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A Study of Building Structure Resilience to Seismic in the Batu Pahat Area using Rapid Visual Screening Method

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ABSTRACT

This study is aimed at evaluating the durability of buildings in Batu Pahat area against seismic activity. To carry out this assessment, data about the building structure is collected, including architect plans, site investigations, and photos. This data is then processed and analysed using manual methods. To determine the Peak Ground Acceleration (PGA) value, the coordinates of Batu Pahat area are needed. This value can be calculated using Mathematica software, which gives a PGA value of 0.0553 g for Batu Pahat area. Based on this value, the Low Map Area form is used for the evaluation, using the ATC-21 form. The evaluation results indicate that 70% of the buildings in the area are in good condition, 25% are in a satisfactory condition, and only 5% are in a weak condition. However, it is important to note that even though only a small percentage of buildings are classified as weak, it does not mean that seismic hazards can be ignored. The study also suggests that the durability of building structures depends on various factors, such as the columns' strength, the building's bottom situation (e.g., empty space or unit), the building's shape (e.g., plan or upright), and the surrounding area's situation. Overall, this study offers valuable insights into the durability of buildings in the Batu Pahat area against seismic activity. It provides crucial information for stakeholders to make informed decisions regarding building safety in the region. The study's findings will guide decision-making processes, helping determine necessary precautions, retrofitting measures, or potential relocation of high-risk buildings. By enhancing the resilience of buildings, this evaluation contributes to the safety and well-being of occupants in the face of seismic hazards. Ultimately, the study's comprehensive assessment and subsequent insights lay the groundwork for informed decision-making and proactive measures to mitigate seismic risks, benefiting the overall resilience of buildings in the Batu Pahat District.

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1. Research Overview

Predicting the occurrence of natural phenomena, such as earthquakes, is a daunting task. Assessing the seismic safety of existing buildings in advance of a potential earthquake is a highly complex endeavour. The primary objective of evaluating the seismic safety of buildings is to enable informed decision-making regarding the existing building stock through inspections and calculations, all in preparation for a potential earthquake. There exist various methods for examining the structural stability of buildings. In this study, the Rapid Visual Screening (RVS) method has been chosen because it is more practical compared to other methods. This is because the study uses a rapid assessment form to identify whether a building's structure is potentially at risk from seismic movement. The assessment form is divided into three types: high-intensity seismic, moderate-intensity seismic, and low-intensity seismic. The procedure or workflow is more like a sidewalk survey, where only the assessment form will be used. RVS is a qualitative approach that uses correlations between a building's predicted seismic performance and to assess its seismic risk. Among the various rapid evaluation methods available, the street screening method is the quickest and most straightforward. The visual survey should take no longer than 30 minutes [1]. Basically, RVS was introduced to identify unsafe buildings during large earthquakes, and to estimate the cost of construction to improve building quality that can prevent further destruction during earthquakes. RVS employs a scoring system that evaluates a building's level of risk based on a basic score, also known as a structural score, and modifiers that reflect the building's strength and deficiencies during a seismic event. The final score obtained from RVS can predict a building's seismic performance. Although RVS is less precise than extensive modelling, it is still a simple and straightforward method for identifying regions of a city that are more susceptible to seismic events than others [2-4]. The use of RVS as a preliminary screening process has gained widespread popularity due to its ability to identify structures with high seismic vulnerability quickly and efficiently, thereby saving valuable time and resources. It has been implemented in various seismically active regions worldwide, where it has proven to be a valuable tool in seismic risk assessment.

To improve the accuracy and efficiency of RVS, several studies have been carried out, resulting in the development of various methodologies from different countries. For instance, the United States has developed the RVS-US method, while Canada has its RVS-Canada method. New Zealand has also developed its RVS-NZ method, and Japan has its RVS-Japan method. RVS is a method used to rapidly evaluate the seismic vulnerability of many structures. It is based on correlations between the predicted seismic performance of buildings and their structural characteristics, such as frame, shear walls, masonry, and infills [5]. The development of different RVS methodologies from different countries demonstrates the growing importance and popularity of this method in seismic risk assessment. By using RVS as a preliminary screening process, engineers and policymakers can quickly and efficiently identify structures that require further detailed testing and analysis, allowing for effective risk management strategies to be implemented.

To complete this research, RVS is used to determine whether a building needs to be repaired or not [6]. If the RVS examination results find that it involves the safety of occupants during a large earthquake, then a detailed study of the structure is necessary [7,8]. If the RVS score is below than 2, basic score values that have been set by the Applied Technology Council (ATC), the building should be given attention if an earthquake occurs because its structure is no longer safe if there is even a small movement. If the score exceeds 2, the building is considered safe for its occupants [9].

Applied Technology Council (ATC) is an organization established in 1973 as a result of the efforts of the Structural Engineers Association of California. Its main mission is to develop and introduce applications to reduce the impact of natural disasters and other hazards in the built environment.

ATC-21 is a report on RVS of Building for Potential Seismic Hazards. The following is a summary of ATC-21. This report explains the RVS procedure for identifying buildings that have a high risk of damage and destruction or unfitness in the event of an earthquake. This imaging method uses a brief review method that identifies the main load-bearing system and building materials and reports on the basic value of structural hazards and variable factors based on observations of building characteristics. The methodology for identifying buildings with potential hazards and requiring more detailed observation and analysis by experienced professional seismic design engineers [9].

