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SUZI-SAEE EARTHQUAKE IMAGE DATABASE: A FRAMEWORK FOR TAGGING EARTHQUAKE-INDUCED DAMAGE

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Abstract

The Serbian Association for Earthquake Engineering (SUZI-SAEE) has developed a database platform with images taken during the reconnaissance missions after the earthquakes, with the aim to provide a comprehensive framework for documenting and analyzing earthquake-induced structural damage. This paper presents the main aspects of the database platform with the images of the SAEE team members. The initial database is developed from extensive post-earthquake field investigations carried out by the members of SAEE. This platform tends to gather and label images of damaged buildings from seismic events, incorporating crucial metadata such as structural type, damage level, and failure modes. The importance of this framework also lies in its ability to facilitate the extraction of important statistics, enabling deeper insights into damage patterns, structural vulnerabilities, and responses to seismic forces. Due to its ability to systematically analyse data gathered from past earthquakes, the database is expected to serve as a valuable resource for researchers and practitioners to improve seismic codes, optimize retrofitting strategies, and improve the understanding of the behavior of structures under earthquakes. In addition to providing a direct benefit to earthquake mitigation, the database is expected to serve as an educational and research tool, accessible to the wider community. Due to high seismic risks around the world, the SAEE database also stands as a tool for advancing the field of earthquake engineering and improving the resilience of our built environment, making it a valuable contribution to civil engineering research and practice. By facilitating the study of past seismic events, the SAEE database provides a valuable contribution toward reducing seismic risks.

Keywords: earthquake engineering, post-earthquake analysis, damaged structures, educational tool, suzi-saee tagger, database

1. INTRODUCTION

Earthquakes are among the most destructive natural disasters, causing significant damage to infrastructure and profound social losses, including human casualties [1], [2]. Effective post-earthquake damage assessment is essential for improving building resilience, optimizing retrofitting strategies, and enhancing seismic codes. However, the systematic documentation and analysis of earthquake-induced damage remain challenging due to the diversity of structural systems, materials, failure modes, etc.

The Serbian Association for Earthquake Engineering (SUZI-SAEE) has developed the SUZI-SAEE Earthquake Image Database, associated with a platform designed to address these challenges. This database is supported by the SUZI-SAEE Tagger, a Python-based tool [3] that enables efficient annotation and classification of earthquake damage images. The framework integrates metadata with images, offering a comprehensive resource for researchers, practitioners, and educators. Photographic documentation has long been recognized as important resource in earthquake engineering. The Earthquake Engineering Slide Information System (EASY), developed by Fischinger et al. [4], demonstrated the value of annotated image databases for understanding structural behavior during seismic events. EASY's emphasis on metadata integration and accessibility laid the groundwork for modern systems like the SUZI-SAEE Tagger, which builds on these principles by leveraging

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advancements in digital tools and novel technologies. The SUZI-SAEE Earthquake Image Database also builds on other notable initiatives, such as the Earthquake Image Information System (EqIIS), currently known as the Earthquake Engineering Online Archive [5] which provided access to thousands of images from seismic events worldwide.

The primary objective of the SUZI-SAEE Earthquake Image Database is to streamline the documentation and analysis of post-earthquake damage. The Tagger facilitates this by allowing users to annotate images with selected metadata. This capability enhances the understanding of structural vulnerabilities and promotes informed decision-making in earthquake engineering.

This paper presents the development and current functionalities of the SUZI-SAEE Earthquake Image Database, highlighting its potential role in advancing damage assessment methodologies. Engineers, researchers, and students can benefit greatly from the database's open-access collection of annotated earthquake damage images. In order to promote a more thorough understanding of structural performance under seismic excitations, this framework seeks to close the gap between unprocessed post-earthquake visual data and useful insights.

