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Damage Catalogue Software and the Role of Architecture & Architects: A Comprehensive Review

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Abstract

This scientific paper explores several aspects related to damage catalogue software while also highlighting the importance of including accurate architecture when analyzing structural damage. With modern architecture continuously evolving in complexity, employing specialized tools that can efficiently evaluate damages has become increasingly necessary. We investigate various available solutions while stressing the need for incorporating precise references from building designs within these systems as a means to ensure credible documentation. Our research findings demonstrate that integrating these references within such software aids data interpretation while creating bridges between experts working on diverse areas related to structural analysis/design.

Keywords: *Damage catalogue software, structural damage assessment, software applications, architectural considerations, classification system.*

Hasar Katalog Yazılımlarında Mimarlık ve Mimarların Rolü Üzerine Kapsamlı Bir İnceleme

Öz

Bu bilimsel çalışma, hasar kataloğu yazılımının kapsamlı bir incelemesini sunar ve yapısal hasarın analiz edilmesi ve belgelenmesi bağlamında mimari alıntıların önemini araştırmaktadır. Mimari tasarımların artan karmaşıklığı ve verimli hasar değerlendirmesinin artan önemi ile özel yazılım araçlarının kullanımı hayati hale gelmiştir. Bu çalışma, çeşitli hasar kataloğu yazılım uygulamalarını incelemekte ve mimari alıntıların doğru ve güvenilir belgeleme sağlamadaki rolünü vurgulamaktadır. Bulgular, veri yorumlamayı geliştirmek, bilgi transferini kolaylaştırmak ve yapısal analiz ve tasarım alanında disiplinler arası iş birliğini teşvik etmek için mimari alıntıları hasar kataloğu yazılımına entegre etmenin önemini vurgulamaktadır.

Anahtar kelimeler: *Hasar kataloğu yazılımı, yapısal hasar tespiti, yazılım uygulamaları, mimari uygulamalar, sınıflandırma sistemi.*

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1. Introduction

In order to comprehend potential vulnerabilities pertaining to structures, it is imperative to conduct a precise evaluation and maintain meticulous documentation. This approach enables the identification of faults that may have detrimental consequences, thereby facilitating the implementation of appropriate mitigation strategies during investigations. The conventional approach of handwritten methods has been found to be problematic due to their susceptibility to errors and time-consuming nature. Nevertheless, recent significant advancements have enabled extensive innovation in the field of damaged cataloging software applications, which have revolutionized the way structural damage is addressed. This has been achieved through the implementation of multiple related innovations.

Newman et al., (2017) describe a novel approach in software catalogs that allows for the creation of typographical documentation that is highly accurate and up-to-date in terms of reliability measures. The present article aims to offer an impartial analysis of the crucial role that architectural concepts play in the effective implementation of damage cataloging software. The intricacy and complexity of contemporary building designs have increased considerably in the built environment, encompassing structures such as skyscrapers and complex bridges that present significant structural challenges. Therefore, the effectiveness of damage assessment is crucial in identifying potential hazards to accurately assess the severity of harm and implement appropriate remedial actions.

The conventional manual methods of categorizing structural damages through handwritten notes have been found to be inadequate due to limited data capture and inconsistencies. To address this issue, automated systematic categorization has been introduced, which utilizes computer vision algorithms and Building Information Modeling (BIM) capabilities. This approach has been made possible through the application of rigorous technological advancements, as highlighted by Huang et al. (2021). The utilization of digitized data recording protocols presently affords construction professionals, architects, and engineers the ability to promptly retrieve and scrutinize substantial quantities of data.

The benefits of damage cataloging software are not limited to the mere recording of information. The inclusion of architecture enhances its usefulness by providing construction details and material properties that are crucial in assessing the impact of damage on load paths and structural behavior. These features are primarily referenced within the software tools. In order to conduct a thorough evaluation of earthquake damage within the realm of construction stakeholders, including architects, facility managers, and engineers, it is imperative to utilize extensively researched architectural references that facilitate effective knowledge dissemination.

The utilization of embedded software information through efficient collaborative endeavors mitigates conflicts that may arise from misinterpretations of complex structures by facilitating precise shared comprehension. In order to make well-informed decisions regarding the repair and rehabilitation of structures, it is imperative to utilize appropriate architectural references to bolster rebuilding endeavors. This entails the contemplation of innovative designs for the reconstruction of structures, which enables the attainment of alignment with the intended function. The preservation of resultant structural integrity can be ensured while simultaneously addressing all relevant architectural considerations.

In essence, the integration of architecture within established guidelines involves estimating losses resulting from earthquakes, thereby offering dependable solutions aimed at enhancing the resilience of the built environment, as well as facilitating efficient disaster planning across diverse locations. The seismic performance of a structure is influenced by various factors, including the building type, its shape, size, materials used, and construction techniques employed. These parameters play a crucial role in determining the functionality of the structure. Incorporating such particulars can enhance the precision of evaluations and refine the techniques employed for estimating losses.

Catalogs are a valuable outcome of earthquakes that enhance the efficiency and accuracy of post-earthquake evaluations. These points serve as crucial sources of information collection, documenting valuable observations on patterns of damage, building composition, materials, architectural characteristics, and material performance attributes. Accurate architectural assessments have a fundamental positive impact as they facilitate reconstruction decisions that are resilient to future seismic events.

The assessment of potential damage in the event of an earthquake necessitates a critical consideration of the role of architecture in influencing the vulnerability of building structures. The proportional consideration of architecture plays a crucial role in determining the methods used for estimating loss. The act of systematically organizing and documenting the effects of seismic activity on buildings is an essential component in evaluating the repercussions on edifices. The utilization of systematic documentation, such as damage catalogues, provides valuable insights into the nature and extent of damage incurred by buildings. The acquisition of such data is of utmost importance in comprehending building typologies, construction techniques, and materials employed, as well as in refining loss estimation models to augment the precision and exactness of forecasting future calamities. The integration of architectural considerations in loss estimation enables the construction of resilient structures capable of withstanding seismic events. The aforementioned objective is accomplished through the integration of loss estimation data and structural assessments, which serve to detect any inadequacies or vulnerabilities in existing structures. Furthermore, the implementation of retrofitting techniques can be utilized to augment resilience in the face of forthcoming earthquakes, surpassing the constraints of seismic design principles exclusively.

2. Material and Method

This study involved a meticulous examination of earthquake damage cataloguing software and current standards for documenting building infrastructure losses resulting from seismic activity. Additionally, it was gathered data on successful reservoirs' functional applications at an international level, rather than limiting our analysis to local solutions.

The methodology employed aimed to collect and evaluate crucial information from credible sources, including academic databases, scholarly journals, conference proceedings, and pertinent literature, among other resources. The present study involved an analysis of case studies, research papers, and reports pertaining to analogous research endeavors conducted across diverse nations globally.