The National Earthquake Hazard Reduction Program (NEHRP) Map Area is a geographic region in the United States that has been designated by the U.S. Geological Survey (USGS) as having a certain level of seismic hazard. The NEHRP Map Area is a scale used to measure earthquake intensity ranging from 1 to 7. It can be divided into three parts as can be obtained in Table 1. The map is used by engineers, architects, and other professionals to determine building codes and design standards for new construction or retrofitting existing structures to improve their seismic resilience. The NEHRP map area is an important tool in promoting earthquake safety and reducing the risk of damage and loss of life from earthquakes.

Table 1
Scale of NEHRP Map Area

NEHRP Map Area	Category	Description
1, 2	Low	These areas are considered to have a low probability of experiencing earthquakes.
3, 4	Moderate	These areas have a moderate probability of experiencing earthquakes.
5, 6 and 7	High	These areas have a high probability of experiencing earthquakes.

The ATC-21 assessment form has several sections that need to be considered when assessing a building. Next paragraph is some of the sections that need to be considered when making an assessment.

Occupancy refers to the use of a building and the number of occupants in each building. The use of the building is divided into several categories, including:

i. Residential
ii. Commercial
iii. Office
iv. Industrial
v. Public Assembly
vi. School
vii. Government Building
viii. Emergency Service
ix. Historic Building

The categorization of building types according to Table 2 can be found in the ATC-21 form.

Table 2
Type of buildings based on ATC-21 assessment form

Bil.	Types	Description
1.	W	Wood
2.	S1 (MRF)	Steel 1 (Moment Resisting Frame)
3.	S2 (BR)	Steel2 (Bracing Frame)
4.	S3 (LM)	Steel 3 (Look Baring)
5.	S4 (RC SW)	Steel 4 (Reinforcement Shear Wall)
6.	C1 (MRF)	Concrete (Moment Resisting Frame)
7.	C2 (SW)	Concrete (Moment Resisting Frame)
8.	C3/S5 (URM INF)	Concrete and Steel (Unresisting Moment)
9.	PC1 (TU)	Precast
10.	PC2	Precast
11.	RM	Resisting Moment
12.	URM	Unresisting Moment

The basic score is determined based on Table 3, which varies depending on the type of building and the level of earthquake hazard. It is crucial to identify the category of each building type prior to initiating the assessment.

Table 3
Basic Score for type of buildings

Types of Building	W	S1	S2	S3	S4	C1	C2	C3/S5	PC1	PC2	RM	URM
1,2 Low	8.5	3.5	2.5	6.5	4.5	4.0	4.0	3.0	3.5	2.5	3.5	2.5
3,4 Moderate	6.0	4.0	3.0	6.0	4.0	3.0	3.5	2.0	3.5	2.0	3.5	2.0
5,6,7 High	4.5	4.5	3.0	5.5	3.5	2.0	3.0	1.5	2.0	1.5	3.0	1.0

The most important aspect is the building's modifiers. Each modifier will be assigned a value that will be accumulated, and it will determine the building's resilience level. Based on the ATC-21 assessment form, these modifiers have specific requirements that must be met. If these requirements are met, they will be assigned a value as provided in the table, otherwise they will be ignored. Each requirement is as follows:

i. High Rise - if a building has a height of more than 20 storeys or 240 feet (73.152 meters).
ii. Poor Condition - if a building has severe damage such as cracks or erosion, and the like, it means that the building is categorized as being in poor condition.
iii. Vertical Irregularity - a building that has different heights exceed 20%.
iv. Soft Story - a building that has few pillars on a particular level.
v. Torsion - it refers to a building that is not symmetrical or has uneven loads, which causes pressure on certain parts only.
vi. Plan Irregularity - a building that has an asymmetrical plan overall.
vii. Pounding - refers to the position between one building and another. For example, the distance between them is less than 20 feet (6.096 meters). This means that the building is categorized as pounding.
viii. Large Heavy Cladding - if a building has a very heavy wall divider.
ix. Short Column - a building that has a height of less than 12 feet (3658 meters).
x. Post Benchmark Year - if a building has been assessed by ATC-21 before.
xi. SL2 (Soft Soil) - a building that has a soft soil condition.
xii. SL3 (Medium Soft Soil) - a building that has a moderate soft soil condition.

xiii. SL3 & (8 to 20 stories) - a building that has soft soil and can only accommodate 8 to 20 storeys or 240 feet (73.152 meters).

The final score is the result obtained from the basic score after deducting the values of the variables related to the building being studied. This final decision determines the level of resilience of a building. The resilience level can be divided into four parts, namely by [10]:

i. Good
ii. Satisfactory
iii. Weak
iv. Very weak

1.1 Earthquake

An earthquake can occur due to the sudden release of energy stored inside the Earth's crust. This energy is built up over a long period of time due to tectonic forces within the Earth. Most earthquakes occur when one part of the Earth's crust moves faster than another. This sudden movement causes shockwaves to radiate from the point of origin, or the focus, and move beneath the Earth's surface. The movement beneath the surface causes an earthquake to occur. Every year, thousands of earthquakes are recorded. Strong seismic waves can travel long distances and cause significant damage. However, even small waves can cause damage when they travel long distances. The movement can be measured using a device called a seismograph.

