Copyright Statement

AN ASSESSMENT OF THE PERFORMANCE OF CONCRETE AT CONCEPCION-LICAROS BUILDING

A Practicum Report
Presented to
The Graduate School of the College of Engineering
De La Salle University

In partial fulfillment
of the Requirements for the Degree of
Masters of Engineering Major in Civil Engineering

By
Bernard S. Villaverde

2003

SUMMARY

The author had undergone an on-the-job training at **vnr villaseñor and associates**. He was assigned in one of their projects which is the **Assessment of the Performance of Concrete at Concepcion-Licaros Building**.

The Concepcion-Licaros Building is an eight story with basement and roof deck reinforced concrete structure designed in 1966 and constructed sometime in 1969. The Building was originally designed for future expansion of two additional floors as indicated in the structural drawings (S-13). The building therefore was designed as a ten-story building. This indicates that the structure as designed shall be able to carry 25% more load than its current capacity.

Ocular inspections or visual inspections reveal that the structure has undergone normal wear and tear. There are signs of deferred maintenance and minor structural damage.

Field tests show that the concrete strength is about 16.1 Mpa, 4.6 Mpa lower than the specified 28th day concrete compressive strength of 20.7 Mpa. The apparent deterioration assuming the average in– situ concrete strength reached its design value may be attributable to concrete deterioration with age. This lower concrete strength negates the additional load carrying capacity of the entire structure.

As recommended by the consultant, since the building was not designed to conform to current structural code's safety and reliability requirements, there is a need to undertake retrofit measures to upgrade the buildings capability to withstand earthquake forces. To improve the live load carrying capacity of the building, the concrete floor topping may be removed and replaced by lighter floor finish material.

Based on the author's observations, the company should have done the assessment and investigation in a greater detail and in more accuracy to increase the reliability of the resulting recommendations. Moreover, to improve the company's performance in their future projects, it needs to adopt a holistic approach in determining the condition of concrete structures before considering the expensive and elaborate rehabilitation procedure. A systematic evaluation of the concrete can eventually help save substantial amount of repair cost.

ACKNOWLEDGEMENT

This project has indeed given the author new information, knowledge and experiences, truly essential as preparatory builder of the domain.

This is likewise an instrument that prepared the author as he faces the challenges of the next generation.

However, such instrument would not have reached the curious mind of the author without the initiated effort exerted by the following: my adviser, Dr. Judy Sese, my mentors, the late Prof. Flaviano V. Santos, Engr. Vinci Nicholas R. Villaseñor, Engr. Flordeliza C. Villaseñor and Dr. Dante L. Silva. They have indeed opened a new venture of learning in the author. Their boundless energies and enthusiasm as gurus is an inspiration.

This paper would not have been possible also if not for the mental energy of numerous people who have contributed much to its development.

Alma, my wife, thanks for the love and for believing in the author when he almost stopped believing in himself.

Evs, Cel, Gary, Mervs and Dan who in their most special way have given their support and encouragement vital during the critical period in the process of writing this paper.

Tatay, Nanay and Jason for their immeasurable support, understanding and love.

Brainard, my son, for the inspiration and most of all to

God almighty, for his endless divine guidance and for providing the author equally endless wisdom and courage to pursue and finish such challenging tasks.

burney

TABLE OF CONTENTS

Title Page 1

Summary 2

Acknowledgement 3

Table of Contents 4

List of Appendices 5

Chapter I Introduction

1.1 Background of the Company 6

1.2 Objectives of the Practicum Project 7

1.3 Significance of the Practicum Project 7

Chapter II The Practicum Program

2.1 Type of Training Undergone 8

2.2 Practicum Schedule 8

2.3 Problems Encountered 8

Chapter III The Practicum Project

3.1 Description of the Structure 10

3.2 Structural Framing 11

3.3 Design Criteria 11

3.4 Scope and Limitations 15

3.5 Methodology of the Assessment and Investigation 15

3.6 Comments and Analysis of Results 17

3.7 Summary of Findings and Laboratory Evaluation 22

Chapter IV Summary and Conclusions

4.1 Summary and Conclusions. 26

Bibliography 28

Appendices 29

LIST OF APPENDICES

Appendix A – Vicinity Map

Appendix B – Building Structural Configuration

Appendix C – Ocular Inspection Field Report Photos

Appendix D – Drilled Concrete Core Test Results

Appendix E – Schmidt Hammer Field Test Data

Appendix F – Results of Petrographic Analysis

Appendix G – Core Sampling and Schmidt Hammer Test Locations

Appendix H – Slab, Beam and Girder Levels

Chapter I

INTRODUCTION

1.1 Background of the Company

This decade of the new millennium presents challenges and opportunities for growth in the Philippines' engineering and construction industry. Political and socio-economic developments show promise of a more active and dynamic construction sector in the efforts towards national development. Since 1990 **vnr villaseñor & associates** an engineering, architectural and construction firm has provided architectural, engineering and construction services to varied clients both in the public and private sector.