Through a comparative analysis of earthquake-damage catalogue software solutions in various international contexts and the Turkish context, it was examined the potential benefits of integrating architectural references into damage cataloguing software. The comparative analysis methodology employed in our study has also brought to light efficacious country-specific practices that have been assimilated from diverse architectural restoration projects.

The present study scrutinized case studies pertaining to Turkey and detected plausible inadequacies that necessitated crucial enhancements in the realm of architecture integration best practices, with the aim of augmenting assessment and mitigation methodologies. Through the utilization of a qualitative research approach, the data collected was analyzed and common themes and significant findings were extracted. These findings have provided expert insights on the potential efficacy of incorporating architecture as a means of enhancing functionality, reliability, and accessibility in regions that are susceptible to seismic activity.

Research undertaken through this investigation suggests incorporating cutting-edge technologies and architecture into established protocols, with architectural reference integral to critical infrastructure assessment planning evaluation. Such an approach has the potential to significantly enhance seismic damage assessment accuracy while hastening repair efforts as well as mitigating risks related to seismic events like earthquakes.

3. Literature Review

3.1. Damage Catalogue Software: Overview and Functionality

Damage Catalogue Software is an innovative digital tool used by engineers, architects, and construction specialists for efficiently documenting, classifying and assessing structural harm. The system features various functions designed to streamline evaluation of recorded instances of structural harm with precision; sophisticated computer vision algorithms and machine learning tasks combined with modern data capture approaches provide enhanced efficiencies for efficient use of this digital solution (Schweier & Markus, 2004).

3.2. The Key Functionalities of Damage Catalogue Software Include

The software for cataloguing damages optimizes the procedure of recording and handling damage-related data by means of effective data gathering, classification, and evaluation. The input of detailed information such as photographs, descriptions, and location data by users facilitates efficient searching and identification of patterns. The software produces informative reports and visual representations that facilitate informed decision-making and allocation of resources. The automation and centralization of damage documentation can improve efficiency and accuracy, as well as facilitate prompt response and recovery efforts (Erdik et al., 2011). The prominent features of the damage catalog are as follows;

1. Image and Data Capture: The utilization of damage catalogue software facilitates the acquisition of both visual and informational data pertaining to structural damage. Diverse methods, including but not limited to photographs, videos, or sensor data, can be employed to achieve this objective. Sophisticated software applications frequently incorporate cameras, drones, or sensors to gather visual or quantitative data pertaining to the scope and characteristics of damage.

2. Damage Classification: The categorization and classification of various types of damage is facilitated by the utilization of advanced algorithms in damage cataloging software. Through the analysis of captured images or data, these tools possess the ability to automatically identify and assign labels to distinct damage patterns or anomalies. The implementation of automated classification techniques improves the reliability and impartiality of evaluating the extent of damage.

3. Annotation and Documentation: The utilization of damage catalogue software enables the process of annotating and documenting identified instances of damage. Engineers have the capability to append annotations, measurements, and other pertinent data to every documented instance of damage. The act of annotating provides significant points of reference for subsequent analysis and facilitates improved communication among the various stakeholders engaged in the evaluation and restoration procedures.

4. Report Generation: The utilization of damage catalogue software facilitates the production of all-inclusive reports that provide a summary of the documented damage occurrences. The aforementioned reports have the potential to encompass various forms of data, such as graphical illustrations, numerical figures, and explanatory notes, thereby furnishing a comprehensive summary of the evaluated structural state. Reports of this nature are of utmost importance in facilitating decision-making processes, conducting risk assessments, and devising maintenance plans.

5. Automation and Efficiency: The use of computer vision algorithms and machine learning techniques in damage catalogue software facilitates the automation of specific aspects of the damage assessment process, thereby enhancing efficiency. The implementation of automation results in a reduction of manual labor and mitigates the possibility of human fallibility. Moreover, it facilitates engineers to effectively handle substantial amounts of data, resulting in time and resource conservation.

6. Integration with Other Software Tools: The integration of damage catalogue software with other software tools utilized in structural analysis and design is a common practice. The integration facilitates a smooth transfer of data, enabling engineers to utilize the information obtained from damage assessment in subsequent structural evaluations or retrofitting endeavors. The incorporation of Building Information Modeling (BIM) platforms is of significant worth, as it guarantees the connection between the documented impairment and the initial design data.

For engineers to conduct a systematic evaluation of potential structural impairments, it is imperative to employ an analytical tool such as a damage catalogue package. Efficient communication channels and streamlined report generation procedures enhance coordination among engineers, thereby enabling well-informed decision-making in the face of potential damages.

The attributes that facilitate the acquisition of comprehensive information frequently encompass data collection methods utilizing automated annotation, such as image documentation handling, which improves the management of workflow across multiple chains within the team responsible for structural repairs. These applications have demonstrated their ability to enhance efficiency and reduce the need for repetitive revisions in comparable projects, leading to an improvement in overall productivity levels.

3.3. Types of Damage Catalogue Software

There are different types of damage catalogue software available that assist in documenting and analyzing structural damage. These software applications offer various features and functionalities to support the assessment and management of structural damage. Here are some common types of damage catalogue software:

Visual-based Software:

The process of cataloging structural damage can be accomplished through the utilization of image processing techniques that are commonly employed in visual-based software. This technique is particularly valuable in the identification of cracks, corrosion solutions, or deformations in structures and buildings that have been visually captured through cameras, drones, videos, or images. The application of pattern recognition algorithms facilitates efficient and objective assessment procedures, ultimately leading to effective communication and documentation practices, as well as mitigation procedures (Hallermann & Morgenthal, 2014).

Sensor-based Software:

Sensor-based software presents a viable alternative for ongoing structural monitoring and identification of potential damage through the utilization of various sensors such as accelerometers, strain gauges, and temperature sensors. Sophisticated signal processing algorithms enable instantaneous data comparison to detect possible anomalies that signify potential harm necessitating prompt maintenance or repair interventions (Anaissi et al., 2018).

Building Information Modeling (BIM) Integration:

Building Information Modeling (BIM) integration provides another cataloging software solution that comes with rich BIM model data representations depicting a building's geometry, materials, and attributes. This technique helps accurately identify and catalog potential damages while keeping a holistic view of the building vulnerabilities by relating the damage information to design/construction stages data, ultimately promoting a streamlined collaboration within stakeholders while enabling better lifecycle management practices (Kazado et al., 2019).

Visual/sensor/BIM integrated software tools offer different avenues in cataloging/assessing structural vulnerability tailored to suit unique needs; thus, enhancing documentation practices and refining assessment procedures for professionals in the industry. Studying gender neutral pronouns has been a purview of linguistics and scholarship for many decades with experts emphasizing their crucial role in promoting inclusivity while respecting everyones choice of gender identity with equal weightage given to such personal choices in communication.

