INTERNATIONAL JOURNAL OF ADVANCE RESEARCH, IDEAS AND INNOVATIONS IN TECHNOLOGY

IJARIIT

ISSN: 2454-132X
Impact Factor: 6.078
(Volume 9, Issue 2 - V9I2-1340)
Available online at: https://www.ijariit.com

Assessment of the seismic vulnerability of San Guillermo parish church and San Agustin parish church in Pampanga

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ABSTRACT

The Pacific Ring of Fire is the location to which where the Philippines is located making it vulnerable to seismic activities. Because of this, heritage churches are in need of seismic assessment, not only for the community to know the structures' safeness when an earthquake occurs but also for the local government to allocate funds for the preservation, and restoration of these structures. This study was intended to assess the vulnerability of San Guillermo Parish Church and San Agustin Parish Church to seismic hazards using rapid visual screening. The researchers chose RVS as a method to be used for the seismic vulnerability assessment of San Agustin Parish Church and San Guillermo Parish Church because it is a straightforward approach that negates the need for intricate numerical analysis while yet being accurate. Churches in Bacolor and Lubao Pampanga that are considered as heritage are selected in this research. In the community survey there were 226 respondents from of barangay Cabambangan in Bacolor, Pampanga and 345 respondents from barangay San Nicolas 1st in Lubao, Pampanga, ranging between 15 and 65 years old and above. Results revealed that the San Guillermo Parish Church and San Agustin Parish Church both scored 0.6 and lie in damage grade 3 which results in substantial to heavy damage, which means it is needed for a detailed evaluation and retrofitting. In conclusion, despite the churches being old and may suffer substantial to major damages when there's a major earthquake, the findings of this study showed that most people want to ensure that the churches are accurately preserved, since they have been considered as historical heritage and tourist spots in their town.

Keywords: *Bacolor, Community Survey, Earthquake, Historic Church, Lubao, Rapid Visual Screening*

1. THE PROBLEM AND A REVIEW OF RELATED LITERATURES AND STUDIES

1.1 Introduction

A severe problem that can result to loss of life, property, resources, or destruction of the environment is what we call a disaster. The most frequent that the Philippines experience includes earthquakes, typhoons, flooding, landslide, and drought.

As stated by the Philippine Institute of Volcanology and Seismology, when rocks underneath the surface suddenly move it makes the ground to move or shake brutally of briefly. As a result of earthquakes between 1998 and 2017, almost seven-hundred fifty-thousand people died around the world. The number of people that were affected by earthquakes during this time period is about one-hundred-twenty-five-million, which means that they were hurt, had their homes destroyed, relocated, or sent to safe places during the disaster (World Health Organization).
The Pacific Ring of Fire is the location to which where the Philippines is located making it vulnerable to seismic activities. In Accord to Medina, (2019), the Central Fault in the Philippines, Fault in the south of Mindanao, fault in the eastern part of the Philippines, and the fault in the western part of the Philippines are the most seismic faults in the Philippines.

Given the fact that we are located in the seismically active part in the world, the Philippines is frequently hit by different types of calamities such as typhoons, flooding, earthquakes, and volcanic eruptions that take the lives of our countrymen. Every decade the Philippines experiences earthquakes that lead to loss due to collapsed infrastructures. Having the most population that are exposed to dangers and disaster makes the Philippines as top three nations in terms of exposure. Based on previous events, the effects of these calamities, specifically earthquakes, have caused unimaginable destruction especially to old structures like heritage churches.

Earthquake events in the Philippines result in a number of casualties, particularly to heritage structures such as churches. Bohol island which is located in the Philippines experienced a magnitude seven-point-one magnitude earthquake last October 2013, damaging several structures, including historical landmarks like old churches and tourist attractions. Almost all of Tagbilaran's 25 churches were damaged, including Aglipayan Church and The Nuestra Seora de La Paz in Poblacion, La Paz, Abra, which is known as one of the Philippines' oldest and most beautiful Iglesia Filipina Independiente churches.

The Mindanao which is located in the Philippines also experience a six-point-nine earthquake last December fifteen, twenty-nineteen. According to the diocesan Caritas director, Father Consorcio Lopez Jr., at least six churches in the Digos Diocese experienced major damage rendering them unusable.

In a similar vein, on April 22, 2019, Pampanga, Zambales and other nearby provinces experienced a magnitude six-point-one earthquake causing 18 deaths and 256 injuries (NDRRMC, 2019). Numerous buildings, including more than 20 Pampanga historic churches, were damaged. The San Agustin Parish Church in Lubao, where a portion of the tower dome fell, is one of them.

Furthermore, the magnitude 7 earthquake that jolted the island of Luzon last July 27, 2022, did not spare the churches and bell towers in the northern regions of the Philippines, several of which originate from the period of Spanish colonization. The earthquake severely demolished the front of the Metropolitan Cathedral of the Conversion of St. Paul, better known as the Vigan Cathedral, which was situated in Vigan City, Ilocos Sur.

According to Jambalos et. al. (2020), the least standard for the structural system of buildings using calculations and perspective is defined by the National Structural Code of the Philippines (NSCP), has served as the country's guide for civil and structural engineers since 1972. The seismic provisions weren't taken into account until the third edition of the book, which was published in 1987. This only means that structures in the Philippines that were built before the year 1987 do not follow the NSCP seismic provisions.

Heritage churches are some of the examples of structures that do not follow the seismic provisions in the country. These structures were built hundreds of years ago making them prone to collapse due to earthquakes. Due to these reasons, heritage churches are in need of seismic assessment, not only for the community to know the structures safeness when an earthquake occurs but also for the local government to allocate funds for the preservation, and restoration of these structures.

1.2 Review of Related Literature

The Philippine Mobile Belt (PMB), a zone of deformation and strong seismicity that accommodates the strains induced by the north-westward movement of the Philippine Sea Plate, is where the province of Pampanga and the majority of the Philippines are located. This zone is bordered on the west by the Manila, Sulu, Negros, and Cotabato trenches' east-dipping subduction zones, and on the east by the Philippine Trench's main west-dipping subduction zone. Additionally, the left lateral Philippine fault, which spans practically the entire nation and is located within the PMB, is around 1400 km long (Garciano et al., 2019).

Historic building preservation is essential for making communities identity and cultural traditions last for the cultural development in a country. Modern construction methods are greatly influenced by historical architecture. Additionally, the preservation of historic buildings helps the economy of the nation by promoting tourism (Feilden, 2007). These ancient structures can be built using conventional procedures as well as a variety of empirical strategies that mitigate regional risks. But to preserve their endurance throughout time, these buildings need ongoing care and strong preservation techniques (Mishra, 2021).

The necessity to conserve historic buildings is further highlighted by the frequency and size of disasters that are on the rise. The heritage building asset value was added as a component of the risk index using an innovative risk assessment method. This preliminary assessment, which uses a RVS method, enables the selection of various heritage buildings for additional research and retrofitting procedures based on the degree of risk and the value of their assets.

Heritage structures are essential to defining who we are as a people because they carry stories of our cultural heritage. These structures emit stories that we inherit, expand upon, and transmit. It is our privilege and duty to conserve these historic structures so that the next generation can benefit from a rich cultural heritage. However, because of their vulnerability, heritage buildings are more difficult to maintain and preserve. These structures' design and construction did not yet use particular structural design codes for severe loads. This leads to a lack of adequate structural protection from numerous dangers leading to weak conditions. On the other side, the building materials' deterioration over time (such as concrete scouring and rebar corrosion) reduces the structure's ability to support its own weight. Heritage structures actually outlive their design years and put their physical state to the test. In light of this, it is clear that risk assessment is essential for risk minimization.

Rapid Visual Screening (RVS), a Federal Emergency Management Agency procedure (FEMA 154) has been utilized in the US and Canada as a simple method to assess the potential performance of a structure when it comes to earthquake. It is currently one of the tools the DPWH uses to assess structural flaws and decide whether a thorough examination is necessary (Cammayo, 2007).

RVS is a straightforward but efficient technique. It is a universal technique that may be applied to vulnerability assessment in any country. By doing an assessment on the vulnerability fo a structure followed by making the necessary procedure like restoration and the necessary rehabilitation, adverse effects of earthquakes can be reduced. Authorities who manage disasters, those who plan for the urban development, residents of the affected area would benefit from studies on seismic vulnerability assessment as they develop a more safe and effective countermeasures in the future (Khan, S.U., et al., 2019).

The assessment of seismic risk requires consideration of the magnitude of earthquakes in a specific area as well as the exposure and susceptibility of buildings. It may be able to apply retrofitting solutions through a thorough study, hence it is crucial to examine a building's seismic susceptibility. Knowing the area's seismic risk level can greatly lessen the amount of physical harm, the number of fatalities, and the possible economic impacts of future seismic events (Vicente et al., 2011).

The structure characteristics that may contribute to the anticipated earthquake performance must be identified by the user in order to employ the scoring methodology used by the RVS technique as described in FEMA 154. Depending on how seismically active the area is, the findings are documented on a form. Each of the three seismicity consideration locations has its own Data Collection Form. This method uses score modifiers based on the structure’s vulnerability assigned on the structural score such as the effect of the number of floor level, type of soil where the structure is built, vertical irregularities, and pre-code or post-benchmark-code detailing (Perrone, 2015).

According to Ceroni et. al. (2012), what makes an assessment of the behavior of a structure and safety level of an building made of masonry a complex issue is due to interaction with surrounding buildings, having a architectonic and the intervention on the structure using different kinds materials and process in making it, the inevitable uncertainty regarding typologies, shape of the structure, and what the materials are made of, foundations and knowledge of foundation soil properties, and service and accidental loads like earthquake, fire, and flood from the past history of the structure due to its age.

An example of general methodology to assess a historical structure made of masonry’s seismic vulnerability are as follows: the history and description of the structures were researched first; after that is the assessment of masonry properties such as the compressive strength, shear strength without vertical loads, and tensile strength of the structure; the foundation soils are also characterized by borehole, standard penetration test, and down-hole test; in situ dynamic monitoring through the use of continuous monitoring system made of nine couples of mono-axial accelerometers. (Ceroni et. al., 2012).

1.3 Background of the Study

A province in Central Luzon is Pampanga, the province is one of the top ten provinces most at risk of earthquakes due to the existence and close proximity to active faults and trenches (Manila Observatory, 2005). The province has soft soil, it is an alluvial area so the shaking during earthquakes is amplified (PHIVOLCS, 2019).

1.3.1 San Guillermo Parish Church (SGPC) in Bacolor, Pampanga

Considered an old church in Pampanga is the SGPC, due to lahar mudflows in early 90's the church is now half buried. It was founded by the Augustinians in 1576. Before being reconstructed in 1886, its original construction had been harmed by two earthquakes and a fire. Residents continue to go to the SGPC to show their faith and worship despite being partially buried, notably by the residents of Bacolor who have shown how strong their faith is, and how strong they are as a community, despite having to face such disaster. The SGPC is constructed in the Baroque architectural style and appears to be made of concrete. Due to the materials used, which are mostly masonry material, the structure has a brittle and vulnerable structure making it vulnerable to seismic events. Even if the majority of it is already covered by contemporary finishing, notably in the interior of the church, closer study reveals that it's about one-meter in thickness wall is made of materials like bricks and other stone works (Giolagon, 2019).

By 1995, the 350-year-old, half-buried SGPC was a famous visual representation of the destruction caused by Pinatubo lahars. Restoring the church was a top priority, not just to meet religious requirements but also to represent the town's ongoing existence. The main doorway was buried, therefore the choir loft window above it served as the new entrance. The interior of the church resembled a dark cave since lahar deposits had obscured all but the top few centimeters of the arched side windows and stretched enormous chandeliers almost to the floor. The ceiling was removed in order to raise the interior height since the large brick construction was far too heavy to lift. Large dormer windows were installed in the roof to let in light and lined with silvery, reflective insulation to deflect solar heat. A chamber next to the sanctuary was made into a museum in 1998, which received donations from a rising number of visitors. As resources become available, renovation and restoration work are continued.

Lahar deposits buried the smaller archdiocesan shrine five meters in height by 1955. Some of the concrete structure of the church had to remain buried, but they rehabilitate the old chapel and did it in two stages. The first that they do is to create a new entrance above the original, and redecorated the interior of the San Guillermo Parish Church. By 1997, a remodeled sanctuary was constructed about 2 meters above the land surrounding the church, and in order to do this they lifted the cupola and roof of the church by five meters (Rodolfo et. al., 2002).

1.3.2 San Agustin Parish Church (SAPC) in Lubao, Pampanga

A Neo-classical Spanish stone and brick church constructed in the 17th century is the SAPC, where in other terminology known as the church of Lubao. According to Layug (2005), Fr. Juan Gallegos first constructed this church from lightweight materials and began the construction on the current brick and adobe church. Due to the year that it was built, the materials used during its construction are weak and easy to be damaged to seismic events. It was constructed using materials that could be found nearby, including heavy-duty wood such as Acli, Anibiung, Bulaun, Apalait or Narra, Tindalo, Saplungan or Yakal, as well as stones, egg white, lime, and molasses. On April 22, 2019, the province of Pampanga, Zambales, and other nearby experienced a magnitude six-point-one earthquake causing 18 deaths and 256 injuries (NDRRMC, 2019). Numerous buildings, including more than 20 Pampanga historic churches, were damaged. The San Agustin Parish Church in Lubao, where a portion of the tower dome fell, is one of them. According to Josie (personal communication, December 7, 2022), the secretary at San Agustin Parish, the church was renovated seven months ago, specifically the dome due to the damage that the parish experienced in the earthquake on April 22, 2019.

The Archdiocesan Committee on Church Heritage (ACCH) recommended to temporarily close all of the heritage churches in Pampanga (no activities allowed inside and the whole premises must be secluded) until they are deemed safe after the 6.1 magnitude earthquake. To ensure everyone's safety, the Technical Secretariat worked with specialists and national agencies. Additionally, it was claimed that historic churches in surrounding communities including Santa Rita, Lubao, Minalin, and Angeles City had suffered damage. The brick spire of the ancient Saint Augustine Parish Church in Lubao town was destroyed by the earthquake. The SAPC was designated as a Vital Cultural Property by the National Museum in 2013. Rene Escalante, chairman of the National Historical Commission of the Philippines (NHCP), and a group of specialists in heritage conservation and repair, visited Pampanga to evaluate the harm done to the city's historic churches. Escalante stated that the magnitude 6.1 earthquake in Lubao damaged the church's belfry, the cross, and several tiles, and that restoration work may cost around P10 million. He said that the damage to the churches in Betis and Guagua was "minimal." In order for experts to examine the structural soundness of 24 heritage churches in Pampanga, the Archdiocese of San Fernando had already closed the buildings. San Agustin in Lubao and San Guillermo in Bacolor are two of the churches that were examined.

