful analysis and design appliance with advanced limited element and dynamic analysis performance. From model generation to output visualisation and result verification, STAAD-Pro is the expert's best choice for concrete, steel, aluminium, timber, and cold-formed steel design of low and high-rise buildings.

D. MIDAS

This software provides good interface for analysis of bridges. Seismic forces acting on bridge type constructions on the basis of vibration analysis and dynamic performance is carried out with the help of this software.

Other noteworthy software programs include SketchUp, E-TABS, SAFE, RISA, Autodesk, SAP2000 and eTakeoff which are applied for structural analysis of a structure considering seismic forces action on it.

VI. Conclusion

This paper presents a study on advancements in construction technologies in terms of construction material, design aspects and analysis software which are used for reducing the effect of earthquake or seismic forces acting on them. ACC, MSC and precast concrete are now widely for building various structures and have properties to absorb seismic forces. Braces, dampers or isolators and sheer wall are increasingly used in earthquake resistant buildings due to their flexibility and load bearing ability. Various software programs are used to analyse effect of seismic forces on any specific design and material before construction. These technologies help save many lives and loss of property in case of an earthquake.

References

[1] Takagi, Jiro, and Akira Wada. "Recent earthquakes and the need for a new philosophy for earthquake-resistant design." *Soil Dynamics and Earthquake Engineering* 119 (2019): 499-507.
[2] Ortega, Javier, Graca Vasconcelos, Hugo Rodrigues, Mariana Correia, and Paulo B. Lourenco. "Traditional earthquake resistant techniques for vernacular architecture and local seismic cultures: A literature review." *Journal of Cultural Heritage* 27 (2017): 181-196.
[3] Krinitzsky, Ellis L., James P. Gould, and Peter H. Edinger. *Fundamentals of earthquake-resistant construction*. Vol. 51. John Wiley & Sons, 1993.
[4] Elnashai, Amr S., and Luigi Di Sarno. *Fundamentals of earthquake engineering*. New York: Wiley, 2008.
[5] Aiello, Carolina, Nicola Caterino, Giuseppe Maddaloni, Antonio Bonati, Annalisa Franco, and Antonio Occhiuzzi. "Experimental and numerical investigation of cyclic response of a glass curtain wall for seismic performance assessment." *Construction and Building Materials* 187 (2018): 596-609.
[6] Sayin, Baris, Baris Yildizlar, Cemil Akcay, and Baris Gunes. "The retrofitting of historical masonry buildings with insufficient seismic resistance using conventional and non-conventional techniques." *Engineering Failure Analysis* 97 (2019): 454-463.
[7] Artino, Antonio, Gianpiero Evola, Giuseppe Margani, and Edoardo Michele Marino. "Seismic and energy retrofit of apartment buildings through autoclaved aerated concrete (AAC) blocks infill walls." *Sustainability* 11, no. 14 (2019): 3939.
[8] Deng, En-Feng, Liang Zong, Yang Ding, Zhe Zhang, Jun-Feng Zhang, Feng-Wei Shi, Li-Ming Cai, and Shu-Cai Gao. "Seismic performance of mid-to-high rise modular steel construction-A critical review." *Thin-Walled Structures* 155 (2020): 106924.
[9] Wang, Chuanlin, Vasilis Sarhosis, and Nikolaos Nikitas. "Strengthening/retrofitting techniques on unreinforced masonry structure/element subjected to seismic loads: A literature review." *The Open Construction and Building Technology Journal* 12, no. 1 (2018).
[10] Patil, R., A. Naringe, and JS Kalyana Rama. "Novel techniques for seismic performance of high rise structures in 21st century: state-of-the art review." In *IOP conference series: materials science and engineering*, vol. 330, p. 012126. 2018.
[11] Jereen, Ann Thomas, Soumya Anand, and Binu M. Issac. "Seismic evaluation of buildings with plan irregularity." In *Applied Mechanics and Materials*, vol. 857, pp. 225-230. Trans Tech Publications Ltd, 2017.
[12] Ugalde, David, José Luis Almazán, Hernán Santa María, and Pablo Guindos. "Seismic protection technologies for timber structures: a review." *European Journal of Wood and Wood Products* 77, no. 2 (2019): 173-194.
[13] Kurama, Yahya C., Sri Sritharan, Robert B. Fleischman, Jose I. Restrepo, Richard S. Henry, Ned M. Cleland, S. K. Ghosh, and Patricio Bonelli. "Seismic-resistant precast concrete structures: state of the art." PhD diss., American Society of Civil Engineers, 2018.

ISSN: 2005-4289IJDRBC

[14] Nath, Snehansu, Nirmalendu Debnath, and Satyabrata Choudhury. "Methods for improving the seismic performance of structures: A review." In *IOP Conference Series: Materials Science and Engineering*, vol. 377, p. 012141. 2018.
[15] Zahrai, Seyed Mehdi, and Abdullah Cheraghi. "Reducing seismic vibrations of typical steel buildings using new multi-level yielding pipe damper." *International Journal of Steel Structures* 17, no. 3 (2017): 983-998.
[16] Xiao, Junhua, Miao Liu, Tieyi Zhong, and Guangzhi Fu. "Seismic performance analysis of concrete-filled steel tubular single pylon cable-stayed bridge with swivel construction." In *IOP Conference Series: Earth and Environmental Science*, vol. 218, no. 1, p. 012087. IOP Publishing, 2019.
[17] Tannert, Thomas, Maurizio Follesa, Massimo Fragiacomo, Paulina Gonzalez, Hiroshi Isoda, Daniel Moroder, Haibei Xiong, and John van de Lindt. "Seismic design of cross-laminated timber buildings." *Wood and Fiber Science* (2018): 3-26.
[18] Quezada, Eder, Yaneth Serrano, and Guillermo Huaco. "Dynamic Amplification Factor Proposal for Seismic Resistant Design of Tall Buildings with Rigid Core Structural System." In *Proceedings of the 5th Brazilian Technology Symposium*, pp. 245-256. Springer, Cham, 2021.
[19] Arya, Anand Swarup. "Earthquake resistant design of masonry buildings." In *Advances in Indian Earthquake Engineering and Seismology*, pp. 259-271. Springer, Cham, 2018.
[20] Mashal, Mustafa, and Alessandro Palermo. "Emulative seismic resistant technology for accelerated bridge construction." *Soil Dynamics and Earthquake Engineering* 124 (2019): 197-211.
[21] Shekhar, Sudhanshu, Sureshwar Prasad Shukla, and Sana Zafar. "Seismic Isolation Devices." *no. October* (2018).
[22] Saravanan, M., Rupen Goswami, and G. S. Palani. "Replaceable fuses in earthquake resistant steel structures: A review." *International Journal of Steel Structures* 18, no. 3 (2018): 868-879.
[23] Stanikzai, Mohammad Hamayoun, Said Elias, Vasant A. Matsagar, and Arvind K. Jain. "Seismic response control of base-isolated buildings using multiple tuned mass dampers." *The Structural Design of Tall and Special Buildings* 28, no. 3 (2019): e1576.
[24] Guan, Xingquan, Henry Burton, and Thomas Sabol. "Python-based computational platform to automate seismic design, nonlinear structural model construction and analysis of steel moment resisting frames." *Engineering Structures* 224 (2020): 111199.
[25] Anwar, Ghazanfar Ali, and You Dong. "Seismic resilience of retrofitted RC buildings." *Earthquake Engineering and Engineering Vibration* 19, no. 3 (2020): 561-571.
[26] Website: https://www.designingbuildings.co.uk/wiki/Braced_frame_structures

ISSN: 2005-4289IJDRBC