Typhoons are hazard that is threatening the Philippines every year. Design and construction of the houses and shelter in Catanduanes changes rapidly incorporating provision against wind speed. The effect of typhoon become the basis in the design of structures and the windows components. The study sought to answer what is the type of house built in Catanduanes, what is typical window system used for houses, building in Catanduanes, what are the protection and provision being implemented to withstand the effect of high winds pressure, and what are the safety practices to counter the effect of high winds of typhoon? Most designs and houses constructed in the late 80’s already introduced these provisions that make them easy to install the windows shutter locally termed as “typhoon guard”. This was also implemented by architects, engineers, and owners as a mandatory inclusion in the building construction and design. The selection criteria for designer and owner include the budget, structural integrity of the window, and aesthetical appearance. Respondents acknowledge that windows must be protected from the force of gusty winds and debris impact and this will also ensure that your entire house or building stays safe and intact. Many respondents agree that it is vital to protect the window from breakage by using materials that can withstand the full force of the wind pressure or employing protection components to keep the window intact and safe. However, most owners of nipa hut and a handful of owners of bungalow houses suffer minor and major damages during super typhoon Rolly, and they have common concerns about their safety and evacuation to safe buildings is the ultimate safety practice to mitigate the risk pose by the typhoon. It is recommended that typical windows systems to be used in homes and buildings must be rigid enough to withstand wind forces. Safety practices to counter the effect of high winds of typhoon includes removal of possible debris and projectile must be practiced. Also, Integrated windows protection design such as windbreaker must be re-integrated into the design of the building and adopt new window design to mitigate typhoon wind forces.

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Keywords: housing category, typhoon guard, typhoon wind force, windows protection.

I. INTRODUCTION

Typhoons are hazard that is threatening the Philippines every year. There is an average of twenty typhoons that enter the Philippine area of responsibility yearly, and is the most exposed country in the world to tropical storms or bagyo. Most of the worst typhoon in the Philippines have hit Catanduanes includes super typhoon Rosing (November 1, 1995) that hit the northern tip of the island with gust reaching 260kph [1]. Super Typhoon Reming December 1, 2006 hit the southernmost tip of the island with 320kph winds and become the worst typhoon ever recorded, resulted in destroying around 80% of all its houses and buildings, and ramming ships and tankers aground. It is reported that the anemometer at PAGASA’s weather station at Virac conked out after registering a 320 kph gust. It was the signature of the country’s most powerful typhoon in history. Super Typhoon Sisang on November 25, 1987 hit southern part of Catanduanes. According to some account from our grandparents that Sisang eventually wreaked havoc in Virac, reported deaths and uprooted houses was recorded in Barangay Calatagan. Super Typhoon Sening on October 13, 1970 hit Virac with a 275 kph wind speed. Super Typhoon Lolong on October 21, 1998 hit Virac, Catanduanes with a gust of 260kph. Wind force destroyed, partially, and totally damaged buildings, houses during the rampage of these super typhoons that hit the island.

For four decades now, the design and construction of the houses and shelter in Catanduanes changes rapidly incorporating provision against wind speed. We have witnessed how the effect of typhoon become the basis in the design of structures. But the design of structure has evolved on today’s modern designs. We try to replicate from different regions and cultures due to its pleasing appearance thus affecting the way we design our houses. Windows are component of house or building. It is an opening on the building that is fitted with glass or other material to admit light and allow occupant to see the other side. They are often open to allow ventilation. Windows also gives beauty in the appearance of the building. Windowpanes are often damaged by wind pressure or wind-borne debris. Breakage of windows may not only damages property inside the building, but also may blow the roof apart [2]. Window must be design to adequately withstand the effect of wind pressures and debris impact. Likewise, protecting window will also save the damage inside the building and also causes building failure. Post-disaster investigations on dwelling, school, and industrial buildings, and others in the Philippines.
found that the most easily damaged in wind hazards, and wind-borne debris in wind hazards where serious issues are remarkable were the roofs and claddings [3], [4]. The jalousie windows in the Philippines are an important factor for its wind-induced damage; the lack of connections between roofs and walls in rural buildings made the roofs hardly resist any strong upward wind forces and be easily blown off.