1.3.3 Rapid Visual Screening

Seismic assessment is done because the inability to examine the effects of a seismic event on a structure may lead to fatality, and also poverty because of destruction of properties. Also recommended to undergo to assessment of seismic risk are buildings that appear to be of low quality or have degraded over time. These structures weren't designed to withstand seismic forces, or were built before the present seismic codes were published. According to American Society of Civil Engineers (2014), it is suggested to perform a seismic vulnerability assessment for any structures that were not built to withstand seismic pressures, were built before the present seismic regulations were published, appear to be of low quality, or have deteriorated over time. The decision to if a structure might be destroyed, upgraded in order to expand its ability to house people, or changed to reduce its weakness to earthquake, those options will be determined by the findings of this evaluation.

One of the widely used in assessing a structure's seismic vulnerability is Rapid Visual Screening. According to Khan (2019), RVS is a straightforward but efficient technique. It is a universal technique that may be applied to vulnerability assessment in any country. Using three tiers which includes RVS of a structure, assessment of the structure preliminary to the use of RVS, and having evaluation covering all the important information is when seismic vulnerability assessment is done. The RVS approach is used to study vulnerabilities both before and after an earthquake. The preliminary assessment acknowledges how the structure will perform in seismic events, whereas the final assessment determines if the structure is still suitable for use (Murty et al., 2012).

Assessing the seismic vulnerability of SGPC and SAPC is what the researchers intended to do. The Rapid Visual Screening Method will be used to make the assessment possible. Once the seismic assessment is performed, the future seismic safety of the structure will be assessed. In addition, a survey to the local community will be conducted by the researchers to gain insight about how community members perceive the churches' current situation.

1.4 Study Area

The seismic vulnerability assessment will be done to the SGPC in Bacolor and the SAPC in Lubao. The selected study areas are among the oldest churches in the province of Pampanga.

According to the Philippine Institute of Volcanology and Seismology (PHIVOLCS), the main source of seismic events that can affect the area of Central Luzon, which includes the province of Zambales and Pampanga, are the Manila Trench, East Zambales Fault, the main Philippine Fault, and Iba Fault According to PHIVOLCS Fault Finder, San Guillermo Parish is approximately 50.8 km away from Iba fault while the San Agustin Parish is approximately 49.3 km away from Iba Fault, which means that they most likely experience earthquakes.

Due to the fact that these are well known as heritage tourist spots in the province, a lot of people either local or foreign come to these churches. People from these churches' respective locations often go there for worship and religious practices despite their old age because these churches have a cultural significance. Due to their, age these structures are more vulnerable when it comes to earthquakes that is why assessing their seismic vulnerability is important.

1.5 Objectives of the Study

1.5.1 General Objective

assessment of the seismic vulnerability of SGPC and SAPC in Pampanga using Rapid Visual Screening.

1.5.2 Specific Objectives

The specific aims of the study are:

● to perform RVS using FEMA-154 data collection form and get the results reviewed and verified by experts.

● to determine if the San Guillermo Parish and San Agustin Parish are still safe when an earthquake occur based on scores derived.

● to differentiate the validated result of RVS and the perspective of the community of Brgy. Cabambangan, Bacolor and Brgy. San Nicolas 1st, Lubao, Pampanga regarding the seismic vulnerability of SGPC and SAPC.

1.6 Statement of the Problem

Assessment of the vulnerability of SGPC and SAPC to seismic hazards using rapid visual screening is the intention of the study. The study will focus on:

1. Provide a vulnerability assessment of SGPC and SAPC by using RVS.
2. Determine if SGPC and SAPC are still safe in accord to the results of RVS after doing seismic vulnerability assessment.
3. Conduct a community survey to determine how community members perceive the churches' current situation.

1.7 Significance of the Study

Assessing the Seismic Vulnerability of SGPC in Bacolor and SAPC in Lubao Pampanga to provide data of the current status of the church is the aim of the study. The following sectors are among those who will gain from the study:

- To the Community, the study will serve as a guide for them to be aware of the current status of the SGPC and SAPC.
- To the Local Government Unit, the study will be a good help to know the possible outcomes and to prepare to minimize the possible damage of an earthquake.
- To the National Commission for Culture and Arts (NCCA), Archdiocesan Committee on Church Heritage (ACCH), National Historical Commission of the Philippines (NHCP) and United Nations Educational, Scientific and Cultural Organization (UNESCO), the results of the study will provide concrete seismic evaluation that will assist them in making effective solution in dealing with earthquake.
- To Engineers and Architects, this study will serve as their reference to determine the next actions in prolonging the lifespan of the SGPC and SAPC.
- To Future Researchers, the study will serve as basis for the next phase their seismic assessment research.

1.8 Scope and Limitations

The study's scope is to evaluate the seismic vulnerability assessment of the heritage churches in Pampanga, namely, San Guillermo Parish Church in Bacolor and San Agustin Parish Church in Lubao using the RVS method. Utilizing a survey to collect data; the data collection was conducted to 226 residents of Barangay Cabambangan, Bacolor and 345 residents of Barangay San Nicolas 1st, Lubao.

This study used RVS as the primary method in assessing the structures' seismic vulnerability observing the physical appearance of the exterior and interior of the church. It will be conducted through the completion of the level one form with High Seismicity category.

All the fundamental data needed for the identification of seismic activities in Bacolor and Lubao Pampanga will be limited to online research from Philippine Institute of Volcanology and Seismology (PHIVOLCS) along with the active participation of SGPC and SAPC in providing information. Furthermore, the type of retrofitting appropriate for the churches, consequences of the earthquake's aftershock, such as differential settling of the building, liquefaction of the soil, interaction of the structure to the soil, and other site effects that are related to soil are excluded from the study's scope.

1.9 Conceptual Framework

Figure 1 is the visual representation and description of the whole framework of this research. The first phase was planning and definition, which involves preliminary site investigation, pre-field data collection, creating a survey questionnaire based from the objectives and calculating the sample size of the chosen study areas. The second phase is the collection of data, it includes the execution of RVS and conducting community survey. In conducting RVS, the researchers acquired the church address, church name, year the church was built, and other information in accordance with the FEMA 154 data collection sheet. In conducting the community survey, the researchers initially started in Bacolor, Pampanga and later conducted the survey in Lubao Pampanga. The Data Analysis was the final phase of the research framework. Using the FEMA 154 checklist, the researchers assigned a score that matched the observed findings on each building's vulnerability. Then, the RVS scores were validated by the supervising engineer. The result of the community survey was assessed and evaluated. After acquiring the necessary information, interpretation of data and analysis of the results were conducted.

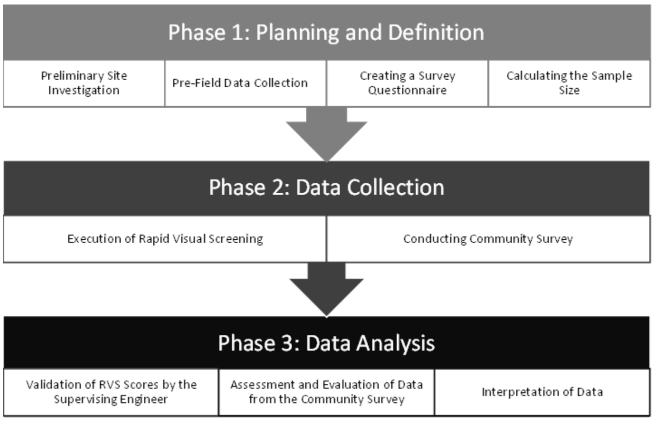


Figure 1. Conceptual Framework

1.10 Definition of Terms

For the readers to better understand the terms, the following are defined both theoretically and when used in operation:

FEMA 154 – Data collection form used to assess a structures seismic vulnerability

Perception – According to Desiderato as quoted by Hudastate (2017) is an experience about an object, an event that has already happened and even what is happening, or to be able to infer information or decipher a message contained therein, a connection may be established. The term "perception" may also refer to a process that involves a variety of highly relevant senses or prior experiences and aims to present an organized image as well as meaning in certain contexts.

Rapid Visual Screening (RVS) – According Ishack et. al. (2021), is used to distinguish structures that needed a more comprehensive evaluation to those that need a simple one. Through the use of RVS one can determine the performance of a structure to earthquake without using computations. By assessing the physical appearance of a structure to fill out the form. The form has a positive and negative score depending on the features of the structure. The final score will be compared to the requirement score to know which structure needs a comprehensive evaluation to those that needed a simple one.

Seismic Assessment – is a branch of structural analysis that involves calculating how buildings and other structures will respond to seismic events. It is essential for the course of structural design, earthquake engineering or structural analysis, and retrofitting in regions where earthquakes are common (Definitions, n.d.).

Seismic Vulnerability – According to Trizio et. al. (2019), is defined as the tendency of a structure to experience damage to seismic events which is determined based on factors such as type of materials used, quality of materials used, how the structure is built, how the structure is being maintained, and the use of preventive measures in the structure.

Survey – the way of asking questions to respondents the collect data. All civil engineering projects are planned, constructed, and maintained using surveys, according to the Occupational Outlook Handbook for Civil Engineers published by the U.S. Department of Labor and the Bureau of Labor Statistics in 2022. To determine the precise bounds of the target area and to ensure the security of any buildings or other structures placed there, a detailed survey is often necessary.

2. METHODOLOGY

2.1 Introduction

It is a challenging and complex process to perform vulnerability assessment on historical structures. As a result of the building's state, its past and construction stages, the morphology of its structural parts, and the connections between them, among other factors, there are many unknowns. Modeling and analysis tools have significantly improved in recent years as a result of society's growing awareness of heritage structures. At the present time, there is a variety of successful techniques for evaluating the mechanical performance of historic buildings. Additionally, many approaches for the evaluation of seismicity of historical structure have been presented (Lourenço, 2002).

2.1.1 Vulnerability Assessment Methodologies

For conducting assessments of a structure's seismic susceptibility, many approaches have been established. These strategies fall into three categories: integrated interdisciplinary approaches, empirical approaches based on macro elements, and analytical approaches. Analytical techniques for assessing the vulnerability of a structure may be grouped into simple and complex ones. The simplified methods include the collapse-mechanism-based methods, capacity-spectrum-based, and fully displacement-based methods, whereas the detailed methods include nonlinear static analysis (push-over analysis) and nonlinear time history analysis (incremental dynamic analysis). Seismic vulnerability techniques generally involve methods for RVS and vulnerability of sesimicity index. The "Hybrid" vulnerability assessment approach, Euro Code 8, New Zealand Guidelines, the Modified Turkish method, and NRC Guidelines are a few more techniques that are now in use. (Alam et. al., 2012).

The researchers chose RVS as a method to be used for the assessment of a structure's vulnerability to seismic evernts of SGPC and SAPC because it is a straightforward approach that negates the need for intricate numerical analysis while yet being accurate. According to Danish (2014), it is a very useful technique that helps to determine critical structures which are in need of in-depth vulnerability assessment and to shortlist structures that require simplified vulnerability assessment procedures. It is based on a straightforward scoring system that makes it possible to identify the architectural aspects that may contribute to the performance of a structure seismicly without the need for any structural calculations, which makes the assessment rapid and inexpensive. RVS is commonly used in identifying the churches' seismic vulnerability because of its simple and on-destructive approach. Additionally, due to the age of the church, no structural or architectural drawings were accessible, making alternative approaches unfeasible.

2.2 Respondents of the Study

Churches in Bacolor and Lubao Pampanga that are considered as heritage are selected in this research. During the preliminary planning, two churches were selected, one from each municipality. The selection was based on the age of the structure. The SGPC and the SAPC are selected among the oldest churches in Bacolor and Lubao Pampanga.

$$n = \frac{\mathbf{N}}{\mathbf{1} + \mathbf{N}e^{2}}$$

Where,

N is the size of the population
e is the margin of error
n is the sample size

In order to determine the sample size, the Slovens formula if used especially if the population is known. It is a statistical method of sampling if you want to have unbiased selected samples. Because the PRC's usual target is the community, it is difficult to survey every member of its population due to lack of resources and/or time to survey for its staff to gain preliminary statistical knowledge about the target, such as the mean. As a result, employing the SLOVIN method for its baseline and VCAs is strongly recommended. (Isip, F.)

Residents of Barangay Cabambangan, Bacolor and San Nicolas 1st, Lubao were selected as respondents in the community survey. The selection was made based on where San Guillermo Parish Church and San Agustin Parish Church were located. A barrio in the municipality of Bacolor in the province of Pampanga is called Cabambangan, formerly known as Poblacion. The number of people living in Cabambangan are seven-hundred five as of the 2022 Census. San Nicolas 1st, formerly known as

Poblacion, is a barrio in the Pampanga provincial municipality of Lubao. The number of people living there as of the 2022 Census was three-thousand three-hundred eighty-nine. The sample size from each Barangay was established using Slovin's Formula.

2.3 Data Collection

After determining which churches are within the scope of the study, the necessary information of each church was collected in accordance with the data collection form. This information is vertical irregularities, elevation of the building, number of stories, total floor area, soil classification, and the year the structure was built. Within the information office of each church, information on the building's age, total floor area, and other details were available.

The researchers used the survey questionnaires in order to conduct a community survey after determining the sample size. The survey asks about the respondents' knowledge of the church's age and the previous earthquakes that affected Pampanga, whether they have observed damage to the church or its surroundings, whether they believe the church will survive a major earthquake, and whether they believe the church needs to be restored.

2.4 Seismic Vulnerability Assessment of the SGPC and SAPC using RVS Method

The seismic vulnerability of SGPC and the SAPC was done through Rapid Visual Screening using the following steps:

1. Identify the FEMA building type and document the related basic scores.
2. Identify the basic scores such as; Vertical Irregularity, Plan Irregularity, Pre-Code, Post-Benchmark, Soil type, and minimum score.
3. Determining the final Level 1 score.

2.5 Research Instrument

2.5.1 Community Survey Questionnaire

One of the study instruments that the researchers used is a survey questionnaire. It is used in which a group of respondents is examined by gathering and examining data from a portion of the population by selecting the respondents making them as representative of the entire group, but the results of the survey will apply to the entire population.

A validation procedure was used to the study's questionnaire design. Professors received copies of the questionnaire and the research question as part of the validation procedure for this study. To determine the suitability and sufficiency of the instrument, these specialists thoroughly reviewed the study questions and the questionnaire.

