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A Case Study of Site Conditions and Ground Stability of Town Homes

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Abstract

Many houses in Villa Milagrosa Town Homes in San Pedro, Laguna are in substandard condition. This means that families often suffer from unsafe and uncomfortable indoor condition. Holes in roofs or gaps in doorways allow hot air to get inside in the summer and to flow out in the rainy season. Sustainable technologies must be applied to structurally sound homes to make them more resource efficient, improve their quality of life and benefit the environment.

Keywords: *Ground stability, site condition, substandard, sustainable technologies, townhomes*

1. Introduction

Everyone dreamed to live in a place that is affordable and will give him comfort. The purpose of a building is to provide shelter as one of the major needs of man. During prehistoric times, man dwells in caves or built their houses using wood products. When the world of engineering is introduced, the evolution on the design and construction of buildings and houses emerged. There were different types of houses introduced. Some of them are bungalow, low cost/socialized housing apartment and duplex. With the continuous demand on affordable but quality houses, the construction of townhouses invaded the Philippines. More people chose to live in these types of houses because of scarcity of land in the urban area.

In response, PHINMA Property Holdings Corporation answers the basic need in social housing in the Philippines to accommodate low and middle income families. One of its housing projects is a Villa Milagrosa Townhomes.

Villa Milagrosa Townhomes is located in a one-hectare property at San Vicente, San Pedro, Laguna and completed in 1991. It is consist of 155 row houses ranging from 41.70 to 55.20 square meters in floor area.

This is a particular townhouse because of its artificial location beside the crest of San Pablo River. One of the main concerns of study is to have an assessment on the stability of this townhouse in relation with geotechnical engineering, the science that deals with the application of the laws of mechanics and hydraulics involving problems in soil. The study of its geological properties of a soil provides technique for selecting the appropriate type of foundation and for predicting the performance of the completed structure. One of the roles of a civil engineer is generally consisting of the design of substructure, which is necessary to obtain the stability of any structure [1,2].

After long years, the residence of the area noticed valuable changes in the structure of their houses. They cited that the cracks on the walls are getting even worst due to failure of retaining walls and riprap caused by slight soil erosion and overflow of san Pedro River. Although there are already safety measures and repairs done on some houses, this still frightens them that their houses will collapse if major soil erosion occurs.

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The residents of Villa Milagrosa cited some changes on the structure of their houses. The residents of Block 3 and 9 noticed crack on the walls and slabs brought by the collapse of the riprap that support its foundation shown in figures 1 and 2. The water pump that supplies the residents is also affected due to the effect of soil erosion on the pipes and steel reinforcements.

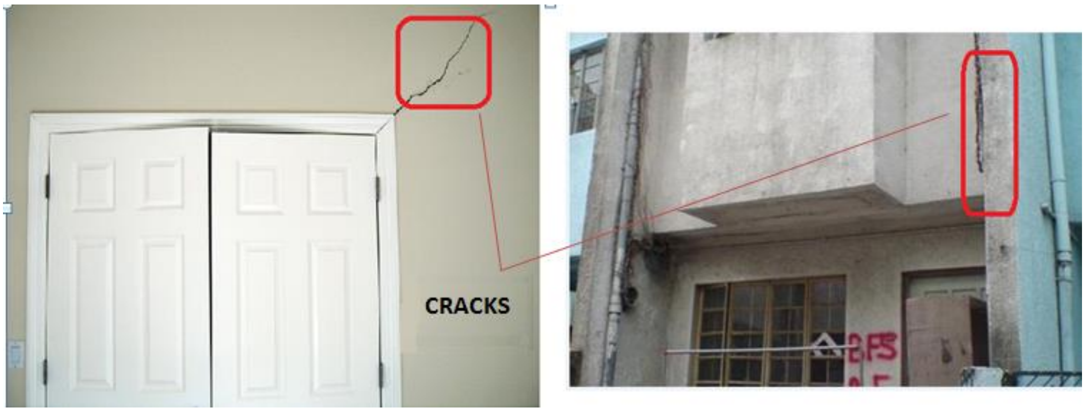

Figure 1. Cracks in Walls

Figure 2. Cracks in Slabs

This case study is to concentrate on identifying the causes that brought unsatisfactory conditions to the residents of Villa Milagrosa and find some of the possible solutions to these problems.