The joint damage survey during typhoon Yolanda in 2013, reveals that many of the non-engineered houses were extensively damaged or completely collapsed. Most of the observed damage on engineered buildings occurred on the building envelope that is non-structural elements and seldom checked in design computations [5], [6]. These observed damages reveal the need to update conventional construction details that can no longer resist the demands of increased wind loading. Hernandez et.al [5] suggested reviewing the Building Codes for Wind Resilient Design. During that time, the latest edition of the NSCP was published in 2010 with wind loading provisions based on the ASCE 7-05 and design wind speed for Eastern Samar is just 250kph. Wind speed maps can be considered part of a bigger set of ‘typhoon hazard maps’ that can be used for ‘typhoon engineering’ and disaster reduction efforts. The wind speed maps should consider all the requirements for use in the NSCP, but also for use as a typhoon hazard map, as well as for wind power development and other similar purposes [7].

School buildings in the Philippines are mostly made up of reinforced concrete (RC) structures with steel or timber-roof frames covered by corrugated iron sheets or folded steel plates [3] [8] [10]. Jalousie windows are also common, and also glass windows are not used. The general features of buildings in the Philippines are that they have many wall openings, including jalousie windows and affect the aerodynamics of the building. The external pressure coefficient on the windward wall becomes positive, but those on the other walls and the roof are all negative when the wind is normal to a windward wall and the negative pressure on the roof edge and those on the sidewalls near the leading corners show high negative local pressures. The resultant force acting on the windward wall becomes large, which can cause the failure of the windward wall. Once the windward wall is damaged, the internal pressure becomes positive and can result in serious damage to the roof and the entire building. They conclude that window breakage can lead to serious damage to the entire building.

Typical windows system used in homes and buildings in Catanduanes includes, fixed, sliding, pivoted/swing, jalousie windows, awning, louvered, casement, and bay windows. This type of windows is used in building to provide ventilation & air, admit light inside and give a view of the outside. Windows also give a beautiful appearance to the building. The selection criteria are based on the factors that contribute to the choice of a typical window system for the house or building. The main factors and issues for selection includes; aesthetics and appearance, costs, climatic condition, energy related issues, air and water tightness, structural performance, and acoustic performance. During typhoons, windows must be protected from the force of gusty winds and debris impact. Protecting windows will also ensure that the entire house or building stays safe and intact. A damaged window glass or window panel facing directly onto the gust of winds increases the pressure inside the building, thus creating more risk of roofs being rift and blown away. It is vital to protect the window from breakage by using materials that can withstand the full force of the wind pressure or employing a protection component to keep the window intact and safe. Protection includes window grills and typhoon guards. Since the island I often visited by typhoon every year, provision for employing protection must be integrated with the design as to easily assemble or attached the module for protection. The provision includes typhoon guard holder, brackets and anchors, and guard railings. Windows can also be protected by putting masking tapes on the glass, removal of possible debris nearby, and removal of the potential projectile.

This study aims to determine the adaptation of Catandunganons on how to protect their houses and buildings from the effect of strong winds and typhoon.

II. RESEARCH METHODOLOGY

In the design of components of the building or houses, the engineers and architects use modern methods and design for its pleasing appearance but take into account the safety of the components. Though most of the houses or buildings in the provinces did not even have proper planning and the owner have to design and supervise the construction of the structure. A poorly designed building may lead to damage and even collapse due to
This study focuses on the house or building that was engineered or designed by the owner with or without knowledge of building construction and construction methodology. The study is conducted in the 11 municipalities of Catanduanes and covers 155 respondents for upland areas and 83 for coastal areas.

The collecting of data will be thru a questionnaire, conducting interviews with the residence or the owner of the building or house. A corresponding ocular or visual examination and assessment of the house or building will be done by a Civil/Structural Engineer, and or Civil Engineering technician on the component of the house or building under study. Data collection protocols includes questionnaire/interview guides. The actual interview is translated into local language of Bikol. The first part of the interview is the basic information of the respondents; name, address, type of respondents, locations (upland/coastal), and building/shelter/house structure type. The main part of the interview guide is to answer the statement of the problems listed in order. The discussion guide informs the interview but does not determine the sequence and phrasing of the questions in a fixed manner. In order to build relationship, and further clarity and truthfulness, utilize the flow and energy of respondents’ conversation.