After all the necessary modifications, the survey questionnaires were given to the respondents directly through house-to-house method.

1	May kamalayan ba kayo na mahigit apat na daang taon (400) na ang simbahan ng San Guillermo Parish Church?
2	May kamalayan ba kayo sa mga nakaraang pag lindol na naka-apektos probinsya ng Pampanga?
3	May nakita ka na bang mga bitak o anumang sira sa simbahan ng San Guillermo Parish Chruch?
4	Sa iyong palagay, magagawa pa kayang makayanan ng San Guillermo Parish Church ang isang malakas na lindol?
5	Sa iyong palagay, kailangan na bang gawan ng pagsasaayos o pagpapatibay ang simbahan ng San Guillermo Parish Church?

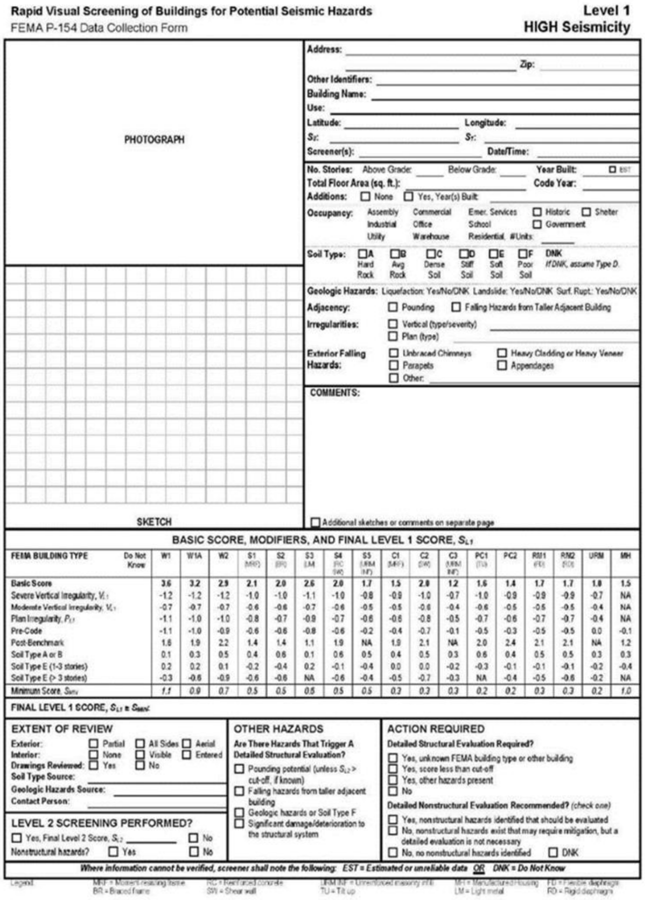
Figure 2. Survey Questionnaire for the Residents of Barangay Cabambangan, Bacolor

1	May kamalayan ba kayo na mahigit apat na daang taon (400) na ang simbahan ng San Agustin Parish Church?
2	May kamalayan ba kayo sa mga nakaraang pag lindol na naka-apektos probinsya ng Pampanga?
3	May nakita ka na bang mga bitak o anumang sira sa simbahan ng San Agustin Parish Chruch?
4	Sa iyong palagay, magagawa pa kayang makayanan ng San Agustin Parish Church ang isang malakas na lindol?
5	Sa iyong palagay, kailangan na bang gawan ng pagsasaayos o pagpapatibay ang simbahan ng San Agustin Parish Church?

Figure 3. Survey Questionnaire for the Residents of Barangay San Nicolas 1st, Lubao

2.5.2 FEMA P-154 2015 Rapid Visual Screening

The RVS data collection form in figure 2 is used, the researchers will assess the seismic vulnerability of the chosen historic Churches in Bacolor and Lubao Pampanga. This method doesn't need any mathematical calculations as well as structural in order to be done. The procedure is simple to apply, mainly requires a visual assessment, and is economical. Using the form, the researchers utilize it in order to know the building's potential seismic risk.



Rapid Visual Screening of Buildings for Potential Seismic Hazards
FEMA P-154 Data Collection Form

Level 1
HIGH Seismicity

PHOTOGRAPH

Address: ____ Zip: ____
Other Identifiers: ____
Building Name: ____
Use: ____
Latitude: ____ Longitude: ____
S_S: ____ S_1: ____
Screener(s): ____ Date/Time: ____

No. Stories: Above Grade: ____ Below Grade: ____ Year Built: ____ ☐ EST
Total Floor Area (sq. ft.): ____ Code Year: ____
Additions: ☐ None ☐ Yes, Year(s) Built ____
Occupancy: Assembly, Commercial, Emer. Services, ☐ Historic, ☐ Shelter, Industrial, Office, School, ☐ Government, Utility, Warehouse, Residential, #Units: ____
Soil Type: ☐A Hard Rock ☐B Avg Rock ☐C Dense Soil ☐D Stiff Soil ☐E Soft Soil ☐F Poor Soil DNK *If DNK, assume Type D.*
Geologic Hazards: Liquefaction: Yes/No/DNK Landslide: Yes/No/DNK Surf. Rupt.: Yes/No/DNK
Adjacency: ☐ Pounding ☐ Falling Hazards from Taller Adjacent Building
Irregularities: ☐ Vertical (type/severity) ____ ☐ Plan (type) ____
Exterior Falling Hazards: ☐ Unbraced Chimneys ☐ Heavy Cladding or Heavy Veneer ☐ Parapets ☐ Appendages ☐ Other: ____

COMMENTS:

SKETCH

☐ Additional sketches or comments on separate page

BASIC SCORE, MODIFIERS, AND FINAL LEVEL 1 SCORE, S_{L1}

FEMA BUILDING TYPE	Do Not Know	W1	W1A	W2	S1 (MRF)	S2 (BR)	S3 (LM)	S4 (RC SW)	S5 (URM INF)	C1 (MRF)	C2 (SW)	C3 (URM INF)	PC1 (TU)	PC2	RM1 (FD)	RM2 (RD)	URM	MH
Basic Score		3.6	3.2	2.9	2.1	2.0	2.6	2.0	1.7	1.5	2.0	1.2	1.6	1.4	1.7	1.7	1.0	1.5
Severe Vertical Irregularity, V_{L1}		-1.2	-1.2	-1.2	-1.0	-1.0	-1.1	-1.0	-0.8	-0.9	-1.0	-0.7	-1.0	-0.9	-0.9	-0.9	-0.7	NA
Moderate Vertical Irregularity, V_{L1}		-0.7	-0.7	-0.7	-0.6	-0.6	-0.7	-0.6	-0.5	-0.5	-0.6	-0.4	-0.6	-0.5	-0.5	-0.5	-0.4	NA
Plan Irregularity, P_{L1}		-1.1	-1.0	-1.0	-0.8	-0.7	-0.9	-0.7	-0.6	-0.6	-0.8	-0.5	-0.7	-0.6	-0.7	-0.7	-0.4	NA
Pre-Code		-1.1	-1.0	-0.9	-0.6	-0.6	-0.8	-0.6	-0.2	-0.4	-0.7	-0.1	-0.5	-0.3	-0.5	-0.5	0.0	-0.1
Post-Benchmark		1.6	1.9	2.2	1.4	1.4	1.1	1.9	NA	1.9	2.1	NA	2.0	2.4	2.1	2.1	NA	1.2
Soil Type A or B		0.1	0.3	0.5	0.4	0.6	0.1	0.6	0.5	0.4	0.5	0.3	0.6	0.4	0.5	0.5	0.3	0.3
Soil Type E (1-3 stories)		0.2	0.2	0.1	-0.2	-0.4	0.2	-0.1	-0.4	0.0	0.0	-0.2	-0.3	-0.1	-0.1	-0.1	-0.2	-0.4
Soil Type E (> 3 stories)		-0.3	-0.6	-0.9	-0.6	-0.6	NA	-0.6	-0.4	-0.5	-0.7	-0.3	NA	-0.4	-0.5	-0.6	-0.2	NA
Minimum Score, S_{MIN}		*1.1*	*0.9*	*0.7*	*0.5*	*0.5*	*0.5*	*0.5*	*0.5*	*0.3*	*0.3*	*0.3*	*0.2*	*0.2*	*0.3*	*0.3*	*0.2*	*1.0*

FINAL LEVEL 1 SCORE, $S_{L1} \geq S_{MIN}$:

EXTENT OF REVIEW
Exterior: ☐ Partial ☐ All Sides ☐ Aerial
Interior: ☐ None ☐ Visible ☐ Entered
Drawings Reviewed: ☐ Yes ☐ No
Soil Type Source: ____
Geologic Hazards Source: ____
Contact Person: ____

LEVEL 2 SCREENING PERFORMED?
☐ Yes, Final Level 2 Score, S_{L2} ____ ☐ No
Nonstructural hazards? ☐ Yes ☐ No

OTHER HAZARDS
Are There Hazards That Trigger A Detailed Structural Evaluation?
☐ Pounding potential (unless S_{L2} > cut-off, if known)
☐ Falling hazards from taller adjacent building
☐ Geologic hazards or Soil Type F
☐ Significant damage/deterioration to the structural system

ACTION REQUIRED
Detailed Structural Evaluation Required?
☐ Yes, unknown FEMA building type or other building
☐ Yes, score less than cut-off
☐ Yes, other hazards present
☐ No
Detailed Nonstructural Evaluation Recommended? *(check one)*
☐ Yes, nonstructural hazards identified that should be evaluated
☐ No, nonstructural hazards exist that may require mitigation, but a detailed evaluation is not necessary
☐ No, no nonstructural hazards identified ☐ DNK

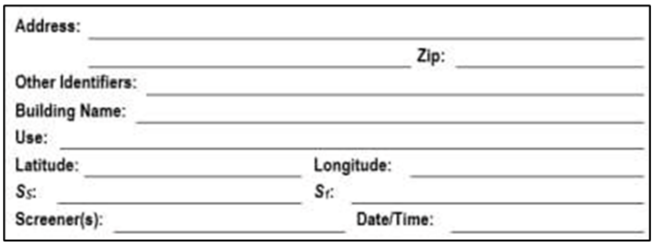
Where information cannot be verified, screener shall note the following: EST = Estimated or unreliable data OR DNK = Do Not Know

Legend: MRF = Moment-resisting frame; BR = Braced frame; RC = Reinforced concrete; SW = Shear wall; URM INF = Unreinforced masonry infill; TU = Tilt up; MH = Manufactured Housing; LM = Light metal; FD = Flexible diaphragm; RD = Rigid diaphragm

Figure 4. FEMA P-154 2015 Rapid Visual Screening (RVS)

2.5.2.1 Building Identification Information

The Level 1 Data Collection Form has a section in the top right corner where you may record building identification details such the address, name, and use of the facility, the name of the screener, when the structure was screened, and the time when the structure was screened.



Address: ____
Zip: ____
Other Identifiers: ____
Building Name: ____
Use: ____
Latitude: ____ Longitude: ____
S_S: ____ S_1: ____
Screener(s): ____ Date/Time: ____

Figure 5. Building Identification Information Portion of Level 1 Data Collection Form

2.5.2.2 Number of Stories

The height of a structure can occasionally affects the amount of damage it takes. Approximately nine to ten feet per story for residential buildings and twelve feet per story for commercial or office structures serve as good indicators of a building's height. If the structure is built on a slope or has numerous distinct roof levels, counting the number of stories might not be an easy task. In general, it is best to utilize the maximum number. To show differences in the amount of tales, utilize the comment area and the drawing. If the screener can confirm the amount, it should also be stated how many articles are below grade. If the neighborhood decides later to look into flooding concerns, gathering this information is especially helpful.

2.5.2.3 Year Built

One of the important components of the Rapid Visual Assessment process is information the design and code year on the building's information. Building age and design and construction techniques are intimately related. Age may therefore influence the type of building according to FEMA and, consequently, the derived score.

2.5.2.4 Total Floor Area

The estimated total floor size by getting the length and width of the structure, which information may be accessible from building department or assessor files in some circumstances. The building's length and breadth might be measured on the job site or estimated during pre-field planning. "EST" should be added if the value is an estimate.

No. Stories: Above Grade: ____	Below Grade: ____	**Year Built:** ____	☐
Total Floor Area (sq. ft.): ____		**Code Year:** ____	
Additions: ☐ None	☐ Yes, Year(s) Built: ____		

Figure 6. Building Characteristics portion of the Level 1 Data Collection Form

2.5.2.5 Photographing the Building

On the Level 1 form, there is a spot for you to attach a picture of the structure. For identification, at least one photo of the structure should be obtained. The screener is not constrained to a single image. The screener should, if at all feasible, take pictures of the building's four sides as well as any noteworthy elements (such as any apparent anomalies and potential fall dangers).

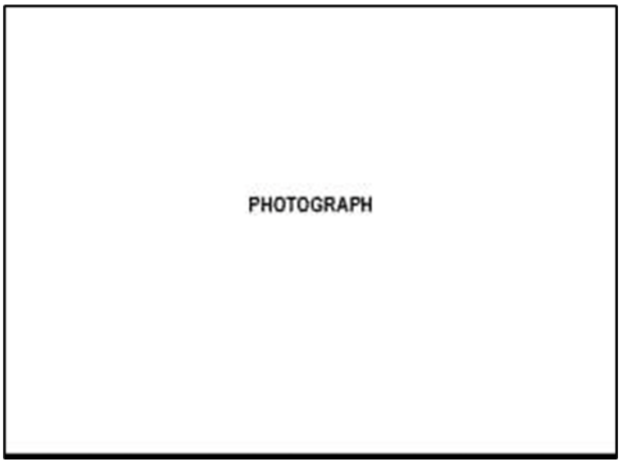


Figure 7. Photograph Portion of the Level 1 Data Collection Form

2.5.2.6 Sketching the Building

On the Data Collection Form Level one, provides a space for you to sketch out the structure. The screener should at the very least sketch out the idea. An elevation drawing might be helpful for highlighting important features. In order to make the drawing, the screener must thoroughly examine all features of the building, which is a crucial step in the screening process since it will disclose to the screener many of the structure's characteristics. A drawing can better highlight key aspects while an image can provide more in-depth information.

The building's form from above and any anomalies in the plan needs to be seen in the sketch of the building's plan. Additionally, it may display the building's location on the property as well as the distance in relation to nearby structures. To create the plan sketch during the pre-field planning, the screeners may use satellite pictures for the aerial view of the structure. The sketch in question has to be checked out in the real world. The screener will most frequently create the drawing while out in the field. The satellite picture of the structure may be viewed by screeners who have access to a smart device while doing the screening. When there is no access between buildings, this is extremely useful.