2. Location of Villa Milagrosa Townhomes

Villa Milagrosa Townhomes (VMT) is situated in village of San Vicente, San Pedro. Laguna. It is centered in geographic coordinate’s 14^{0}21’13’’north latitude and 121^{0}02’36’’east longitude. The townhouse is situated on a very well constrained area width ranging from 10-50 meters plate1 sandwiched by the provincial road and crest of the bank of San Pedro River.

San Pedro River is an east draining perennial river roughly 10 kilometers length of plate 1 and 15 meters width, portion near VMT. At the time of the inspection conducted by the geologists from mines and Geo-sciences Bureau, Region 1V, the river is low and has moderate flow.

The townhouse encompasses an area of 8,717 square meters with 147 lot/units ranging from 41.40 to 55.20 square meters in floor area. The residential units consist of light roofed houses with hollow block wall and reinforced concrete columns on isolated footings. The two storey houses are arranged in row housing. Some houses have undergone additions such as extensions in floor areas and perimeter fence.

3. Technical Conditions of Villa MilagrosaTownhomes (VMT)

The damaged riprap was made of massive gravity walls made of mortared stones, masonry, and unreinforced concrete. Gravity wall depends entirely on its weight for stability [3,4]. This is usually used for wall 10meters high. The newly constructed retaining wall that supports houses at block 9 was failed. The retaining walls are constructed in concrete hollow blocks (CHB) reinforced concrete construction.

In an interview with Mrs. Elizabeth Seva, the President of Villa Milagrosa Homeowners Association, she cited that the houses mostly affected by cracking's are block 1, block 3 and block 9. Some four units in block 1 is the model unit of Villa Milagrosa constructed using light material such as striper in the walls to reduced loads to structure. One owner of the unit is Mrs. Fe Ramillo. Her unit is now experiencing slight deformation due to soil that is eroding. On the other side, block 3 and block 9 is located near San Pedro River. The soil beneath of block 1 came from the filling materials gathered from the upper portion of block 3. They concluded that this might have contributed to soil erosions. Another resident, Mrs. Neneth Baluyot of block 7, lot 6 and also an officer of VHMA supported the statements of Mrs. Seva. Mrs. Baluyot added that 9 units from block 7 were affected by the failure of riprap and other units are also in danger if there's no immediate action and remedial measures. A resident of block 9, Engineer Manuel Reyes stated the riprap behind his unit were also affected and a newly constructed retaining wall, now support the house in the said area.

Regarding this, VMHA requested different agencies to conduct investigations and inspection on the site to know the causes of the problems. These are some findings and observations:

1. Several portion of rip-rapping together with the CHB perimeter fence collapse due to the wakening caused by excessive ground water flow brought by typhoon.

2. Debris from collapsed rip-rap was found scattered in different places at the river while debris from collapsed CHB perimeter fence were seen on top of the roots of a tree.

3. The fence remains unsupported except by its footing which is practically changing several section of perimeter fence are presently in danger of collapsing due to erosion found in the foundation bed. If no mitigating measure is undertaken, the fence will surely collapse and could affect the structural stability of the adjacent residential units.

4. Some homeowners had constructed structures beyond their property line obviously without any approval form from the board or building official. This is quite unsafe because slope failure occurs due to the increased loading on the slope caused by illegal structures.

5. The grouted rip-raping constructed by the owners/developer was not designed to withstand the combined water and soil pressure.

6. Drainage system was not properly maintained as evidence by clogged manholes.

7. Portions of concrete pavement developed severe transverse cracks.

8. Water tanks need clearing and repainting.

9. The foundation materials underlying VMT are interbedded tuffaceous clay siltstone and sandstone. The tuffaceous clay siltstone are characterized as having moderate plasticity (can be rolled to about 3 millimeters without breaking), friable (breaks on slight finger pressure), and poorly consolidated. Tuffaceous sandstone on the other hand, is a little stiff, moderately consolidated but friable in nature. Both rock types have beds range from 50 to 100 centimeters in thickness [5].

