Technologique: A Global Journal on Technological Developments and Scientific Innovations
2025, Vol. 4, No.1, 66 – 83 | ISSN Online: 3028-1415 | ISSN Print: 3028-1407
DOI: https://doi.org/10.62718/vmca.tech-gjtdsi.4.1.SC-0425-012

Resiliency Assessment on the Structural Durability of Selected Concrete Buildings in Virac, Catanduanes

Article History:
Received: 23 April 2025
Accepted: 30 May 2025
Published: 11 June 2025

Rene Constantine J. Avila, ORCID No. 0009-0000-1228-4846
Master of Science in Construction Management, Polytechnic University of the Philippines-OUS, Manila, Philippines

Abstract

This study investigated the structural durability of selected public or government concrete buildings in Virac, Catanduanes. It examined the socio-economic profile of construction professionals, assessed the durability of different building types, evaluated rehabilitation measures, and analyzed structural damages. It used descriptive method to gather both quantitative and qualitative data. Primary data were collected through interviews and survey questionnaires. Descriptive statistics, including frequencies, percentages, ranks, and weighted means, were used to analyze the data. The study revealed that school and health facilities exhibited high durability having weighted means ranging from 3.60 to 3.87 (very durable) while other concrete buildings showed varying degrees of resilience with a mean rating of 3.33 (durable). Typhoons primarily affected non-structural elements like windows and roofs showing that these elements have weighted ratings of 4.70 and 4.03, and respectively indicating a descriptive rating of very severe damage while the structural elements, like walls, posts and beams, show slight damage with mean ratings ranging from 1.40 to 2.13. Rehabilitation measures, such as structural reinforcement with retrofitting and column jacketing, deemed most effective with mean ratings of 3.67 and 3.80, respectively. Key factors influencing building durability included construction quality, material quality, and environmental factors. The study emphasizes the importance of high-quality materials, disaster resilient design, and efficient construction practices to enhance building resilience against typhoons which can serve as basis in updating the NSCP to address the increasing intensity of typhoons as effect of climate change. Recommendations include improving construction quality by promoting the use of high-quality materials, strengthening building codes, promoting awareness on disaster resilience, and addressing project delays by streamlining bureaucratic processes, improving access to construction materials, and enhancing project coordination and communication.

Keywords: Typhoon Impact; Concrete Buildings; Building Durability; Rehabilitation Measures; Disaster Preparedness

INTRODUCTION

The world is continuously evolving and modernization, a significant contributor of climate change, has significantly impacted our environment. The Philippines, particularly Catanduanes province, faces severe and escalating natural disaster risks, primarily from typhoons. Its location in the Pacific Ring of Fire and typhoon belt makes it highly susceptible to frequent seismic activity. In fact, the province averages around 20 typhoons annually, and many of which are destructive.

Despite advancements in concrete construction, recent super typhoons, like Yolanda in 2013, with ₱95.5 billion damages, and Odette in 2021, with ₱47.6 billion damages, demonstrate the persistent vulnerability of infrastructure. In 2023 alone, tropical cyclones caused ₱13.37 billion in infrastructure damages. Climate change is intensifying tropical cyclones, even if their overall frequency doesn't significantly increase. Studies, including a World Weather Attribution report in late 2024, indicate that the potential intensity of typhoons in the Philippine Sea is significantly higher (e.g., 1.7 times in 2024) than in pre-industrial times. Projections suggest more frequent major typhoon landfalls and increased wind speeds and rainfall. The Intergovernmental Panel on Climate Change (IPCC) also confirms an increase in intense tropical cyclones (Category 4 and 5) globally due to warming. This "rapid intensification" poses a significant challenge for forecasting.

Known as the "Land of the Howling Winds," Catanduanes is often the first province hit by typhoons. Recent events like Super Typhoon Rolly (2020), Paeng (2022), and Pepito (2024) have caused immense damage, with Rolly alone destroying an estimated 90% of the island's structures. (Morales, 2020) Pepito, for example, destroyed 500 houses and caused ₱266 million in agricultural damages. (Alabaso, 2024)

The increasing severity of these events demands urgent adaptation and mitigation, including reinforcing infrastructure, enhancing early warning systems, and revitalizing coastal ecosystems. For construction, this means building designs that specifically counter extreme wind pressures, uplift forces, and storm surges. Investing in resilient concrete construction, stricter building codes, and integrating natural hazard assessments into urban planning are crucial for protecting lives and minimizing economic losses in highly vulnerable regions like Virac, Catanduanes, the provincial capital and a key hub for government, education, and commerce.

Given the vulnerability of Catanduanes, this study aims to assess the structural durability of concrete buildings in Virac, the provincial capital. The research seeks to answer the following:

1. The socio-economic profile of respondents.
2. The types of concrete building projects handled by respondents and their durability rating against super typhoons.
3. The rehabilitation measures implemented for concrete buildings and their effectiveness rating by respondents.
4. The structural damage to concrete buildings from typhoons.
5. The adaptations/innovations implemented in constructing new concrete buildings.
6. The observations on concrete building projects regarding:
   6.1 Life span
   6.2 Factors affecting durability and serviceability
   6.3 Repair duration after a typhoon
   6.4 Causes of construction delays.

This study specifically focuses on the structural durability of selected concrete buildings used for various occupancies in Virac, Catanduanes. It excludes residential and recreational infrastructures and buildings outside Virac. The findings of this study will be beneficial to the following sectors:

1. *Local Government Agencies.* Provide essential input for local resource management and the implementation of programs for typhoon-resilient concrete buildings.
2. *National Disaster Risk Reduction Management Council (NDRRMC).* Serve as benchmark data and guides for mitigating typhoon impacts.
3. *Department of Public Works and Highways (DPWH).* Contribute insights to enhance infrastructure's ability to withstand powerful typhoons.
4. *Stakeholders of Government Agencies.* Raise awareness about the structural status of existing concrete buildings and inform precautionary measures.
5. *Project Engineers/Architects.* Provide inputs for the efficient and high-quality restoration or reconstruction of damaged concrete buildings.
6. *Construction Material Manufacturers.* Encourage innovations in products for greater durability and typhoon resilience structures.
7. *Researchers.* Inspire further research on the impacts of typhoons on other infrastructures, their assessment, durability, and rehabilitation measures.

LITERATURES

How the Philippines Deals with Typhoons. The Philippines, situated just north of the equator and facing the Western Pacific, is highly vulnerable to typhoons, experiencing an average of 20 annually. These storms gain destructive power from consistently warm ocean waters (above 26.5°C). Past events like Super Typhoon Haiyan (2013), which caused an estimated 10,000 fatalities and displaced millions, starkly illustrate this vulnerability. Climate change is projected to intensify these typhoons, making their impact even more severe. (FutureLearn, 2021).

Frequency of Visits of Typhoons in Catanduanes. Bicol Region is exposed on its eastern shore in the Pacific Ocean and has a large density of disaster-prone inhabitants who are exposed to frequent flooding, earthquakes and typhoons. Catanduanes was identified as the highest priority province in Bicol. Catanduanes is known as the Land of Howling Winds due to its location in the typhoon belt, which makes it susceptible to typhoons and their associated hazards (Castillo, 2021).

