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Case studies on the restoration and retrofitting of heritage churches and buildings in the Philippines

Études de cas sur la restauration et la modernisation des églises et des bâtiments patrimoniaux aux Philippines

R. A. C. Luna, E. B. Abiad, J. C. E. L. Santos, E. P. Kasilag, R. C. C. Perez, M. G. L. Casuncad, M. P. V. Follosco, R. M. Garcia, F. J. T. Bernales, & J. V. D. Razon
AMH Philippines, Inc, Philippines, rodora.perez@amhphil.com

ABSTRACT**:** Having been a Spanish colony for more than 300 years and being occupied by the Americans for around 40 years, heritage churches and buildings have been part of the landscape not just in the capital city of Manila, but in various towns and cities in the Philippines. In the past 10 years, with the publication of more stringent seismic design codes and standards, the preservation and retrofit of several heritage churches and historic buildings has become imperative. Moreover, some buildings were actually damaged by recent earthquakes, necessitating repair and rehabilitation. This paper presents case studies for the rehabilitation and retrofitting of a few heritage churches and buildings in Manila and in the island-province of Bohol - with emphasis on the necessary ground improvement works and foundation retrofit.

RÉSUMÉ Ayant été une colonie espagnole pendant plus de 300 ans et étant occupée par les Américains pendant environ 40 ans, les églises et les bâtiments du patrimoine font partie du paysage non seulement dans la ville capitale de Manille, mais dans des diverses villes des Philippines. Au cours des dernières dix ans, avec la publication des codes et des normes de conception sismique plus stricts, la préservation et la renovation de plusieurs églises patrimoniales et bâtiments historiques sont devenues impératives. De plus, certains bâtiments ont été endommagés par des récents tremblements de terre, nécessitant des réparations et des réhabilitations. Cet article présente des études de cas pour la réhabilitation et la renovation de quelques bâtiments patrimoniaux et églises à Manille et dans la province insulaire de Bohol - en mettant l'accent sur les travaux nécessaires d'amélioration des sols et de rénovation des fondations.

Keywords: Heritage structures, foundation restoration and retrofitting in the Philippines

1 INTRODUCTION AND BACKGROUND

The wave of foreign colonization in the Philippines brought along religious ideas that largely inspired architectural elements of church designs. Spanish colonization formally started during the Spanish re-expedition of 1565. Spanish colonies were quickly established throughout the Philippines, starting from Cebu, expanding to Panay and Mindoro islands, then eventually to Manila in 1570. Manila was then declared capital (and still is) of the new Philippines. A year later, the Manila Cathedral was established by a secular priest—just the second church in the country after the Santo Niño Church in Cebu. To protect the capital city and its important buildings against invaders and revolutionaries, stone wall fortifications were intermittently built starting from 1590 until 1872, enclosing an area known eventually and until now as *Intramuros*. Following the cession of the Philippines by Spain in 1898, American colonization took over. In this period, the heritage structures were retained, and even more churches were built by new religious orders.

The type of construction for the churches is primarily dependent on contemporary authorities. Earliest churches were built using Spanish experience in construction using locally available materials. The practice essentially evolved from timber materials, but when frequent fires were realized as threats, the approach eventually shifted to masonry and concrete materials. It was until the American colonial period where, in Bohol, churches started using (lightly) reinforced concrete, a newly introduced material to the Philippines at the time, slowly departing from unreinforced masonry construction. These churches are smaller and more modest than the older churches, but with classical facades more carefully designed and articulated in proper proportion to their smaller size. The latter reflects the development of engineering, on par with architecture, in building religious structures in the Philippines.

2 GEOLOGY AND GEOHAZARDS

2.1 *Manila*

Old Manila is mostly soft silty clay, with high water table, near West Valley Fault, highly seismic, highly liquefiable, and flood prone.

Generally, locations near the Manila Bay area are underlain with soft sedimentary deposits. It may also vary from soft tuffaceous marine silt to coralline limestone. The sedimentary deposits thicken toward the direction of Manila Bay in the west. Towards Quezon City, San Juan and Makati in the east, the Guadalupe Tuff Formation (GTF) is normally encountered at a shallow level, usually within a few meters depth. The GTF, which underlies most of Metro Manila, is a horizontally bedded rock commonly referred to as 'adobe'. It consists of well-laid rock formation of tuffaceous sandstone, tuffaceous siltstone and shale being the weakest member.

At one time in the geologic past, Manila and its immediate vicinity used to be a submerged area with the sea extending to the mountains on the East. Volcanic activities followed intermittently and after which, deposition of volcanic materials occurred.

During the intervening periods of inactivity, transported sediments were deposited on top of the previously laid volcanic materials. Thus, interbeds consisting of tuff beds and transported sediments became a characteristic feature of the deposit.