The questionnaire to evaluate the project will be carefully studied, and results will be treated and judged accordingly in terms of building component integrity and usefulness. For the purposes of providing inspections, the term "engineering inspection” shall apply essentially to a structural and non-structural component inspection of the building. This type of inspection can only be performed by a registered Civil/Structural Engineer and engineering technician. Items related specifically to the window components and design will be examined and evaluated. These may include framing, cladding, hinges and connectors, lock mechanism, protections, and materials.

III. RESULTS

Observed damage from the typhoon that hit Catanduanes in the past

Most designs and houses constructed in the late 80’s already introduced these provisions that make them easy to install the typhoon guard. This was also implemented by architects, engineers, and owners as a mandatory inclusion in the building construction and design. However modern buildings, lack of this provision was not implemented due to the use of tempered glass panels or they call typhoon-proof glass windows. The new design and construction methodology of the building is now using tempered glass for windows to maximize the flow of light and airflow inside the building. According to one respondent, during typhoon Nina in December 2016, in one of the commercial buildings in downtown Virac that use tempered glasses to withstand the force of typhoon and debris flow fails and some panels were blown away. Architects and engineers who make a study of this were puzzled how the typhoon damages the window panel even that it was designed to withstand the typhoon wind gust. They conclude that the wind force inside that forms a vortex pushes the windows panel outside. According to the tenants and employees of the building, one door on that specific floor was not fully lock and damage by the force of the typhoon. It started to accommodate wind and objects including, chairs and tables start to fly in a circular motion, just like a tornado inside the building, and eventually smashes the window and pushed the entire windows panel outside. The design of the windows is like the car windshield where it was designed to withstand the wind force from the out but not from the inside.

![Figure 2. School building damage by typhoon Nina in 2016.](image-url)
They also found out that the provision of connecting the window panel to the wall is not sufficient for that specific wind speed. Architects and engineers learned from this case and tempered window glass panels are now being retrofitted and have provisions to withstand both outside active pressure and inside passive pressure.

Types of houses built in Catanduanes
Home is one of the basic human needs and requirements. We find comfort and protection from the harms caused by our environment. The following are the most common types of houses built in the island; Bungalow, Single Attached/ Detached, Nipa hut, Row Housing, and Temporary Shelter

Windows system used in houses and building.
Windows are used in building to provide ventilation & air, admit light inside and give a view of the outside. Windows also give the beautiful appearance of the building. Casement window is the preferred type of windows both by the majority of community both coastal and upload. Sliding windows comes next as preferred by the upland community over jalousies, sliding windows are a common windows type for modern houses and building. However, jalousie windows are preferred by the coastal communities over sliding windows. This type of window is mostly found in indigenous and low-cost housing. Pivoted windows or swing windows are commonly used by indigenous houses and nipa huts. This is also common both in coastal and upland areas because of its low cost and availability of the material in the area. Fixed windows have two distinct types. Fixed windows that have no closing or opening and it is permanently closed. It is widely used for modern buildings and houses; the main purpose is to enable lights (and sunlight) to enter the building. On the other hand, indigenous houses and nipa hut widely use permanently fixed window (fixed frame only), this allows the light and airflow into the house and on the same time protect the window from unauthorized entry. Awning windows open out by pivoting from the top of the window sash, operated by a crank. Common also for modern houses, However, some nipa huts use this also aside from swing windows. Bay windows are common for modern houses. It is a window that is projected wall which is provided to increase the area of the opening, which enables more ventilation and light from outside. Only a few use louvered type and most modern house utilizes this to provide ventilation without any outside vision.

Selection Criteria for Windows
The selection criteria are based on the factors that contributes for the choice of a typical window system for the house or building. The following are the main factors and issues for selection of what type of windows respondent prepares. 1. Cost is the main factor the owner considered in the selection criteria, it deals with the cost of the windows and the budget of the construction. Low cost and indigenous houses prioritize the cost rather than another factor. All they want is to have their house completed and have shelter. They prefer pivoted windows and jalousie for its low cost and simple to construct and is rigid and can withstand the force of typhoon. 2. Structural performance- the integrity of the window system to resist forces like wind speed, gust, and debris impact. This are the factor considered by engineers and owners. Considering the effect of high winds of typhoon, owners and engineers prefer windows that can withstand typhoon force wind. 3. Aesthetics and appearance is the criterion purely on the design appearance of the windows. Most architects prefer this criterion aside from structural performance. Every house and building they made is their masterpiece. Appearance and its beauty will define their masterpiece. 4. Availability of material to build and construct the window system. Most low-cost housing rely on local material that are available in the locality. This includes, wood, bamboo, and shingles.
Protection being implemented to withstand the effect of high winds pressure