The number of floor level, vertical irregularities, and any elevated steps should all be shown on the elevation drawing. Each side of the building's elevation can be drawn if they are all distinct. The screener might remark that the drawing is typical of all sides if all sides are comparable. The drawing can also be used to draw attention to distinctive characteristics such large cracks, risks from fallen objects, and possible pounding levels on the floor.

Sanborn maps, other parcel maps, or satellite pictures can be used to pace off or estimate the building's length and breadth during the planning stage. The building's size may be calculated by measuring and extrapolating repeating modules on the façade. The drawing has to show these guessed dimensions. Drawing the drawing to scale while in the field is typically not practicable for the screener. Screeners might wish to do a pencil drawing on a different piece of paper with grid for guide. In this situation, the drawing can be scanned and put on the form following the format of the form.

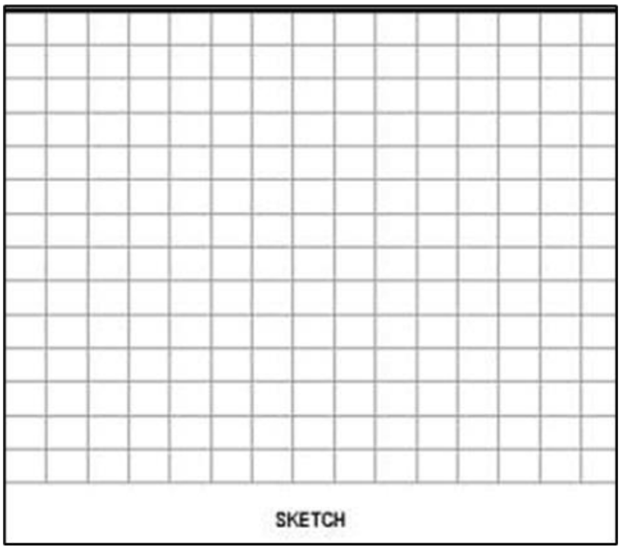

SKETCH

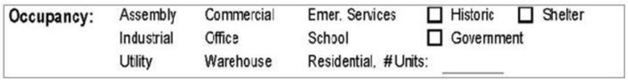
Figure 8. Sketch Portion of the Level 1 Data Collection Form

2.5.2.7 Building Occupancy

When a building is occupied, it is being used. This category for the structure is important to know the structure that needs to be prioritized.

2.5.2.8 Occupancy Classes

A brief visual screening revealed nine general occupancy classifications that are simple to identify. These classes are defined below.



Occupancy:	Assembly	Commercial	Emer. Services	☐ Historic	☐ Shelter
	Industrial	Office	School	☐ Government	
	Utility	Warehouse	Residential, #Units: ____		

Figure 9. Occupancy Portion of the Level 1 Data Collection Form

2.5.2.8.1 Assembly

Public assembly places are the ones where big crowds may congregate simultaneously in a single space. Building codes frequently utilize a threshold of 300 persons, and so do we here. Theaters, auditoriums, community centers, performance spaces, and churches are a few examples.

2.5.2.8.2 Commercial

Restaurants, parking structures, banking institutions, retail and wholesale enterprises, and other establishments fall under the commercial occupancy class.

2.5.2.8.3 Emergency Services

Any facility that would be required in a catastrophic disaster falls under the emergency services category. These include hospitals, telecommunication hubs, and police and fire stations.

2.5.2.8.4 Industrial

Factories, assembly lines, and large manufacturing facilities all fall within the industrial occupation class.

2.5.2.8.5 Office

Clerical, management, and professional services are typically located in office buildings.

2.5.2.8.6 Residential

Residential structures including homes, townhouses, dorms, motels, hotels, apartments, condos, and housing for the elderly or disabled are included in this occupancy class. On the line underneath the phrase "Residential," indicate how many apartments the building has.

2.5.2.8.7 School

Either available for the public or private institutions, ranging from prekindergarten through college level, fall under this occupation category.

2.5.2.8.8 Utility

Any structural utilities either private or for public, such as power source, facilities where they treat water for human use, and substations of electricity source, fall under this occupation class.

2.5.2.8.9 Warehouse

Used for storage of goods and commercial warehouses used for the sale of goods fall under this occupation type.

On the form, you should circle classification of occupancy that most accurately reflects the structure that is being assessed. All relevant kinds should be circled if the building has a variety of functions, such as commercial and residential. In the form's Building Identification section, you can provide the building's real usage.

2.5.2.9 Additional Designations

The building's historical significance, it might contain services related to the government, and if it is used as shelter when experiencing emergencies are all of extra relevance. These are not occupancy classes, but they can be used to determine the order in which hazards should be mitigated.

2.5.2.9.1 Historic

Might have a different specification depending on the community. It is mentioned due to the reason that historic structures could be governed by certain laws and regulations.

2.5.2.9.2 Government

Local, state, and federal non-emergency related structures are included in this.

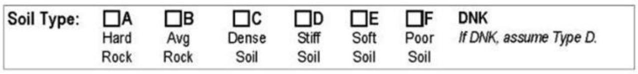
2.5.2.9.3 Shelter

There are certain structures that may be recognized as emergency shelters. The community could give these improvements a higher priority.

Encircling and checking the box is what the screeners need to do if the building falls under any of these categories.

2.5.2.10 Soil Type

During pre-field planning, the type of soil the type of soil is needed to be determined on the form. The screener must identify the soil type while visiting the building site if it was not done as part of that procedure. The screener will encircle the "DNK" and assume that the structure has a soil type D only if there is no information about the structures soil type.



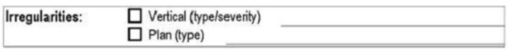
Soil Type:	☐A Hard Rock	☐B Avg Rock	☐C Dense Soil	☐D Stiff Soil	☐E Soft Soil	☐F Poor Soil	DNK *If DNK, assume Type D.*

Figure 10. Soil Type portion of the Level 1 Data Collection

2.5.2.11 Irregularities

Buildings are frequently asymmetrical for aesthetic, practical, or financial reasons. In buildings with business space on the ground level and flats above, the first floor is frequently higher than the stories above. On the two sides that face the street, a structure can have a lot of windows if it is on a corner. Id the demands are concentrated on specific floor levels, irregularities like these can make a structure have a negative impact when it comes to its seismic performance. The intense demands may result in harm, failure, and even collapse in some circumstances.

Vertical irregularities and plan irregularities are the two categories into which building irregularities are often divided. Vertical irregularities are further broken down for the Level 1 RVS method into severe and moderate. There are negative scores on the RVS, these values depend on the severity of the building's irregularity.

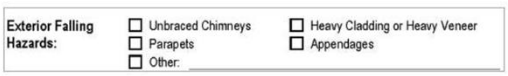


Irregularities: ☐ Vertical (type/severity) ☐ Plan (type)

Figure 11. Irregularity Portion of the Level 1 Data Collection Form

2.5.2.12 Plan Irregularities

Building made up of wood, tilt-up, pre-cast frame, reinforced masonry, and structures made up of bricks are the main areas of concern for this irregularity. A gravity load-carrying element's capability may be greatly reduced by damage at roof connections, which might cause partial or complete collapse. According to the Plan Irregularity Reference Guide, there are five typical forms of plan irregularities, as follows:



Exterior Falling Hazards: ☐ Unbraced Chimneys ☐ Parapets ☐ Other: ☐ Heavy Cladding or Heavy Veneer ☐ Appendages

Figure 12. Exterior Falling Hazards portion of the Level 1 Data Collection Form

2.5.2.12.1 Torsion

When there is a high or excellent lateral load resistance of a building on the opposite side but not on the other one or when the seismic force-resisting system exhibits significant stiffness eccentricities that might result in twisting or torsion along a Y axis. Torsion-causing plan flaws are particularly common in corner structures, where two of the street sides have sizable window openings while the other two are typically solid.

2.5.2.12.2 Non-Parallel Systems

Triangular-plan buildings with a wedge form that are located on corners of streets that don't meet at a 90-degree angle are also more prone to torsion, greater damage, and collapse.

2.5.2.12.3 Re-entrant Corners

Structures that are E, L, T, U, or + shaped and with projections of more than twenty are examples of structures with reentrant corners. At reentrant corners, stress concentrations can form and cause damage or collapse. These structures might perhaps endure torsion as well. The screener should, wherever feasible, determine if the intersection of the wings is subject to seismic separation. If so, it is possible to screen each section of the structure independently while taking pounding into account.

2.5.2.12.4 Diaphragm Openings

The distribution of earthquake forces to the vertical parts of the part that resist earthquake forces system is a critical function of a building's floors and roof. The diaphragm is weakened and loses some of its capacity to transmit seismic forces by large holes in the floors or roof. A huge aperture, as a general rule, is one that is wider than the diaphragm by more than 50%. These apertures are present for architectural elements like transparent roofs for skylight.

2.5.2.12.5 Beams do not align with columns

When the columns and beams on the exterior of the structure are not aligned or have a displacement. In concrete constructions, if surrounding of the column is not aligned to the beam is when this is applied.
If there is an irregularity seen, then the screener should mark the plan irregularity portion on the forms' irregularity portion.

2.5.2.13 Exterior Falling Hazards

If not securely fastened to the structure, non-structural falling dangers such chimneys, parapets, cornices, veneers, overhangs, and heavy cladding can endanger life.
Even though the building's fundamental seismic force-resisting system could be acceptable and not need any further inspection, the existence of such dangers could nevertheless put building inhabitants and bystanders in danger. The Exterior Falling Hazards section of the form has many checkboxes to make it easier for the screener to locate possible dangers.

Among the most dangerous falling risks are:

2.5.2.13.1 Unbraced Chimneys

This are very common to old houses; they usually have chimneys that are unreinforced and unbraced. They frequently have poor structural tying, which causes them to collapse during severe to moderate shaking. If a chimney's bracing or lack thereof is in question, proceed as though it is the latter.

2.5.2.13.2 Parapets

The section of the outer wall or façade that rises over the roof is known as a parapet. Parapets made of unreinforced masonry, including brick, stone, or concrete blocks, are the main cause for worry. There is a possibility for these parts to fall on the roof the neighboring buildings or on the street. It might be challenging to determine whether a façade rises over the line of the roof to create a parapet and, if one does, whether it is supported. On three sides of the building, parapets are frequently present, and their height is sometimes apparent from the rear of the building. In rare circumstances, satellite photography can be used to confirm the existence of bracing. It is safe to presume that the parapet made of URM is braced.

2.5.2.13.3 Heavy Cladding or Heavy Veneer

If not securely secured, large, bulky cladding components, most often made of cut stone or precast concrete, might come loose from the structure during an earthquake. In addition, the removal of panels might significantly alter the stiffness of the structure, leading to torsion or plan abnormalities when only few are lost. Masonry veneer may potentially pose a risk of falling if it is not securely fastened. As opposed to attached veneer, which makes use of partial thickness masonry units, there is more cause for worry with heavy veneer, such as full thickness bricks utilized as the façade material in front of wood frame structure. If the connections were made before the jurisdiction implemented seismic anchoring regulations (often based on forces that are double those for gravity loads), the presence of thick cladding or heavy veneer is cause for worry. The Supervising Engineer should decide when to implement such codes, which will depend on the jurisdiction, during the planning phases of the RVS process. The cladding connections may be safely engineered and not provide a threat if the structure was constructed after the enacted regulations.

2.5.2.13.4 Appendages

If not adequately secured, building apexes might come loose during an earthquake. These add-ons include canopies and architectural accents that provide the façade more depth and ornamental charm. Larger pieces that represent a substantial danger of falling provide a higher issue. If there are heavier appendages, just those should be ticked in the box.

2.5.2.13.5 Other

A falling danger that does not come under one of the aforementioned categories may be seen by the screener. If so, click the "Other" option, and if necessary, enter further information in the comments section and the area next to it. The relevant box (or boxes) should be checked if any of the nonstructural falling dangers mentioned above present. The comments area can be used to offer further information. It's also advised that you take a snapshot of the potential for falling objects. Later on, the RVS authorities may utilize this data to create a mitigation plan.

2.5.2.14 FEMA Building Types Considered and Basic Scores

On alphanumeric reference code are the types of buildings according to FEMA P-154.

- Buildings with a light wooden frame for single or multiple family with one or more floor levels (W1)
- Buildings with a floor area larger than three-thousand square feet with a light wooden frame (W1A)
- Buildings with a floor area larger than five-thousand square feet with a wooden frame (W2)
- Buildings with frames that are steel moment-resisting (S1)
- Buildings with frames that are braced steel (S2)
- Buildings made of light metal (S3)
- Buildings with frames with cast-in-place shear walls made of concrete (S4)
- Buildings with frames made of steel with unreinforced masonry infill walls (S5)
- Buildings with moment resisting frame made of concrete (C1)
- Buildings with sheer walls made of concrete (C2)
- Buildings with frames made of concrete with unreinforced masonry infill walls (C3)
- Tilt-up buildings (PC1)
- Buildings with frames made of precast concrete (PC2)
- Buildings that made of reinforced masonry with floor that is flexible and diaphragms on the roof (RM1)
- Buildings that made of reinforced masonry with floor that is rigid and diaphragms on the roof (RM2)
- Buildings made of unreinforced masonry bearing-wall (URM)
- Houses that are manufactured (MH)

For each FEMA structure Type, a Basic Score that depicts the anticipated possibility that a structure would collapse if it is subjected to risk-targeted maximum considered earthquake floor movements has been computed using existing damage and loss assessment methods.

The form includes the basic scores. According to seismicity, the scores change. As a result, each of the seismicity forms—Very High, High, Moderately High, Moderate, and Low—has a different set of fundamental scores.

The Basic Scores are applicable to structures constructed in Very High, High, Moderately High, and Moderate seismicity regions after the before the relatively recent considerable code update, seismic codes were first adopted and enforced. They apply to all structures built on a low seismic area, with the exception of those constructed after the relevant benchmark year, which is set at the pre-planning stage. Determining the year when the seismic regulation is introduced might be a crucial problem and is needed to be addressed in the planning stage. Score Modifiers on the form offer a way to change the Basic Score depending on the design and construction dates.

2.5.2.15 Identifying the FEMA Building Type

Finding the building type in accord to FEMA from the street is the main objective of the RVS method. When the type of building is determined the screener then encircle the alpha numeric code on the form and continue in encircling the score modifiers related to the structure.