In general, the delta deposits are stratified and cross-bedded, and consist of sands, pebbly gravels, silts and clays of various colors and plasticity. Fossil remains included in the sediments are marine seashells, decayed wood and other organic particles. The latter suggests a swampy environment – a condition which could have prevailed during shallow water level. Lateral persistency among individual beds is said to be poorly developed that it is not uncommon for a thick bed to terminate abruptly in a few meters distance (Mines and Geosciences Bureau, MGB)

The most prominent seismic source in Metro Manila is the Valley Fault System (VFS), the trace of which has been mapped from the western edge of Marikina Valley, bordering the Payatas and Loyola Hills in Quezon City, and then southward parallel to the South Luzon Expressway, along the western margins of the Laguna Lake flatlands.

2.2 *Bohol*

Bohol is mostly underlain with limestone, highly porous and dissolvable soil. Antequera is generally underlain by the Maribojoc Formation which generally consists of conglomerate, marl, and limestone. According to the *Geology and Minerals Resources of the Philippines* (GMRP 2004), "the term Maribojoc Limestone was originally used by Arco (1962) to designate the youngest limestone unit blanketing most of the western part of the island and all the other islets fringing Bohol." In recent research by Mula and Maac (1995), other units relating to the Maribojoc Limestone were found. These units, which were also previously identified as members of the Carmen Formation, are the Tubigon Conglomerate and the Sevilla Marl. In addition to the Tubigon Conglomerate and Sevilla Marl, the Cortes Limestone is also considered under the Maribojoc.

The Tubigon Conglomerate is dominantly tuffaceous congolomerate with intercalations of ash tuff and volcanic breccia located at the mid-western portion of the island. Meanwhile, the Sevilla Marl is dominantly tuffaceous marl with occasional sandstone, shale and limestone located at the southern part of the island. The Cortes Limestone, which is widely distributed southwest of the island particularly at the Cortes and Tagbilaran districts with proximity to Antiquera and is thus expected to largely underlay the site, is coralline limestone which caps all the older formations in Bohol and represents the upper member of the Maribojoc Formation. It is also the youngest limestone body in the island. The limestone is described by the GMRP 2004 as "soft, chalky, non-compact, marly and coralline, varying from cream to brownish yellow or buff; usually massive to poorly bedded, porous and characterized by numerous caverns and sinkholes; fossiliferous with abundant corals and algae associated with some foraminifers and mollusks." However, no index fossil was recognized from the limestone despite being evidently fossiliferous.

Moreover, the Carmen Formation, which is associated to the Maribojoc and consists of shale, sandstone, conglomerate, and limestone, may be present. At large portion of the island, the Carmen Formation is mostly covered by the Maribojoc Formation save for some portions south of the island where the Carmen Formation is found at the surface.

The most prominent seismic sources at Antequera are the North Bohol Fault, South Bohol Faults and Maribojoc Fault capable of producing up to intensity eight ground shaking and causing earthquake-induced landslides. On October 15, 2013, the North Bohol Fault generated a magnitude 7.2 earthquake which caused approximately Php 2.25 billion worth of infrastructure damages both in Bohol and Cebu and affected more than 3.2 million people. The earthquake is considered as one of the deadliest earthquakes in the Philippines.

Based on the Liquefaction Hazard Map of Bohol by PHIVOLCS, Antequera is not known to be susceptible to liquefaction.

3 SITE CHARACTERIZATION

3.1 *Manila*

Manila is adjacent to the Manila Bay. With the high water table and recent deposits of clay and sands, the subsurface is generally soft with low bearing capacities and high liquefaction potential.

This greatly influences the limit of structure heights built in the area to remain economical. A number of high rise towers have been constructed in recent times using long driven piles to bypass the top layer and reach the bedrock.

3.2 *Bohol*

Subsurface investigation at Antequera, Bohol shows that the site subsurface generally consists of 0 to 5.5 meters of soil with stiff to very hard consistency or very dense relative condition. This is underlain by fractured gray sandstone or brown limestone to termination of 15-meter borehole depth. Additionally, ground water was not encountered in any of the boreholes.

4 CASE STUDIES

4.1 *Manila Cathedral*

Manila Cathedral is situated near the Manila Bay, inside the walled city of Intramuros. It was established sometime in 1579 but the current structure is its eighth reincarnation and was rebuilt in 1958 after it was ruined during the second world war. It has an area about 3,000 sqm and a Latin-cross footprint. It underwent repairs for earthquake retrofitting and subsidence prevention in 2012 until 2014.