Respondents acknowledge that windows must be protected from the force of gusty winds and debris impact and this will also ensure that your entire house or building stays safe and intact. A damaged window glass or window panel facing directly onto the gust of winds increases the pressure inside the building, thus creating more risk of roofs being rift and blown away. Many respondents agree that it is vital to protect the window from breakage by using materials that can withstand the full force of the wind pressure or employing a protection component to keep the window intact and safe. Protection implemented includes; 1. Typhoon guards – a component to protect the window from the force of the typhoon. It is a form of a shutter, but Catandunganons widely uses the term typhoon guard, literally to protect the windows from the destruction of high winds from typhoons. Typhoon guards are made up of wooden planks that can easily be attached to the window grills before the typhoon hits. It is designed that anyone can attach the typhoon guard. Provisions were also added to the grills and windows to accommodate this typhoon guard. 2. Window grills – window grills have been a choice from the ‘80s to early 2000 to protect the windows from the force of typhoons. A lot of design, modern and contemporary made it through the style of the windows grills. However, to fully protect the window, a typhoon guard is also been part of the protection. 3. No Protection. Indigenous houses have no protection at all, they simply closed and nail the window, and string to keep the windows intact during the typhoon.

Provision to protect the windows from typhoons and strong winds

Since the island I often visited by typhoon every year, provision for employing protection must be integrated into the design as to easily assemble or attached the module for protection. Unlike in places where typhoons are not prevalent, they did not put in place provisions for protection. Whenever a typhoon comes, that is the time when they will put a shutter to guard the windows. Some respondents share the ideas of the provision they are implemented and are using. Typhoon guard holder – guard holders are provisions for windows that can accommodate the typhoon guard. It is integrated into the windows as a component. Typhoon guard brackets and anchors – components that can easily lock and hold the typhoon guard. Typhoon guard railings – an integral part of the window system that accommodates typhoon guards.

Safety practices to counter the effect of high winds of typhoon

Evacuation – Most of the owners of the nipa hut and a handful of owners of bungalow houses suffer minor and major damages during super typhoon Rolly, and they have a common concern for their safety. They said that evacuation to safe buildings and evacuation centers is the ultimate safety practice to mitigate the risk pose by the typhoon. Removal of possible debris. Tree branches and leaves are removed because they will cause damage to the glass panel. But a few individuals, practice this method which is why potential damage to windows and also to the structure are eminent. Removal of possible projectile – like removing possible debris, possible projectiles are loose metals, woods, tree branches that can be blown by high winds and become projectile. But like the removal of possible debris, removal of a possible projectile is not being practices.

Protection integrated to the design of the building

The Catanduanes State University main building has a window protection integrated into the design of the building. The fins are used as wind breaker to reduce the effect of wind force. The building is already 5 decades old and the steel casement window does not even have typhoon guard for protection. The fins serve as the window guard by reducing the maximum effect of the wind. This design is a good example of integrated wind protection for building. It is likewise aesthetically integrated to the design.

Figure 4. The Catanduanes State University main façade with integrated windows protection system. This design does not need to employ window protection as the fins serves as wind breaker to reduce the intensity of the wind force.
Proposed window system design to withstand the force of typhoon

Suggested window design by architects and engineers to counter the force of typhoon as a lesson learned from super typhoon Rolly in 2019 is shown in the figure below. This design provides adequate protection and decreases the surface area exposed from the wind force. Computation for windows protection using design maximum wind speed of a super typhoon category of 340 kph (211 mph) as stated in the National Building Code of the Philippines, 2015. To determine the maximum pressure sustained during high winds, computation using the latest code requirements are applied. To facilitate the computation, the researcher employs online wind load application with consideration to the NSCP, 2015 code. Considering the design parameter and using wood planks of locally available wood planks;