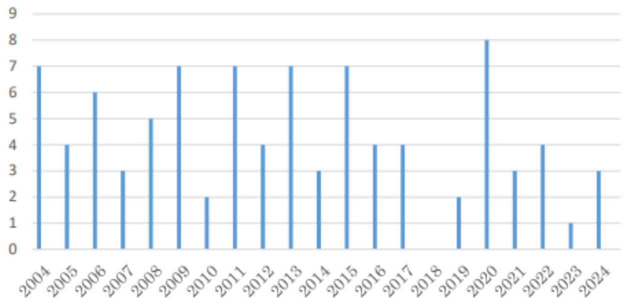

Figure 1
Frequency of Typhoons Affecting Catanduanes, 2004-2024

Figure 1 illustrates that Catanduanes experiences an average of 4.3 typhoons annually, despite not always being in their direct path. These storms, intensified by erratic weather, consistently cause significant damage. Only 2018 recorded no typhoons affecting the province, while 2020 saw the highest number with 8, including a destructive super typhoon. Most of these events inflict considerable damage on infrastructure and lives.

Inherent Vulnerability of the Philippines and Catanduanes. The Philippines' geographic location along the Pacific typhoon belt and within the Pacific Ring of Fire makes it highly susceptible to natural disasters (Sarmiento, 2009). Catanduanes, specifically, is positioned on the Pacific side within this typhoon belt, experiencing an average of four typhoons annually out of the 20 tropical cyclones that enter the Philippine area of responsibility (from 2004-2024 data). This inherent susceptibility is a defining feature of the "Catandunganon Experience" (Sarmiento, 2009).

Escalating Impacts of Typhoons. Typhoons cause widespread damage through strong winds, torrential rains, and storm surges, leading to catastrophic floods, landslides, and coastal erosion (Manila Typhoon Center, 2022). The impacts are extensive:

1. *Infrastructure Destruction.* Typhoons like Rolly (Goni) in 2020, with sustained winds of 315 km/h, caused severe damage to buildings, particularly those of light materials, leading to roof failures, disrupted power and communication, and damaged water systems (Pagkatotohan, 2023; IFRC, 2021). Super Typhoon Pepito (ABS-CBN News, 2024) damaged around 4,000 homes in Catanduanes, highlighting the scale of destruction. Typhoon Paeng in 2022 led to Catanduanes being declared a state of calamity due to significant damage to agriculture, fisheries, and public infrastructure, along with forced evacuations (Catanduanes Tribune, 2022).

2. *Economic and Livelihood Losses.* Agricultural damage alone from Pepito was estimated at P266 million, adding to previous P7 billion losses from other storms (ABS-CBN News, 2024). The 2020 typhoon season (including Goni/Rolly) resulted in 407 deaths, affected 7.3 million people, and left 2.4 million in urgent need of humanitarian assistance (Climate Adaptation Platform, 2022). Such economic tolls hinder progress and poverty reduction (Lagmay, cited in Kimball, 2023).

Challenges to Recovery. Widespread power outages due to downed lines and trees disrupt crucial communication and delay rescue efforts (Manila Typhoon Center, 2022; Cabilao, 2022). The destruction of essential facilities makes transporting aid challenging (Manila Typhoon Center, 2022).

The Role of Climate Change in Intensifying Typhoons. There is a recognized link between rising ocean temperatures and typhoon intensity (University of the Philippines Diliman College of Science, 2022; Kimball, 2023). Climate change exacerbates the power of these storms by providing more energy to atmospheric systems (Holden, cited in Kimball, 2023). The Intergovernmental Panel on Climate Change (IPCC) also underscores the escalating severity of extreme weather events (Tibig, cited in Kimball, 2023). While some studies note the challenges of drawing definitive conclusions due to limited satellite data and variations in cyclone frequency (University of the Philippines Diliman College of Science, 2022), the consensus is that the intensity of typhoons, particularly "Super Typhoons," is increasing (PAGASA definition of Super Typhoon, University of the Philippines Diliman College of Science, 2022).

Beyond direct storm impacts, climate change also poses broader risks to infrastructure through thermal expansion, temperature gradients, increased CO_2 leading to carbonation, and sea level rise causing inundation, erosion, and corrosion (Kuba, 2017).

Climate-Resilient Design and Materials. Structures should be designed to withstand extreme wind loads, uplift forces on roofs, and storm surges (Cabilao, 2022). Indigenous stone houses in Batanes, with their thick stone walls and minimal window openings, serve as a model for typhoon-adaptable buildings, demonstrating concrete's superior resistance to strong winds and rainwater (Cabilao, 2022).

Improved Construction Practices. Recommendations include limiting roof eaves to 0.50 meters, securely bracing canopies, and making roofs over extended spaces independent of the main structure (UAP Emergency Architects, cited in Cabilao, 2022). Securing doors and windows, and using storm shutters, are also crucial (Cabilao, 2022).

Urban and Environmental Planning. Proper community planning and preparation are crucial, as disasters are often a result of "unresolved development problems" rather than purely natural occurrences (Lagmay, cited in Kimball, 2023). Proactive adaptation strategies generally result in lower costs and improved road connectivity (Schweikert et al., 2014). This includes proper tree trimming along roadsides to prevent damage to power lines and buildings (Cabilao, 2022).

Infrastructure Management and Investment. Infrastructure, despite being planned for long-term use, faces failures exacerbated by extreme weather (Pudyastuti & Nugraha, 2018). Investing in climate-resilient design, improved materials (e.g., stainless steel reinforcement), controlled permeability formwork, regular inspections, maintenance, surface treatments, external reinforcement (e.g., FRP), and cathodic protection are crucial (Kuba, 2017).

Policy and Guidelines. Implementing guidelines from the United Nations Office for Disaster Risk Reduction and emphasizing climate change adaptation through proactive community planning and nature-based solutions like mangrove protection are vital (Lagmay, cited in Kimball, 2023).

METHODS

Research Design. This study assessed the concrete building durability in Virac, Catanduanes using descriptive research employing mixed-method approach that combines quantitative and qualitative data.

While this approach offers a comprehensive understanding of the selected structures, it comes with inherent limitations. The use of purposive sampling for building selection introduces potential selection bias, meaning, findings may not be generalizable to all concrete buildings in Virac or other municipalities. For example, if the sample favored newer or specific contractor-built structures, it might not accurately represent the durability of older or less robust buildings.

Furthermore, qualitative data collection (e.g., interviews, observations) can be subjective, influenced by researcher interpretation or participant candidness. This means the in-depth insights gained, while valuable, may not be easily quantifiable or broadly applicable.

Therefore, the study's conclusions on structural durability provide a valuable but specific snapshot, not a universal finding, and should be interpreted within these methodological considerations.

Research Setting. This study strategically focused on Virac, Catanduanes, a provincial capital and a vital hub for government, education, and commerce. Its status as a first-class municipality with significant development potential makes it an ideal location to examine infrastructure resilience in a rapidly developing, yet highly disaster-prone, area.

The study specifically assessed the structural durability of selected concrete buildings used for public occupancies, including schools, multi-purpose buildings, offices, and health facilities. Recognizing the critical role of location in Disaster Risk Reduction and Management (DRRM), a systematic approach was employed to select representative buildings.