3.4. Damage Catalogue Software Examples: A Global Perspective

Structural damage documentation and analysis is facilitated by the widespread use of damage catalogue software applications across the globe. This paper offers a comprehensive overview by showcasing prominent illustrations from various geographical areas, thereby presenting a global outlook (Table 1).

Table 1. Summary of the seismic risk assessment softwares (Daniell et al., 2014)

Software	Institute	Country
HAZUS-MH	FEMA	U.S.
OpenQuake	GEM	Italy (Develop for Global application)
SELENA	NORSAR	Norway
EQRM	Geoscience Australia	Australia
CAPRA	World Bank	Central America
InaSAFE	Indonesia National Disaster Agency	Australia Indonesia
ELER	Bogazici University-Kandilli Observatory and Earthquake Research Institute	Turkey

Region: U.S.

Description: In the U.S. FEMA developed HAZUS MH (Hazards U.S. Multi Hazard) to analyze natural hazards like earthquakes, floods, hurricanes, and tsunamis. The software uses databases and models to estimate property damage, casualties, and disruptions to essential services caused by these hazards (Figure 1). Emergency management professionals use HAZUS MH for planning, preparedness, and decision making related to disaster mitigation and response (FEMA, 1997) (Kircher et al., 1997).

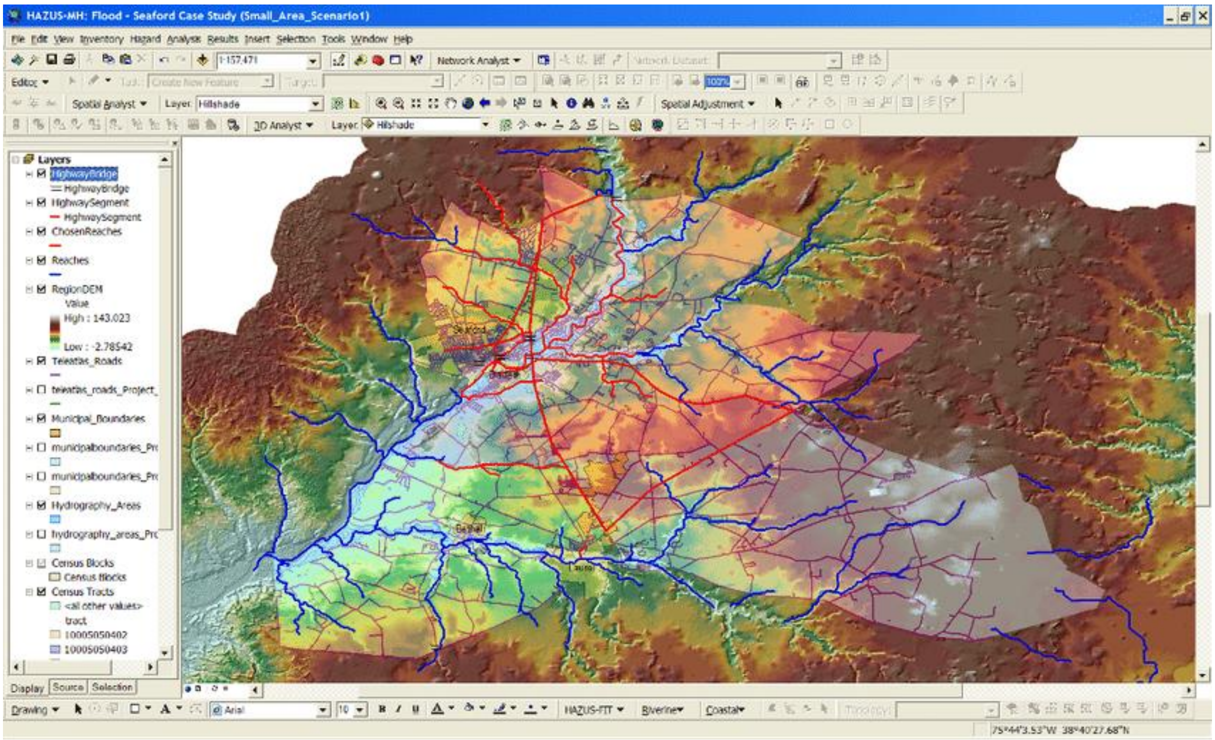

Figure 1. HAZUS Program interface example (Croope, 2009)

OpenQuake:

Region: Italy (Developed for Global application)

Description: OpenQuake is an open source platform developed by Italy based Global Earthquake Model (GEM) initiative for earthquake risk analysis worldwide (GEM, 2012). The software enables researchers, engineers, and policymakers to model seismic hazard. Evaluate exposure and vulnerability of assets. And assess the potential impacts of earthquakes on populations and infrastructure.

OpenQuake helps in quantifying risks that further aid in the development of risk reduction strategies (Crowley et al., 2015).

SELENA:

Region: Norway

Description: Norway based NORSAR developed SELENA to analyze seismic events associated with underground nuclear explosions for compliance monitoring with nuclear test ban treaties (NORSAR, 2010). SELENA processes data with advanced algorithms to detect, locate, and analyze seismic signals contributing towards global non proliferation efforts (Molina-Palacio et al., 2017).

EQRM:

Region: Australia

Description: EQRM (Earthquake Risk Model) is a program created by Geoscience Australia, the Australian national geological survey agency (Robinson et al., 2007). It is intended to evaluate and quantify earthquake risk in Australia. EQRM integrates a number of modules to simulate seismic hazard, estimate the potential impacts of earthquakes on structures and infrastructure, and assess the socioeconomic consequences of seismic events. The software facilitates the comprehension and management of seismic risks, contributing to Australia's risk mitigation and emergency planning efforts (Robinson et al., 2006).

CAPRA:

Region: Central America

Description: CAPRA (Catastrophe Planning and Risk Assessment) was developed by the World Bank specifically for use in Central America. This software application aims to facilitate evaluation and management of natural hazards like earthquakes, hurricanes and flooding across this region (World Bank, 2018). With multiple modules that simulate hazards exposure vulnerability estimation thus providing estimates of impacts to buildings infrastructure social factors; policymakers and practitioners may use CAPRA software as part of disaster resilience plans in Central America (Bernal & Cardona, 2018).

InaSAFE:

Region: Indonesia (Developed by Indonesia National Disaster Agency, with contributions from Australia)

Description: InaSAFE was developed through collaboration between Indonesia National Disaster Agency and Australian partners (National Disaster Agency, 2014). The study focused on evaluating and studying potential outcomes of natural calamities such as seismic activities, volcanic outbursts, inundations and tidal waves in Indonesia. Integrated modules support modeling hazard exposure vulnerability factors; estimation of damage casualties disruption of essential services along with decision-making procedures related to disaster risk mitigation and emergency response plans can all be accomplished using InaSAFE software (Pranantyo et al., 2015) (Figure 2).