2.5.2.16 Score Modifiers

The screener is prepared to use the scoring matrix to determine the buildings' RVS score after completing the top half of the Form and determined the type of building in accord to FEMA. The grading matrix offers the basic score and score modifiers pertaining to the quality's visual aspects of the building. Favorable Score Modifiers and an increase in score are associated with building qualities that have a more desired buildings' performance impact. Building attributes that have a negative buildings' performance impact have negative score modifiers, which lower the score.

The given Score Modifiers are dependent on the type of building in accord to FEMA since each building type has different performance structurally. The Score Modifier is marked with "N/A," which denotes that it is not relevant, if a performance attribute does not apply to a certain FEMA Building Type. The scoring matrix on the form lists the score modifiers connected to each architectural specification.

BASIC SCORE, MODIFIERS, AND FINAL LEVEL 1 SCORE, S_{L1}																	
FEMA BUILDING TYPE Do Not Know	W1	W1A	W2	S1 (MRF)	S2 (BR)	S3 (LM)	S4 (RC SW)	S5 (URM INF)	C1 (MRF)	C2 (SW)	C3 (URM INF)	PC1 (TU)	PC2	RM1 (FD)	RM2 (RD)	URM	MH
Basic Score	**3.6**	**3.2**	**2.9**	**2.1**	**2.0**	**2.6**	**2.0**	**1.7**	**1.5**	**2.0**	**1.2**	**1.6**	**1.4**	**1.7**	**1.7**	**1.0**	**1.5**
Severe Vertical Irregularity, V_{L1}	-1.2	-1.2	-1.2	-1.0	-1.0	-1.1	-1.0	-0.8	-0.9	-1.0	-0.7	-1.0	-0.9	-0.9	-0.9	-0.7	NA
Moderate Vertical Irregularity, V_{L1}	-0.7	-0.7	-0.7	-0.6	-0.6	-0.7	-0.6	-0.5	-0.5	-0.6	-0.4	-0.6	-0.5	-0.5	-0.5	-0.4	NA
Plan Irregularity, P_{L1}	-1.1	-1.0	-1.0	-0.8	-0.7	-0.9	-0.7	-0.6	-0.6	-0.8	-0.5	-0.7	-0.6	-0.7	-0.7	-0.4	NA
Pre-Code	-1.1	-1.0	-0.9	-0.6	-0.6	-0.8	-0.6	-0.2	-0.4	-0.7	-0.1	-0.5	-0.3	-0.5	-0.5	0.0	-0.1
Post-Benchmark	1.6	1.9	2.2	1.4	1.4	1.1	1.9	NA	1.9	2.1	NA	2.0	2.4	2.1	2.1	NA	1.2
Soil Type A or B	0.1	0.3	0.5	0.4	0.6	0.1	0.6	0.5	0.4	0.5	0.3	0.6	0.4	0.5	0.5	0.3	0.3
Soil Type E (1-3 stories)	0.2	0.2	0.1	-0.2	-0.4	0.2	-0.1	-0.4	0.0	0.0	-0.2	-0.3	-0.1	-0.1	-0.1	-0.2	-0.4
Soil Type E (> 3 stories)	-0.3	-0.6	-0.9	-0.6	-0.6	NA	-0.6	-0.4	-0.5	-0.7	-0.3	NA	-0.4	-0.5	-0.6	-0.2	NA
Minimum Score, S_{MIN}	1.1	0.9	0.7	0.5	0.5	0.6	0.5	0.5	0.3	0.3	0.3	0.2	0.2	0.3	0.3	0.2	1.0

Figure 13. Scoring Matrix Portion of the Level 1 Data Collection Form for High seismicity

2.5.2.16.1 Vertical Irregularity

If the structure has a vertical irregularity that is considered to be severe, then the severe vertical irregularity is encircled on the form. If the structure has a vertical irregularity that is considered as moderate only, then the moderate vertical irregularity is encircled on the form.

2.5.2.16.2 Plan Irregularity

If the screener found a plan irregularity in the structure being screened, then plan irregularity is encircled on the form.

2.5.2.16.3 Pre-Code

If a structure being screened was built before seismic codes are created, then this score modifier will be applied. The screener will determine the year when the structure was built during the preliminary phase. The Pre-Code Score Modifier will be encircled if the year of construction was earlier than the year seismic codes were made or introduced to the country. Buildings in regions with little seismic activity are not covered by this Score Modifier because of how the Basic Scores are determined.

2.5.2.16.4 Post-Benchmark

This Score Modifier is applied if the building being screened was planned and built after the local jurisdiction enacted and implemented considerably enhanced seismic codes applicable for that FEMA Building Type. The "benchmark" year is the one in which these advancements were made. During the pre-planning phase, benchmark year for the various FEMA Building Types need to have been determined and put to the Quick Reference Guide. The screener should contrast the year constructed with the benchmark year using the Quick Reference Guide. The screener applies the Post-Benchmark Score Modifier if the year-built is the same as or later than the benchmark year.

2.5.2.16.5 Soil Type

The screener circles the Soil Type A or B Score Modifier if Soil Type A or B was indicated in the Soil Type section of the form. Score Modifiers are also offered for Soil Type E. The Soil Type E for one to two stories Score Modifier is circled if Soil Type E has been found and there are three or less stories. The Soil Type E for more than three stories Score Modifier is circled by the screener if Soil Type E has and the structure fits that category.

Basic Scores were computed on the assumption of Soil Type CD, which is the average of Soil Types C and D. As a result, if any of the soil type is present or is determined, no Score Modifier is used. Because RVS cannot properly filter structures on Soil Type F, there is no Score Modifier for Soil Type F. The screener should write "Geologic hazards or Soil Type F" are present under the “Other risks section” of the form if the building is built on a soil with a type F. This will cause a Detailed Structural Evaluation to be performed on the structure.

2.5.2.16.6 Minimum Score, Smin

By assessing the likelihood of collapse while changing a single condition, individual score modifiers were created. Multiple Score Modifiers added together may overstate the aggregate impact of many variables and provide a final score that is less than to zero. A low score suggests a collapse probability larger than one-hundred percent, which is illogical.

A Minimum Score, Smin, is offered to remedy this. The worst conceivable confluence of type of the soil where the structure is built, vertical and plan imperfections, and age of the building was taken into account for determining the minimum score.

2.5.2.17 Determining the Final Level 1 Score

The structures’ encircled scores are added to the building's basic score to get the Final Level-one score, or SL1, for that structure. If the Minimum Score, SMIN, is greater than the total of the basic score and score that modifies, the screener should utilize the Minimum Score rather than the sum.

If the screener is not sure about the type of the building, then DNK should be encircled, if they have little or no confidence in whichever option they make for the structural system, as is the case with structures whose façade treatment is unknown. No SL1 score is calculated in this instance.

2.6 Data analysis

In line with the preliminary stage, the researchers will utilize the assessment technique in the actual site. Seismic zone 4, which corresponds to most of the nation, may be calculated to account for 40%, or 0.4g, of the gravity-related acceleration in terms of equivalent spectral acceleration. Table 1 displays the seismicity levels and associated spectrum acceleration response. After completing the structures information part on the form, the vital components of the final score will be accordingly recognized. The final score can be used to assess if a structure requires further inspection.

Table 1. Seismicity Region

Seismicity Region	Spectral Acceleration Response, S_S (short-period, or 0.2 seconds)	Spectral Acceleration Response, S_1 (long-period, or 1.0 second)
Low	less than 0.250g	less than 0.100g
Moderate	greater than or equal to 0.250g but less than 0.500g	greater than or equal to 0.100g but less than 0.200g
Moderately High	greater than or equal to 0.500g but less than 1.000g	greater than or equal to 0.200g but less than 0.400g
High	greater than or equal to 1.000g but less than 1.500g	greater than or equal to 0.400g but less than 0.600g
Very High	greater than or equal to 1.500g	greater than or equal to 0.600g

Note. From Table 2.2 in Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook (Third Edition), p. 34.

2.6.1 Grades of Damageability

Based on the data that will be gathered during the survey, a score will be derived to give an indication of the structure's likely seismic performance. The seismic vulnerability of San Guillermo Parish Church and San Agustin Parish Church will be classified using this way. The grade of damageability, which relates to the type of destruction the building would experience, will be used to calculate the expected damage level, this is a function of the RVS score and is included in the final building score.

Table 2 illustrates the structural damage graded according to the influence of the ground movement on the building using the European macro seismic scale (EMS-98). The following categories are used to classify these damages: grade one for no structural damage, slight non-structural damage, grade two for slight structural damage, moderate non-structural damage, grade three for moderate structural damage, heavy non-structural damage, grade four for very heavy structural damage and grade five for destruction.

Table 2. Damage Grade

Grade	Description
Grade 1	Negligible to slight damage
Grade 2	Moderate damage
Grade 3	Substantial to heavy damage
Grade 4	Very heavy damage
Grade 5	Destruction

Note. From From Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook (Third Edition)

2.6.2 Damage Level

Table 3 illustrates indicators for the anticipated behavior of a structure when it comes to earthquake. A score of S 0.7 generally indicates a structure is highly vulnerable and needs to be retrofitted. The final RVS score serves as the foundation for the various damageability grades assigned to each building

Table 3. Damage Level

RVS Score	Potential Damage
S<0.30	High probability of Grade 5 damage, very high probability of Grade 4 damage
0.30<S<0.70	High probability of Grade 4 damage, very high probability of Grade 3 damage
0.70<S<2.0	High probability of grade 3 damage, very high probability of Grade 2 damage
2.0<S<3.0	High probability of Grade 2 damage, very high probability of Grade 1 damage
S>3.0	Probability of grade 1 damage

Note. From From Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook (Third Edition)

3. RESULTS AND DISCUSSIONS

The screening and survey results that were conducted and covered in the previous chapter will be discussed in this chapter. The outcome will make reference to the information acquired from the Rapid Visual screening and the completed survey questionnaires. The discussion of the effects of the aforementioned churches' vulnerability is also included. The results of the survey will be compared in terms of perception between the community and a registered civil engineer.

3.1 Determining the Final Level 1 Score

The researchers conducted a survey with the use of form and analyzed the results on what causes these churches to be vulnerable based on buildings' design structurally. There were two churches that were assessed using the high seismicity level. Both of the churches were built using unreinforced masonry bearing wall buildings. This is a typical way of how historic churches were built in the Philippines.

3.1.1 Data Analysis

Based on the Seismicity Region Table, Pampanga is categorized as a highly seismic region with a Spectral Acceleration Response of 0.40.

3.1.2 Grades of Damageability

Results revealed that the SGPC and SAPC both scored 0.6 and lie in damage grade 3 which results in substantial to heavy damage, which means it is needed for a detailed evaluation and retrofitting.

3.2 Assessment of San Guillermo Parish Church

The screeners observed the San Guillermo Parish Church as a whole and began the process of verifying the information in the building identification portion of the form (upper right corner), starting with the address, zip code and building name. The screeners added the date and time of the field screening to the building identification portion of the form. The number of story (1) was confirmed by inspection, and the year built noted on the form (1576). The church's floor dimensions were determined by using a tape measure, and they were 195.75 feet by 53.083 feet. Based on this, the screeners calculated a floor area of 10390.99725 square feet.

Sketch of the church was drawn in the "Sketch" portion of the form. Several digital photographs were taken to be added to the form later. The building use (assembly) and the additional designation (historic) were circled and marked respectively in the "Occupancy" portion of the form

The next step for the screener was to identify any vertical or plan irregularities. The screeners consulted the Vertical and Plan Irregularity Reference Guides and found that Plan irregularity (reentrant corners) is applicable to the San Guillermo Parish Church being screened. The screeners observed an exterior falling hazard that does not fit into any of the categories. So, they marked the box which says "Other" and specified the nonstructural falling hazard which is cornice. The next step in the process was to circle the appropriate Basic Score and the appropriate Score Modifiers. Plan irregularity was observed, so plan irregularity modifier was circled.

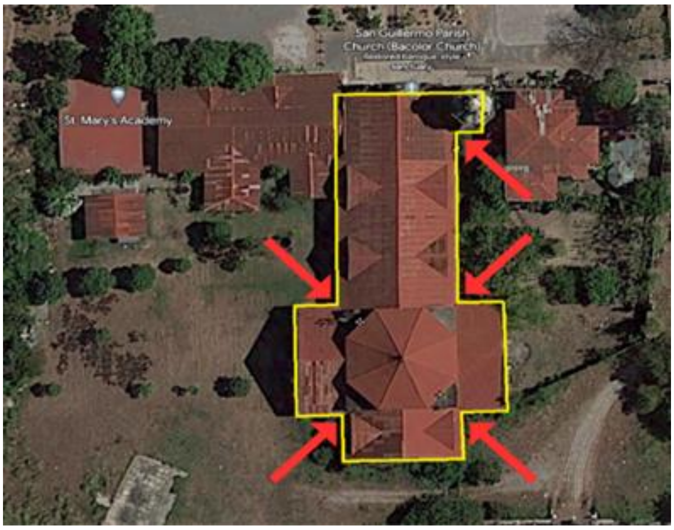
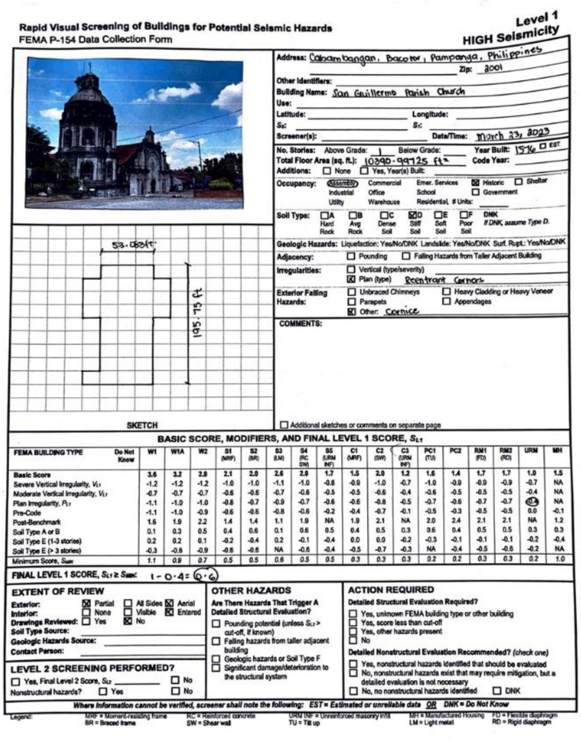


Figure 14. Aerial View of San Guillermo Parish Church, Note. Retrieved from Google Maps, April 10, 2023

Figure 14 shows the aerial view of San Guillermo Parish Church through the use of a mapping and navigation application, wherein the church plan irregularity is seen. The church has a cross shape pattern and is considered as a building with reentrant corners. This type of building is more prone to cracking on the corners. Arrows indicate possible areas of damage.