Table 1
Type of Concrete Building Projects Handled by Respondents

Building Name/Occupancy Type	Specific Location (Barangay)	Primary Hazards Considered	Key Characteristics/Notes
School Building A	San Juan	Coastal Flooding, Storm Surge, Strong Winds	Located within 500m of the coastline, serving a densely populated area.
Multipurpose Building B	Concepcion	Riverine Flooding, Strong Winds	Situated near the Virac River, often used as an evacuation center.
Office Building C	Sto. Niño	Strong Winds, Seismic Activity	Central business district location, representing administrative infrastructure.
Health Facility D	Palnab Del Sur	Landslide Risk, Strong Winds	Located on slightly elevated terrain, vital for emergency response.
School Building E	Cavinitan	Coastal Flooding, Strong Winds	Exposed coastal area, frequently affected by typhoon-induced high tides.
Multipurpose Building F	Danicop	Flash Floods, Strong Winds	Inland location but susceptible to flash floods from heavy rainfall.
Office Building G	Gogon	Strong Winds, Coastal Erosion	Near the airport, serving as a critical regional administrative hub.
Health Facility H	Capilihan	Riverine Flooding, Strong Winds	Provides essential services to a rural community prone to river swelling.

This methodology considered both building occupancy and geographical vulnerability to prevalent hazards in Virac, such as coastal proximity (for storm surge), proximity to rivers (for flash floods), and historical typhoon impact areas. This ensured the assessment of structural durability accurately reflected the actual exposure and vulnerability of these critical public facilities. To provide transparency and facilitate understanding of the selected buildings' context, the following tabulation details their location, primary hazards, and other relevant information is shown in Table 1. As shown in the table, the selected concrete buildings are based on their vulnerability due to their location. Moreover, the respondents selected in this study have handled such projects.

Sources of Data. The researcher obtained primary data from interviews and survey questionnaires. Interviews were conducted with the Provincial Engineer of Catanduanes, the Municipal Engineer of Virac, and the District Engineer of the Department of Public Works and Highways Catanduanes District Engineering Office (DPWH-Cat DEO). Survey questionnaires were given to building officials and project engineers/architects or civil engineers/architects that handle construction projects in Virac, Catanduanes. These experts assessed the durability of concrete buildings.

Sampling Procedure. This study involved 30 building officials, project engineers/architects, and civil engineers actively engaged in construction and quality assurance of concrete buildings in Virac, Catanduanes. Respondents were primarily Civil Engineers from various government agencies involved in building construction. The limited number of practicing architects in Virac (e.g., only one at DPWH Catanduanes) is likely due to the recent offering of an Architecture degree in Catanduanes (starting 2021) and the tendency for engineering graduates to seek opportunities in larger cities.

A purposive sampling method was used to select participants, ensuring they had at least one year of experience in building construction, including roles such as project inspectors and laboratory technicians (Creswell, 2014; Graunke, 2018). While exact professional population numbers are unavailable, a sample size of 30 is generally considered sufficiently large for statistical analysis for the Central Limit Theorem to apply, implying that the sampling distribution of the mean will be approximately normal, irrespective of the population size (Frost, 2018; Glen, 2024).

Instrumentation and Validation. Preliminary interviews with 10 building officials and project engineers helped refine the survey questionnaire. Upon refinement, the questionnaire underwent content validation by experts from the College of Engineering and Architecture. The reliability test yielded a Cronbach's alpha of 0.704626, indicating acceptable internal consistency.

Data Gathering Procedure. Data for this study was collected through interviews and structured questionnaires, administered during scheduled appointments. This dual approach provided both qualitative insights and quantitative data.

To ensure ethical conduct, informed consent, confidentiality, and participant protection were prioritized. Consent letters were sent to relevant agencies (DPWH, Virac Municipal Engineering Office, Catanduanes State University, DepEd – Catanduanes Division Office) and signed by agency heads. Before participation, respondents received a clear explanation of the study's purpose, their involvement, time commitment, and right to withdraw. Formal signed consent was obtained from each volunteer.

Confidentiality was meticulously maintained by anonymizing data, separating identifying information from responses, and storing all data securely, accessible only to the research team. Measures were also implemented to protect participants from harm or discomfort.

Statistical Treatment. This study analyzed its data using descriptive statistics, specifically frequencies, percentages, ranks, and weighted means.

Frequencies, percentages, and ranks were used to evaluate the socio-economic profile of respondents, types of concrete buildings, rehabilitation methods, adaptive innovations/actions, building lifespan, factors affecting durability, repair duration after typhoons, and causes of construction delays.

For assessing the durability of concrete buildings, the effectiveness of rehabilitation methods, and the structural damage due to typhoons, a 5-point Likert scale was applied to ordinal data, alongside weighted mean analysis. This was used to rate the durability of the existing concrete buildings against super typhoons as follows:

1 – Not Durable. Very heavy damage or critical damage. Cannot be maintained or demolished.
2 - Less Durable – Heavy damage. Structure needs to be strengthened, or load needs to be reduced.
3 - Durable – Medium damage. Further testing is needed as soon as possible.
4 – Very Durable – Light damage. Repair is needed in routine maintenance.
5 – Highly Durable – No damage. No repairs are needed, but routine maintenance is required.

Definition of "durability" in this study is based on the inspection done by the engineers on existing concrete buildings after a disaster.

Moreover, rehabilitation methods were also generated for the repair of concrete buildings. A 5-point Likert Scale was used to rate the effectiveness of the rehabilitation methods as follows:

1 – Not Effective
2 – Less Effective
3 – Effective
4 – Very Effective
5 – Highly Effective

The effectiveness of rehabilitation measures was assessed by the respondents based on their experience in implementing such construction methods in the projects they handled.

The second part also included the categorization of structural damage on the concrete buildings due to typhoons. A 5-point Likert Scale was used to rate these structural damage as follows:

1 – Very Slightly Damage. Has isolated fractures and cracks visible under close visual inspection with maximum width of 1mm. The differential settlement ranges from 3 to 4 cm.

2 – Slightly Damaged. Has cracks with 3 mm width or with a width greater than 3 mm. The differential settlement is from 4 to 5 cm.

3 – Moderately Damaged. Has cracks with 5 to 15 mm width or with a width greater than 5 mm. The differential settlement is from 5 to 8 cm.

4 – Severely Damaged. Has large cracks with 15 to 25 mm width alongside leaning of walls, sloping of floors and distortion of door and window frame, disrupted pipes and beams with low bearings. The differential settlement is between 8 to 13 cm.

5 – Very Severely Damaged. Has cracks with more than 25 mm width. Stability of the building is in serious danger as the beams are severely damaged while the building is losing bearing. It requires partial or complete rebuilding. The differential settlement is more than 13 cm.

Furthermore, Qualitative data was also gathered through open-ended questions, capturing respondents' experiences and observations on: Adaptive innovations in new concrete construction, Concrete building lifespan, Factors influencing durability, post-typhoon repair times, and causes of construction delays.

Methodology Framework. This study utilized an Input-Process-Output (IPO) model to assess the structural durability of concrete buildings in Virac, Catanduanes.

The input includes the frequent occurrence and typical tracks of typhoons in the Bicol Region (where Catanduanes is often first hit), the types of concrete buildings in Virac assessed by respondents, and the socio-economic profile of the engineer-respondents.