2. OVERVIEW OF SUZI-SAEE RECONNAISSANCE MISSIONS

In the last 5 years SUZI-SAEE organized several post-earthquake reconnaissance missions, demonstrating its commitment to advancing earthquake engineering and contributing to post-disaster recovery efforts. The teams visited several cities affected by the 26.11.2019. Albania earthquake, the December 29, 2020 Petrinja (Croatia) earthquake, and the February 8, 2023 Türkiye earthquake sequence.

These missions were organized to provide vital assistance to local colleagues in the immediate aftermath of earthquakes, focusing on critical tasks such as assessing the usability of buildings, determining damage states, and prioritizing interventions to ensure public safety. The team members collaborated with local authorities and engineers in tagging buildings according to their usability and safety status. A core aspect of these missions was meticulous documentation of earthquake-induced damage. The teams conducted detailed visual inspections of affected structures and captured extensive photographic records of damaged buildings, and documented various types of structural and non-structural damage. This documentation serves as a valuable dataset for further research aimed at understanding the earthquake damage mechanisms and improving resilience of future construction.

In addition to their field efforts, SUZI-SAEE teams have actively disseminated their findings to both the scientific community and practicing engineers, in the form of presentations which shared lessons learned from the missions, focusing on practical insights into damage patterns, building performance, and the effectiveness of existing design and construction practices. These presentations have been instrumental in bridging the gap between academia and practice, fostering collaboration, and promoting the application of research findings to real-world challenges. Moreover, the knowledge and data gathered during these reconnaissance missions have been formalized in the form of several conference and journal papers [6-13], contributing significantly to the global body of knowledge in earthquake engineering. These publications provided detailed analyses of observed damage patterns, evaluated the performance of different construction techniques, and offered recommendations for improving building design and construction practices in seismically active regions. Also, lessons learned in organizing the SUZI-SAEE's reconnaissance missions were published with the aim of helping other organizations to organize and act after future earthquake events [14].

Through these reconnaissance missions, SUZI-SAEE collaborated with other associations and institutions actively working in the field of earthquake engineering all over the world. This initiative exemplifies the importance of collaboration, both in responding to seismic disasters and in translating lessons learned into actionable strategies for improving resilience, and presents strong basis for activities after future earthquake events.

Images and information collected during these reconnaissance missions present the basis for developing the SUZI-SAEE Earthquake Image Database.

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3. EXISTING EARTHQUAKE IMAGE DATABASES

Although large number of earthquake damage-related images are collected by reconnaissance teams after major earthquakes, usually only a small fraction of all collected images are included in various field reports, journal and conference papers, and presentations. Most frequently, majority of these images are stored in archives by individual researchers, research labs at universities, and/or professional organizations engaged in earthquake engineering. Very few organizations have made an effort to share the images collected during post-earthquake reconnaissance missions with professionals and general public. In this section a few of the existing earthquake image databases will be described to illustrate their organization/structure and the type of information that has been presented.

The most comprehensive earthquake image database, called the Earthquake Engineering Online Archive [5], was developed by the National Information Service for Earthquake Engineering (NISEE) at the University of California (UC) Berkeley, USA (https://nisee.berkeley.edu/elibrary/). The database includes more than 8,000 records from 80 earthquakes from the USA and other countries, and is a valuable repository of earthquake damage information. The same web site also features a special collection of 875 images documenting historic earthquakes called the "Kozak Collection". Access to the NISEE image database is available only to the members of NISEE e-Library (https://nisee.berkeley.edu/elibrary/register.jsp).

Each record in the database consists of an image and the following fields: i) title (type of structure or a structural element), ii) creator (author of the image), iii) date (when the image was taken), iv) location (including city, province/state, and country), v) earthquake (description of the earthquake epicenter, including city and state, date, and magnitude), and vi) a description (characterization of the damage). Besides that, an image has a unique alphanumerical ID, consisting of two letters (abbreviated earthquake name) and a number. Figure 1 illustrates a typical record from the NISEE database related to the January 17, 1994 Northridge, California earthquake (M 6.7), which is a part of the collection comprising 598 records related to that earthquake. The image shows a two-storey unreinforced masonry building in Santa Monica which experienced a failure of out-of-plane walls at the upper floor. The image was taken on January 20, 1994 (3 days after the earthquake) by Božidar Stojadinović, current president of the SUZI-SAEE, who was a PhD student at the UC Berkeley at the time of the earthquake. The database is accessible free of charge, however high-resolution images are available at a nominal fee.