vnr villaseñor & associates is a 100% Filipino-owned and managed engineering and architectural firm with commitment to provide value by design and construction thru innovative solutions to varied and complex multi-functional programs. It is a group of dedicated professional engineers and architects whose primary objective is to provide quality, innovative and comprehensive engineering, architectural, construction and construction management services ranging from feasibility studies, planning, detailed architectural and engineering design, and construction management. It relies upon its multi-disciplinary professional base and collective expertise to accomplish projects of varied types and magnitudes.

Vinci Nicholas R. Villaseñor and his associates are specialists in their field of professional practice with varied experiences in consulting work. Their individual accomplishments include among others the planning, design, management, and supervision of public and private infrastructure project. They maintain close links with the leading specialist firms for technical cooperation as required by the client and project specifications. Its professional expertise likewise makes it possible for **vnr villaseñor & associates** to eliminate unnecessary overhead costs and submit very competitive bids.

Recognizing the need to maintain an optimum level of data processing and engineering design output, **vnr villaseñor & associates** has on hand up-to-date computer software library.

vnr villaseñor & associates is a private firm of professional engineers and architects managed by Vinci Nicholas R. Villaseñor and his associates. The firm has the following address and telephone number:

Office & Mailing Address:	Unit A-9 Amina Building, Tandang Sora Ave., Quezon City
Telefax:	952-02-19
Cell No.:	0918-9424599

1.2 Objectives of the Practicum Project

The assessment of the performance of concrete as implemented by the consultant, **vnr villaseñor and associates** was undertaken with the purpose of detecting occurrence of deterioration and/or change in the performance of concrete by visual examination and laboratory evaluation and getting more information required if it is necessary to undertake a major repair or rehabilitation.

1.2 Significance of the Practicum Project

Although concrete is considered to be a durable construction material it is subject to deterioration because of different factors such as constitute materials, environmental effects and poor workmanship or errors in mixing, forming or placing. The visual signs of concrete deteriorations are cracks, spalls and rust stains. In addition to inspection and observation by experienced architects and structural engineers, materials testing and analysis may also be needed. Procedures for testing and inspection involve field analysis and documentation, review of documents, testing and monitoring and laboratory analysis.

A study such as this is essential in gaining a basic understanding of the various causes of concrete deterioration on a particular structure and this would also help in making intelligent choices concerning selection of repair materials and methods. Structural deterioration can have life-safety implications and threaten a structure's existence.

CHAPTER II

THE PRACTICUM PROGRAM

2.1 Type of training undergone

In the practicum program the author was given the chance of being a part of Concepcion-Licaros Project from the start up to the writing of recommendations as to the appropriate course of action.

To assess the causes and extent of flaws or other concrete conditions that are detrimental to the durability of concrete, the author was assigned to conduct an ocular inspection together with **vnr villaseñor** engineers and representatives of the owner. The author also had the chance of witnessing the sampling and testing of concrete core samples. Cores samples where taken at specific points on each level of the building. He was oriented on the use of the Schimdt (Rebound) Hammer for the non-destructive testing (NDT). To indicate the location of relatively weaker concrete, Hammer readings were taken at different points from each level of the building. Relative strengths were computed based on the hammer readings.

2.2 Practicum Schedule

The author reports for the on-the-job training at least four (4) hours a day from Monday to Friday. The practicum program commenced November 4, 2002 and ended June 6, 2003.

2.3 Problems Encountered

In the course of the project and on-the-job training there were no major problems encountered except for some minor delays in the project implementation and some difficulties in the ocular inspection. Visual inspection was limited to structural elements that are readily accessible. Inspection was hampered by the inspector’s inability to view conditions of the structural elements that were covered by the architectural finishes. These finishes varies from painted cement paste finishes to marble covered wall finishes.

Although majority of the ceiling were particle board supported by aluminum runner it was difficult to view the entire floor soffit with the presence of criss-crossing utilities and ducts.