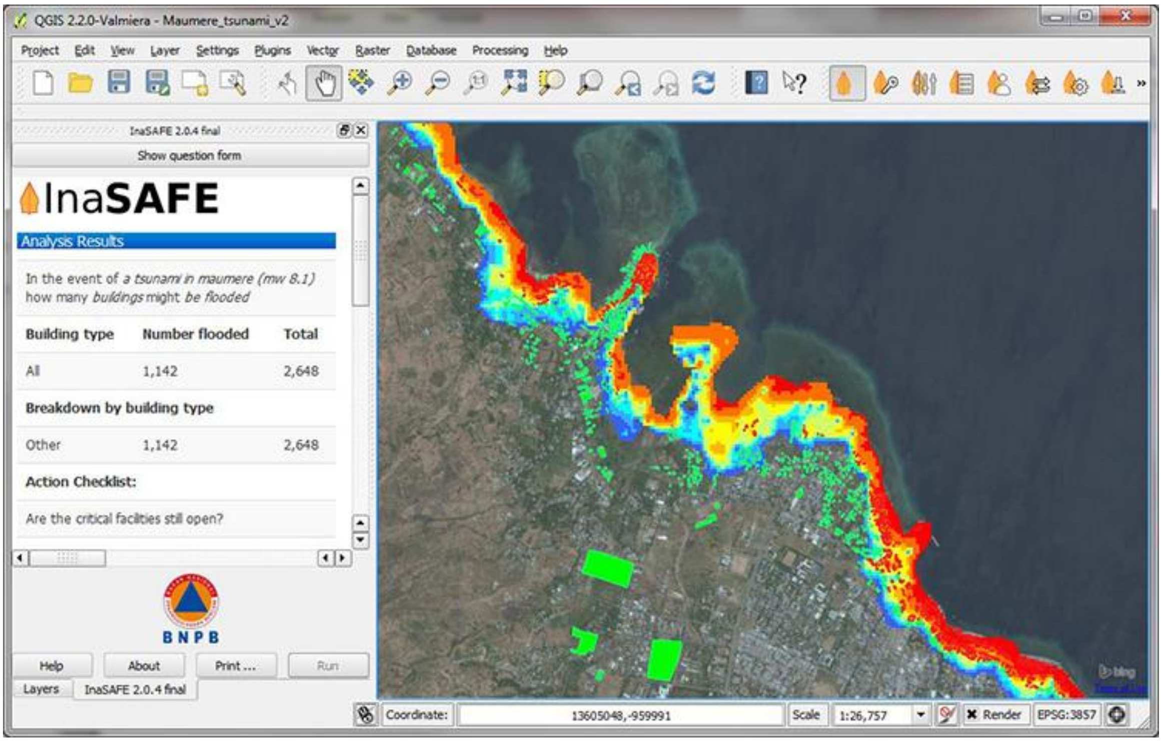

Figure 2. InaSAFE Program interface example (Geoscience Australia, 2014)

ELER:

Region: Turkey

Description: The ELER software was created by the Bogazici University-Kandilli Observatory and Earthquake Research Institute in Turkey for the purpose of earthquake loss estimation and risk assessment (KOERI, 2009). The research centers on the estimation of earthquake losses and the assessment of risks in the context of Turkey. ELER utilizes diverse modules and methodologies to simulate seismic hazard, evaluate the susceptibility of edifices and infrastructure, and approximate potential losses in relation to economic harm, fatalities, and societal repercussions. The software facilitates the comprehension and administration of earthquake hazards for researchers, engineers, and policymakers, thereby bolstering the decision-making procedures associated with disaster mitigation and response efforts in Turkey (Hancilar et al., 2010).

STAAD.Pro:

Region: Global

Description: STAAD.Pro is widely utilized for structural analysis and design purposes, offering functionalities which assist engineers with documenting damage assessment as well as generation of documentation (REI, 1997). Furthermore, this software facilitates analysis of diverse configurations with different loading scenarios; although lacking an in-built damage catalogue module this application provides engineers with all of the information required to document damage assessment within its analysis/design framework (Naveen et al., 2016) (Figure 3).

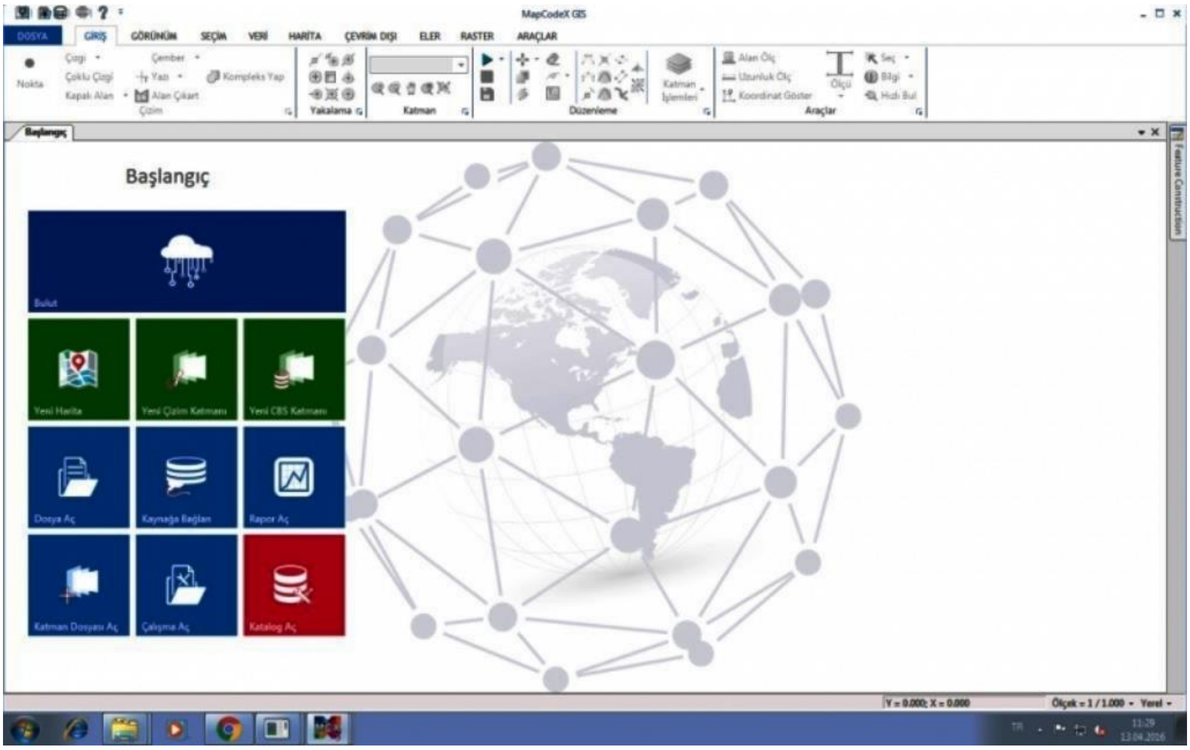

Figure 3. ELER Program interface example (Minister of Environment, Urbanisation and Climate Change, n.d.)