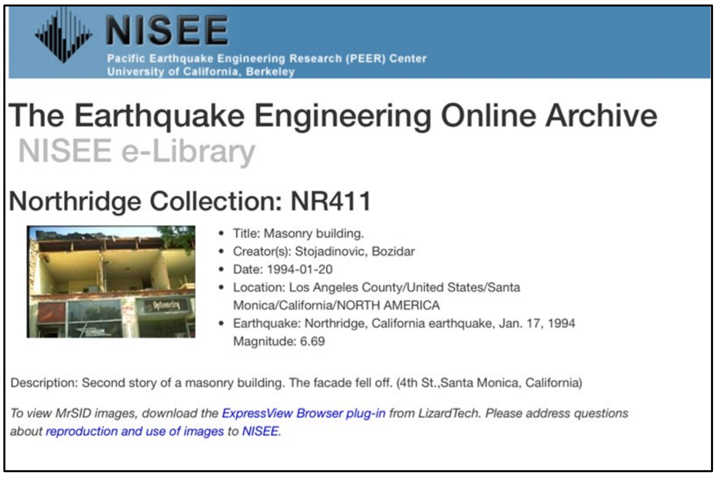

Figure 1. A record from the NISEE's Earthquake Engineering Online Archive (NR411), related to the 1994 Northridge, California earthquake

In terms of the organization/structure and extent of detail, the most relevant database is the Earthquake Engineering Slide Information System (EASY), which was developed in 1997 at the Faculty of Civil and Geodetic Engineering, University of Ljubljana under the leadership of Prof. Matej Fischinger [4]. The database contains 500 images from 4 major earthquakes (1979 Montenegro, 1985 Mexico City,

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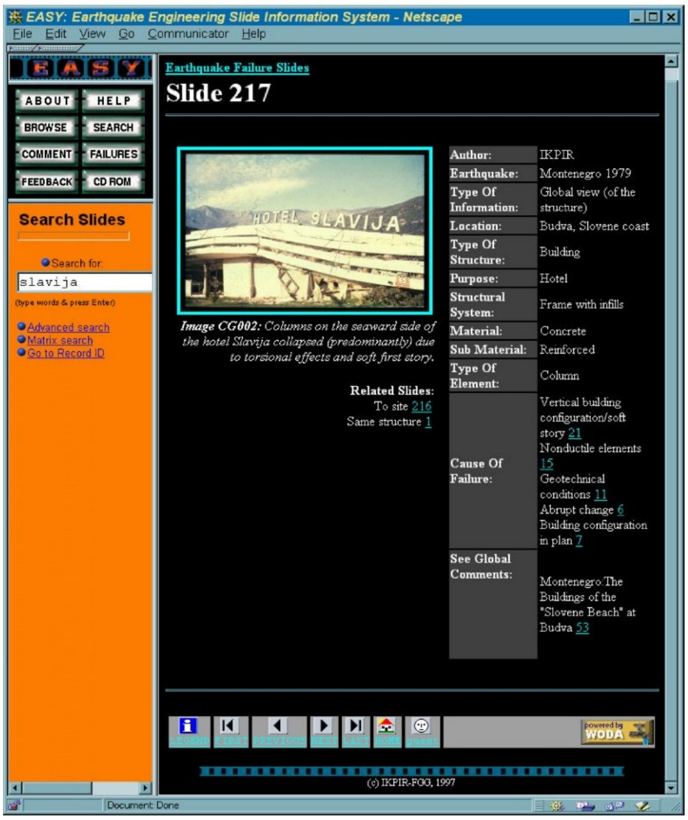
1994 Northridge, and the 1995 Kobe earthquake). The database used to be accessible free of charge at the web site of the the Faculty of Civil and Geodetic Engineering, University of Ljubljana, and a complementary CD version was also available.