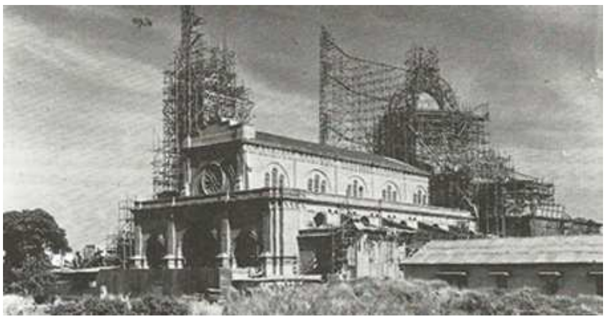

Figure 1. The ruins of Manila Cathedral after the WWII destruction in 1945. (Source: http://manilacathedral.com.ph/)

The subsurface condition at each borehole, based on the results of the field investigation and laboratory testing, are summarized in the following table.

Table 1. Summary of SPT N-value of 4 boreholes conducted in Manila Cathedral.

	BH-01		**BH-02**		**BH-03**		**BH-04**	
Depth, m	SPT-N	USCS	SPT-N	USCS	SPT-N	USCS	SPT-N	USCS
1.00	coring	SM	50	GM	22	GM	6	SM
2.00	7		50	SM	50	SM	coring	ROCK
3.00	1		50		50			
4.00	4		50		coring	rock		
5.00	13		50		16	SM	7	SM
6.00	32		13		16		12	
7.50	12		16	ML	13	ML	26	
9.00	23	CL	10		8	SM	36	ML
10.50	14		8		9		10	
12.00	7		5	MH	12	CL	6	MH
13.50	3	MH	5	SC	1		4	
15.00	3	CL	3	SM	1		4	SM
16.50	8	SM	4		3		3	ML
18.00	7	ML	7	ML	9	ML	38	SM
19.50	6	CH	5	SC	5	CH	9	
21.00	7		7		4		8	
22.50	6		7	MH	5	CL	8	ML
24.00	7		10		6		6	SM

In general, the results of the liquefaction analysis using the JSCE Method, indicate that the upper portions of dense sands are not susceptible to liquefaction except for layers of loose silty sand found in Boreholes 1 and 4 at a depth region of 3 to 5 meters. However, especially for Boreholes 2 & 3, majority of the layers starting at a depth of 12 meters and beyond are potentially liquefiable.

It should be noted though that there exist interspersed layers of plastic materials (of clays and high-plasticity silts) that diminish the thicknesses of the potentially liquefiable layers. Consequently, depending on the type of existing foundation that supports the Cathedral, this stratification may decrease possible damage should liquefaction take place.

Pending the advent of more information related to the existing foundation, bearing capacities were estimated based on footing information gleaned from available As-built plans as well as data obtained from the soil investigation.

Table 2 shows the bearing capacities of the soil for different depths down to 5 meters from the ground level. The rightmost column indicates the minimum of the bearing capacities based on the results of the four (4) boreholes.

Table 2. Bearing capacities for boreholes 1-4 to their corresponding depths.

Depth (m)	q_{allow} (kPa)
1.0	60
2.0	75
3.0	50
4.0	100
5.0	110

The recommended engineering measure was to inject jet grout around the soil of the foundation to ensure lateral confinement even in the event of liquefaction. Lateral confinement is crucial because it provides (i) frictional resistance along the shaft of the massive foundation, and (ii) lateral resistance around the massive foundation.

A significant increase in bearing capacity was found when modeled as a bored pile with cross-sectional dimensions (3.0m x 3.0m) and 10.0 penetration length, the allowable axial capacity is 8,920kN, considering an allowable settlement of 25mm.

4.1 *Antequera Church in Bohol*

Officially named Nuestra Senora Del Rosario Church, it may be the first significant concrete construction in the region. The stone foundations date to as early as 1896. It was progressively constructed until 1960s.

Unfortunately, a major earthquake occurred in Bohol in October 15, 2013 and critically damaged the church structure. Structural cracks, permanent displacement and localized collapse were observed all throughout the structure.

Figure 2. The façade of the Antequera Church showing structural damage after the major Bohol 2013 earthquake.

Material sampling and testing are currently being conducted to obtain more data about the structure and the nature of structural damage.

5 CONCLUSION

Catholicism celebrates its 500th year in the Philippines since the Spanish colonizers brought it to the archipelago. The deep roots and widespread of Catholicism is evident in the numerous baroque churches still existing nationwide and the effort to conserve takes a lot of support.

These churches underwent numerous rehabilitations throughout the years as they sustained damages from many earthquake and typhoon events, the Philippines being located along the Pacific Rim of Fire and having the Pacific Ocean to the East.

The old engineering methods needed retrofitting to keep up with the evolving and improving practices in Engineering and Construction. These heritage churches lack reinforcement and lack connection of walls to foundations that results to a much-needed retrofitting while conserving their heritage architecture.

Liquefaction, being a recently known phenomena, needed to be addressed through ground improvement techniques, which also increases the bearing capacity as a two-fold effect of these mitigations.