Other software not included in Table 1 are described below;

SAP2000:

Region: Global

Description: SAP2000 is another popular software tool used for structural analysis and design (Computers and Structures Inc., n.d.). Although it does not have a specific damage catalogue module, it provides functionality for engineers to record and analyze structural damage. It offers comprehensive analysis capabilities for various types of structures and allows engineers to incorporate damage information into the analysis and design process (Karaman, 2013) (Figure 4).

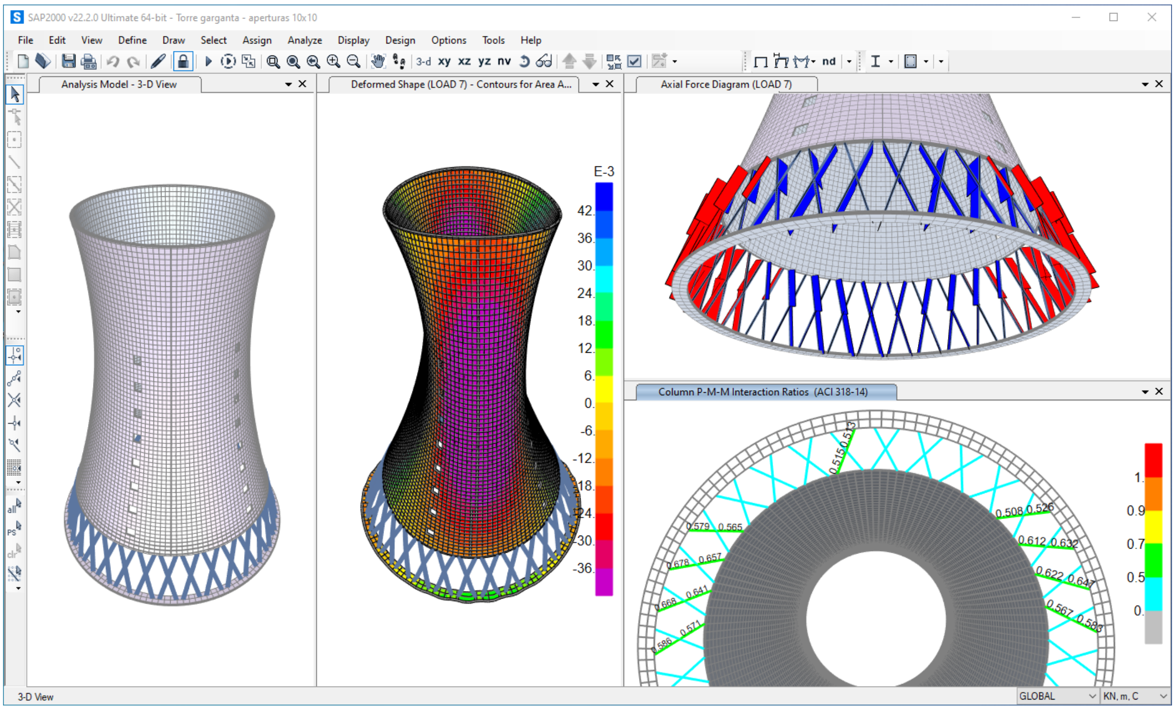

Figure 4. SAP000Program interface example (Computers and Structures Inc, n.d.)

STRUREL:

Region: New Zealand

Description: STRUREL was developed at New Zealand's University of Canterbury as an evaluation and tracking system tailored to evaluate earthquake-inflicted harm on buildings and infrastructure, specifically integrated computational models with algorithms for damage identification that enable precise capture and analysis of damage patterns for better decision making regarding retrofitting/repair strategies resulting in improved outcomes (STRUREL, n.d.) (Betz et al., 2017).

The instances constitute a subset of prominent software programs for cataloguing damage that are utilized on a worldwide scale. Distinctive functionalities and capabilities are provided by each software tool, thereby enhancing efficacy and precision in the evaluation and recording of structural harm. The utilization of software can augment the proficiency of engineers and professionals in the domain of structural engineering to effectively scrutinize, supervise, and uphold structures.

3.5. Comparison of Damage Catalogue Systems Sofwares

In Table 2, there is a comparison of several damage catalogue software systems, including ELER, STAAD.Pro, SAP2000, STRUREL.

Table 2. Comparison of several damage catalogue software systems (Prepared by authors).

Software	Description	Open Source	Hazard Assessment	Loss Estimation	Scenario Generation	Data Availability	User-Friendly Interface
HAZUS-MH	HAZUS-MH is a software developed by FEMA for estimating potential losses from earthquakes, hurricanes, and floods in the United States.	No	Yes	Yes	Yes	Limited	Yes
OpenQuake	OpenQuake is an open-source software developed by the Global Earthquake Model Foundation (GEM) for seismic hazard and risk assessment worldwide.	Yes	Yes	Yes	Yes	Yes	Yes
SELENA	SELENA is a software developed by the Italian Civil Protection for seismic risk assessment and loss estimation in Italy.	No	Yes	Yes	Yes	Yes	Yes
EQRM	EQRM (Earthquake Risk Model) is an open-source software developed by Geoscience Australia for seismic risk assessment and loss estimation in Australia.	Yes	Yes	Yes	Yes	Yes	Yes

CAPRA	CAPRA (Comprehensive Approach to Probabilistic Risk Assessment) is a software developed by the International Atomic Energy Agency (IAEA) for nuclear and radiological risk assessment worldwide.	No	Yes	Yes	Yes	Yes	Yes
InaSAFE	InaSAFE is an open-source software developed by the Indonesian National Disaster Management Agency (BNPB) for evaluating potential impacts of natural hazards in Indonesia.	Yes	Yes	Yes	Yes	Yes	Yes
ELER	ELER (Earthquake Loss Estimation and Risk Assessment) is a software developed by Bogazici University-Kandilli Observatory and Earthquake Research Institute in Turkey.	No	Yes	Yes	Yes	Limited	Yes
STAAD.Pro	STAAD.Pro is a structural analysis and design software widely used for various types	Yes	Yes	Yes	Yes	Yes	Yes

Table 2 presents a comparative analysis of the essential characteristics and functionalities of the ELER damage catalog system utilized in Turkey, in addition to various other globally recognized systems, including OpenSeesPy, ATENA, DAMAS, OptimumCS-Damage, WinDAMAS, STAAD.Pro, SAP2000, DAMAGEID, COCO, STRUREL, and DMAT. The following are some observations pertaining to the table:

• **Focus:** The table indicates the specific focus or specialization of each system. ELER primarily focuses on seismic damage in Turkey, while other systems have a broader scope, considering seismic activity and other hazards globally.