EASY is organized in the form of a relational database. Several fields are assigned to each record, including i) author, ii) earthquake, iii) location (where image was taken), iv) type of structure (e.g. building, bridge, etc.), v) structural system, vi) structural element (e.g. column, beam, wall), vii) material of the structural system (e.g. reinforced concrete), viii) type of failure (failure mode), e.g. flexure, shear, etc. and ix) additional comments. Figure 2a) shows a sample record (Slide 217), which documents the collapse of Hotel "Slavija" in Budva in the 1979 Montenegro earthquake. It can be observed from the figure how various fields were used to explain the image.

Data entry for the records was organized in a user-friendly manner, through drop-down menus which facilitated the selection of appropriate attributes for a specific image. In some cases, e.g. cause of failure, it is possible to select more than one option (e.g. soft storey irregularity, nonductile elements, building configuration in plan, etc.).

A very useful feature of the database is section "Related slides", which contains hyperlinks from specific records to other records (e.g. overall building damage and damage of a structural element in the same building. Also, in some cases there are links to general comments (section "See Global Comments"), which are usually related to several slides. For example, for Slide 217 shown in Figure 2a), a Global Comment is hyperlinked (Slide 53), and it discusses the building and its deficiencies which led to collapse (see Figure 2b).



a)

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Global Comments to Earthquake Damages Slides

Comment 53

53

Montenegro:The Buildings of the "Slovene Beach" at Budva

The most important cause for the failure of the buildings on the "Slovene Beach" was undoubtedly the exceptionally poor geological conditions. Without this statement it is not possible to explain the disproportionately severe damage to the buildings. It is proved by the fact that the lower buildings, which were built nearer the sea, failed on poorer ground. The majority of the buildings were not built according to the seismic technical regulations, as their construction was finished from the structural point of view before these were passed. The majority of the buildings had a framed structure, and the infill walls were made of brick. The panoramic photograph has taken in June 1979, and the ruins of the Slavia hotels, which lie roughly at right-angles to the beach, can be seen in the picture. On the right-hand side of the picture are, in front, the two International hotels, and behind them the Adriatic Hotel. Roughly at right-angles to the latter lie, in front of the copse, the ruins of the Stara and Nova Plaža hotels. All these buildings were demolished in the summer of 1979, as it was found to be impossible to repair them. The heaviest damage occurred to the Stara and Nova Plaža hotels. In the case of both these hotels the complete failure of columns occurred already during the earthquake of 15.4.1979. Among the ruins it was possible to observe widely spaced stirrups in spite of heavy longitudinal reinforcement. In the case of both buildings it could be observed that the columns had failed at top and bottom. The mechanism which leads most rapidly to failure had been established. The Slavia hotels consisted of three pairs of buildings. Of each pair of buildings one of them contained a restaurant in the ground-floor, all of whose perimeter openings were glazed. At the section where the frame was connected to the neighboring building it was infilled with a brick wall. The floors above the ground-floor contained, in both the buildings, bedroom accommodation. The partition walls were made of brick. During the earthquake of 15.4.1979 the heads of the columns on the seaward side of the buildings failed, whereas in the landward direction the damage to the columns gradually reduces. In the transverse direction the columns had greater stiffness, as without the consideration of earthquake loads the loading case with a wind loading was more critical. When failure occurred the floor-slabs shifted landwards. In the case of the two buildings which did not fail completely the uneven lowering of the roof slab was observed. The reason for the greater damage to the columns on the seaward side lay in the influence of the infilled frame next to the dividing joint between the two buildings of an individual pair. Because of this, torsional oscillations occurred, which caused larger displacements and forces in the columns nearer the sea. The fact that the columns were more damaged at the top than at the bottom can be probably attributed to poorer concrete towards the top and to the widely spaced stirrups, which frequently slip down during concreting. On the landwards side of the pair of buildings the wall between the frames was built of brick, being partly built of concrete below. The columns were in fact damaged during the first earthquake, but at this location the buildings were no lower than they had been before the earthquake. After the second earthquake the damage to the columns was similar to that occurring before to the columns at the other end of the building. When the second earthquake occurred the buildings next to the sea collapsed completely. The upper stories of the buildings on the landward side remained almost undamaged. Due to its slenderness the staircase followed the horizontal movement of the building, and because of differences in the vertical movements the fracture of the landings took place. The structure of the Hotel Adriatic consisted of reinforced-concrete frames, which were partly infilled with brick walls. As a result of the earthquake the brick infills cracked in the characteristic way, and the reinforced-concrete columns were badly damaged, too. All the columns with visible damage failed due to insufficient shear load carrying capacity. The marble cladding of the columns fell off in all cases. The harmful influence of various types of infills was observed. The structure of the Hotel International was divided into two parts by a seismic-joint. As the gap at this joint was too narrow, and was even completely shut in some parts, damage occurred next to it.