Since the building is on Soil Type D, no soil modifiers were applied. The Final Level 1 Score, SL1, was determined to be 1.0. The screeners noted that no Level 2 screening was performed. Figure 13 shows the completed form for San Guillermo Parish Church including the photograph that was added digitally at a later date.



Rapid Visual Screening of Buildings for Potential Seismic Hazards
FEMA P-154 Data Collection Form

Level 1
HIGH Seismicity

Address: Cabambangan, Bacolor, Pampanga, Philippines
Zip: 2001
Other Identifiers:
Building Name: San Guillermo Parish Church
Use:
Latitude: **Longitude:**
S_S: S_1:
Screener(s): **Date/Time:** March 23, 2023
No. Stories: Above Grade: 1 Below Grade: **Year Built:** 1576 ☐ EST
Total Floor Area (sq. ft.): 10390.99125 ft² **Code Year:**
Additions: ☐ None ☐ Yes, Year(s) Built:
Occupancy: (Assembly) Commercial Emer. Services ☒ Historic ☐ Shelter Industrial Office School ☐ Government Utility Warehouse Residential, # Units:
Soil Type: ☐A Hard Rock ☐B Avg Rock ☐C Dense Soil ☒D Stiff Soil ☐E Soft Soil ☐F Poor Soil DNK If DNK, assume Type D.
Geologic Hazards: Liquefaction: Yes/No/DNK Landslide: Yes/No/DNK Surf. Rupt.: Yes/No/DNK
Adjacency: ☐ Pounding ☐ Falling Hazards from Taller Adjacent Building
Irregularities: ☐ Vertical (type/severity) ☒ Plan (type) Reentrant Corners
Exterior Falling Hazards: ☐ Unbraced Chimneys ☐ Heavy Cladding or Heavy Veneer ☐ Parapets ☐ Appendages ☒ Other: Cornice
COMMENTS:
☐ Additional sketches or comments on separate page

SKETCH: 53.083 ft; 195.75 ft

BASIC SCORE, MODIFIERS, AND FINAL LEVEL 1 SCORE, S_{L1}

FEMA BUILDING TYPE	Do Not Know	W1	W1A	W2	S1 (MRF)	S2 (BR)	S3 (LM)	S4 (RC SW)	S5 (URM INF)	C1 (MRF)	C2 (SW)	C3 (URM INF)	PC1 (TU)	PC2	RM1 (FD)	RM2 (RD)	URM	MH
Basic Score		3.6	3.2	2.9	2.1	2.0	2.6	2.0	1.7	1.5	2.0	1.2	1.6	1.4	1.7	1.7	1.0	1.5
Severe Vertical Irregularity, V_{L1}		-1.2	-1.2	-1.2	-1.0	-1.0	-1.1	-1.0	-0.8	-0.9	-1.0	-0.7	-1.0	-0.9	-0.9	-0.9	-0.7	NA
Moderate Vertical Irregularity, V_{L1}		-0.7	-0.7	-0.7	-0.6	-0.6	-0.7	-0.6	-0.5	-0.5	-0.6	-0.4	-0.6	-0.5	-0.5	-0.5	-0.4	NA
Plan Irregularity, P_{L1}		-1.1	-1.0	-1.0	-0.8	-0.7	-0.9	-0.7	-0.6	-0.6	-0.8	-0.5	-0.7	-0.6	-0.7	-0.7	(-0.4)	NA
Pre-Code		-1.1	-1.0	-0.9	-0.6	-0.6	-0.8	-0.6	-0.2	-0.4	-0.7	-0.1	-0.5	-0.3	-0.5	-0.5	0.0	-0.1
Post-Benchmark		1.6	1.9	2.2	1.4	1.4	1.1	1.9	NA	1.9	2.1	NA	2.0	2.4	2.1	2.1	NA	1.2
Soil Type A or B		0.1	0.3	0.5	0.4	0.6	0.1	0.6	0.5	0.4	0.5	0.3	0.6	0.4	0.5	0.5	0.3	0.3
Soil Type E (1-3 stories)		0.2	0.2	0.1	-0.2	-0.4	0.2	-0.1	-0.4	0.0	0.0	-0.2	-0.3	-0.1	-0.1	-0.1	-0.2	-0.4
Soil Type E (> 3 stories)		-0.3	-0.6	-0.9	-0.6	-0.6	NA	-0.6	-0.4	-0.5	-0.7	-0.3	NA	-0.4	-0.5	-0.6	-0.2	NA
Minimum Score, S_{MIN}		1.1	0.9	0.7	0.5	0.5	0.6	0.5	0.5	0.3	0.3	0.3	0.2	0.2	0.3	0.3	0.2	1.0

FINAL LEVEL 1 SCORE, $S_{L1} \geq S_{MIN}$: 1 - 0.4 = (0.6)

EXTENT OF REVIEW
Exterior: ☒ Partial ☐ All Sides ☒ Aerial
Interior: ☐ None ☐ Visible ☒ Entered
Drawings Reviewed: ☐ Yes ☒ No
Soil Type Source:
Geologic Hazards Source:
Contact Person:

LEVEL 2 SCREENING PERFORMED?
☐ Yes, Final Level 2 Score, S_{L2} ______ ☐ No
Nonstructural hazards? ☐ Yes ☐ No

OTHER HAZARDS
Are There Hazards That Trigger A Detailed Structural Evaluation?
☐ Pounding potential (unless S_{L2} > cut-off, if known)
☐ Falling hazards from taller adjacent building
☐ Geologic hazards or Soil Type F
☐ Significant damage/deterioration to the structural system

ACTION REQUIRED
Detailed Structural Evaluation Required?
☐ Yes, unknown FEMA building type or other building
☐ Yes, score less than cut-off
☐ Yes, other hazards present
☐ No
Detailed Nonstructural Evaluation Recommended? *(check one)*
☐ Yes, nonstructural hazards identified that should be evaluated
☐ No, nonstructural hazards exist that may require mitigation, but a detailed evaluation is not necessary
☐ No, no nonstructural hazards identified ☐ DNK

Where information cannot be verified, screener shall note the following: EST = Estimated or unreliable data OR DNK = Do Not Know

Legend: MRF = Moment-resisting frame; BR = Braced frame; RC = Reinforced concrete; SW = Shear wall; URM INF = Unreinforced masonry infill; TU = Tilt up; MH = Manufactured Housing; LM = Light metal; FD = Flexible diaphragm; RD = Rigid diaphragm

Figure 15. Completed Level 1 Data Collection Form for the San Guillermo Parish Church

3.3 Assessment of San Agustin Parish Church

The screeners observed the San Agustin Parish Church as a whole and began the process of verifying the information in the building identification portion of the form (upper right corner), starting with the address, zip code and building name. The screeners added the date and time of the field screening to the building identification portion of the form. The number of story (1) was confirmed by inspection, and the year built noted on the form (1572). The church's floor dimensions were determined by using a tape measure, and they were 231 feet by 56.5 feet. Based on this, the screeners calculated a floor area of 13051.5 square feet.

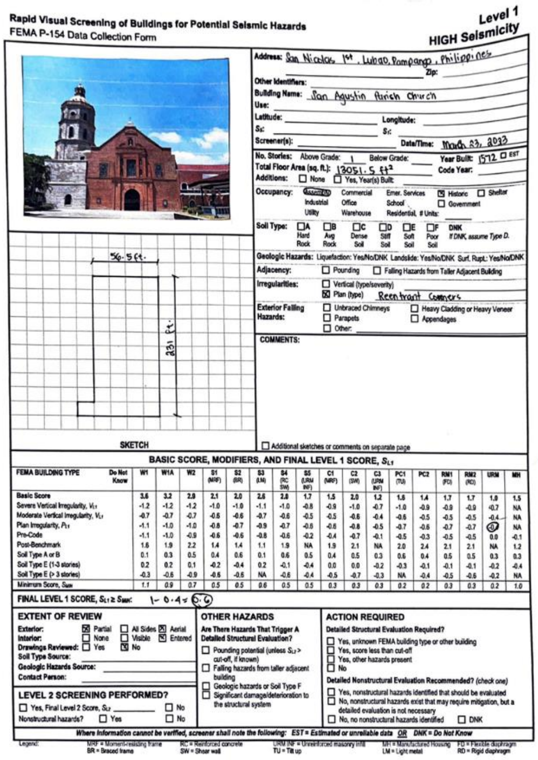
Sketch of the church was drawn in the "Sketch" portion of the form. Several digital photographs were taken to be added to the form later. The building use (assembly) and the additional designation (historic) were circled and marked respectively in the "Occupancy" portion of the form.

The next step for the screener was to identify any vertical or plan irregularities. The screener consulted the Vertical and Plan Irregularity Reference Guides and found that Plan irregularity (reentrant corners) is applicable to the San Guillermo Parish Church being screened. The next step in the process was to circle the appropriate Basic Score and the appropriate Score Modifiers. Plan irregularity was observed, so plan irregularity modifier was circled.

Figure 16. Aerial View of San Agustin Parish Church, Note. Retrieved from Google Maps, April 10, 2023

Figure 16 shows the aerial view of San Agustin Parish Church through the use of a mapping and navigation application. The church has a plan irregularity having an L shape pattern and is considered to have reentrant corners where damage is more prone and visible to the corners. Arrows indicate possible areas of damage.

Since the building is on Soil Type D, no soil modifiers were applied. The Final Level 1 Score, SL1, was determined to be 1.0. The screeners noted that no Level 2 screening was performed. Figure 15 shows the completed form for San Guillermo Parish Church including the photograph that was added digitally at a later date.



Rapid Visual Screening of Buildings for Potential Seismic Hazards
FEMA P-154 Data Collection Form

Level 1
HIGH Seismicity

Address: San Nicolas 1st, Lubao, Pampanga, Philippines
Zip:
Other Identifiers:
Building Name: San Agustin Parish Church
Use:
Latitude: Longitude:
S_S: S_1:
Screener(s): Date/Time: March 23, 2023
No. Stories: Above Grade: 1 Below Grade: Year Built: 1572 ☐ EST
Total Floor Area (sq. ft.): 13051.5 ft² Code Year:
Additions: ☐ None ☐ Yes, Year(s) Built:
Occupancy: (Assembly) Commercial Emer. Services ☒ Historic ☐ Shelter
Industrial Office School ☐ Government
Utility Warehouse Residential, # Units:
Soil Type: ☐A Hard Rock ☐B Avg Rock ☐C Dense Soil ☐D Stiff Soil ☐E Soft Soil ☐F Poor Soil DNK If DNK, assume Type D.
Geologic Hazards: Liquefaction: Yes/No/DNK Landslide: Yes/No/DNK Surf. Rupt.: Yes/No/DNK
Adjacency: ☐ Pounding ☐ Falling Hazards from Taller Adjacent Building
Irregularities: ☐ Vertical (type/severity)
☒ Plan (type) Reentrant Corners
Exterior Falling Hazards: ☐ Unbraced Chimneys ☐ Heavy Cladding or Heavy Veneer
☐ Parapets ☐ Appendages
☐ Other:
COMMENTS:

56.5 ft.
231 ft.
SKETCH

☐ Additional sketches or comments on separate page

BASIC SCORE, MODIFIERS, AND FINAL LEVEL 1 SCORE, S_{L1}

FEMA BUILDING TYPE	Do Not Know	W1	W1A	W2	S1 (MRF)	S2 (BR)	S3 (LM)	S4 (RC SW)	S5 (URM INF)	C1 (MRF)	C2 (SW)	C3 (URM INF)	PC1 (TU)	PC2	RM1 (FD)	RM2 (RD)	URM	MH
Basic Score		3.6	3.2	2.9	2.1	2.0	2.6	2.0	1.7	1.5	2.0	1.2	1.6	1.4	1.7	1.7	1.0	1.5
Severe Vertical Irregularity, V_{L1}		-1.2	-1.2	-1.2	-1.0	-1.0	-1.1	-1.0	-0.8	-0.9	-1.0	-0.7	-1.0	-0.9	-0.9	-0.9	-0.7	NA
Moderate Vertical Irregularity, V_{L1}		-0.7	-0.7	-0.7	-0.6	-0.6	-0.7	-0.6	-0.5	-0.5	-0.6	-0.4	-0.6	-0.5	-0.5	-0.5	-0.4	NA
Plan Irregularity, P_{L1}		-1.1	-1.0	-1.0	-0.8	-0.7	-0.9	-0.7	-0.6	-0.6	-0.8	-0.5	-0.7	-0.6	-0.7	-0.7	-0.7	NA
Pre-Code		-1.1	-1.0	-0.9	-0.6	-0.6	-0.8	-0.6	-0.2	-0.4	-0.7	-0.1	-0.5	-0.3	-0.5	-0.5	0.0	-0.1
Post-Benchmark		1.6	1.9	2.2	1.4	1.4	1.1	1.9	NA	1.9	2.1	NA	2.0	2.4	2.1	2.1	NA	1.2
Soil Type A or B		0.1	0.3	0.5	0.4	0.6	0.1	0.6	0.5	0.4	0.5	0.3	0.6	0.4	0.5	0.5	0.3	0.3
Soil Type E (1-3 stories)		0.2	0.2	0.1	-0.2	-0.4	0.2	-0.1	-0.4	0.0	0.0	-0.2	-0.3	-0.1	-0.1	-0.1	-0.2	-0.4
Soil Type E (> 3 stories)		-0.3	-0.6	-0.9	-0.6	-0.6	NA	-0.6	-0.4	-0.5	-0.7	-0.3	NA	-0.4	-0.5	-0.6	-0.2	NA
Minimum Score, S_{MIN}		1.1	0.9	0.7	0.5	0.5	0.6	0.5	0.5	0.3	0.3	0.3	0.2	0.2	0.3	0.3	0.2	1.0

FINAL LEVEL 1 SCORE, $S_{L1} \geq S_{MIN}$: 1 - 0.4 = 0.6

EXTENT OF REVIEW
Exterior: ☒ Partial ☐ All Sides ☒ Aerial
Interior: ☐ None ☐ Visible ☒ Entered
Drawings Reviewed: ☐ Yes ☒ No
Soil Type Source:
Geologic Hazards Source:
Contact Person:

LEVEL 2 SCREENING PERFORMED?
☐ Yes, Final Level 2 Score, S_{L2} ____ ☐ No
Nonstructural hazards? ☐ Yes ☐ No

OTHER HAZARDS
Are There Hazards That Trigger A Detailed Structural Evaluation?
☐ Pounding potential (unless S_{L2} > cut-off, if known)
☐ Falling hazards from taller adjacent building
☐ Geologic hazards or Soil Type F
☐ Significant damage/deterioration to the structural system

ACTION REQUIRED
Detailed Structural Evaluation Required?
☐ Yes, unknown FEMA building type or other building
☐ Yes, score less than cut-off
☐ Yes, other hazards present
☐ No
Detailed Nonstructural Evaluation Recommended? (check one)
☐ Yes, nonstructural hazards identified that should be evaluated
☐ No, nonstructural hazards exist that may require mitigation, but a detailed evaluation is not necessary
☐ No, no nonstructural hazards identified ☐ DNK

Where information cannot be verified, screener shall note the following: EST = Estimated or unreliable data OR DNK = Do Not Know

Legend: MRF = Moment-resisting frame, BR = Braced frame, RC = Reinforced concrete, SW = Shear wall, URM INF = Unreinforced masonry infill, TU = Tilt up, MH = Manufactured Housing, LM = Light metal, FD = Flexible diaphragm, RD = Rigid diaphragm

Figure 17. Completed Level 1 Data Collection Form for the San Agustin Parish Church

3.4 Static Analysis

When an earthquake occurs, old churches can experience various types of damage due to the shaking of the ground. In the Philippines, which is located in a seismically active region, historical churches are particularly vulnerable to seismic events. Some of the possible effects of earthquakes to SGPC and SAPC 4are the following.