Chapter III

THE PRACTICUM PROJECT

Walled City Securities Corporation engaged the services of **vnr villaseñor & associates** to undertake an assessment of the performance of concrete of the existing Concepcion - Licaros Building located at Muralla St. corner Victoria St. Intramuros, Manila. The study aims to determine the integrity of the existing concrete structure and recommend measures to make it functional.

3.1 DESCRIPTION OF THE STRUCTURE

The Concepcion-Licaros Building is an eight story with basement reinforced concrete building resting on concrete piles. It measures about 21 m. x 38 m. in plan and is about 30 m. in height. Building floor spaces are mainly used as offices. It is provided with a cistern located at the lower basement and two steel water tanks each about 3 meters in diameter and around 4 m. in height. Aside from the side stairs, it is provided with two elevators located near the rear center of the building.

Available documents that were retrieved are engineering drawings and partial structural specifications. Based on available documents and interviews with the building administrators, the structure is about 34 years old. It was designed in 1966 and construction of the building was finished sometime in 1969.

Over the years several architectural refurbishments were undertaken to conform to requirements of tenants.

3.2 STRUCTURAL FRAMING

The building is a special moment resisting space frame with shear walls. Gravity loads are transferred via concrete beams and girders to the main frames and bearing wall. The framing suggests "one-way" load transfer of floor loads to beams and to frames in the east-west direction. As indicated in the structural drawings, concrete slabs are 125mm thick. This is confirmed by core samples obtained.

Secondary beams transferring gravity loads to the frames measure about 46 cm x 51cm while the main girder framing into the columns measure about 91 cm x 51 cm. Lateral load resisting system consists of frames and walls. In the east-west direction, girders measure 91 cm x 51 cm and columns are about 61 cm x 100 cm. 8" thick bearing walls, which also serve as shear walls, are located along the rear building in the north-south direction. Elevator shafts also serve as shear walls that carry part of the lateral loads.

3.3 DESIGN CRITERIA

Codes and Standards (as per documents gathered)

a. Material Strengths

Minimum 28-day concrete compressive strength (fc')	=	3000psi
Minimum concrete compressive stress (fc)	=	1360psi
Minimum allowable stress of steel reinforcement (fs)	=	18000psi

b. Live Loads

Offices	60psf
Public Spaces (lobby, stairway, corridor)	100psf
Air Conditioning Room/Machine Room	300psf
Storage	300psf

c. **Pile Bearing Capacity** 90tons(800kN)

Among the documents obtained from the building administrators include:

- Partial Construction Specifications
- Photograph of construction
- Construction drawings
    - Architectural Drawings

A-1	Vicinity Map;
	Location Plan
A-2	Basement Floor
	First Floor Plan
A-3	Typical Floor Plan
	Deck Roof Plan
A-4	Roof Plan & Details
A-5	Elevation Facing Calle Victoria
	Elevation Facing Calle Baluarte
A-6	Elevation Facing Callejon Novales
	Rear Elevation
A-7	Cross section & Longitudinal Section
A-8	Basement Ceiling Plan
	Ground Floor Ceiling Plan
A-9	Typical Floor Ceiling Plan
	Machine Room Ceiling Plan
A-10	Detail of Toilets
	Schedule of Doors & Windows
A-11	Bay Sections of Windows

    - Structural Drawings

S-1	Pile Foundation Details
S-2	Details of Foundation Beams & Retaining Walls
S-3	Detail of Ramp
S-4	Schedule of Columns

S-5	Basement Floor Framing Plan
	First Floor Framing Plan
S-6	Typical Floor Framing Plan
	Deck Roof Framing Plan
S-7	Machine Room Framing Plan & Other Details
S-8	Details of Beams & Girders
S-9	Details of Beams
S-10	Details of Beams & Girders
S-11	Schedule of Bars & Beam Elevations
S-12	Detail of Beams
S-13	Detail of Elevator Wall & Elevator Shaft
S-14	Detail of Marquee Beams, Girder, Column and Media
S-15	Schedule of RC Wall Panels
	Detail of Fire Escape Stair
S-16	Detail of Stair 1
S-17	Details of Stairs 2 & 3
S-18	Details of Stairs 2 & 3