The process involved assessment of engineers of the concrete buildings based on their durability, structural damage, implemented rehabilitation measures, and adaptations/innovations. Additionally, their observations on building lifespan, factors affecting durability and serviceability, post-typhoon repair duration, and causes of construction delays were documented.

The output is the culmination of the assessment of the structural durability of selected concrete buildings, leading to specific findings and recommendations.

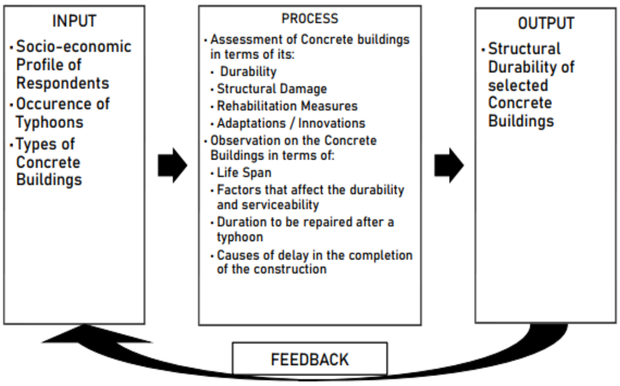

Figure 2
Conceptual Framework

RESULTS

Socio-Economic Profile. A respondent's socio-economic profile—including their age, gender, civil status, agency, position, and length of service—provides vital context for interpreting their views on concrete building durability.

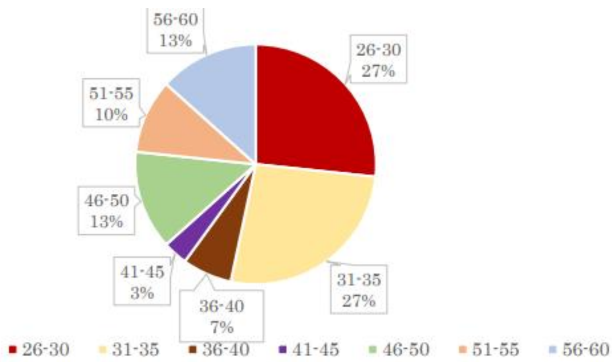

Figure 3
Age of Respondents in years

While not a direct technical assessment, these factors reveal their exposure to various building codes, construction practices, and natural disasters, offering a richer background for understanding their insights into building resilience.

Figure 3 shows that the majority of civil engineer respondents are between 26-35 years old. This age group, largely Millennials, represents a significant portion of the Filipino working class and typically brings technology proficiency and familiarity with modern construction methods.

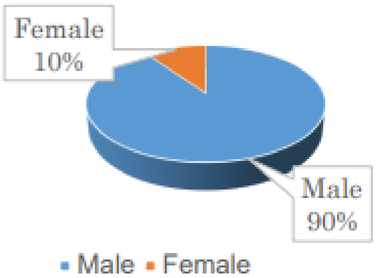

Figure 4
Gender of Respondents

Figure 4 shows a significant gender imbalance: 27 out of 30 respondents were male, and only 3 were female. This reflects the continued male dominance in engineering fields, a trend influenced by historical societal norms that stereotype engineering as a masculine career, potentially unwelcoming workplace cultures, and differing encouragement in STEM education for boys and girls. (Quora, n.d.)

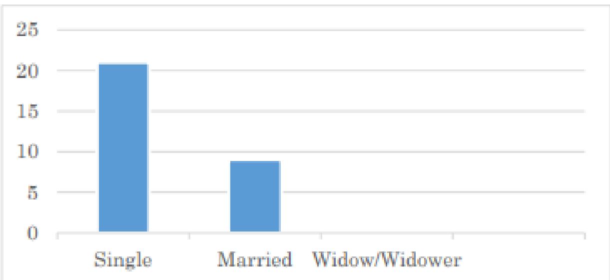

Figure 5
Civil Status of Respondents

Figure 5 revealed that 21 of 30 respondents are single, and 9 are married. This demographic aligns with the younger age profile of the engineers, many of whom are early in their careers. The demanding nature of engineering, often involving long hours and a focus on professional development, can contribute to delaying marriage. ("Why software developers don't date"💘, 2024) (Quora, n.d.) While civil status doesn't directly affect technical assessment, it offers subtle insights into respondents' perspectives and professional engagement within a disaster-prone context like Virac.

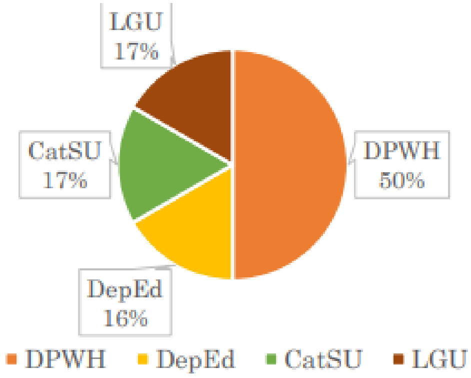

Figure 6
Agencies where the respondents are employed

Figure 6 illustrates the distribution of respondent employment agencies. The Department of Public Works and Highways (DPWH) is the dominant employer, reflecting its extensive role in national infrastructure. Local Government Units (LGUs) employ fewer engineers due to their smaller scope. The Department of Education (DepEd) hires civil engineers for school construction, while Catanduanes State University (CatSU) employs engineers for its Project Monitoring and Technical Planning Units, overseeing university infrastructure.

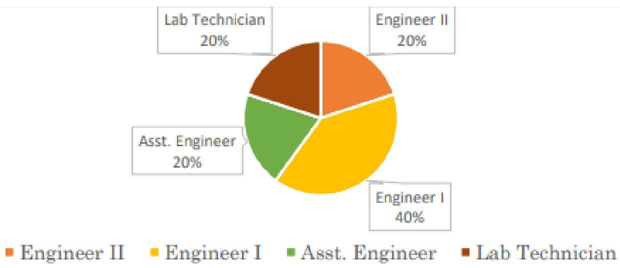

Figure 7
Position of the Respondents in their respective agency

Figure 7 shows the job positions of the 30 respondents: 40% are Engineer I, with Engineer II, Assistant Engineer, and Laboratory Technicians each at 20%. These roles generally align with age and employment at the Department of Public Works and Highways (DPWH). Younger engineers typically start as Assistant Engineer or Engineer I, with promotions to Engineer II often occurring around age 26 or older. Middle-aged engineers (40+) commonly hold Engineer II positions. Laboratory Technicians (civil engineers in the Quality Assurance Section) focus on material inspections, while engineers in Planning and Design, Construction, and Maintenance Sections hold Engineer I and Engineer II titles.

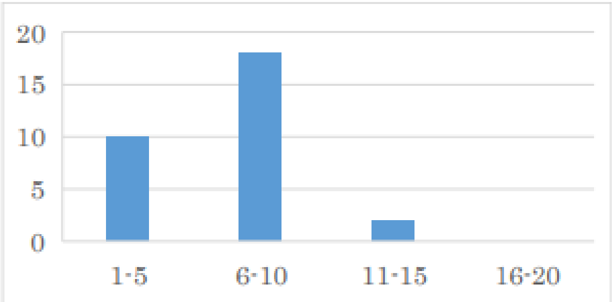

Figure 8
Length of Service of the Respondents

Figure 8 illustrates the respondents' length of service in their respective positions. None of the respondents have worked for 16-20 years. The majority of Engineer I positions have over 5 years of experience, reflecting that this role is typically a promotion from the entry-level Assistant Engineer position. Promotion within the agency, especially DPWH, requires several years of relevant experience.