Find slides to which this global comment applies.

b)

Figure 2. A sample record from the EASY image database: a) a record (Slide 217) which documents collapse of Hotel “Slavija” building in the 1979 earthquake, and b) a Global Comment (Slide 53) providing additional information related to the collapsed building.

4. SUZI-SAEE TAGGER TOOL

The SUZI-SAEE Tagger presented in Fig. 3 is a Python-based [3] application developed to support the systematic annotation of earthquake damage images. Built using the Tkinter library, the tool provides a user-friendly interface and a wide range of functionalities, which are described in the following sub-sections.

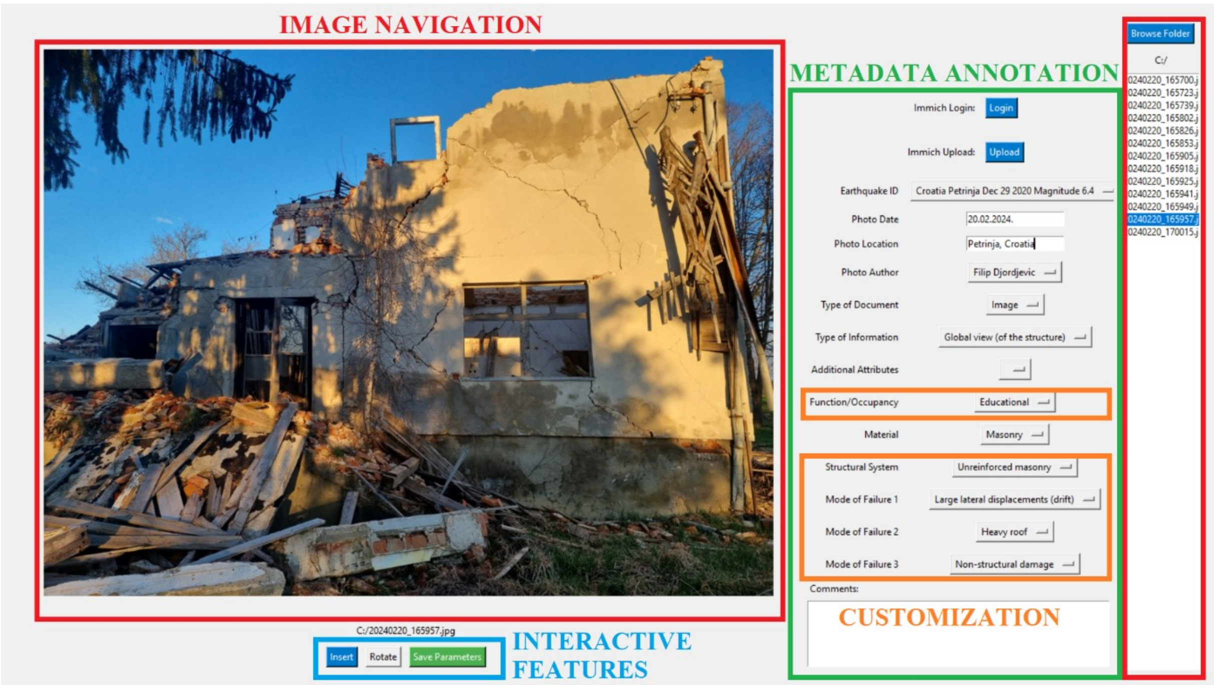

