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FORENSIC ANALYSIS OF COLLAPSE OF SURFSIDE CONDMINIMUM, MIAMI

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Abstract - *Forensic engineering is a process of locating failures and providing solutions or preventive solutions. This used to find problems or know problems that may arise due to utility and act accordingly before failure occurs. This helps us uncover many hidden facts or discoveries in the performance of a building in different service conditions and during construction. Forensic engineering can benefit for new buildings and flats providing elements to include into the design that will enhance life-cycle and lower maintenance costs. The process results in enhancements that solve immediate problems and bring about cost savings and efficiencies for the long term. This paper is a preliminary analysis of the collapse of the 40-year Building in Miami. This reveals the possible trigger and stressor of the building collapse on 24th June*

Key Words: Forensic, Engineering, Diagnostic, Consolidation

1. INTRODUCTION

Forensic engineering is a process of locating failures and providing solutions or preventive solutions. This used to find problems or know problems that may arise due to utility and act accordingly before failure occurs.

The lessons from forensic engineering, coupled with a reliability-centred maintenance process, enable a facility manager to adjust the scope and frequency of periodic maintenance and preventive maintenance based on the past performance of existing equipment.

Champlain Towers South Condominium , a 12-13 storey 40-year old undergone a sudden partial collapse on June 24.This building is located near the Miami suburb. The building contained 136 apartments in which 55 apartments have collapsed.

1.1 Detection Devices

Forensic engineers use both Non-invasive tests and invasive tests for the investigation. The non-destructive methods include a detailed visual examination by an expert and the use of electromagnetic detection equipment, infrared imaging, ground-penetrating radar, and X-ray imaging. Invasive methods of test for investigation cut, break and tear specimen to inspect it. Tools such as borescopes, fluoroscopes, and video scopes can minimize the amount of material that must be removed for inspection. The benefit of the analysis is, it provide the reason for failure or stressor component leading to failure.

2.INVESTIGATION BY NIST

The Forensic study is conducted by the National Institute of Standards and Technology(NIST). The NIST team will:

- Establish the likely technical cause .
- Check building standards,codes and practices;
- Action required to improve safety.

2.1 Test Conducted

Remote sensing is used for where pieces of evidence were located in the debris pile. LIDAR - used for mapping of the debris site and . It is used from nearby apartments. Time-lapse cameras are used to record all the details during investigations in the changing scene.

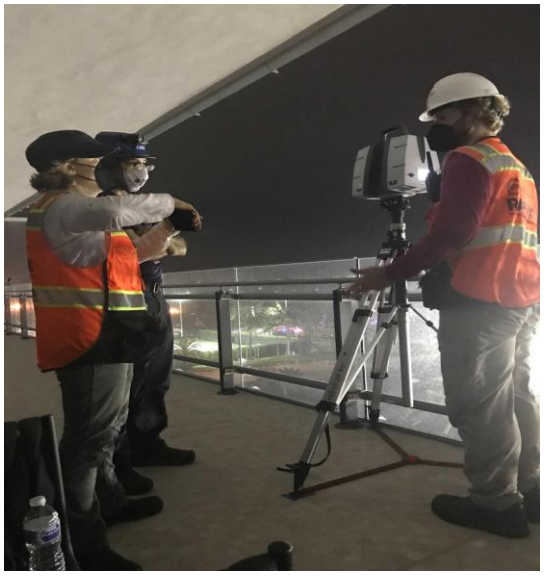


Fig -1: Cameras and LIDAR used by NIST and its partner's scan and record the site of the Champlain Towers South condominium.

The NIST team continues to refine and update procedures for evidence identification, marking and tagging and has collected more than 200 building elements including columns, beams and pieces of a concrete slab. All the evidence are stored in Miami Police Department

NIST will be deploying an electronic evidence tagging system that uses RFID chips so that electronic records are associated with every piece of evidence collected as shown in Fig. 1&Fig. 2.

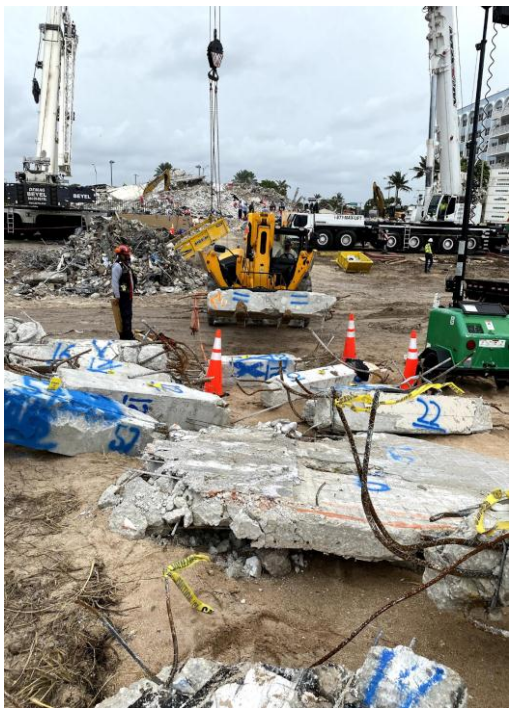


Fig -2: Evidence collected and tagged by NIST

NIST conducts geologic studies in the foundation region. The subsurface investigation groundwater. The laboratory testing of the soil and rock. Field testing will bring out the nature and image of the foundation region,subsurface soils and soil below it also.