Type of Concrete Building Projects Handled by Respondents and their Assessment of its Durability. Table 2 presents the type of concrete building projects handled by the respondents. The table shows multipurpose buildings, school buildings, office buildings, health facilities, and others with their corresponding number and ranks.

School buildings (28.85%) were the most common concrete type handled by respondents, closely followed by health facilities (23.08%). This aligns with the DPWH's prioritization of these structures under programs like HFEP and "Build, Build, Build." Multipurpose and "other concrete structures" tied, while office buildings ranked lowest (9.61%).

Table 2
Type of Concrete Building Projects Handled by Respondents

Type of Concrete Building Projects Handled by Respondents	Frequency	%	Rank
Multipurpose building	10	19.23	3.5
School building	15	28.85	1
Office building	5	9.61	5
Health facility	12	23.08	2
Others	10	19.23	3.5
Total	52	100	

Most buildings handled were low-rise (1-3 floors), including multipurpose (13), school (9), office (10), and health facilities (10). Respondents also managed six multi-story school buildings, one middle-rise commercial building, and two short high-rise hotel buildings. The tallest in Catanduanes is the 12-floor ARDCI Building Hotel 2. Durability was assessed on a scale of 1 (not durable) to 5 (highly durable), with higher ratings indicating greater resilience.

Table 3
Assessment of durability of concrete buildings handled by respondents

Type of Building	Rating Scale					Weighted Mean	Interpretation
	5 Highly Durable	4 Very Durable	3 Durable	2 Less Durable	1 Not Durable		
Multipurpose building	0	25	5	0	0	3.83	Very Durable
School building	2	18	10	0	0	3.73	Very Durable
Office building	5	9	15	1	0	3.60	Very Durable
Health facility	3	20	7	0	0	3.87	Very Durable
Others	2	10	15	2	1	3.33	Durable

Durability was assessed by comparing the design compressive strength (f'c,d) with the in-situ concrete compressive strength value (rf'c). Wiyanto et. al. (2022). This comparison, following established criteria, provides a factor indicating the concrete's actual strength relative to its design specification.

A 5-point scale was used to assess the durability of existing concrete building structures (Table 4). Multipurpose buildings (mean: 3.83), school buildings (mean: 3.73), office buildings (mean: 3.60), and health facilities (mean: 3.87) were all rated as very durable. "Other concrete buildings" received a mean rating of 3.33, indicating they are generally considered durable. This aligns with findings by Cabilao (2022) that concrete structures exhibit resilience against typhoon winds and are largely impermeable to rainwater.

Table 4
5-point scale to assess the durability of existing concrete building structures

Condition Rating	Description	Criteria	Damage Condition and Measure
1	Very Good (VG)	$r_{f'c} \geq 100\%\ f'c,d$	No damage. No repairs are needed, but routine maintenance is needed.
2	Good (G)	$85\%\ f'c,d \leq r_{f'c} < 100\%\ f'c,d$	Light damage. Repair is needed in routine maintenance.
3	Medium (M)	$75\%\ f'c,d \leq r_{f'c} < 85\%\ f'c,d$	Medium damage. Further testing is needed as soon as possible.
4	Bad (B)	$50\%\ f'c,d \leq r_{f'c} < 75\%\ f'c,d$	Heavy damage. Structure needs to be strengthened, or load needs to be reduced.
5	Very Bad (VB)	$r_{f'c} < 50\%\ f'c,d$	Very heavy damage or critical damage. Cannot be maintained or demolished.

Source: https://www.mdpi.com/2075-5309/12/6/776

Rehabilitation Methods Implemented in the Repair of Existing Buildings and the Assessment of their Effectiveness. Table 5 details the various rehabilitation methods employed by respondents for repairing existing buildings, encompassing more than just traditional retrofitting. These methods include: Retrofitting, Concrete column micro-jacketing, Application of carbon fiber, Extension of existing structure, and Demolition of existing structure. Each method's effectiveness was also assessed.

Table 5
Rehabilitation Methods Implemented in the Repair of Existing Building

Rehabilitation Methods	Frequency	Percent	Rank
a. Retrofitting	15	25.86%	2
b. Concrete Column Micro-jacketing	16	27.59%	1
c. Application of Carbon fiber	10	17.24%	4
d. Extension of existing structure (additional area)	12	20.69%	3
e. Demolition of existing structures	5	8.62%	5
Total	58	100%	

Table 5 outlines the rehabilitation methods used for concrete buildings:

- Concrete Column Micro-jacketing – Implemented by 27.59% of respondents, this method strengthens columns, reduces lateral movement, and increases load capacity.

- Retrofitting – Used by 25.85%, retrofitting involves modifications to existing buildings to enhance performance, safety, and resilience against hazards. It is a cost-effective alternative to demolition.

- Extension of Existing Structures – Employed by 20.69%, this method involves adding new areas to existing structures to improve functionality and accommodate additional equipment.

- Application of Carbon Fibers – Implemented by 17.24%, carbon fibers provide exceptional strength, stiffness, and durability. They enhance the mechanical properties of structures and extend their service life.

- Demolition of Existing Structures – Used by 8.65%, this method involves demolishing buildings beyond repair and constructing new structures.

Choosing the right rehabilitation method for concrete buildings, especially in places like Virac, Catanduanes, demands more than just a technical structural assessment. For government projects particularly, a comprehensive feasibility study is essential. This study must consider economic viability, environmental impact, social considerations, regulatory frameworks, and technical and logistical feasibility to ensure the chosen method is truly sustainable and effective.

Table 6
Effectiveness of Rehabilitation Methods in the Repair of Existing Buildings

Rehabilitation methods	Rating Scale					Weighted Mean	Interpretation
	5 Highly Effective	4 Very Effective	3 Effective	2 Less Effective	1 Not Effective		
Retrofitting	5	10	15	0	0	3.67	Very Effective
Concrete Column Micro-jacketing	2	20	8	0	0	3.80	Very Effective
Application of Carbon fiber	0	10	15	5	0	3.17	Effective
Extension of existing structure (additional area)	2	10	15	3	0	3.37	Effective
Demolition of existing structures	0	7	13	10	0	2.90	Effective

Table 6 summarizes the effectiveness of various rehabilitation methods, rated on a scale where higher means indicate greater effectiveness:

- Concrete Column Micro-jacketing (Mean: 3.80) and Retrofitting (Mean: 3.67) were rated very effective. These methods are highly valued for significantly enhancing a building's structural performance against natural hazards (seismic, wind, load-bearing capacity).

- Extension of Existing Structures (Mean: 3.37) and Application of Carbon Fiber (Mean: 3.17) were considered effective. While extensions offer increased space and cost-effectiveness, carbon fiber enhances strength but requires specialized application.

- Demolition of Existing Structures (Mean: 2.90) was also rated effective, primarily for allowing redevelopment despite its significant environmental and financial costs.