Structural damage, the primary concern during an earthquake is the structural integrity of the church. Seismic shaking can cause cracks or partial collapses in walls, columns, arches, and roofs. Vulnerable areas include masonry walls, stone or brickwork, and unreinforced elements that may not have been designed to withstand seismic forces.

Foundation failure, churches with compromised or inadequate foundations are at greater risk during earthquakes. The shaking can cause the foundation to shift, settle unevenly, or fail altogether, leading to structural instability and potential collapse.

Damage to architectural elements, elaborate architectural features, such as delicate sculptures, intricate ornaments, and stained-glass windows, can be damaged or destroyed during an earthquake. The shaking can cause these elements to detach from the main structure or suffer structural failures.

Bell tower collapse, many historical churches in the Philippines feature bell towers that are separate from the main building. These tall structures can be particularly vulnerable during seismic events and may collapse or suffer significant damage, endangering nearby structures and people.

Loss of interior contents, earthquakes can cause the displacement or destruction of valuable religious artifacts, including altars, statues, paintings, and other decorations. These losses can be devastating to the cultural and religious heritage associated with the church.

Soil liquefaction, in areas with loose or saturated soil, earthquakes can induce a phenomenon called liquefaction. This occurs when the ground temporarily loses its strength and behaves like a liquid. Liquefaction can lead to the sinking or tilting of structures, including church buildings.

It is important to note that the vulnerability of an old church to earthquakes depends on various factors, such as its age, construction techniques, maintenance history, and previous retrofitting efforts.

3.5 Validation of the Completed Level 1 Data Collection Form

A structural engineer in active practice in the area with training in risk analysis and seismic evaluation should serve as the supervising engineer. Ideally, the engineer that supervised the screeners will also have knowledge of the FEMA rapid visual screening technique. If the engineer that supervised the screeners is unfamiliar with the technical underpinnings of FEMA P-154, he or she should examine FEMA P-154 in order to get that expertise.

The Supervising Engineer, Trisha Anne Y. Guiao, RCE, reviewed the content of FEMA P-154. The researchers conferred the Rapid Visual Screening results together with images that served as a basis for their findings. After thorough review of the findings, the Supervising Engineer validated the results of the accomplished forms.

3.6 Community Survey

The community questionnaire contained five closed-ended questions. Designing the questionnaire in this way allowed the researchers to generate a high survey response rate and rapidly collect large quantities of data.

The purpose of the questionnaire was to determine the perceptions of the community regarding the seismic vulnerabilities of the two churches, the SGPC and the SAPC.

3.6.1 Respondents of the Study

Table 4. Total Population of Barangay Cabambangan, Bacolor, Pampanga

Barangay Cabambangan	
Total Population	705
Total Population (0-14 yrs. old)	188
Total Population (15 and above yrs. old)	517

Note. From "Age-Specific Population Projection, 2022, Region 3," by DOH, p. 26.

Table 5. Total Population of Barangay San Nicolas 1st, Lubao, Pampanga

Barangay San Nicolas 1st	
Total Population	3,389
Total Population (0-14 yrs. old)	904
Total Population (15 and above yrs. old)	2,485

Note. From "Age-Specific Population Projection, 2022, Region 3," by DOH, p. 28.

$$n = \frac{N}{1 + Ne^2}$$

$$n = \frac{517}{1 + (517)(0.05)^2}$$

$$n = 226 \text{ Respondents from Barangay Cabambangan}$$

$$n = \frac{N}{1 + Ne^2}$$

$$n = \frac{2485}{1 + (2485)(0.05)^2}$$

$$n = 345 \text{ Respondents from Barangay San Nicolas 1st}$$

The respondents were chosen using Slovin's formula. The survey included 226 respondents from the 517 residents of barangay Cabambangan in Bacolor, Pampanga, ranging between 15 and 65 years old and above, and 345 respondents from the 2485 residents of barangay San Nicolas 1st in Lubao, Pampanga, ranging between 15 and 65 years old and above.

Table 6. Demographic Profile of Brgy. Cabambangan, Bacolor, Pampanga

Age Range	Number of Respondents
15 – 24 Years Old	38
25 – 44 Years Old	115
45 – 64 Years Old	67
65 Years Old and Above	6
TOTAL	226

Table 6 shows the demographic profile of Brgy. Cabambangan, Bacolor, Pampanga. There were 38 respondents between the ages of 15 and 24 years old, 115 respondents between the ages of 25 and 44 years old, 67 respondents between the ages of 45 and 64 years old, and 6 respondents between the ages of 65 and above.

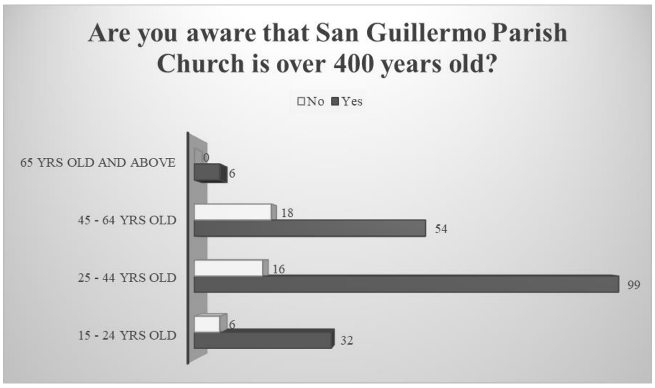


Figure 18. The number of people who are aware that the San Guillermo Parish Church is over 400 years old.

Figure 18 shows that between ages 15 and 24, 32 respondents are well aware that San Guillermo Parish Church is over 400 years old while 6 others are not; between ages 25 and 44, 99 respondents are well aware that San Guillermo Parish Church is over 400 years old while 16 others are not; between ages 45 and 64, only 54 respondents are well aware that San Guillermo Parish Church is over 400 years old while 13 others are not; and lastly, for ages 65 and above, only 6 respondent are well aware that San Guillermo Parish Church is over 400 years old.

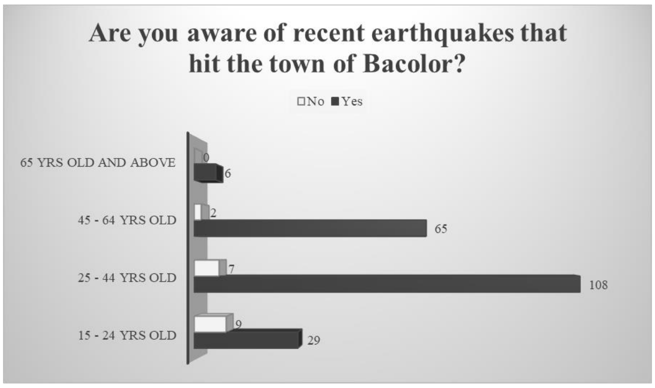


Figure 19. The number of people who are aware of the Recent earthquakes that hit the Town of Bacolor, Pampanga.

Figure 19 shows that between ages 15 and 24, only 29 respondents are well aware of the recent earthquakes that recently hit the town of Bacolor, Pampanga, while 9 respondents are not; in the age group of 25 and 44, only 108 respondents are aware of the recent earthquakes and 7 are not; in the age group of 45 and 64, only 65 respondents are aware of the recent earthquakes and 2 are not; and in the age group of 65 and older, only 6 respondents are aware of the recent earthquakes.

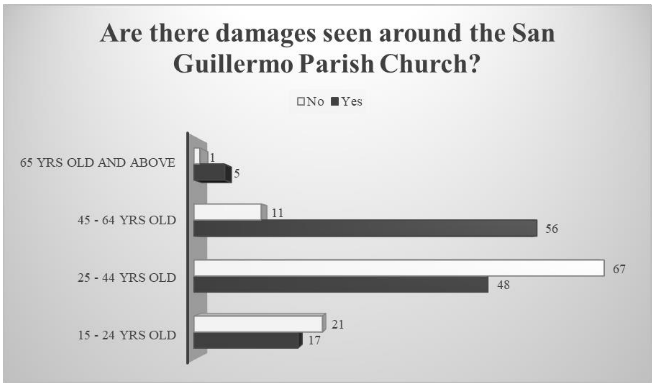


Figure 20. The number of people who have seen damages around San Guillermo Parish Church

Figure 20 shows that between ages 15 and 24, only 17 respondents have seen damages around the San Guillermo Parish Church, while 21 respondents have not; in the age group of 25 and 44, only 48 respondents have seen damages and 67 have not; in the age group of 45 and 64, 56 respondents have seen damages and only 11 have not; and in the age group of 65 and older, 5 respondents have seen damages and only 1 has not.

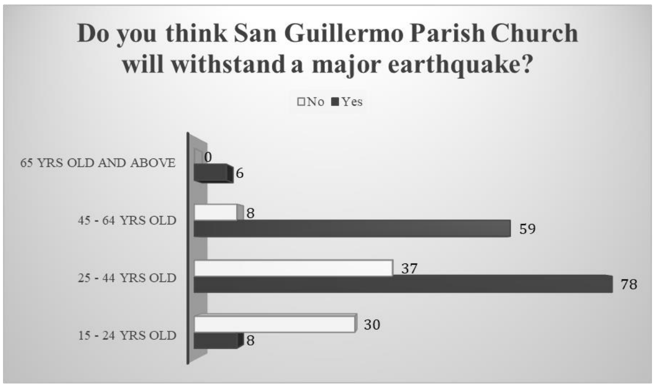


Figure 21. The number of people who think that San Guillermo Parish Church will withstand a major earthquake

Figure 21 shows that between ages 15 and 24, only 8 respondents think that San Guillermo Parish Church will withstand a major earthquake, while 30 respondents think it will not; in the age group of 25 and 44, 78 respondents think that San Guillermo Parish Church will withstand a major earthquake and only 37 respondents think it will not; in the age group of 45 and 64, 59 respondents think that San Guillermo Parish Church will withstand a major earthquake and only 8 respondents think it will not; and in the age group of 65 and older, 6 respondents think that San Guillermo Parish Church will withstand a major earthquake.

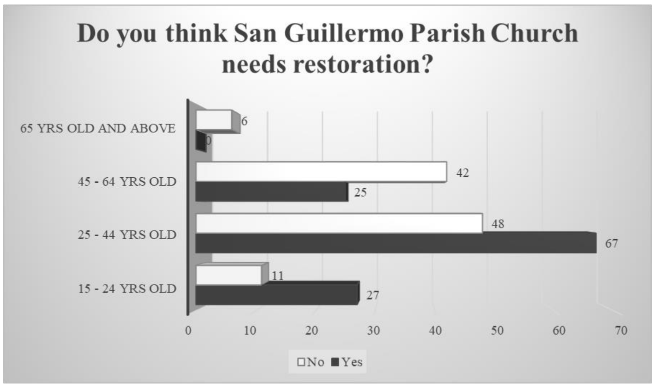


Figure 22. The number of people who think that San Guillermo Parish Church needs to undergo restoration

Figure 22 shows that between ages 15 and 24, only 27 respondents think that San Guillermo Parish Church needs restoration, while 11 respondents do not; in the age group of 25 and 44, only 67 respondents think that San Guillermo Parish Church needs restoration, while 48 respondents do not; in the age group of 45 and 64, only 25 respondents think that San Guillermo Parish Church needs restoration, while 42 respondents do not; and in the age group of 65 and above, all 6 respondents think that San Guillermo Parish Church doesn't need restoration.

Table 7. Demographic Profile of Brgy. San Nicolas 1st, Lubao, Pampanga

Age Range	Number of Respondents
15 – 24 Years Old	158
25 – 44 Years Old	104
45 – 64 Years Old	72
65 Years Old and Above	11
TOTAL	345

Table 7 shows the demographic profile of Brgy. San Nicolas 1st, Lubao, Pampanga. There were 158 respondents between the ages of 15 and 24 years old, 104 respondents between the ages of 25 and 44 years old, 72 respondents between the ages of 45 and 64 years old, and 11 respondents between the ages of 65 and above.

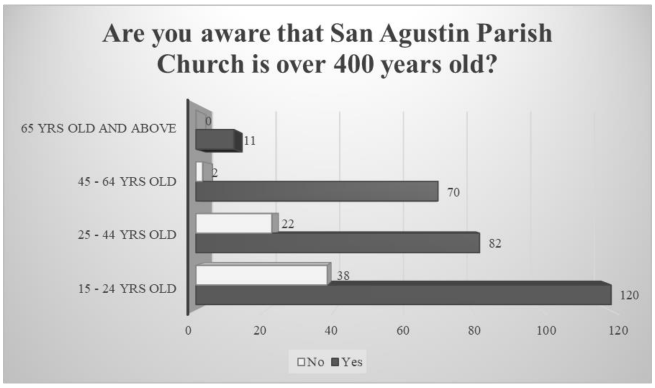


Figure 23. The number of people who are aware of the San Agustin Parish Church is over 400 years old

Figure 23 shows that between ages 15 and 24, only 120 respondents are well aware that San Agustin Parish Church is over 400 years old, while 38 respondents are not. In ages between 25 and 44, only 82 respondents are well aware that San Agustin Parish Church is over 400 years old, while 22 respondents are not. In ages between 45 and 64, only 70 respondents are well aware that San Agustin Parish Church is over 400 years old, while 2 respondents are not. Lastly, for ages 65 and above, 11 respondents are well aware that San Agustin Parish Church is over 400 years old.