Earthquake waves are the transfer of energy from one point to another within the Earth. Although seismologists recognize various types of waves, the most common are P (Primary) waves and S (Secondary) waves among the richer wave types. P waves can move through both solid and liquid media, while S waves can only move through solids. The speed of wave movement changes with depth and the type of rock it passes through. P waves move at an average speed of 6 km/s to 13 km/s, while S waves are slower, averaging between 3.5 km/s and 7.5 km/s [11]. The earth's crust is formed of brittle, cold rocks that are different from the hotter, inner layers. Earthquakes occur along faults and fractures in the Earth's crust. When the crust fractures, it breaks into pieces or rock fragments. These fragments collide with each other, creating pressure on the rock and moving it to a different location. The release of this pressure causes vibrations that are felt as an earthquake. The classification of earthquake measurements can be categorized into four parts: good, moderate, bad, and very bad. An earthquake is defined as good when a part of the structure or non-structural material is damaged but does not pose a threat to human life. Good structures usually have a level of protection and prevention against earthquakes.

An earthquake that is classified as moderate is when a part of the structure or non-structural material is damaged and poses a threat to human life or other living beings. Buildings that are classified as moderate usually have a low level of protection and prevention against earthquakes and need to be improved to reduce danger and become a good category. A bad earthquake occurs when a part of the structure or non-structural material is damaged and threatens the surrounding life [12]. Buildings or structures that are classified as bad should be given financial priority to improve the level of protection and prevention against earthquakes and reduce failure [13]. Earthquakes can greatly affect buildings and structures in urban areas, causing extensive damage and loss of life [14].

Magnitude is measured by calculating the release of energy from an earthquake and takes a long time. It is a difficult process and involves accurate measurements of failure dimensions, amount of destruction, and other factors. An easy method used by American seismologist Charles Richter is a method based on the amplitude of the recorded wave using a device called a seismograph. This method is used worldwide and has been able to produce magnitude measurements based on the recorded duration of earthquake events. The Richter scale is in logarithmic form. The change in magnitude is equal to a tenfold increase in the size of the earthquake. For example, magnitude 6 is 10 times larger than magnitude 5 and 10 times larger than magnitude 4. Earthquake intensity is measured by the effective vibration strength on humans, structures, and the natural environment. This strength is measured using a 12-point arbitrary scale modification of the original equipment made by Italian seismologist Giuseppe Mercalli. This scale is obtained from information provided by residents involved in the earthquake-affected area. Detailed classification as shown in Table 4.

Table 4
Intensity, Magnitude, Classification and Criteria

Bil	Intensity	Magnitude	Classification	Criteria
1	1	1.0 - 3.0	Instrumental	Not felt, only detected by seismograph
2	2	3.0 - 3.9	Weak	Only felt by a few people, especially on upper floors of buildings
3	3	3.0 - 3.9	Light	Felt inside buildings, similar to vibrations from passing trucks or heavy traffic
4	4	4.0 - 4.9	Moderate	Felt by many people inside buildings. Dishes, windows, and doors may rattle and can startle those who are sleeping
5	5	4.0 - 4.9	Strong	Felt by almost everyone and cement structures may crack
6	6	5.0 - 5.9	Very Strong	Felt by everyone and furniture may shift and break
7	7	5.0 - 5.9	Very Strong	General warning and people will evacuate from the building area
8	8	6.0 - 6.9	Destructive	Failure of most buildings and some will collapse
9	9	6.0 - 6.9	Devastating	Damage and collapse of some buildings and ground cracks
10	10	>7.0	Catastrophic	Severe ground cracking, landslide, and many buildings will be destroyed
11	11	>7.0	Catastrophic and severe	Large cracks in the ground, massive landslides, complete collapse of buildings, bridges, and flooding will occur
12	12	>7.0	Disaster	Widespread cracks and undulating ground surface. Property will be thrown into the air.

Although Malaysia has no experience with earthquakes and has never experienced a major earthquake, this does not mean that we should not take precautions against the threat of earthquakes. Malaysia is located at a stable tectonic plate, but it should be noted that Malaysia is located near the Sumatra Islands in the Republic of Indonesia and the Philippines, where the fault movements are still active. In addition, Malaysia is also near the Pacific Ring of Fire. The fault line closest to Malaysia is the Barisan Line on the island of Sumatra, which is 400 kilometres away, while the other fault lines are 700 kilometres away [15]. Peninsular Malaysia sits on the stable Sundaland, where the Indian-Australian, Philippine, and Eurasian plates meet, surrounded by active convergent borders. Penang Island shares the same tectonic setting as it is part of Peninsular Malaysia. The Sumatran Subduction Zone and Sumatran Fault, both seismically active, have historically affected Penang [16].

Earthquakes have occurred and been felt in Tanjung Kupang, Johor. About 100 residents of Block B of the Civil Servants Housing Complex of Sultan Abu Bakar rushed downstairs following the tremor. The incident occurred at around 11 p.m. on Monday, July 26, 2004. The tremor lasted for 10 seconds, and it was understood that the tremor had a magnitude of 7.3 on the Richter scale. It was centred about 100 kilometres northwest of Palembang, South Sumatra, and was also felt throughout most of the surrounding republic. After inspection, the cracks only involved the patching part and did not involve the structure of the building. This does not mean that this incident will not recur and should not be ignored because it is not impossible for mini disasters to recur and the tremors can be more severe, involving the structure of buildings and endangering lives [17].

Malaysia was shocked by the strong tsunami waves resulting from the earthquake that hit the sea floor and struck Penang, Kedah, and Perlis. On Sunday, December 26, 2004, a large tsunami wave caused loss of life and property damage, and this destruction could have been reduced if we had an efficient and effective information dissemination system. The strong earthquake centred far to the north occurred about 700 kilometres from Kuala Lumpur. This is equivalent to the earthquake in Bangkahulu in 2000, with its centre far to the south, about 700 kilometres from Johor Bahru. Now the focus should be on the strong earthquake predicted to occur in the Sumatran Slip Area. This earthquake can occur about 350 kilometres from Kuala Lumpur.