The respondents' "effectiveness" ratings reflect a holistic judgment, balancing the technical benefits of each method with practical considerations such as cost and implementation complexity.

Assessment of the Structural Damage on Concrete Buildings. Table 6 presents the respondents' assessment of the structural damage on the concrete buildings. It is rated on a scale from 1 to 5, where 5 is Very Severely Damaged, 4 is Severely Damaged, 3 is Moderately Damaged. 2 is Slightly Damaged, and 1 is Very Slightly Damaged. See chapter 3 for the definition of the structural damage.

Table 7

Assessment on the Structural Damage on Existing Concrete Buildings

Concrete Building Elements	5 Very Severely Damaged	4 Severely Damaged	3 Moderately Damaged	2 Slightly Damaged	1 Very Slightly Damaged	Weighted Mean	Interpretation
Roof	5	22	2	1	0	4.03	Severe Damage
Walls	0	3	7	8	12	2.03	Slight Damage
Posts	0	3	5	15	7	2.13	Slight Damage
Windows	22	7	1	0	0	4.70	Very Severe Damage
Doors	5	5	12	4	4	3.10	Moderate Damage
Beams	0	0	2	8	20	1.40	Very Slight Damage

Typhoons cause varying degrees of damage to concrete buildings, with non-structural elements bearing the brunt. As shown in Table 7:

- Windows experienced the most significant impact, being very severely damaged (weighted mean: 4.70).
- Roofs were also severely damaged (weighted mean: 4.03).

- Doors sustained moderately damaged (weighted mean: 3.10).

In contrast, core structural components showed far less damage:

- Walls and Posts were only slightly damaged (weighted means: 2.03 and 2.13, respectively).

- Beams incurred the least impact, being very slightly damaged (weighted mean: 1.40).

This pattern underscores the critical need for climate-responsive architectural design that prioritizes the resilience of vulnerable non-structural elements to mitigate the widespread and costly damage from extreme weather events.

Adaptation Innovations and Actions Implemented in the Construction of New Concrete Buildings. Table 8 enumerates the adaptation actions made to ensure the durability of newly constructed concrete buildings against typhoons and their assessment by the respondents.

Table 8

Adaptation Actions Made to Newly Constructed Concrete Buildings

Adaptive Innovations /Actions	Frequency	Rank
All materials to be used are according to the standard specifications	30	2
Making sure all the construction materials to be used have passed the quality test	29	4.5
Use of different software systems to determine the strength of a building before it is constructed	25	6
Use of Type A concrete mixture with a compressive strength of 3,000 psi using Type 1 cement	30	2
Utilizing the design of buildings to its maximum strength	29	4.5
Designing a typhoon/earthquake-resilient structure	30	2

Table 8 outlines key adaptive measures used to ensure the durability of new or rehabilitated buildings against typhoons:

Standard and Quality-Tested Materials. All materials must meet standard specifications and undergo rigorous quality testing (e.g., Rapid Chloride Penetration, Water Permeability, Absorption tests) to ensure longevity.

Strength Assessment Software. Software like Reinforced Concrete Design Software and FEM-Design are utilized for pre-construction strength evaluation.

Optimized Concrete Mixture. A minimum 3000 psi compressive strength concrete (Type A) with Type 1 cement is used; for coastal areas, Portland Pozzolana Cement (PPC) is recommended for corrosion resistance. (Century Peak Cement, 2024) (Philippine Mining Club, n.d.)

Maximized Building Design Strength. Designs prioritize load-bearing capacity, stability, and overall strength to withstand significant forces. Typhoon/Earthquake-Resilient Design.

Structures incorporate flexible foundations, damping, and vibration deflection technologies to resist natural disasters.

These measures are crucial for building structural integrity and resilience, providing a comparative framework to identify existing weaknesses and inform evidence-based rehabilitation strategies for a safer built environment in Virac.

Observations on the Concrete Building Projects that the Respondents have Handled.

Life span. Table 9 shows that the majority of the respondents, that is 66.67% or 20 out of 30 respondents, said that the estimated lifespan of concrete buildings is more than 15 years. A majority of respondents (66.67%) estimate the lifespan of concrete buildings to be more than 15 years, aligning with the goal of engineers to construct long-lasting, serviceable structures. This perception also reflects familiarity with the Civil Code of the Philippines (Article 1723), which holds engineers and contractors liable for structural failures due to defects within 15 years of construction.

Table 9
Estimated Life span of Concrete Buildings

Duration	Frequency	Percent	Rank
Less than 5 years	3	10.00%	3
5 to 15 years	7	23.33%	2
More than 15 years	20	66.67%	1

While the Code doesn't explicitly state a building's total lifespan, this 15-year period establishes a baseline expectation for structural soundness, after which maintenance responsibility shifts to the owner. A smaller percentage of respondents (23.33%) estimated a 5–15-year lifespan, and 10% estimated less than 5 years.

Factors that affect the durability and serviceability of concrete buildings. Table 10 shows the factors that affect the durability and serviceability of concrete buildings. These are based on the factors the respondents have encountered, and this study recorded their answers since this is an open-ended question. Listed in the table are several factors answered by the respondents.

Table 10
Factors that affect Durability and Serviceability of Concrete Buildings

Factors	Frequency	Rank
Environmental factors – changes in moisture content due to temperature, sunlight, and groundwater action	29	3
Natural calamities like typhoons & earthquakes	25	4
Construction methodology	30	1.5
Improper concrete mixture preparation	20	5
Quality of construction materials	30	1.5

Table 10 identifies five key factors that impact the durability and serviceability of concrete buildings:

Construction Methodology - Proper planning and execution are crucial for structural quality.

Quality of Construction Materials - High-quality materials are essential for long-term robustness.

Environmental Factors - Water quality and the water-cement ratio affect concrete mix and properties.

Natural Calamities - Events like typhoons and earthquakes necessitate resilient construction.

Improper Concrete Mixture Preparation - Incorrect mixes lead to structural weaknesses, emphasizing the need for quality control tests.

These factors collectively highlight the need for careful consideration in construction practices and material selection to ensure lasting building performance.

Duration for a concrete building to be repaired after a natural calamity. Table 11 shows the duration for a concrete building to be repaired after a natural calamity like a typhoon. The respondents answered based on their experience regarding the duration such as 1 to 3 weeks after the typhoon, 1 to 3 months, 4 to 6 months, almost a year, or more than a year after the typhoon.

Table 11
Duration for a concrete building to be repaired after a natural calamity

Duration	Frequency	Percent	Rank
1 to 3 weeks after the typhoon	6	20%	3
1 to 3 months after the typhoon	9	30%	1.5
4 to 6 months after the typhoon	9	30%	1.5
almost a year after the typhoon	3	10%	4.5
more than a year after the typhoon	3	10%	4.5
Total	30	100%	

As outlined in Table 11, concrete building repairs in Catanduanes often take months up to years during post-typhoon. This is primarily due to persistent challenges like material availability, budget release, and manpower shortages. Despite the inherent resilience of Catanduanes residents, these hindrances cause significant delays. Studies on past disasters, such as Super Typhoon Haiyan, confirm that even "safer" concrete structures sustain widespread damage, particularly to non-structural elements or due to poor construction. The immense scale of destruction, coupled with logistical hurdles and aid complexities, prolongs comprehensive repair and reconstruction efforts, even with a preference for reinforced concrete in rebuilding.