Figure 3. SUZI-SAEE Tagger: data entry screen

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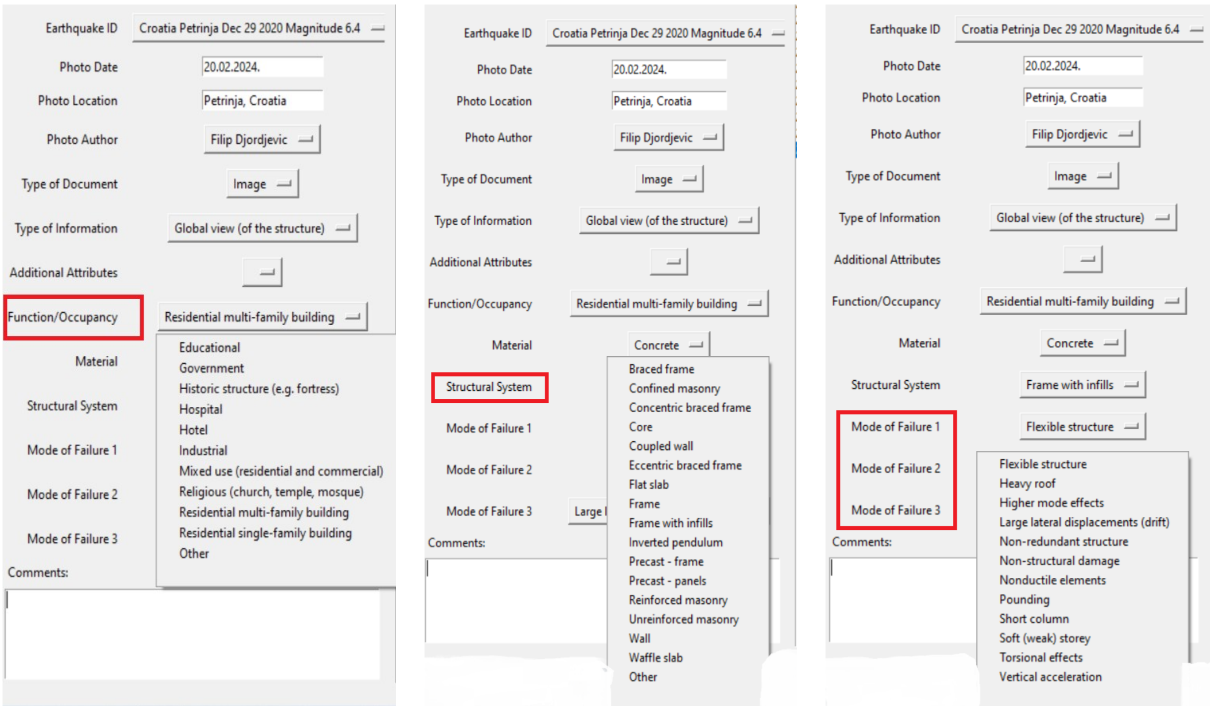
4.1. Image Navigation and Interactive Features

One of the key features of the Tagger is its ability to efficiently navigate through large datasets. Users can browse through folders containing earthquake damage images, select specific documents, and load them onto the main canvas for detailed analysis. The interface also includes a fullscreen mode, which enhances the viewing experience by allowing users to focus on image details without distraction. These navigation capabilities ensure that even extensive datasets remain accessible and manageable.