- Eectrical Dawings

E-1	Power Riser Diagrams
E-2	Auxiliary Systems Riser Diagrams
	Legend & Specifications
E-3	Vicinity Map & Location Plan
E-4	Basement Floor Power Layout
	Ground Floor Power & Auxiliary Layout
E-5	Typical Floor Power & Under floor Raceway Layout
	Deck Roof Power Layout
E-6	Basement Floor Lighting Layout
E-7	Typical Floor Lighting Layout
E-8	Basement Auxiliary System Layout
E-9	Typical Floor Auxiliary Systems Layout

- Plumbing Drawings

SA-1 Basement Floor Plumbing Layout

Ground Floor Plumbing Layout

SA-2 Typical Floor Plumbing Layout

Deck Roof Plumbing Layout

SA-3 Isometric Plumbing Diagram

Fire Protection Line Diagram

BW - 1

SCHEDULE OF BEARING WALL AT REAR

LEVEL	WALL THICKNESS	VERTICAL REINFORCEMENT	HORIZONTAL BARS & STIRRUPS	REMARKS
BASEMENT FLOOR TO GROUND FLOOR	10 @ BOTT 12 @ TOP	#4 @ 8" O.C. EF	FOLLOW RW-1 FOR REINF.	(WALL TAPERING) W/ 4 - #8 @ ENDS
GROUND FLOOR TO THIRD FLOOR	8"	#4 @ 10" O.C. EF	#4 @ 10 O.C. EF	W/4 - #8 @ ENDS
THIRD FLOOR TO SIXTH FLOOR	8"	#4 @ 12" O.C. EF	#4 @ 12" O.C. EF	W/4 - #8 @ ENDS
SIXTH FLOOR TO 10TH FLR (FUTURE)	8"	#4 @ 12" O.C. EF	#4 @ 12" O.C. EF	W/4 - #8 @ ENDS

BW - 2

SCHEDULE OF BEARING WALL ALONG LINE B

LEVEL	WALL THICKNESS	VERTICAL REINFORCEMENT	HORIZONTAL BARS & STIRRUPS	REMARKS
BASEMENT FLOOR TO GROUND FLOOR	16" @ BOTT 12" @ TOP	#3 @ 12" O.C. EF	#3 @ 12" O.C. EF	W/4 #7 @ ENDS
GROUND FLOOR TO THIRD FLOOR	10"	#3 @ 10" O.C. EF	#3 @ 10" O.C. EF	W/4 #6 @ ENDS
THIRD FLOOR TO SIXTH FLOOR	8"	#3 @ 8" O.C. EF	#3 @ 8" O.C. EF	W/4 #6 @ ENDS
SIXTH FLOOR TO 10TH FL (FUTURE)	7"	#3 @ 8" O.C. EF	#3 @ 8" O.C. EF	W/4 #6 @ ENDS

SCHEDULE OF WALL : : ELEVATOR				
LEVEL	WALL THICKNESS	VERTICAL REINFORCEMENT	HORIZONTAL BARS & STIRRUPS	REMARKS
BASEMENT FLOOR TO SECOND FLOOR	12"	#4 @ 8" O.C. EF	#4 @ 8" OC EF	USE # 9 BARS FOR ALL CORNERS
SECOND FLOOR TO FIFTH FLOOR	11"	#4 @ 10" O.C. EF	#4 @ 10" O.C. EF	-DO-
FIFTH FLOOR TO EIGHT FLOOR	10"	#4 @ 12" O.C. EF	#4 @ 12" O.C. EF	-DO-
EIGHT FLOOR TO 10TH FL (FUTURE)	9"	#4 @ 14" O.C. EF	#4 @ 14" O.C. EF	-DO-

(From Sheet S-13 of the Building Plan)

3.4 SCOPE AND LIMITATIONS

Due to the urgency of the need of data and the availability of samples, the study was limited to two areas only. The first was the ocular inspection of the walls, beams, columns and slabs. The second was the laboratory evaluation of core samples from the ground floor to the 8th floor slabs and the petrographic analysis of samples from the 2nd and 3rd floor slabs.

3.5 METHODOLOGY OF THE ASSESSMENT AND INVESTIGATION

The assessment and investigation was undertaken in two phases namely:

1. Ocular inspection
2. Field and laboratory testing
    a. Core sampling and compression testing
    b. Schmidt Hammer testing
    c. Petrographic Analysis of core samples.