Causes of the delay in the completion of the construction of concrete buildings. A significant challenge exists in meeting concrete building repair timelines in Virac, Catanduanes. As shown in Figure 9, a substantial 83% of respondents reported that repair completion dates are not met, while only 17% achieved their deadlines. This clearly indicates that the majority of repairs are consistently delayed.

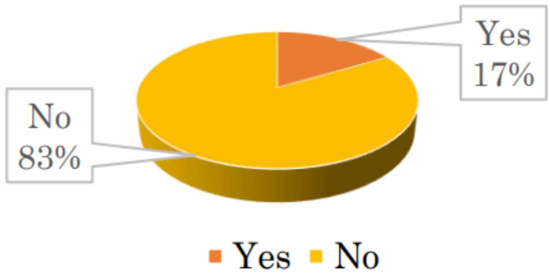

Figure 9
Answer of Respondents whether the target completion dates for repairs are met

Quantitative findings are strongly supported by qualitative insights from respondents, detailing specific reasons for delays. These reasons fall into two categories: uncontrollable external factors and internal management issues, reflecting historical challenges in disaster-prone regions like the Philippines.

External and Uncontrollable Factors

Adverse Weather and Natural Calamities. Virac's location within the Pacific Ring of Fire and its frequent exposure to typhoons (with Catanduanes experiencing an average of four typhoons annually) are primary disruptors. Consistent heavy rains and successive typhoons can halt construction and repair efforts, often leading to a cycle where new damage occurs before previous repairs are finished. This aligns with historical data showing severe weather consistently derails schedules.

Limited Site Accessibility. Natural disasters frequently render roads and bridges impassable, particularly in rural areas of Catanduanes. This logistical nightmare directly impedes the transport of essential materials, equipment, and personnel to repair sites, significantly contributing to missed deadlines and delays.

Scarcity of Construction Materials and Equipment. Following widespread destruction, there's an immediate surge in demand for materials like cement, rebar, and roofing. This often leads to critical shortages and price spikes, causing supply chain disruptions that directly impact repair timelines.

Internal and Management-Related Factors

Political Interference and Bureaucracy. "Political issues" often translate to delays in funding release, shifts in leadership priorities, or general bureaucratic inefficiencies within government agencies. Such political shifts can slow down or reroute critical recovery efforts, affecting project continuity.

Permitting, Regulatory Hurdles, and Slow Inspections. Administrative bottlenecks, including cumbersome permit processes and slow inspections by various government bodies, are frequently cited challenges. These systemic issues can independently impede timely project completion, regardless of external conditions.

Suboptimal Project Management. Deficiencies in internal project management are also a significant contributor to delays. This includes poor construction activity scheduling and improper distribution of manpower by project engineers, architects, and foremen. While external factors present challenges, these internal inefficiencies in planning, resource allocation, and supervision play a considerable role in missing completion dates, indicating a need for enhanced training and protocols.

Changes in Project Scope. Unforeseen site conditions or evolving requirements often lead to variations in project plans and specifications. These common changes can result in substantial delays, preventing projects from adhering to original timelines.

Conclusions. This study in Virac, Catanduanes, assessed the structural durability of concrete buildings to identify factors affecting their resilience in a disaster-prone area. The findings provide insights into local building challenges and practical resilience strategies.

Key Findings and Implications. The study revealed important aspects of concrete building durability and repair in Virac:

Demographics of Expertise and Perceived Durability. The engineering workforce, primarily young male engineers from DPWH, mainly handles public infrastructure such as schools, health facilities, and multi-purpose buildings. These structures are consistently considered highly durable, suggesting effective construction standards and quality control. However, "other concrete buildings" are perceived as less durable, highlighting a need for improved practices and maintenance in this sector and a potential disparity in construction quality not often covered in literature focusing solely on code compliance.

Prioritizing Structural Reinforcement for Rehabilitation. Local engineers overwhelmingly prioritize structural reinforcement methods like concrete column micro-jacketing and retrofitting for rehabilitation. This indicates an understanding of primary failure modes in earthquake and typhoon-prone areas. Less favored methods like extension, carbon fiber application, and demolition are likely due to perceived cost or complexity. This finding quantifies local professionals' practical evaluations of rehabilitation techniques, moving beyond theoretical effectiveness.

Vulnerability of Non-Structural Elements. Typhoons primarily damage non-structural elements like windows, roofs, and doors, leading to widespread, costly damage and immediate shelter needs. Conversely, minor structural damage to walls, posts, and beams suggests inherent typhoon resilience in the primary concrete structures. This highlights the need to focus future efforts on improving non-structural component design and installation for overall building functionality and post-disaster recovery.

Emphasis on Quality, Design, and Structural Analysis. Respondents consistently prioritize high-quality materials, strict adherence to construction standards, and earthquake-resistant design. The crucial role of structural analysis software before construction is also emphasized, reinforcing its importance for safety and long-term performance and corroborating established engineering principles.

Lifespan Expectations and Project Delays. Concrete buildings are expected to last beyond the 15-year liability period, indicating a broader expectation of long-term durability. However, this is challenged by poor construction practices, substandard materials, and inadequate quality control. Repair works are frequently delayed, with 83% of respondents reporting missed deadlines. These delays stem from uncontrollable factors like weather and natural disasters, as well as manageable issues such as political interference, bureaucratic hurdles, material unavailability, and deficiencies in project management.

Broader Implications and Future Directions. The findings have significant implications for practices and policies in typhoon-prone regions like the Philippines:

Targeted Policy Interventions for Non-Structural Elements. The identified vulnerability of non-structural elements should prompt policymakers to develop and enforce specific, enhanced building code provisions and quality assurance protocols for roofs, windows, and doors, especially in public buildings.

Strengthening Oversight and Capacity Building. Delays due to bureaucratic hurdles and management issues highlight the need for streamlined permitting and inspection processes within government agencies. Enhanced training in project management, scheduling, and logistics for engineers and architects is crucial, particularly for post-disaster repair.

Proactive Resilience Strategies for All Building Types. Concerns regarding "other concrete buildings" signal a need for uniform application of high construction standards and rigorous quality control across all public infrastructure projects, potentially through stricter tender processes and independent quality audits.

Integrating Climate Change Projections into Design and Rehabilitation. Future policies must explicitly integrate updated climate projections into building design codes and rehabilitation guidelines, using this study's empirical evidence to inform adaptive strategies for more resilient structures.

Data-Driven Decision Making for National Resilience. This study's methodology and findings can serve as a template for similar assessments in other vulnerable municipalities, providing comprehensive national data for targeted investments, national disaster preparedness policies, and resource allocation for long-term infrastructure resilience.

Recommendations. Based on the study's findings, the following actionable recommendations are made to enhance future practices and policies in Virac, Catanduanes:

Enhance Construction Quality and Standards. Implement rigorous quality control with independent on-site inspections and material testing. Promote the use of high-quality, resilient materials through incentives. Strengthen and strictly enforce building codes, advocating for the new Philippine Building Act and local ordinances that exceed national wind load requirements.