• **Hazard Consideration:** The systems in the table acknowledge the consideration of seismic activity and other hazards, as they play a crucial role in assessing structural damage and vulnerability.

• Scope: The systems have varying scopes, ranging from specific types of structures (such as reinforced concrete or masonry structures) to more general applications covering various types of structures.

• **Data Collection:** The methods of data collection differ among the systems. ELER relies on field surveys and inspection data specific to Turkey, while others utilize data capture, analysis, simulation, or evaluation techniques.

• **Software Tools:** Each system is associated with specific software tools tailored to its purpose. ELER is a specific software developed for damage catalog purposes in Turkey, while others are either open-source or commercial software packages with varying capabilities.

• **Structural Vulnerability Models:** The systems employ different structural vulnerability models, ranging from empirical models specific to Turkish building types and construction practices in ELER to models that vary based on user preferences and applications in other systems.

- **Loss Estimation Methods:** The methods used for loss estimation and damage assessment also differ among the systems, including simulation, analysis, nonlinear analysis, optimization algorithms, and empirical methods.
- **Government Institutions:** ELER is specifically used by government institutions in Turkey, such as AFAD, while other systems vary in terms of their users and applications.
- **Open Data Availability:** The availability of open data for public use is limited in the case of ELER in Turkey, whereas other systems may provide open-source software or have varying degrees of data availability.
- **Research and Development:** Ongoing research and development are evident across all systems, with updates and improvements based on local and global research.

It is imperative to acknowledge that the data presented in the tabular form is a broad comparison, and the particular functionalities and attributes of each system may exhibit variability. Conducting additional research and investigation into each system would yield a more comprehensive comprehension of their respective functionalities and appropriateness for particular use cases.

4. Damage Catalogue

A damage catalogue refers to a methodical documentation or record of structural damage that transpires in buildings, infrastructure, or other forms of structures. This functions as a storage facility of data that assists in the evaluation, examination, and control of occurrences of harm. The utilization of damage catalogues offers a systematic methodology for recording diverse forms of damage, encompassing but not limited to fractures, distortions, oxidation, and other irregularities in structure (Figure 5).

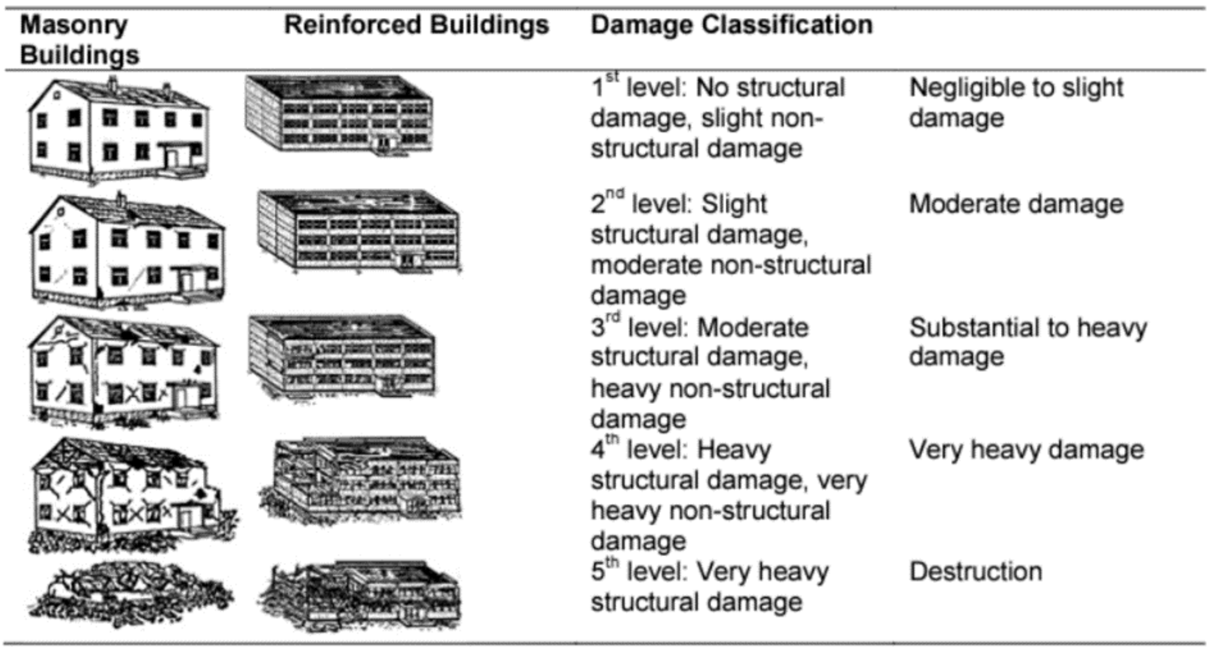

Figure 5. Damage classification in buildings (Schweier & Markus, 2004)

The primary objective of a damage catalogue is to aid in comprehending the scope, intensity, and origins of structural harm. The technology enables professionals such as engineers and architects to monitor and evaluate the evolution of deterioration over a period of time, detect recurring patterns or tendencies, and make well-informed judgments concerning remediation, upkeep, or retrofitting approaches. The utilization of a damage catalogue facilitates the prioritization of resources, allocation of budgets, and planning of necessary interventions through the categorization and quantification of damage instances.

The format of damage catalogues may vary based on the distinct needs and goals of the project or institution. Documentation systems can be either manual, relying on paper-based methods, or digital, utilizing specialized software applications. Digital damage catalogues frequently provide supplementary features, such as the ability to capture images or videos, perform data analysis, utilize visualization tools, and integrate with other software platforms such as BIM (Figure 6).

Key components of a damage catalogue typically include:

- Identification information: Details about the structure, location, date of assessment, and other relevant identifiers.
- Damage description: Clear and concise descriptions of the observed damage, including its location, extent, type, and severity.
- Visual documentation: Images, videos, or sketches that visually depict the damage instances for reference and analysis.
- Categorization and classification: Classification of damage based on predefined criteria, such as damage type, severity level, or impact on structural integrity.
- Quantification: Measurement or quantification of damage parameters, such as crack width, displacement, or corrosion levels, to assess the severity and progression of damage.
- Additional notes or observations: Any additional information or observations related to the damage, potential causes, or recommended actions.