3.5.1 Ocular Inspection

Before a repair work can be undertaken on the building, a thorough inspection to assess the causes and extent of structural distress is necessary. The inspection evaluates the extent and severity of any distress or deterioration that could affect the service life of the structure. An ocular inspection of the building was undertaken to determine the current condition of the concrete structural elements – these structural elements include walls, slabs, beams and columns.

3.5.2 Field and Laboratory Testing

Regardless of the scope of inspection carried out, detailed planning prior to an investigation is essential, particularly to help uncover concealed defects and structural irregularities. This process requires the adoption of appropriate procedures and techniques and the proper use of tools and interpretation of test results.

a. Core Sampling and Compression Test

To establish the existing compressive strength of concrete, limited intrusive sampling and compression testing were undertaken. At least two 3”∅ core samples per floor were taken. Sampling was undertaken in accordance with the ASTM standards. Lengths of samples, which are also indicative of slab thickness, were measured.

A total of fourteen core samples from slabs at different levels were taken. Two beam samples, one at the sixth floor and another at the eight floor were attempted. Samples were crushed as these were being extruded.

Compression tests in all valid samples were performed in accordance with ASTM C – 42. Appendix D shows the tests results on the samples taken.

b. Schmidt Hammer Test

Rebound hammer tests, using the Schmidt hammer, were performed on beams, slabs, columns and walls. Results of the compression tests were correlated with the hammer readings that were used to estimate the average compressive strength of the structural elements. Appendix E shows the rebound hammer readings and the estimated compressive strength of the structural elements as derived from the regression line of the strength tests performed on the concrete samples vs Hammer readings. Correction coefficients taken from the manufacturer recommended correction factors to account for variations due to position of hammer.

c. Petrographic Test

Petrographic Analysis of core samples not suitable for compression testing were conducted. These samples were from the 2nd floor and 3rd floor slabs. The samples were prepared by slicing thin sections of the core samples and subjecting them to microscopy. Petrographic analysis was undertaken at the Bureau of Mines. Appendix F shows the results of the Petrographic Analysis.

3.6 COMMENTS AND ANALYSIS OF RESULTS

3.6.1 Ocular Inspection

Visual inspection was limited to structural elements that are readily accessible. Inspection was hampered by the inspector's inability to view conditions of the structural elements that were covered by the architectural finishes. These finishes vary from painted cement paste finishes to marble covered wall finishes. Although majority of the ceiling were particle board supported by aluminum runner it was difficult to view the entire floor soffit with the presence of criss-crossing utilities and ducts. Ocular inspections were conducted from February 12 to March 22, 2003 by representatives of **vnr villaseñor and associates**, accompanied by Engr. Joseph Reyes and Mr. Avelino Discaya WCSC.

The following observations were made during the ocular inspection: (See Annex C)

Location	Observations
Basement	- Cracks on the wall of the storage room. According to the administrators there are water leaks during rainy seasons.
Ground Floor	- Cracks on the pathway near the entrance.
2nd Floor	- Cracks on slab. - Slab depression.
3rd Floor	- Cracks on reinforced walls. - Hairline cracks on column.
4th Floor	- Hairline cracks at the column. - Slab depression. - Cracks on the CHB wall near the elevator shear wall. - Cracks on the slab.
5th Floor	- Vertical cracks at the CHB wall of the comfort room. - Vertical cracks were on the CHB wall. - Cracks on CHB walls near the shear wall of the elevator.
6th Floor	- Slab depression. - Concrete spalling and corrosion of reinforcement on the reinforced concrete wall outside the building.
7th Floor	- Honeycomb on the beam at 7th floor near the fire exit. - Vertical crack occurs at the connection of the CHB wall and the reinforced concrete wall. - Hairline cracks on beam.
8th Floor	- Vertical cracks at the connection of CHB walls and the

	column. - Cracks on CHB walls adjacent to the shear wall of the elevator.
Roof Deck	- Hairline cracks on the walls. - Slab depression.

Except for the diagonal cracks on the shear wall, which may be structural in nature, most of the cracks found in the comfort rooms in each floor level were non-structural in nature and pose no harm in the stability of the structure. Hairline cracks on columns were also found after chipping off the concrete cover. The external faces of the building show surface hairline cracks. Excessive difference in the floor level was also found near the elevator lobby at the upper floors. Concrete spalling and corrosion of reinforcement were also observed on the reinforced concrete wall on the 6th floor outside the building. There were no visual signs that the reinforcing bars have deteriorated.