The tool also incorporates interactive features for detailed image inspection. Users can zoom in and zoom out image to examine specific areas of interest, rotate images for better alignment, and pan across the canvas to explore different sections of an image. These capabilities allow for a comprehensive visual analysis, enabling users to identify and document discrete damage details effectively.

4.2. Metadata Annotation with Customization

At the core of the Tagger's functionality is its metadata annotation system. This feature enables users to systematically document key information about each image, such as earthquake details (e.g. event name and date), structural characteristics (e.g. structural system and material type), and failure modes (e.g., "Flexural failure" and/or "Liquefaction") (see Fig. 4). Additional fields allow for the inclusion of text comments, occupancy types, and retrofitting details. To minimize errors and enhance efficiency, metadata fields are dynamically filtered based on the selected type of information and occupancy. For instance, selecting a specific type of information, such as "Infrastructure" or "Building element," updates the available structural system and failure mode options to reflect relevant categories. This adaptability ensures the tool's applicability to different types of structures, including buildings and bridges (see Fig. 5).



a) b) c)

Figure 4. Metadata annotation with dynamic filtering and customization – Example 1 (Building): a) Function/Occupancy; b) Structural System; c) Mode of Failure.

4.3. Technical Implementation

The tool leverages the Python Imaging Library (PIL) for image processing and XML for metadata management. Metadata is saved in XMP format, ensuring compatibility with existing image analysis

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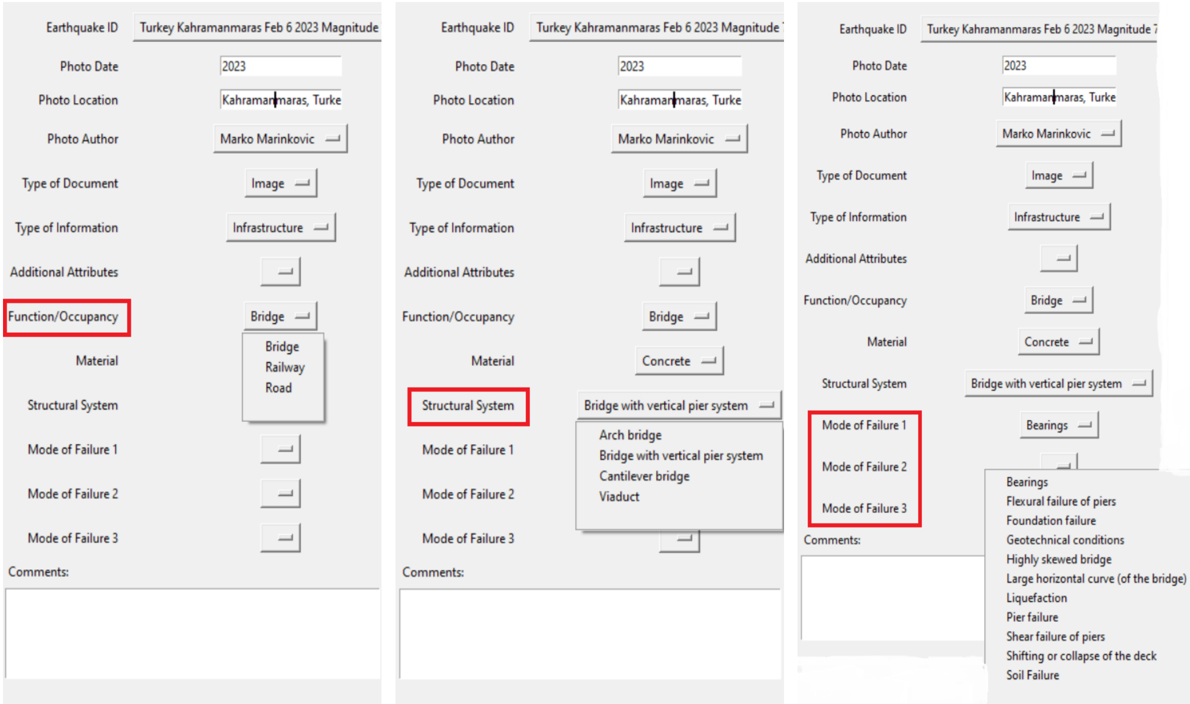
tools. The modular design allows seamless integration with external platforms for data storage and sharing. In its final form the tool is in the form of an executable file; this flexibility makes it a robust solution for post-earthquake damage documentation. Looking ahead, several enhancements are planned for the SUZI-SAEE Tagger. These include the automation of metadata annotation, the expansion of metadata fields, and improvements to the user interface based on feedback from researchers and practitioners.