A strong earthquake with a magnitude of 7.7 on the Richter scale occurred in the middle of the Sumatra Slip in 1892, and the tremors were felt by the residents of the west coast of the peninsula, who did not have high-rise buildings at that time. In addition, the 2001 earthquake in Ahmedabad, Gujarat, India, with a magnitude of 7.9 on the Richter scale, destroyed buildings, and the city was about 400 kilometres from the epicentre. The question is, do tall buildings on the west coast of the peninsula have earthquake resistance of about 7.5 on the Richter scale centred in Sumatra, which is about 350 kilometres away from the building in question? [18]. Most of the tremors that can be felt in Malaysia occur on the west coast and in the southern parts of the country. This shows that the states on the west coast and Johor, which are close to the Sumatra Islands in Indonesia, have the potential to experience seismic events [19,20].

The objective of this study is to evaluate the structural resilience of buildings in the Batu Pahat District against seismic activity using RVS method. By conducting a comprehensive assessment, the study aims to identify buildings at risk and determine the need for further evaluation of seismic risk. This information will provide valuable insights to policymakers and building owners, enabling them to enhance safety and resilience. The evaluation process will consider factors such as building age, construction materials, location, and proximity to active faults. Analysing these factors will help understand the structural strength and vulnerability of the buildings. The study will also utilize the Peak Ground Acceleration (PGA) value, which estimates the seismic zone factor specific to the Batu Pahat District, to assess earthquake risk. The scope of the study includes various building types such as mosques, hotels, shopping centres, and residential areas including parks, flats, and apartments. Additionally, it encompasses the Parit Raja area, comprising administrative buildings, lecture halls, and dormitory blocks within the university campus. The assessment aims to identify buildings at high risk for seismic activity, indicating the need for further analysis of seismic risk. The results will guide decision-making regarding necessary precautions, retrofitting measures, or potential relocation of high-risk buildings to ensure the safety and well-being of occupants in the face of seismic hazards. Overall, this study's comprehensive evaluation and subsequent insights will contribute to enhancing the resilience of buildings in the Batu Pahat District, providing a foundation for informed decision-making and proactive measures to mitigate seismic risks.

2. Research Methodology

2.1 Data Collection

The focus of this study is to determine the possibility of collapse or destruction experienced by each building in the event of an earthquake. To carry out this study, several steps have been taken to ensure its success. The data for this study were acquired through field research, marking a pioneering effort in Batu Pahat, Johor, where the rapid assessment method was implemented. In this methodology, scattered sampling encompassed various building types, including university buildings, residential structures, mosques, hotels, commercial shop lots, and old wooden houses. This comprehensive approach allowed us to determine regional risks and adjust the count of buildings requiring detailed assessments accordingly.

To carry out this study, one area has been selected, namely the district of Batu Pahat, Johor. Figure 1 shows the overall map of Batu Pahat District. Batu Pahat district is in western Johor and covers an area of 1872.5 km2 or 187,257 hectares, which includes various types of buildings. In Batu Pahat, it appears that they have a diverse range of building types, including residential, commercial office, industrial, public assembly, school, government buildings, emergency services, and historic buildings.

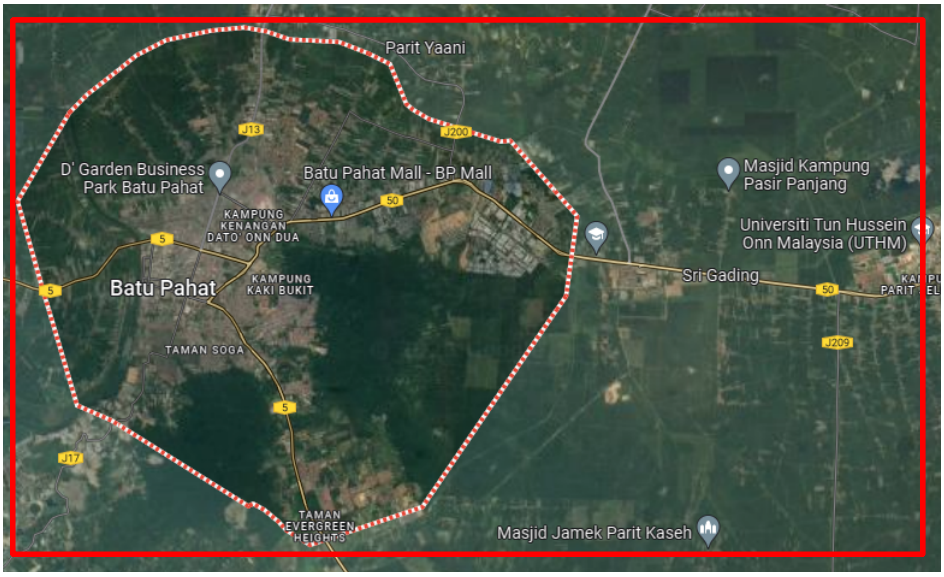

Fig. 1. Overall map of Batu Pahat District

Furthermore, a total of 20 types of buildings in this area were selected to be modelled in this study. In this methodology, a total of 20 scattered samples were taken, representing a diverse range of building types, which included university buildings, residential structures, mosques, hotels, commercial shop lots, and old wooden houses. This diversity in the sample set was designed to yield a wide range of results, allowing to assess the varying levels of sustainability when subjected to earthquake scenarios. Despite on external characteristics such as their shape, height, and location, this selection process was informed by various factors, including accessibility, the functional status of the buildings and occupancy. These considerations were taken into account to enable to assess the wide spectrum of sustainability levels when these buildings are exposed to earthquake which are shown in Figure 2 below. Data related to the Batu Pahat district will be collected from several agencies involved as follows:

i. Department of Survey and Mapping Malaysia (JUPEM)
ii. Batu Pahat Municipal Council (MPBP)
iii. Public Works Department Batu Pahat (JKR)
iv. Involved consulting firms.