3.6.1.1 Floor Slab Depressions

Slab depressions were observed at various floor levels and at the elevator lobby in the upper floors. Visual inspection of the beams and slab soffit show no sign of excessive deflection unlike the depression measurements on the top of the slab. Core samples show an average of 8 cm concrete topping which may have been poured with the depression or deformation to accommodate electrical and telecommunication utilities. Apparently this deformation of slab toppings does not pose an immediate structural concern.

The deflection of the beams and the slabs as determined using a leveling hose from the slab soffit show a range of deflection from 5mm to 12mm. This is much smaller than the slab depressions observed from the top slabs. This suggests that the topping was applied unevenly contributing to the larger deformation observed. Appendix H shows the various beam relative elevations with the corresponding observed deflection relative to a reference line at the next lower floor.

3.6.2 Field and Laboratory Testing

3.6.2.1 Deterioration of Concrete

There is a difference of about 4.6 MPa between the specified 28th day concrete compressive strength and the estimated in-situ strength as determined from the field and laboratory tests as shown in the table of estimated concrete compressive strength in appendix E. The reduction in concrete strength may be attributable to either poor materials and workmanship or concrete deterioration due to environmental factors or both.

Although concrete is considered a durable construction material it is subject to deterioration. The concrete mixed and placed during the construction of the building may have experienced deterioration caused by inferior materials used in the mix or by errors that occurred in mixing, forming or placing.
These problems include among others:

- Improper aggregate sizing
- Incomplete consolidation in tamping (voids and honeycombs)
- Improper handling of cold or weak plane joints
- Inadequate curing

For the purpose of this investigation, it is assumed that supervision and quality control were adequate. The concrete deterioration therefore may be attributable to environmental factors, lack of appropriate maintenance and old age.

The external faces of the building show surface hairline cracks. The exterior cladding, being exposed to weather, was subjected to deterioration caused by absorption of moisture and thermal expansion and contraction. Moisture absorbed by the concrete expands and contracts with temperature changes. This resulted to mechanical action that caused fractures and sometimes spalling in the concrete. Photographs in Appendix C show the external faces of the building along Muralla St. and Victoria St.

The interior structural elements also show signs of concrete deterioration. Although not visually detectable, micro cracks present in some core slab samples and beam samples have rendered them unsuitable for compression testing. These micro cracks caused by shrinkage are termed dormant cracking.

Laboratory tests undertaken at the Bureau of Mines of the samples from the 2nd and 3rd floor slabs show no fractures, no cracks and no alkali-aggregate reactions. The sample obtained from the 2nd floor slab however shows re-crystallization. This is typical to concrete that has aged and that has undergone deterioration.

3.7 SUMMARY OF FINDINGS AND LABORATORY EVALUATION

Part of the Structure Assessed	Design Strength (Mpa)	Actual Compressive Strength (Mpa) after 34 years	Remarks
Beam	20.7		
B		-	Average actual compressive strength is 22.27% less than the design strength. Fine cracks on beams were observed.
1		15.72	
2		16.81	
3		16.63	
4		15.30	
5		17.60	
6		15.30	
7		15.95	
8		16.85	
9		14.66	
	Average	**16.09**	
Column	20.7		Average actual compressive strength is 18.65% less than the design strength. Hairline cracks on columns at various floor levels were found after chipping off the concrete cover.
B		16.87	
1		17.35	
2		17.06	
3		16.76	
4		17.14	
5		16.53	
6		16.59	
7		16.86	
8		16.38	
D		-	
	Average	**16.84**	

Slab B 1 2 3 4 5 6 7 8 D	20.7 Average	 14.86 15.77 16.33 13.86 16.07 14.65 15.54 12.50 15.42 **15**	Average actual compressive strength is 27.54% less than the design strength. Slab depressions were observed at various floor levels.
Wall B 1 2 3 4 5 6 7 8 D	20.7 Average	 17.39 16.44 16.32 16.54 16.32 16.32 16.34 16.49 16.20 16.32 **16.47**	Average actual compressive strength is 20.43% less than the design strength. Concrete spalling and corrosion of reinforcement were observed on the reinforced concrete wall on the 6th floor outside the building. Several cracks on reinforced walls were also observed.

As recommended by the consultant, **vnr villaseñor and associates**, the Concepcion Licaros Building shows normal signs of wear and tear. There are few signs of deferred maintenance and minor structural damage. The apparent reduction of concrete strength from the design compressive strength maybe attributed to the building's age as well as construction defects.