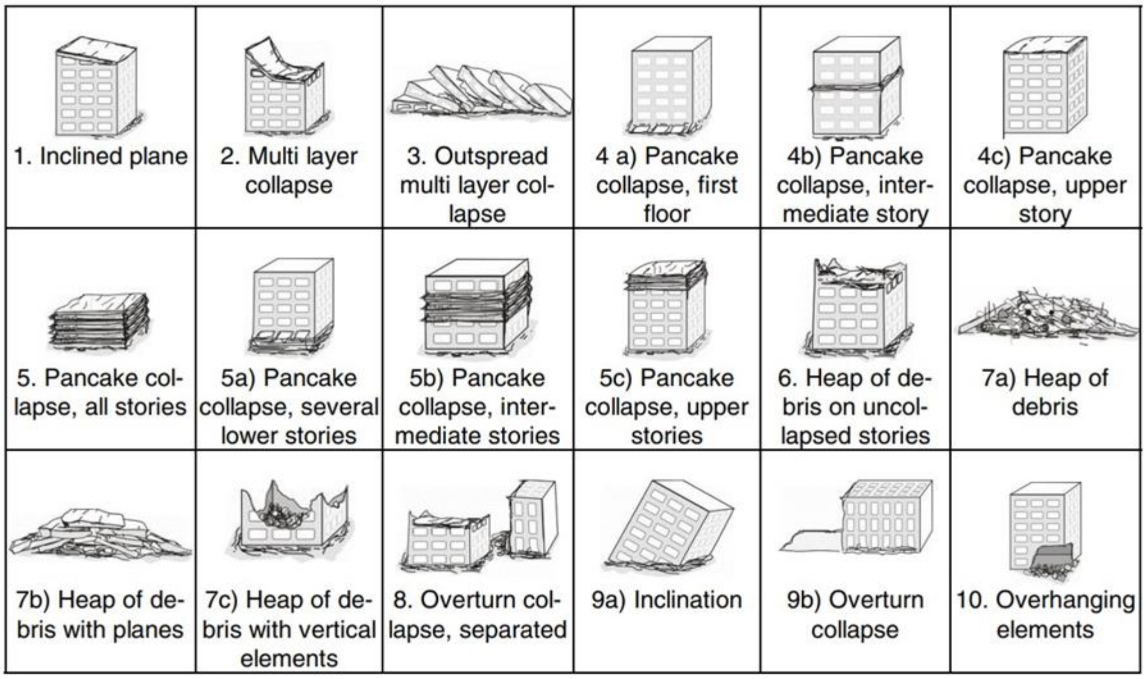

Figure 6. Compilation of the damage types (Schweier & Markus, 2004)

By maintaining a comprehensive and up-to-date damage catalogue, stakeholders can effectively monitor the condition of structures, identify potential risks, and implement appropriate strategies to ensure the safety and longevity of the built environment.

4.1. Earthquake Loss Estimation Methods with Architectural Considerations

The objective of earthquake loss estimation techniques is to evaluate in a numerical manner the probable harm and expenses that could arise for building constructions in the event of seismic occurrences. The assessment of seismic risk involves the quantification of three fundamental input elements. The aforementioned factors comprise the seismic hazard intensity, the assemblage of exposed assets, and their respective vulnerability. Figure 3 illustrates the diverse facets of the damage caused by the earthquake. Various SLE software and techniques for determining each component are illustrated. Incorporating architectural factors into these methodologies is imperative for a thorough assessment of structural susceptibility and precise calculation of seismic-related harm. The utilization of architectural typologies, building materials, structural systems, and design practices enables a more intricate comprehension of the plausible repercussions of earthquakes on architectural edifices (Figure 7).

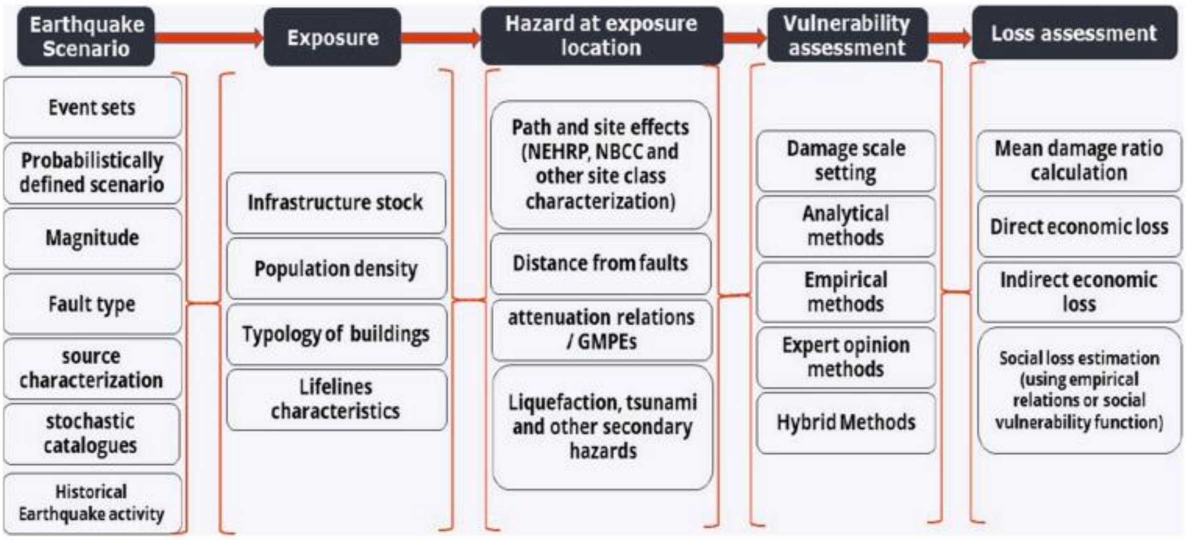

Figure 7. Identified components of seismic loss assessment (Hosseinpour et al., 2021)

Architectural Typologies: Architectural typologies exhibit different levels of exposure to seismic events. When considering architectural typologies when conducting loss estimation methods, specific vulnerabilities associated with each building type are more easily identifiable - for instance high-rises, historic buildings or irregular configurations could each experience unique seismic responses; by including architectural typologies in damage estimation processes more accurate estimates can be given for specific categories of buildings.

Building Materials: Building materials selection plays a decisive role in seismic performance of structures. Loss estimation methods that include architectural considerations account for how different materials such as concrete, steel, masonry or timber behave during earthquakes; knowing their performance under seismic loading enables more precise damage assessments and losses assessments; by considering specific properties and behaviors of architectural materials the vulnerability of structures can also be better assessed.

Structural Systems: Architectural designers utilizing structural systems play a pivotal role in responding to earthquakes through loss estimation methods with architectural considerations. Loss estimation methods with architectural constraints analyze various structural systems like moment-resisting frames, shear walls or braced frames; then calculate damages or losses according to specific features such as moment resisting frames, shear walls or braced frames that meet architectural design parameters based on specific structural configuration. By considering specific attributes and performance aspects for each of these structures in developing loss estimates more precisely tailored for individual configurations which leads to more accurate estimation results and damage estimates more accurately reflecting actual losses and damages estimates that match.