Fig -3: A geophysics specialist performs non-destructive testing, using an impulse echo, to support the evaluation of the integrity of the foundation.

NIST is uses non-invasive test like ultrasonic pulse velocity to evaluate the quality and strength of the concrete specimen. The Fig. 3 and Fig.4 shows use of UPV test conducted by NIST Engineers .

Fig -4: An engineer performing UPV test on a column member.

3. PRELIMINARY ANALYSIS OF CHAMPLAIN TOWER COLLAPSE.

The collapse of buildings can be due to many reasons. Many variables come into place that can influence a building collapse. Some reasons could be overloading, under-maintained building, bad engineering practices etc.

Champlain Tower South collapse a have many stressors in place. This Seminar mainly deals with three issues:-

- Leakage Issues.
- Foundational Issues.
- Structural Issues.

Other issues include maintenance issues, negligence of due process, not maintaining quality standards and assurances.

3.1 Leakage Issue

3.1.1 Leakage In Pool Deck

Miami faces hurricanes, storms and heavy rains every year. In a place where is plenty of rain, if proper drainage is not provided it will very detrimental for any infrastructure. In this case, the pool deck didn't have proper drainage which caused ponding of water. This water will enter into the crack of concrete which will cause rusting of reinforcements. This cause leakage cause dripping water from the ceiling of the garage as shown in Fig. 5.

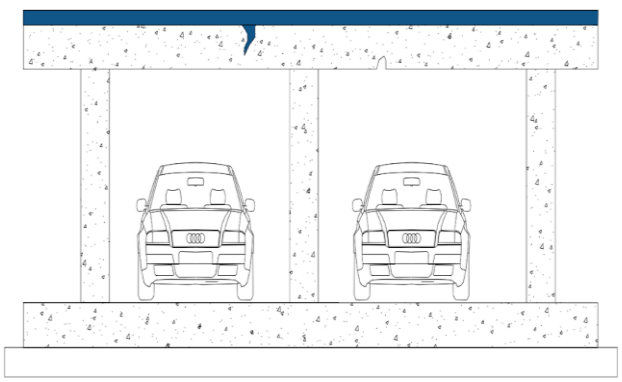


Fig -5: Leakage of water in the cracks of concrete from the pool deck.

Morabito Consultants who did the 40-year re-certification process in 2018 claimed that if this kind of leakage is not solved immediately concrete deterioration will expand exponentially.

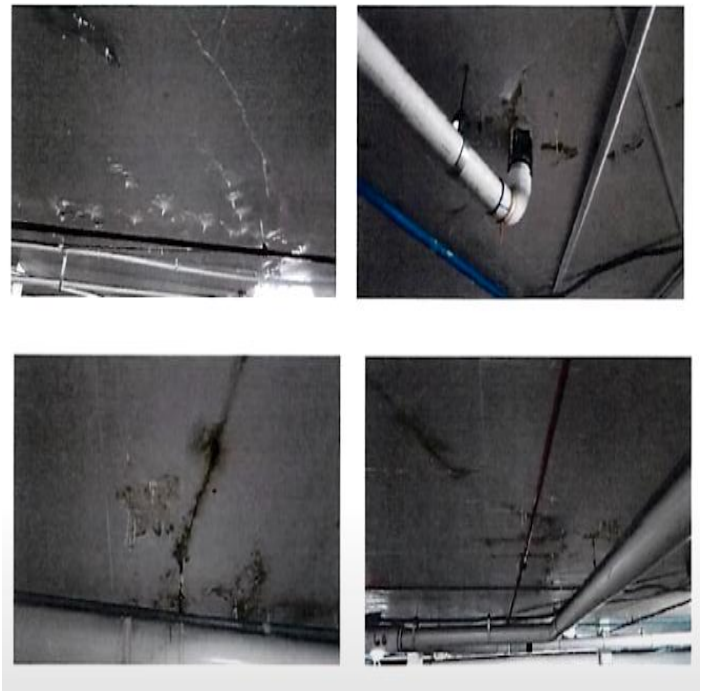


Fig -6: Dripping water from the ceiling of the garage.

Due to this leakage, there were spalling of concrete which was pointed out in the re-certification report like in Fig. 6 and Fig. 7.

Fig -7: Spalling of concrete from garage columns and garage floor.

The steps taken to solve these leakage issues wasn't efficient and did poor work from the management to cut cost was stated by a survivor.