Fig. 2. Sample of data collection for the selected buildings

The information needed to carry out in this study are:

i. Maps of the study area
ii. Architectural drawings and building structure plans to be studied.
iii. Initial records of site investigations to determine soil types.
iv. Photos of the study buildings.
v. The software used, namely Mathematica Program.
vi. ATC-21 Evaluation Form.
vii. Information from reference sources and the internet.

2.2 Mathematica Program

The Mathematica program is used to determine the Peak Ground Acceleration value (PGA) in the Batu Pahat district, Johor. A total of 30 equations are obtained from earthquake data for 100 years, from 1897 to 1996. This program is also based on earthquakes that occurred in Bengkulu, Sumatra, Indonesia in 2000. Earthquake data is obtained from the Malaysian Meteorological Service Catalogue, which covers earthquake data for 20 years. The data covers 100 years of earthquakes from 1897 to 1996. The same data is used to study earthquakes in Indonesia. The content includes 6039 earthquakes that occurred from around 1897 to 1996 [21].

To produce PGA, the coordinate values, namely Latitude and Longitude of the Batu Pahat district based on the Batu Pahat district map, need to be entered into these 30 equations. From these 30 equations, the highest value will be taken and used as PGA.

2.3 Building Assessment using Rapid Visual Screening (RVS) Method

A site visit will be conducted to obtain the necessary data on the 20 selected buildings. Overall, this site visit is conducted to obtain the following data:

i. Each building will be assessed externally only to identify the necessary characteristics as in the ATC-21 form.
ii. A building's shape is drawn as a plan and front view.

iii. Take front and side views photos to be included in the ATC-21 assessment form.

2.4 The Assessment of Each Building

The assessment of each building is done using the ATC-21 assessment form. From the site visit, all the obtained data will be entered into the form. Based on [22,23], the building's shape drawing will be redrawn, and the taken photos will be included in the form. Each building will be assessed based on three ATC-21 assessment forms, namely the high, moderate, or low-rise areas, and the use of these forms will be determined by the maximum ground acceleration values obtained from the Mathematica Program. After filling out these forms, the level of building resilience can be determined by adding the relevant variable values.

The report from [21] explains a rapid observation method for identifying buildings that are likely to be exposed to serious risks in terms of loss, life, and injury due to earthquake disasters. The observation procedure is done through data collection by observing the load and material systems in the structure. This form is categorized into three types of forms based on earthquake intensity:

i. Low Map Area - Areas low earthquake intensity, between 1 and 2.
ii. Moderate Map Area - Areas moderate earthquake intensity, between 3 and 4.
iii. High Map Area - Areas high earthquake intensity, between 5 and 7.

All three forms have basic score values that have been set by the Applied Technology Council (ATC). These basic score values will be subtracted from the data obtained through the observation and information about the building, such as the structure type, site soil conditions, and building size. If the final score is less than 2, the building is at high risk of failure and requires further study by earthquake experts.

3. Results

3.1 Peak Ground Acceleration

Before evaluating the selected building samples, the Peak Ground Acceleration in a study area is determined. The Mathematica software was used to determine the maximum ground acceleration in the Batu Pahat area. The required information for the software includes the coordinates of Batu Pahat, Latitude (1.37 N) and Longitude (102.51 E). Mathematica Program Analyze 30 maximum ground accelerations were obtained by applying this Mathematica program.

The acceleration maps for the Batu Pahat District based on a 100-year earthquake. The colour shown on the acceleration map represents the seismic zones, with darker colours indicating higher seismic zones. Malaysia is divided into three regions based on their level of seismic hazard: Peninsular Malaysia has low hazard (0.05g-0.07g), Sarawak has moderate hazard (0.07g-0.09g), and Sabah has high hazard (0.15g-0.165g). In this case, g refers to gravitational acceleration, which is 9.81 m/s^2 [24].

3.2 Mathematica Program Results

After applying this program, a total of 30 equations were produced. The results obtained indicate that the maximum ground acceleration for the Batu Pahat District is approximately 0.0553 g, based on the Joyner *et al.,* [25] equation. This result is shown in Figure 3, and falls below the low-intensity seismic zone. As the Batu Pahat District is in a low-intensity earthquake zone, to conduct building assessments, the ATC-21 form should be used with the Low Map Area form.