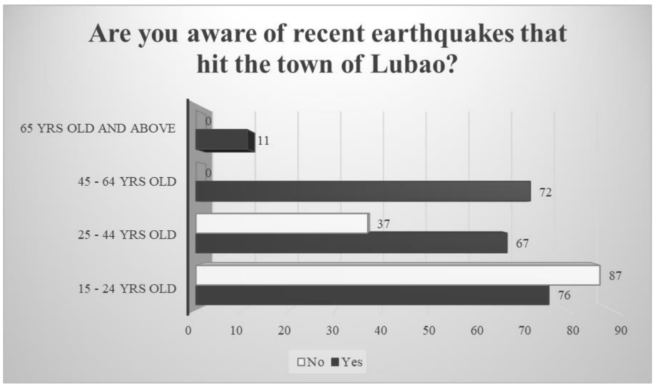


Figure 24. The number of people who are aware of the Recent earthquakes that hit the Town of Lubao, Pampanga

Figure 24 shows that between ages 15 and 24 only 76 respondents are aware of the recent earthquakes that hit Lubao, Pampanga, while 82 respondents are not. In ages between 25 and 44, 67 respondents are aware of the recent earthquakes that hit Lubao, Pampanga, while only 37 are not. In ages between 45 and 64, all respondents are aware of the recent earthquakes that hit Lubao, Pampanga. Lastly, for ages 65 and above, all respondents are aware of the recent earthquakes that hit Lubao.

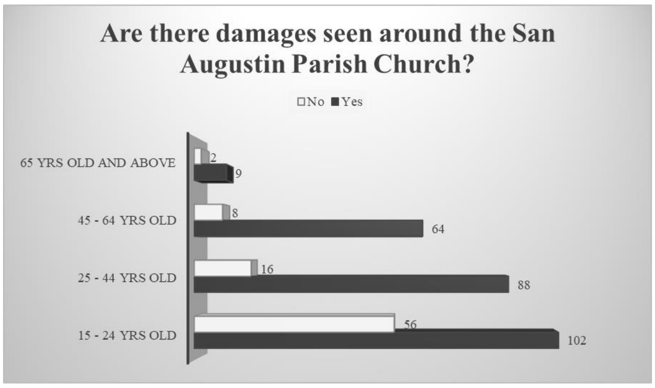


Figure 25. The number of people who have seen damage around San Agustin Parish Church

Figure 25 shows that between ages 15 and 24, 102 respondents have seen damages around San Agustin Parish Church while only 56 have not. In the age group of 25 and 44, 88 respondents have seen damages while only 16 have not. In the age group of 45 and 64, 64 respondents have seen damages while only 8 have not. In the age group of 65 and above, 9 respondents have seen damages while only 2 have not.

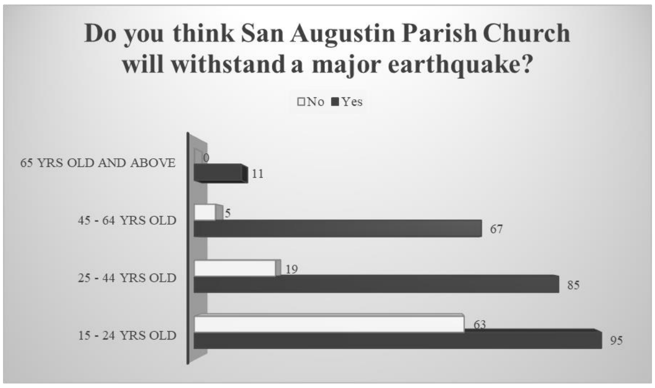


Figure 26. The number of people who think that San Agustin Parish Church will withstand a major earthquake

Figure 26 shows that between ages 15 and 24, 95 respondents think that San Agustin Parish Church will withstand a major earthquake while only 63 respondents think it will not. In the age group of 25 and 44, 85 respondents think that San Agustin Parish Church will withstand a major earthquake and only 19 respondents think it will not. In the age group of 45 and 64, 67 respondents think that San Agustin Parish Church will withstand a major earthquake and only 5 respondents think it will not. Lastly, in the age group of 65 and older, all respondents think that San Agustin Parish Church will withstand a major earthquake.

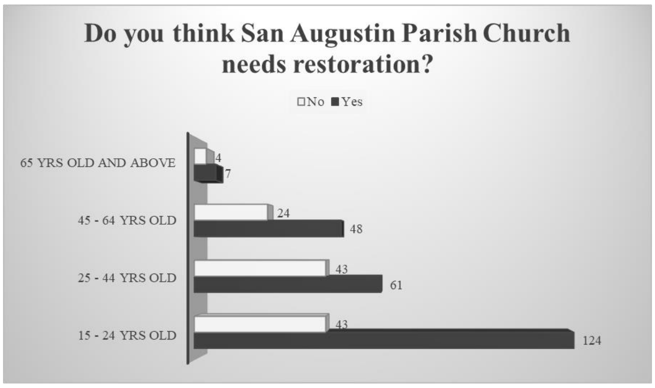


Figure 27. The number of people who think that San Agustin Parish Church needs to undergo restoration

Figure 27 shows that between ages 15 and 24, 115 respondents think that San Agustin Parish Church needs restoration while 43 respondents do not. In the age group of 25 and 44, 61 respondents think that San Agustin Parish Church needs restoration while only 43 respondents do not. In the age group of 45 and 64, 48 respondents think that San Agustin Parish Church needs restoration, while only 24 respondents do not. Lastly, in the age group of 65 and above, all 7 respondents think that San Agustin Parish Church needs restoration while only 4 do not.

4. CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusion

This study's conclusions about the evaluation of the seismic susceptibility of the churches are provided. Based on the study's goals, research questions, and findings, conclusions were reached. There will also be an explanation of the ramifications of these results and the suggestions that follow. Recommendations were based on the study's findings and objectives.

4.1.1 Assessment of the Seismic Vulnerability of the Churches Using Rapid Visual Screening

The "Pacific Ring of Fire" location of the Philippines makes it susceptible to frequent earthquakes. The most noteworthy earthquake fault lines are located in the neighboring provinces of Bulacan, Metro Manila, Nueva Ecija, and Zambales; there are no active fault lines in the province of Pampanga. Since soft sediments make up the majority of Pampanga's landforms, even if the province has no active fault lines, the area might still be impacted by earthquakes in its bordering provinces.

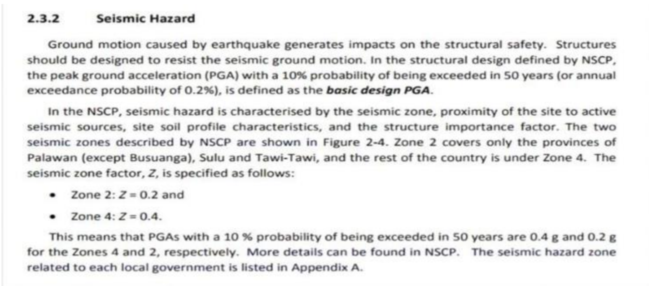
In order to ensure that the old churches are safe from potential near-field or far-field seismic influences, assessing the seismic vulnerability of San Guillermo Parish Church and San Agustin Parish Church was the goal of this study.

The assessment of SGPC in Bacolor, Pampanga and SAPC in Lubao, Pampanga was carried out using a modified FEMA-154 (2002) method that was modified to suit Philippine conditions. The basic final performance score of the churches were governed by building type, building height cluster, vertical irregularities, plan irregularities, construction date and soil type. From the data collected, the churches assessed were unreinforced masonry bearing-wall buildings (URM). The churches were categorized as low-rise buildings with less than 4 stories, which does not affect the RVS scoring.

It was seen that the churches may suffer substantial to heavy damage during a seismic event, with them being classed Grade 3 on the damage scale. It was seen that if an earthquake strikes, hitting the towns of Bacolor, Pampanga and Lubao, Pampanga, the churches would survive with substantial to heavy damage which require them to some form of rehabilitation.

The churches were also observed to have re-entrant corners, which made them susceptible to seismic damages and earthquakes corresponding to lower order periods. The building plan must be regular in order for the structure to have significant seismic resistance.

In section 2.3.2 of the National Structural Code of the Philippines (NSCP) Volume 1, the following figure is excerpted:



2.3.2 Seismic Hazard

Ground motion caused by earthquake generates impacts on the structural safety. Structures should be designed to resist the seismic ground motion. In the structural design defined by NSCP, the peak ground acceleration (PGA) with a 10% probability of being exceeded in 50 years (or annual exceedance probability of 0.2%), is defined as the ***basic design PGA***.

In the NSCP, seismic hazard is characterised by the seismic zone, proximity of the site to active seismic sources, site soil profile characteristics, and the structure importance factor. The two seismic zones described by NSCP are shown in Figure 2-4. Zone 2 covers only the provinces of Palawan (except Busuanga), Sulu and Tawi-Tawi, and the rest of the country is under Zone 4. The seismic zone factor, Z, is specified as follows:

- Zone 2: $Z = 0.2$ and
- Zone 4: $Z = 0.4$.

This means that PGAs with a 10 % probability of being exceeded in 50 years are 0.4 g and 0.2 g for the Zones 4 and 2, respectively. More details can be found in NSCP. The seismic hazard zone related to each local government is listed in Appendix A.

Figure 28. NSCP Specifications on 0.4g PGA for Zone 4

Moreover, the Structural Engineers Association of California (SEAOC) has the following excerpt:

"If a seismic event has a 10% chance of exceeding complete damage or collapse, a structure with a lifespan of 30 years or longer is NOT SAFE. Due to its age, the building is susceptible to earthquakes of a significant size".

Thus, the SGPC and the SAPC are two of the oldest churches in our country and are over 400 years old.

4.1.2 Perception of the Community Based on the Performed Survey

The survey obtained information from a diverse range of age groups in the respective communities of the chosen study areas. The survey data provided results about how the respondents perceive the seismic vulnerability of the churches based on the questions asked that were made in accordance with the objectives of the study.

Although the sample populations differ in age, they are the ones who have a significant relationship with the churches and have experienced previous earthquakes in the towns of Bacolor, Pampanga and Lubao, Pampanga.

For question 1, 84.51% of the respondents from Barangay Cabambangan are well aware that the San Guillermo Parish church is over 400 years old, while 82.03% of the respondents from Barangay San Nicolas 1st are well aware that San Agustin Parish Church is over 400 years old.

For question 2, 92.04% of the respondents from Barangay Cabambangan are well aware of the recent earthquakes that hit the town of Bacolor, while 65.51% of the respondents from Barangay San Nicolas 1st are well aware of the recent earthquakes that hit the town of Lubao.

For question 3, 55.75% of the respondents from Barangay Cabambangan have seen damages in San Guillermo Parish Church, while 76.23% of the respondents from Barangay San Nicolas 1st have seen damages in San Agustin Parish Church.

For question 4, 66.81% of the respondents from Barangay Cabambangan think that the San Guillermo Parish Church will withstand a major earthquake, while 74.78% of the respondents from Barangay San Nicolas 1st think that the San Agustin Parish Church will withstand a major earthquake.

For question 5, 52.65% of the respondents from Barangay Cabambangan think that San Guillermo Parish Church needs restorations, while 66.96% of the respondents from Barangay San Nicolas 1st think that San Agustin Parish Church needs restorations.

In light of the frequent occurrence of earthquakes in the province of Pampanga, the majority of the participants in this study had prior earthquake experience, but they were unfamiliar with the damages that a severe earthquake might bring. Perhaps this is because these old churches survived the majority of the recent earthquakes in Pampanga, and as a result, the respondents do not consider the risk of earthquakes with regard to this structure, and therefore do not consider restoration necessary.

In conclusion, despite the churches being old and may suffer substantial to major damages when there's a major earthquake, the findings of this study showed that most people want to ensure that the churches are accurately preserved, since they have been considered as historical heritage and tourist spots in their town.

4.2 Recommendation

The seismic vulnerability assessment of this study is presented specifically through the use of rapid visual testing using FEMA 154. The authors recommend the following:

- The researchers recommend visiting the National Commission for Culture and the Arts (NCCA) to acquire information about the churches, the SGPC and the SAPC.
- The researches recommend using the SCOSSO application to determine the seismic vulnerability of the SGPC and the SAPC.
- The researchers recommend to assess the church goer instead for a more accurate result in finding the perception of the community about the seismic vulnerability of the SGPC and the SAPC.
- Consider using other methods for the identification of seismic vulnerability such as fragility curves if an as-built plan is available.
- In order to prepare for imminent high-magnitude earthquakes, the researchers suggest doing a study on the retrofitting technique applicable to the SGPC and the SAPC. This is to safeguard the safety of churchgoers; also, the SGPC and the SAPC will be able to rebuild in accordance with earthquake-resistant standards.

5. ACKNOWLEDGEMENT

This study would not have been possible without the guidance and help of several individuals who in one way or another contributed and extended their valuable assistance in the preparation and completion of this study. The researchers would like to extend their deepest gratitude and appreciation to the following individuals.

First and foremost, praise and appreciation to God, the Almighty, for His blessings throughout our research and its successful completion.

To Engr. Ma. Luz Q. Manuntag, their Research Adviser, for her unwavering support, patience, inspiration, insightful remarks and recommendations, and vast expertise and advice in making the study worthwhile.

To the member of the panel, Engr. Irene R. Roque and Engr. Benjamin O. Guiao, who provided encouraging and constructive feedbacks, as well as valuable comments and suggestions in developing their study.

To Engr. Carl Jason A. Coronel, their Research Coordinator, for his advice, guidance and encouragement from the start to the completion of this study.

To the Officer-in-Charge of San Guillermo Parish Church and San Agustin Parish Church, for allowing them to conduct the study and for unselfishly providing the necessary information for this study.

To the Respondents who generously contributed their time and knowledge, allowing the study to be completed smoothly.

To their Parents for their deep consideration for the finances and undying support throughout the making of the study. As well as for their words of encouragement to all those nights that the researchers spent in making the study.

Last but not the least, to Justine Mae Y. Mangalus, for her invaluable contribution in the development of the study. The researchers wish her all the best in her future endeavors.

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