10. San Pablo River experienced intense erosion along its course wherein scouring of its banks (especially on the side where Villa Milagrosa Townhouse is situated) caused the collapse of the riprap wall supposedly protecting the subdivision from erosion. Consequently, the exposed bank wall was left unprotected to another flooding and erosion. Several houses within Villa Milagrosa Townhomes (especially those located adjacent to San Pedro River0 has structural damage during and after flooding event that occurred along San Pedro River. Damages after the incident include hanging of house floors and collapse of peripheral walls.

11. Stream bank collapse along the San Pedro River can be attributed to the effects of high velocity water flow and its being located on the erosive side of the river as well as soft and erodible soil characteristics of foundation material. The weights of the building structures could add up to the stress applied to the bank and may further contribute to the future damage.

The different causes of foundation settlement due to loads imposed on the soils are soil bearing capacity failure including partial failure or creep, failure or deflection of the foundation structure, compression of soil, subsidence due to mines or caves beneath the surface, subsidence due to underground erosion, landslide and creep of the underground, and vibration and shock of loose cohesion less well [5,6].

The settlement caused by these factors is considered as indirectly related to the superstructure load imposed on the soil.

Unconditional high rainfall record for the period of February to November 2014 brought the failure of the riprap in VMT. The first typhoon caused the damage of the riprap followed by the formation of cracks on the houses. The change in climatic conditions may have caused the increased in water pressure that induced swelling and expansion of the highly expansive siltstone layers causing heavy and disturbance of the intensely fractured rocks. The heavy rainfall in days preceding the soil erosion had contributed a critical part in the initiation of the erosion.

4. Application of Sustainable Technologies

4.1. Wall Thickness

The building walls need sufficient strength and lateral support to resist buckling from compressive loads, wind loads and other forces [7]. Empirically designed concrete masonry buildings rely on the thickness of the wall to resist loads, and the codes prescribe a minimum wall thickness that cannot be reduced or changed without engineering analysis [8].

In Villa Milagrosa Townhomes the entire model building codes contains similar requirements for the minimum thickness for masonry bearing walls, and these are listed in table 1.

Given that the house was one story high and empirically designed, the builder could have used a 6-inch thick block. However, the builder chose to use an 8-inch wide, half-high, split-face block for all of the above-grade walls (both bearing and non-loadbearing). If a 6-inch thick block with similar appearance (half-high, split-face) were used, reduced material and labor costs (through smaller and lighter block) could lower the total construction costs. The gable ends (above top plate height) were wood-framed and clad with vinyl siding.

Table 1. Minimum Thickness for Empirically Designed Walls

Wall Type	Minimum Thickness	
	CABO & UBC	SBS & BOCA
Bearing walls more than one story high		
Bearing walls in one story buildings	6 inches (solid masonry)	solid masonry
Non-bearing walls	none prescribed	

4.2. Crack Control

Cracking can occur in concrete masonry walls due to tensile stresses associated with temperature and moisture change (expansion and shrinkage) or differential settlement of foundation soils [9.10]. There are two methods of controlling cracking in masonry walls described below.

4.2.1. Provide Horizontal Steel Reinforcement to Increase Crack Resistance: Steel reinforcement, in the form of bond beams and horizontal joint reinforcement, increases concrete masonry’s resistance to the tensile stress of shrinkage. The most common method of shrinkage crack control is horizontal joint reinforcement, which uses the steel to minimize the width of the crack. The standard horizontal joint reinforcement is 9-gauge wire in either a “ladder” or “truss” formation, and is available in standard lengths of 10 and 12 feet. Bond beams which serve both as structural elements and as a means of crack control are a course or courses of a U-shaped masonry block into which reinforcing steel and grout can be placed.