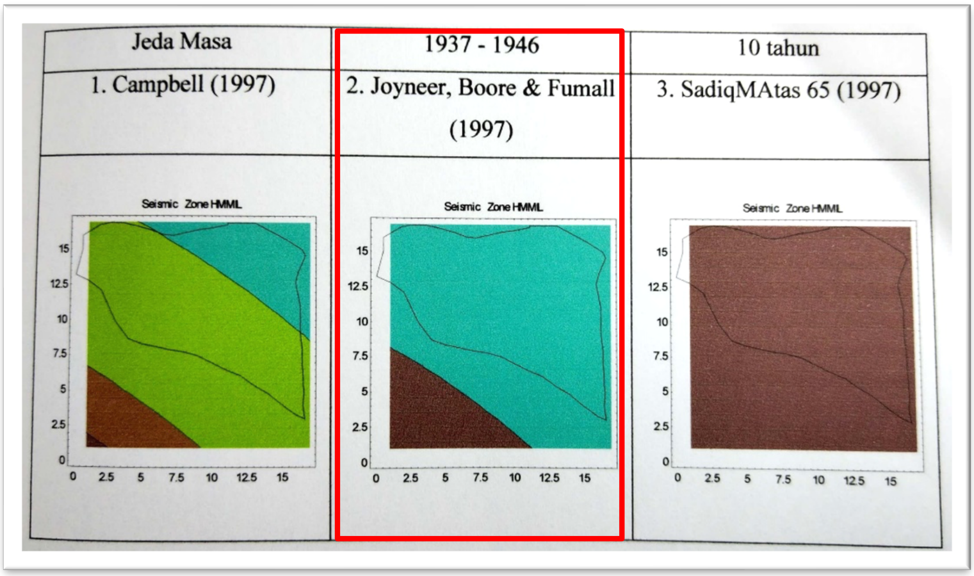

Fig. 3. The seismic zones for seismic assessment of the Batu Pahat District

3.3 ATC-21 Assessment Results

In this study, the main analysis made is the assessment of each selected building using the ATC-21 assessment form. In this section, we will discuss the analysis of 20 completed assessment forms for the sample buildings. These forms are based on the manual analysis prepared by Applied Technology Council (ATC). The result is obtained by subtracting the base value from the relevant variable values, which determines a building's resilience. The results are classified into four categories: good, satisfactory, poor, and very poor, and are shown in Table 5. An example calculation is provided in Eq. (1):

$$4.0\ (\textit{score}) - 1.0 - 0.5\ (\textit{modifier}) = 2.5 \qquad (1)$$

Table 5
Resilience Classification for ATC-21 Assessment Form

Range	Resilience Classification
3 – 4	Good
2 – 3	Satisfactory
1 – 2	Weak
1 and below	Very Weak

The objective of the assessment is to determine the level of resilience of each building. While a sample assessment form is provided in Figure 4.

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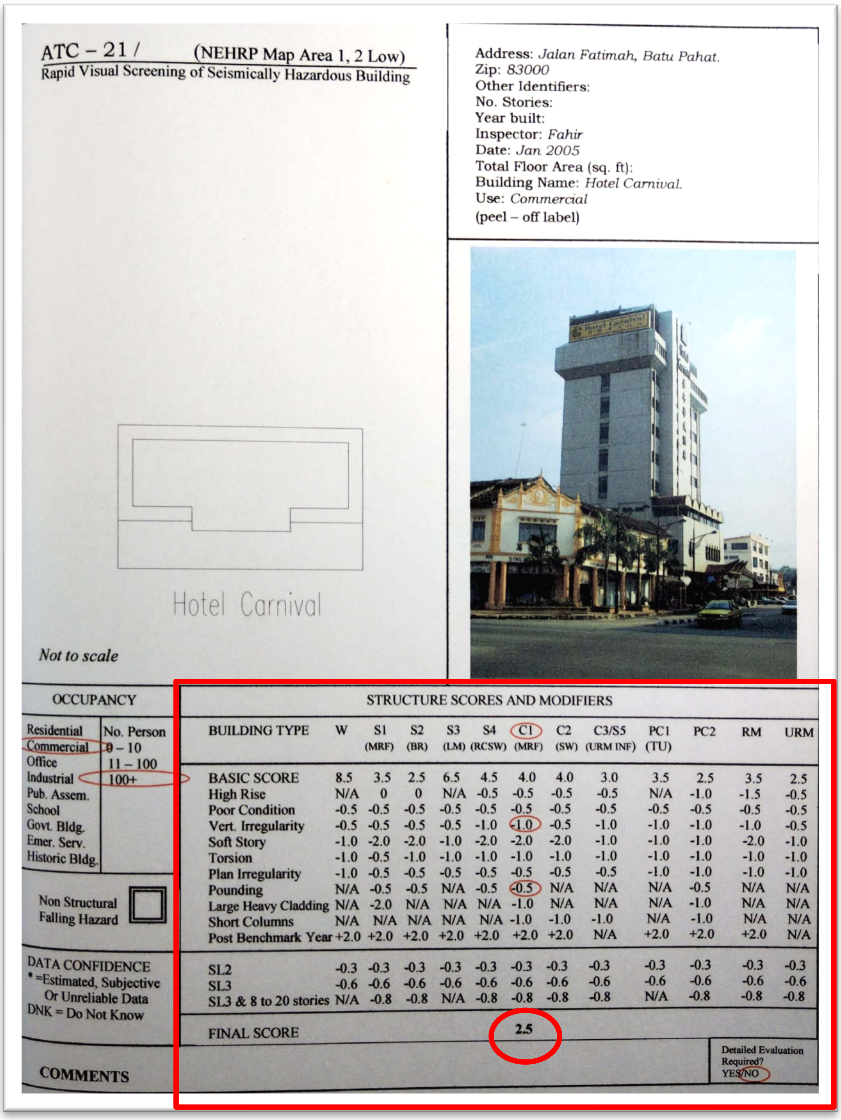

ATC – 21 / (NEHRP Map Area 1, 2 Low)
Rapid Visual Screening of Seismically Hazardous Building

Address: *Jalan Fatimah, Batu Pahat.*
Zip: *83000*
Other Identifiers:
No. Stories:
Year built:
Inspector: *Fahir*
Date: *Jan 2005*
Total Floor Area (sq. ft):
Building Name: *Hotel Carnival.*
Use: *Commercial*
(peel – off label)

Hotel Carnival

Not to scale

OCCUPANCY	
Residential	No. Person
Commercial	0 – 10
Office	11 – 100
Industrial	100+
Pub. Assem.	
School	
Govt. Bldg.	
Emer. Serv.	
Historic Bldg.	