With appropriate upgrading to suit new occupancy requirements, the building appears suitable for occupancy and is still functional although the building style and features are outdated.

Apparent slab depression is mainly due to uneven concrete slab topping. Slab and beam soffit show beam and slab deflection are within allowable values.

As analyzed by the structural engineer of the company using the actual concrete strength and structural properties indicated in the drawings, it shows that the building can accommodate an allowable maximum live load of 2.4Kpa suitable for an office or residential occupancy.

The Concepcion-Licaros Building is intended to be retrofitted or refurbished for new user groups whose operating requirements maybe quite different from earlier occupants. A new design criteria for retrofitting should be developed.

To prolong the structure service life, retrofit or rehabilitation measures, which include strengthening of slabs, beams and columns and improving the structure's earthquake resisting capabilities, should be undertaken.

Composites of fibre reinforced polymer should be considered in the rehabilitation or retrofit works. These offer advantages of higher strength - to – weight and stiffness - to – weight ratios, good chemical and environmental weathering resistance and superior adhesion.

The structural upgrading is also necessary since the building was not designed to conform to the current structural code's safety and reliability requirements for earthquake forces.

To improve or increase the building's live load carrying capacity, the thick concrete topping of about 8 cm. may be replaced by lighter floor finishes. Light partitions to divide floor spaces are likewise recommended.

Cracks that appear at various locations in the building should be repaired using epoxy resin based bonding compound. It is recommended that all architectural finishes be stripped off from structural elements to locate all structural cracks.

CHAPTER IV

SUMMARY AND CONCLUSIONS

The objective of applying the theories and methods learned in the university to actual problems encountered in the practice of engineering profession was attained in the practicum program. It gave the author a chance to put forward suggestions for repair to give the building a reasonable life. The author also learned that there is no need to consider demolition as an option if a system of ongoing maintenance is developed and adhered to. The program was able to present a basic understanding of the various causes of concrete deterioration on a particular structure that would help us in making intelligent choices as to what repair materials and methods should be used.

The program was able to provide a hands-on experience pertinent to the author's profession. Likewise, it gave the author more confidence with regards to his engineering profession and in dealing with people in the actual fieldwork.

In the practicum project the author was given the chance to be a part of the company's Concepcion-Licaros Project from the start up to the writing of recommendations as to the suitable course of action. The author was assigned to conduct an ocular inspection together with **vnr villaseñor** engineers and representatives of the owner. The author also had the chance of witnessing the sampling and testing of concrete core samples. He was also assigned to witness the petrographic analysis of concrete samples conducted at the Bureau of Mines. The author was also able to participate in the performance of the non-destructive testing (NDT) through the use of Rebound Hammer.

On the assessment and investigation conducted by the company, in addition to the evaluation of concrete, the reinforcing steel bars and foundations should have been investigated to determine the actual building's load carrying capacity. More concrete core samples per floor should have been considered for a more accurate result of the actual compressive strength of concrete. The present state of the concrete slabs suggests that extensive repair is not required since slab deflections are within allowable values.

The structural engineer of the company should have used Working-Stress Design (WSD) instead of Ultimate-Strength Design (USD) in the structural computations since in the late 1960's the WSD was in use. Available design and calculations should have been carefully reviewed and analyzed to identify irregularities that may affect its behavior. Documents on the original design and construction, rehabilitation, alteration, and repair of the building should have also been reviewed in more detail.

The structural codes have substantially changed since the building was designed and constructed, standards and local codes in effect at the time of construction should have been reviewed.

Based on the author’s observations, the company should have done the assessment and investigation in a greater detail and in more accuracy to increase the reliability of the resulting recommendations. Moreover, to improve the company’s performance in their future projects, it needs to adopt a holistic approach in determining the condition of concrete structures before considering the expensive and elaborate rehabilitation procedure. A systematic evaluation of the concrete can eventually help to save substantial amount of repair cost.

BIBLIOGRAPHY

Taranath, Bungale S. (1988) *Structural Analysis and Design of Tall Buildings.*

S.S. Bhavikatti (1999). *Structural Analysis*, Vol. 1 and Vol. 2, Vikas, Jangpura, New Delhi.

McCormac, Jack C. (1993), *Design of Reinforced Concrete*, 3rd Ed. New York, McGraw-Hill.

Gaylord and Gaylord, Edwin H. (1979). *Structural Engineering Handbook*, New York, McGraw-Hill.

Asian Concrete Model Code (ACMC).