4.2.2. Provide Control Joints to Accommodate Movement: Control joints relieve horizontal tensile stresses by providing separations or weakened joints in the wall at controlled locations or spacing. This is done with special “control joint” units which provide a shear key to permit free longitudinal movement. Given that there is more than one method of controlling cracks, it is important to distinguish between what is required by model building codes and what is recommended by the concrete masonry industry. For low-rise buildings, there are no provisions in the model building codes prescribing the use of steel reinforcement or control joints. The concrete masonry industry does offer recommendations for controlling cracks. Some of these guidelines are: (a) Bond beams are typically presumed to offer tensile resistance to an area 24" above and below its location in the wall. (b) Horizontal joint reinforcement is usually placed in joints at a vertical spacing ranging from 8-inches to 24-inches. A control joint is often placed at one side of an opening less than six feet in width, and at both sides of openings over six feet wide. For long walls without openings or other points of stress concentrations, the spacing of the control joints depends upon wall height and the amount of horizontal reinforcement.

The Villa Milagrosa Townhomes (VMT) used 9-gauge horizontal joint reinforcement every 32 vertical inches throughout the entire house shown in figure 4. This is not a local code requirement, but VMT chose to use the joint reinforcement as good practice.

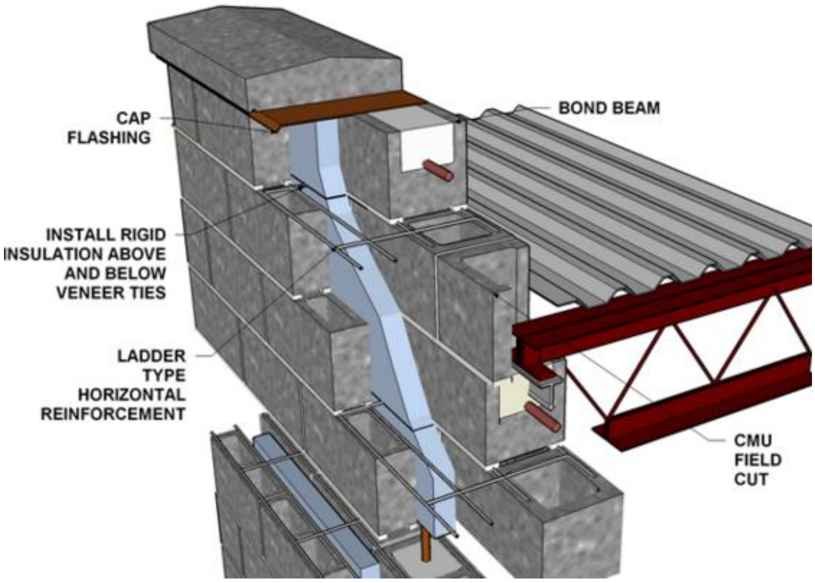

Figure 3. Horizontal Truss Type Joint Reinforcement and Bond Beam

4.3. Lateral Support of Walls

The other primary factor for the design of concrete masonry walls is limiting the spacing between lateral supports [10,11]. The VMT need sufficient strength and lateral support to resist buckling from compressive loads, wind loads, and other horizontal forces. Lateral support can be provided horizontally (by limiting the distance between intersecting walls, pilasters, or buttresses) or vertically (by limiting the height of the masonry wall between roof structures, floor diaphragms, and footings).

Table 2. Minimum Thickness for Empirically Designed Walls

Wall Type	Maximum Ratio: Wall Length to Thickness or Wall Height to Thickness
Bearing Walls	
Solid or solid grouted	20
All other	18
Non Bearing Walls	
Exterior	18
Interior	36

For empirically designed structures (such as the VMT case study), all of the model building codes prescribe essentially the same methods for providing lateral support, including maximum spacing shown in table 2 and the method of anchorage to lateral supports.