Non Structural Falling Hazard

DATA CONFIDENCE
* =Estimated, Subjective Or Unreliable Data
DNK = Do Not Know

STRUCTURE SCORES AND MODIFIERS

BUILDING TYPE	W	S1 (MRF)	S2 (BR)	S3 (LM)	S4 (RCSW)	C1 (MRF)	C2 (SW)	C3/S5 (URM INF)	PC1 (TU)	PC2	RM	URM
BASIC SCORE	8.5	3.5	2.5	6.5	4.5	4.0	4.0	3.0	3.5	2.5	3.5	2.5
High Rise	N/A	0	0	N/A	-0.5	-0.5	-0.5	-0.5	N/A	-1.0	-1.5	-0.5
Poor Condition	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Vert. Irregularity	-0.5	-0.5	-0.5	-0.5	-1.0	-1.0	-0.5	-1.0	-1.0	-1.0	-1.0	-0.5
Soft Story	-1.0	-2.0	-2.0	-1.0	-2.0	-2.0	-2.0	-1.0	-1.0	-1.0	-2.0	-1.0
Torsion	-1.0	-0.5	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0
Plan Irregularity	-1.0	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-1.0	-1.0	-1.0	-1.0
Pounding	N/A	-0.5	-0.5	N/A	-0.5	-0.5	N/A	N/A	N/A	-0.5	N/A	N/A
Large Heavy Cladding	N/A	-2.0	N/A	N/A	N/A	-1.0	N/A	N/A	N/A	-1.0	N/A	N/A
Short Columns	N/A	N/A	N/A	N/A	N/A	-1.0	-1.0	-1.0	N/A	-1.0	N/A	N/A
Post Benchmark Year	+2.0	+2.0	+2.0	+2.0	+2.0	+2.0	+2.0	N/A	+2.0	+2.0	+2.0	N/A
SL2	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3
SL3	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6
SL3 & 8 to 20 stories	N/A	-0.8	-0.8	N/A	-0.8	-0.8	-0.8	-0.8	N/A	-0.8	-0.8	-0.8
FINAL SCORE						2.5						

COMMENTS

Detailed Evaluation Required? YES/NO

Fig. 4. Sample ATC-21 Assessment Form

The results obtained from the assessment form have been converted into a table format, which can be found in Table 6, while the overall percentage can be obtained in Table 7.

Table 6
Result and Resilience Classification for 20 sample buildings

Bil.	Buildings	Area	Result	Resilience Classification
1.	Masjid Jamek Al-Fa'izan	Low	3.5	Good
2.	SMK Sri Gading	Low	2.5	Satisfactory
3.	SK Pintas Raya	Low	3	Good
4.	Villa Penggaram	Low	1	Weak
5.	K.N.Lee Knitting Industries	Low	2	Satisfactory
6.	Carnival Hotel	Low	2.5	Satisfactory
7.	Flat Flora	Low	3	Good
8.	KCT Auto Enterprise	Low	3	Good
9.	Waves Restaurant	Low	2.5	Satisfactory
10.	Hup Chen Furniture Store	Low	4	Good
11.	House 1	Low	7.5	Good
12.	House 2	Low	7.5	Good

13.	Nicollo Furniture Store	Low	3.5	Good
14.	The Store Batu Pahat	Low	3	Good
15.	The Katerina Hotel	Low	2.5	Satisfactory
16.	Student Center (HEP)	Low	3.5	Good
17.	Library & Theater UTHM	Low	3.5	Good
18.	Block D1, UTHM	Low	3.5	Good
19.	Wellward Supermarket	Low	3.5	Good
20.	Melewar Hostel UTHM	Low	3	Good

The seismic resilience levels of 20 sampled buildings are presented in Figure 5, which was generated based on the data provided in Table 7.

Table 7
Overall Percentage

Resilience Classification	Percentage (%)
Good	70
Satisfactory	25
Weak	5
Very Weak	0

Based on the results obtained from the examination of the 20 buildings, the following observations were made: 5% exhibited short columns, 10% displayed soft story characteristics, 40% were attached buildings susceptible to pounding effects, 15% exhibited vertical irregularities, 30% had irregularities in their plans, 20% were in poor condition, and 5% showed torsion.

According to the study, it was found that the majority of buildings in the study area were in good condition, with 70% of the 20 assessments indicating that they were in good shape. This means that out of the 20 sampled buildings, 14 were classified as not being high rise structures and did not have soft story or torsion issues.

However, the remaining 25% of the assessments, which represents 5 sampled buildings, were only rated as satisfactory due to being high rise structures. Additionally, 5% of the buildings, which represents 1 sampled building, were identified as weak due to having soft story, being high rise, and having torsion issues. This is a concerning trend, especially given the increasing risk of earthquakes in our country.