Design Practices: Architectural design practices such as construction methods, detailing techniques and code compliance play an enormous role in building seismic performance. Integrating design practices into loss estimation methods enables an evaluation of their influence on structural vulnerability; factors like reinforcement detailing, connection design and compliance with seismic design codes may all play a part in accurately estimating damage or losses to structures.

Under earthquake loss estimation methods with architectural considerations, various techniques are utilized to assess vulnerability and predict damage potential. Examples of such strategies may include:

a. Performance-Based Analysis: Performance-based analysis incorporates architectural factors into its evaluation of buildings' responses to seismic events. By measuring structural performance under different ground motion levels, performance-based analysis provides more precise damage and loss estimations. By taking into account features such as stiffness, strength, and ductility of architectural features such as stiffness strength ductility performance-based analysis can give insight into structural vulnerabilities as well as inform risk mitigation strategies.

b. Vulnerability Curves: Vulnerability curves measure damage relative to earthquake intensity. Architectural considerations, including building typologies and construction materials are taken into account in developing vulnerability curves for accurate damage estimates based on earthquake intensity; providing valuable insights into any possible adverse consequences that an earthquake could bring upon architectural structures.

c. Damage Matrices: Damage matrices serve to connect observed damage patterns to specific architectural characteristics, and by categorizing their extent and nature according to building typologies, materials, or design features they allow estimations of damage or losses in similar architectural structures post-earthquake recovery or reconstruction processes. They offer invaluable data that is vital for decision-making on recovery efforts after earthquakes have struck.

Overall, including architectural considerations in earthquake loss estimation methods can improve both their accuracy and reliability. By taking into account architectural typologies, building materials, structural systems and design practices alongside earthquake occurrence scenarios these methods provide a more complete picture of structural vulnerability and damage potential; techniques like performance-based analysis, vulnerability curves or damage matrices provide for more nuanced evaluation of earthquake effects on architectural structures - the integration of architectural considerations within earthquake loss estimation is more accurate and reliable due to this factor alone.

5. Role of Architecture in Damage Catalogue Software

Integrating architecture into damage catalogue software increases both its functionality and effectiveness by providing invaluable context data. By including relevant architectural details alongside recorded damage instances, architecture enhance data interpretation, enable knowledge transfer among stakeholders, and foster informed decisions regarding remedial action plans.

Integration of architectural considerations into earthquake loss estimation methods compounds this effect significantly. By including information gleaned from damage catalogues - building typologies, architectural details and material performance data - into vulnerability functions, fragility curves and loss maps, earthquake loss estimation models become much more precise and reliable.

Architectural factors in loss estimation methods allow more precise predictions of damage and loss potential in specific building types, taking into account their varied performance under seismic loading, thus offering more realistic assessments of vulnerability.

Furthermore, including architectural information in loss estimation methods improves estimations of damage for different levels of ground shaking. By considering architectural details and construction techniques in fragility curves, one can better portray their influence on structural performance and earthquake vulnerability.

Integrating architectural data in loss maps enables more precise assessments of expected damage distribution across an affected area, which are vital in emergency response planning, resource allocation and prioritizing mitigation efforts.

Architectural assessments help shape retrofitting strategies by highlighting vulnerable areas and components within existing structures, and by analyzing observed damage patterns associated with specific architectural characteristics analyzed through assessments, targeted retrofitting approaches can be developed that address identified weaknesses.

Finally, architectural considerations inform the development of building codes and standards by studying the performance of architectural structures during earthquakes. By integrating architectural data into the development of building codes, policymakers can ensure that they reflect the latest knowledge and understanding of how architectural elements contribute to seismic resilience.

In summary, the combination of architecture in damage catalogue software and the integration of architectural considerations into loss estimation methods enhances the accuracy, reliability, and functionality of these tools. It improves data interpretation, facilitates knowledge transfer, supports informed decision-making for repair and rehabilitation, and ultimately leads to safer and more resilient buildings in earthquake-prone areas.

5. Result and Conclusion

Integrating architecture into damage catalogue software systems is vital in order to enhance their functionality and effectiveness. By including relevant architectural data with recorded damage incidents, such systems provide more accurate and understandable data which ultimately yields several major benefits.

One key advantage is improved data interpretation. By including architectural information like drawings, design specifications and structural calculations in their analysis of affected buildings' load paths and behavior more effectively. Engineers can then more accurately assess damage severity while also recognizing risks to structural integrity more readily. Considering original design intent allows informed decisions on necessary repairs or rehabilitation measures for more targeted remedial actions that lead to improved remedial solutions.

Architecture plays an integral part in knowledge transfer among stakeholders involved in damage assessment processes. By including architectural drawings, material specifications and maintenance records within damage assessments, architects, engineers, facility managers and other relevant parties can better collaborate to assess structural performance as a whole and devise appropriate repair strategies - creating more informed remedial actions with better informed outcomes than without.

Integrating architecture within damage catalogue software systems helps facilitate informed decision-making when selecting repair and rehabilitation strategies. Engineers can devise repair methods that adhere to architectural details like construction techniques, materials and design intent by drawing attention to architectural considerations such as building techniques and materials used. Integrating structural modifications with architectural requirements ensures they do not clash, thus maintaining integrity and functionality of structures. By eliminating conflicts between modifications to architecture design and modifications made, software systems allow engineers to formulate effective remedial actions which protect architectural integrity.

Integrating architecture into damage catalogue software systems significantly boosts their functionality and effectiveness, providing more accurate and interpretable data about recorded damages instances, leading to improved data interpretation, knowledge transfer between stakeholders and informed decision-making for remedial actions. Collaboration among architects, engineers and other professionals involved in damage assessment supports holistic understanding of structural performance along with developing successful repair or rehabilitation strategies.

One aspect of integration involves Building Information Modeling (BIM). BIM allows architects and engineers to use detailed digital models that accurately represent architectural components for damage assessment and documentation purposes. Architects play a pivotal role in developing and overseeing BIM models to ensure architectural elements are accurately represented within this software system.

BIM integration enhances damage catalogue systems by facilitating precise identification and cataloguing of damage instances, offering comprehensive views of architectural components, and supporting integration between various data sources and analysis tools - improving accuracy while supporting informed decision-making, supporting effective repairs or retrofits and helping ensure smooth operations.

Architects bring expertise and specialized skills, providing invaluable insights through architectural drawings, specifications and BIM models. This allows architects to provide enhanced damage catalogue functionality as well as improve data interpretation and analysis and support interdisciplinary collaboration for effective mitigation and restoration strategies.

Integrating architecture within damage catalogue systems is critical to accurate assessment, effective communication and informed decision-making in structural engineering. Architect contributions help maintain compatibility with design intent while protecting structural integrity; BIM integration further enriches these systems, offering detailed knowledge, advanced assessments and efficient remedial actions.

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