With the 8-inch thick, hollow-core block used at VMT site, table 2 prescribes that the maximum spacing (measured either vertically or horizontally) of lateral support is 12 feet (8 inches x 18 = 144 inches or 12 feet). The floor diaphragm is anchored to the wall with ½" diameter bolts in the sill plate at 4'-0"o.c. as shown in figure 4 and the roof is anchored to the wall with anchor bolts in the top plate at 32"o.c., and wind tie-down straps).

As a single story house with an unsupported height between the floor and roof of 8 feet, adequate lateral support in compliance with the code has been provided. For most empirically designed homes, the location of lateral support is not a design issue, except when using 6-inch thick block or high ceilings.

Figure 4. Tie-Down (Anchor Bolt) at VMT Site

4.4. Wall Assembly

In addition to structural performance, the design of any exterior wall assembly requires consideration of several important elements including interior and exterior finish material, insulation, and weather resistance. In masonry wall design, more so than stick-framed walls, many of the design solutions for one element involve consideration of other elements as well, i.e., the masonry wall is designed as a system.

VMT also used a half-high, split-face block on all four sides of the house, chosen primarily for its appearance and durability shown in figure 5. The exterior sides of the masonry walls were sprayed with a siloxane surface treatment to provide a layer of water repellency. An integral water repellent treatment was not used as the builder felt this would compromise the bond between the unit and the mortar. The VMT was insulated on the interior side of the block with 2½" of polyisocyanurate, which was glued to the face of the block. A narrow cavity (1-5/8" deep) was framed with light-gauge metal studs to provide a cavity for running electrical wiring. This thin metal stud wall was fastened to the floor and ceiling assemblies (bottom of floor trusses and roof trusses, slab, etc.). A small bead of adhesive at mid height (glued to the insulation boards) provided additional stiffness to the metal stud assembly. The interior finish was gypsum wallboard which was fastened to the interior side of the metal stud walls with screws.

Figure 5. Half-High Split-Face Block at VMT Site

5. Conclusions

Lateral support of walls was not a design issue with the VMT case study nor will it be an issue for many low-rise residential structures. Because the clear span distance between floors and roof is typically 8 or 9 feet in most single-family detached homes, the masonry walls rely on lateral support in the vertical direction (floors and roofs) and not the horizontal direction.

VMT concrete masonry offers recommendations for controlling cracks in masonry walls, the model building codes do not include prescriptive requirements for crack control. For typical residential construction crack control has not necessarily been proven to be a problem.

The VMT case study illustrated, the uncertainty surrounding the need for bond beams, horizontal joint reinforcement, and control joints results in decisions made on an individual basis. Details and guidance specifically for use by home builders need to be developed, in particular for the novice masonry builder.

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Tomas U. Ganiron Jr., He obtained his Doctor of Philosophy in Construction Management at Adamson University (Philippines) in 2006, and subsequently earned his Master of Civil Engineering major in Highway and Transportation Engineering at Dela Salle University-Manila (Philippines) in 1997 and received Bachelor of Science in Civil Engineering major in Structural Engineering at University of the East (Philippines) in 1990. He is a registered Civil Engineer in the Philippines and Professional Engineer in New Zealand. His main areas of research interest are construction engineering, construction management, project management and recycled waste materials. He has been the resource person in various seminars in New Zealand (like in Auckland University of Technology, University of Auckland and University of Canterbury). He was connected with Advanced Pipeline System in New Zealand as Construction Manager wherein he supervised the sewerage and waterworks projects. He was the former Department Head of Civil Engineering in FEATI University (Manila) and former Department Head of Physics in Emilio Aguinaldo College (Manila). He is also very active in other professional groups like Railway Technical Society of Australasia and Australian Institute of Geoscientists where he became committee of Scientific Research. He has received the Outstanding Civil Engineer in the field of Education given by the Philippine Media Association Inc. (1996), ASTM Award CA Hogentogler (2008) by IPENZ in New Zealand and Outstanding Researcher (2013) in Qassim University, Buraidah City. On the second week of February 2015, Dr. Ganiron Jr. was included in the Ranking of Scientists in New Zealand institutions according to Google Scholar Citation public profile (http://www.webometrics.info/en/node/100).