While 5% may seem like a small number, it is crucial to take this issue seriously and identify the factors that may have contributed to these structures being at risk. Further investigation is necessary to determine the root causes of these issues and take appropriate measures to prevent similar risks in the future.

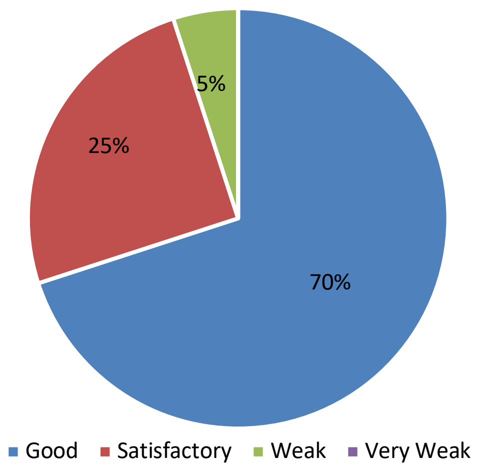

Fig. 5. Overall percentage of 20 sampled building

Upon further observation, it was discovered that several factors could have played a role in the weakened condition of these buildings. These factors included variations in overall geometry shape, high buildings, and building type design concepts. The study used a rapid assessment form to determine the potential risk of seismic movement on the building's structure, highlighting the need for further investigation into the root causes of these issues.

4. Conclusions and Suggestions

Overall, this study has been successfully implemented and achieved the desired research objectives and scope. External assessments have been made on 20 sample buildings in the proposed area. The assessments were made using the ATC-21 assessment form to determine their level of earthquake resistance if one were to occur.

The results of the assessments showed that most of the buildings in the study area were in good condition. Out of the 20 assessments made, 70% were in good condition, 25% were satisfactory, and 5% were weak. Although only 5% were weak, it cannot be taken lightly as our country is increasingly threatened by earthquakes. Through observation, several factors may have contributed to the buildings being in a dangerous condition, including:

i. Overall geometry shape that is not the same
ii. High buildings
iii. Design concept, i.e., building type.

A valid program should be employed to identify Peak Ground Acceleration (PGA) for precise determination of the Map Area type, in conjunction with a detailed assessment form. To guarantee the accuracy of data acquisition during the building data collection process, it is crucial that the inspector possesses ample knowledge and experience to accurately assess and interpret the information requested in the ATC-21 data collection form. It's important to emphasize that this assessment represents just the initial stage of evaluation, and definitive results can only be obtained through further analysis methods.

In general, the method of measuring the rate of structural resistance of buildings to seismic using the ATC-21 form is suitable and relevant. However, further studies need to be conducted if the building structures that have been examined and classified as being at risk of failure. Nevertheless, this study can be considered as a guide and reference for further research for students who wish to continue studying the effects of seismic activity on buildings in our country. Considering the likelihood of Malaysia experiencing earthquakes, a similar study can be conducted in other areas. This is very important, although this study only assesses the external condition of buildings, it is one way to determine the resilience of a building to earthquakes.

Based on the results, it's uncertain whether buildings identified as low risk fully comply with existing earthquake protocols. It's essential to emphasize that this assessment represents only the initial stage of evaluation. The definitive results can only be obtained through further analysis methods. The primary objective of this method is to assess the structural resilience of buildings in the Batu Pahat area in response to seismic activity.

Managing, analysing, and detecting information related to the expanding building stock in urban areas are vital considerations for urban planning and transformation. This study can aid in prioritizing the assessment of high-risk reinforced concrete buildings. Therefore, avoiding all kinds of negativity and proactive measures to prevent any shortcomings will facilitate a more effective approach in reducing potential earthquake damage.

To further advance this research, we recommend selecting study areas that include a variety of building types in different development zones. This approach will yield results that accurately reflect the actual level of building resilience in Malaysia during an earthquake, as well as provide a more comprehensive understanding of buildings with good resilience. Moreover, students are encouraged to explore other research methods that offer a more detailed assessment or focus on structural design. Based on these findings, the level of building resilience is affected by various factors such as column height, ground conditions, available space or units, uniformity of building shape, and surrounding conditions. By conducting similar studies, we can contribute to addressing earthquake-related challenges in Malaysia and other countries.

This study's findings can serve as valuable information for engineers in Malaysia, enabling them to propose new design concepts that incorporate earthquake considerations and align with the requirements of the construction industry. By considering the insights gained from this study, engineers can develop innovative approaches to enhance the structural resilience of buildings in the Batu Pahat area. The overall study provides valuable insights into the durability of buildings in the Batu Pahat area against seismic activity, empowering stakeholders to make well-informed decisions regarding building safety in the region. These insights will play a crucial role in guiding decision-making processes related to necessary precautions, retrofitting measures, or even potential relocation of high-risk buildings. During the design stage, it is crucial to steer clear of negativity and parameters aspects discovered during research in order to implement measures that safeguard lives from seismic activity or hazards.

Ultimately, the aim is to ensure the safety and well-being of occupants in the face of seismic hazards. The comprehensive evaluation conducted in this study, coupled with its subsequent insights, will significantly contribute to improving the overall resilience of buildings in the Batu Pahat District. This study serves as a foundation for informed decision-making and proactive measures aimed at effectively mitigating seismic risks in the region. By integrating the knowledge gained from this study, stakeholders can work towards creating a safer and more resilient built environment.

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