Properties of Apitong Wood

- Bending and tension parallel to grain = 16.5 MPa
- Shear parallel to grain = 1.73 MPa
- Modulus of elasticity in bending = 8.20 GPa

using formulas listed below:

\[ M = \frac{w_o L^2}{8} \quad f_b = \frac{6M}{bd^2} \quad f_o = \frac{3V}{2bd} \]

\[ I = \frac{bd^3}{12} \quad \delta = \frac{5w_o L^4}{384EI} \]

Maximum flexural stress

\[ M = (0.0054) \times (1.2)^2 \times 8 = 0.000972 \text{ kN.m} \]
\[ f_b = \frac{6 \times 0.000972 \times (1000^2)}{400(25^2)} = 0.023 \text{ MPa} \]
\[ f_b < F_b \]

Maximum flexural stress

\[ V = 0.0027 \text{ kN} \]
\[ f_v = \frac{3(0.0027)}{2(25) (400)} = 0.000000405 \text{ MPa} \]
\[ f_v < F_v \]

Maximum deflection

\[ I = \frac{400(25^3)}{12} = 520833.33 \text{ mm}^4 \]
\[ \delta = \frac{5(0.0054) \times (1.2) (1000)^2}{384(7310) (520833.33)} = 0.02216 \text{ mm} \]

Using ¾” thick Plywood/Plyboard as windows protection

- Bending and tension parallel to grain = 27.6 MPa
- Shear parallel to grain = 1.72 MPa
- Modulus of elasticity in bending = 7.31 GPa

Maximum flexural stress

Using previous computation;

\[ M = 0.000972 \text{ kN.m} \]
\[ f_b = 0.023 \text{ MPa} \]
\[ f_b = 0.023 \text{ Mpa} < F_b = 16.5 \text{ Mpa} \]

Maximum flexural stress

\[ V = 0.0027 \text{ kN} \]
\[ f_v = 0.000000405 \text{ MPa} \]
\[ f_v = 0.000000405 \text{ Mpa} < F_v = 1.72 \text{ Mpa} \]

(okay)

Maximum deflection

\[ I = \frac{400(25^3)}{12} = 520833.33 \text{ mm}^4 \]
\[ \delta = \frac{5(0.0054) \times (1.2) (1000)^2}{384(586) (520833.33)} = 0.28 \text{ mm} \]

The wood plank and the ¾ thick plywood is safe to withstand the effect of high wind pressure. The Plywood deflects more than the wooden planks. With the result of the following computation. The study recommends the use of typhoon guard protection system as shown in the figures below.
Figure 5. Window (sliding/fixed/jalousie) with grill and typhoon guard provision.

Figure 6. Window (sliding/awning/casement/jalousies) with typhoon guard provision.

Figure 7. Window/Door rail and grill attachment system.
IV. DISCUSSION

Typhoon is a real threat on the island. Recent typhoon Quinta and Ulysses and super typhoon Rolly that hit the province is a clear and present danger. This study focuses on the typhoon guard that helps protect houses from failure, damage, or even collapse. Most designs and houses constructed in the late 80’s already introduced these provisions that make them easy to install the typhoon guard. This was also implemented by architects, engineers, and owners as a mandatory inclusion to mitigate the effect of strong winds on windows. However modern buildings, lack this provision was not implemented due to the use of tempered glass panels or they call typhoon-proof glass windows. The selection criteria for designer and owner include the budget, structural integrity of the window, and aesthetical appearance. Respondents acknowledge that windows must be protected from the force of gusty winds and debris impact and this will also ensure that your entire house or building stays safe and intact. Many respondents agree that it is vital to protect the window from breakage by using materials that can
withstand the full force of the wind pressure or employing protection components to keep the window intact and safe. However, most owners of nipa hut and a handful of owners of bungalow houses suffer minor and major damages during super typhoon Rolly, and they have common concerns about their safety. They said that evacuation to safe buildings and evacuation centers is the ultimate safety practice to mitigate the risk posed by the typhoon.

CONCLUSION

Typhoon guard as what every Catandunganons knows the term, is very important to protect the windows from shuttering, breakage, and damage. However, with the modern design of buildings, windows protection has been compromised for aesthetic reasons. The study presented the practice and design implementation to protect windows.

REFERENCES