Improve Construction Practices and Professional Development. Invest in continuous professional development for construction workers, focusing on resilient techniques and quality installation of non-structural elements. Promote modern construction technologies like prefabrication and Building Information Modeling (BIM). Implement mandatory project management training for all DPWH engineers and foremen.

Enhance Resilience to Natural Disasters. Mandate strict adherence to the latest NSCP seismic design provisions and prioritize retrofitting vulnerable existing buildings. Systematically review and upgrade specifications for roofing materials, fastening methods, and roof-to-wall connections to withstand extreme wind speeds. Require impact-resistant windows and doors or robust shutters, especially in critical public buildings. Implement minimum finished floor elevations and foundation design requirements for coastal buildings.

Develop and Implement Comprehensive Disaster Preparedness Plans for Buildings. Require each public building to have a regularly updated, publicly accessible disaster preparedness plan, including evacuation routes and emergency repair protocols. Conduct annual multi-hazard drills for occupants and staff.

Address Project Delays Systematically. Streamline bureaucratic processes for permits and approvals, potentially through a "one-stop-shop" or digital platforms. Improve access to construction materials and equipment by maintaining local inventories and establishing pre-qualified supplier agreements. Enhance project coordination and communication through multi-agency task forces and shared online project management tools.

Invest in Research and Development. Allocate funds for localized research on optimizing concrete mixes for tropical climates, developing cost-effective corrosion-resistant rebars, and testing local materials for enhanced durability. Explore and pilot advanced technologies like remote sensing, GIS for damage assessment, and Building Performance Simulation (BPS) tools.

Raise Public Awareness. Launch public awareness campaigns to educate the public on building quality and safety, the risks of substandard construction, and the benefits of investing in resilience. Promote the benefits of sustainable and resilient construction by showcasing successful projects and integrating basic disaster-resilient principles into vocational training and community development initiatives.

REFERENCES

Alabaso, K. (2024, November 20). Around 4,000 houses in Catanduanes damaged by Pepito's onslaught. ABS-CBN news. https://www.abs-cbn.com/regions/2024/11/19/around-4-000-houses-in-catanduanes-damaged-from-pepito-onslaught-2154

Cabilao, K. A. E. F. (2022, June 4). Building Better Homes against Typhoons. SunStar Publishing Inc. https://www.sunstar.com.ph/cebu/lifestyle/building-better-homes-against-typhoons

Castillo, L., & Castillo, N. (2021, February 5). Catanduanes, Philippines: The Land of Howling Winds – Traveling boy. Traveling Archive. https://travelingboy.com/travel/caanduanes-beauty-and-tragedy-in-the-land-of-howling-winds/

Catanduanes Tribune. (2022, November 4). SP Declares Catanduanes In State of Calamity Due to “Paeng” Damage. Catanduanes Tribune. https://catanduanestribune.net/2022/11/04/sp-declares-catanduanes-in-state-of-calamity-due-to-paeng-damage/

Choosing the Right Hydraulic Cement for Your Construction Projects in the Philippines. Cement Supplier Philippines - Century Peak Cement. (2024, May 30). https://centurypeakcement.com/article/choosing-the-right-hydraulic-cement-for-your-construction-projects-in-the-philippines

Climate Adaptation Platform. (2022). IMPACTS OF SUPER TYPHOONS AND CLIMATE CHANGE. https://climateadaptationplatform.com/impacts-of-super-typhoons-and-climate-change/

FutureLearn. (2021). How the Philippines deals with typhoons. https://www.futurelearn.com/info/futurelearn-international/philippines-typhoons

Graunke, S. (2018, December 20). Using qualitative sampling to your advantage. Air. https://www.airweb.org/article/2018/12/20/using-qualitative-sampling-to-your-advantage

Holden, W.N., & Marshall, S.J. (2018). Chapter 24 – Climate Change and Typhoons in the Philippines: Extreme Weather Events in the Anthropocene. *Integrating Disaster Science and Management,* 407-421. https://doi.org/10.1016/B978-0-12-812056-9.00024-5

Kimball, S. (2023, July 4). Typhoons in the Philippines Cripple Development and the poor. Climate Impacts Tracker Asia. https://www.climateimpactstracker.com/typhoons-in-the-philippines/

Kuba, M. (2018, April). (PDF) IMPACT OF CLIMATE CHANGES ON CIVIL ENGINEERING STRUCTURES. ResearchGate. https://www.researchgate.net/publication/324477074_IMPACT_OF_CLIMATE_CHANGES_ON_CIVIL_ENGINEERING_STRUCTURES

Manila Typhoon Center (2022, June 14). Manila TC Storm Basics: Effects of Tropical Cyclones over Land areas http://typhoonmanila.weebly.com/wind-damage.html

Morales, N. J. (2020, November 2). 90% of Catanduanes' infrastructure damaged by Typhoon Rolly. ABS CBN. https://www.abs-cbn.com/news/11/02/20/90-of-catanduanes-infrastructure-damagedby-typhoon-rolly

Pagkatotohan, J. (2023, August 9). Top 10 strongest typhoons in the Philippines: Updated list 2023. Top 10 Strongest Typhoons in the Philippines: Updated List 2023. https://www.moneymax.ph/lifestyle/articles/infographic-the-10-deadliest-typhoons-in-the-philippines

Philippine Mining Club. (n.d.) "13 Types of Cement and Their Uses in Concrete Construction." https://www.philippineminingclub.com/13-types-of-cement-and-their-uses-in-concrete-construction/.

Pudyastuti, P. S., & Nugraha, N. A. (2018, June 26). Climate change risks to infrastructures: A general perspective. Silverchair. https://watermark.silverchair.com/040030_1_online.pdf

Quora. (n.d.). Why are mechanical students mostly single?. https://www.quora.com/Why-are-mechanical-students-mostly-single

Quora. (n.d.). Why are the majority of mechanical engineers men rather than women?..https://www.quora.com/Why-are-the-majority-of-mechancial-engineers-men-rather-than-women

Sarmiento, R. F. A. (2009). The Catanduganons-Making and Seeing Selves Through the Eye of the Typhoon. PSSC. https://pssc.org.ph/wp-content/pssc-archives/Aghamtao/2011/3-

Schweikert, A., Chinowsky, P., Espinet, X., & Tarbert, M. (2014). Climate Change and Infrastructure Impacts: Comparing the Impact on Roads in ten Countries through 2100. Procedia Engineering, 78, 306–316. Doi: 10.1016/j.proeng.2014.07.072

Secret Developer site. (2024, July 10). Why software developers don't date💘. Secret Developer site. https://www.thesecretdeveloper.com/blog/why-software-developers-dontnbspdate

University of the Philippines Diliman College of Science. (2022, October 3). The relationship between super typhoon occurrence and climate change. University of the Philippines Diliman Science. https://science.upd.edu.ph/the-relationship-between-super-typhoon-occurrence-and-climate-change/

Wiyanto, H., Makarim, C. A., Gondokusumo, O., Siregar, J. P., Irawan, A. P., Cionita, T., & Najid, N. (2022, June 6). Determining concrete structure condition rating based on concrete compressive strength. MDPI. https://www.mdpi.com/2075-5309/12/6/776