a) b) c)

Figure 5. Metadata annotation with dynamic filtering and customization – Example 2 (Bridge): a) Function/Occupancy; b) Structural System; c) Mode of Failure.

5. APPLICATIONS AND BENEFITS

The SUZI-SAEE Tagger has important role in advancing earthquake engineering by supporting the identification of structural vulnerabilities through detailed damage classification. This tool provides critical insights into seismic behavior of structures.

The database is a valuable resource for training engineers and conducting advanced research. The repository of labelled images enables the development of predictive models, which are essential for simulating structural response to seismic events. This capability not only advances theoretical understanding but also informs practical decision-making in engineering design and disaster mitigation.

The intuitive interface of the Tagger is expected to attract interest of students and young professionals. By engaging with the tool, users gain hands-on experience in damage assessment and metadata annotation, fostering a new generation of earthquake engineering experts. This educational aspect ensures that the knowledge and skills required for effective seismic resilience are passed on to future practitioners.

The scalability of the overall framework is another significant benefit. The system is designed to accommodate global datasets, allowing for the integration of diverse seismic event records. This adaptability enhances its utility as a universal tool for earthquake damage assessment. Furthermore, the possibilities for integration of machine learning algorithms can automate the tagging process, reducing manual effort and improving the consistency of metadata annotations. These advancements as well as

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interface in English language, have a potential to expand the framework's applicability and efficiency, making it a valuable asset for international collaboration.

Beyond its technical and educational applications, the SUZI-SAEE Tagger has a potential to contribute to disaster preparedness. By analyzing patterns of structural damages and failure modes, the database can inform governmental and institutional strategies for risk reduction. The tool's ability to aggregate and analyze data from multiple seismic events provides a robust foundation for developing targeted interventions that enhance community resilience.

6. CONCLUSIONS

The SUZI-SAEE framework for labelling earthquake-induced damages represents a significant step forward in the field of post-earthquake damage documentation and analysis. By combining systematic tagging with detailed metadata, the framework improves the quality and usability of damage data. This initiative has the potential to enhance seismic resilience by identifying structural vulnerabilities and informing enhanced design and retrofitting practices. The tool's user-friendly interface and customizable metadata fields make it valuable for global community, supporting both advanced research and education.

Future improvements to the framework include expanding its scope to incorporate additional document types and leveraging machine learning for automated tagging by reducing manual effort with increasing the consistency and scalability of metadata annotations, and strengthening international collaborations. These developments are expected to further enhance the database's utility in advancing seismic resilience research and practice. By addressing the challenges of systematic damage documentation, SUZI-SAEE hopes to contribute to the global effort to mitigate seismic risks and improve the resilience of the built environment.

Despite challenges in data consistency and user expertise, the ongoing SUZI-SAEE initiative to create a comprehensive Earthquake Image Database underscores the importance of comprehensive damage documentation for mitigating seismic risk and advancing earthquake engineering research. Its robust functionalities make it a cornerstone of a global effort to mitigate the impact of earthquakes on communities and infrastructure.

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