3.1.2 Waterproofing Of Planter Box

There are many planter boxes in the compound of the building which provide good aesthetics. If proper waterproofing is not done in these boxes can cause unseen deterioration also it will be very difficult to predict or detect any corrosion underneath those plants as shown in Fig. 4.4.

Fig -8: Planter box under columns 13 and 14.

3.2 Foundational Issue

3.2.1 Pile Issue

Initially, the type of proposed pile was precast piles which had a load-carrying capacity of 50 tonnes per pile. Later right before the construction, the type of pile was changed Pressure Injected Footing piles or PIF piles. These PIF piles have a load-carrying capacity of 150 tonnes per pile. This is to reduce the number of precast piles thereby cutting costs. Change of type of piles right before the construction phase is not a common practice. The Figure of piles is as shown in Fig. 9.

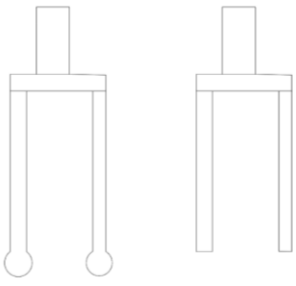


Fig -9:PIF piles at left, precast piles at the right.

3.2.2 Differential Settlement

Uneven settlement of soil strata at different pats of the building can cause differential settlement and can may lead other structural problems. Differential settlement happens when the soil strata under the building begins to change ,which in turn shifts the position of the building. This can be caused by drought conditions, the root systems of mature trees, flooding, poor drainage, frost, broken water lines, vibrations from nearby construction or poorly compacted fill soil.

The study from a researcher at Florida International University found that the area around the building as in the graph shown in Fig. 10 constructed on reclaimed wetlands had been sinking at a rate of two millimetres per year for the last three decades. There is the possibility to cause a differential settlement.

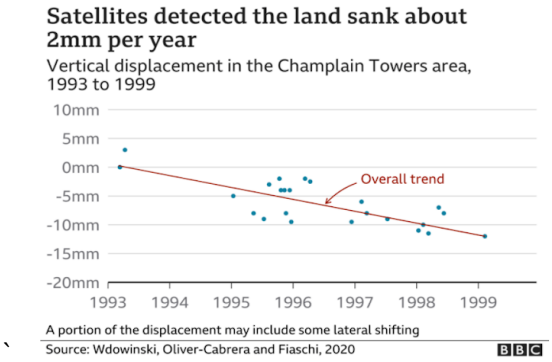


Fig -10: Vertical displacement near Champlain Towers.

3.2.3 Consolidation Settlement

Consolidation settlement is a time-dependent natural process of fully saturated soil due to expulsion of water from the voids and compaction is an instantaneous artificial process of partially saturated soil due to expulsion of air from voids.

The whole building is on top of small columns extending from the foundation. These columns act as a box. During monsoon in the water table rise to the floor of the garage as shown in Fig. 11.

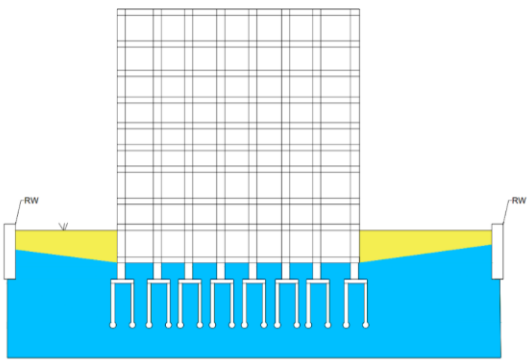


Fig -11: Water table during the monsoon period

Then during summer, the water table goes down along with the soil near the columns, Hence creating a void near the foundation as shown in Fig. 12.

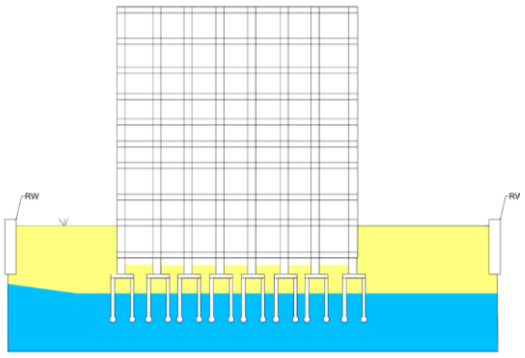


Fig -12: The water table goes down the following summer.

Then the following monsoon period the water table rise filling the void in the foundation as shown in Fig. 13.

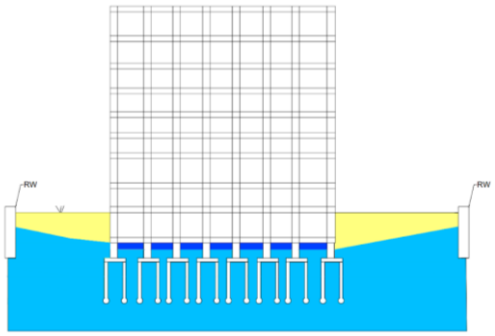


Fig -13: The water table rises in subsequent monsoon.

This waterlogged in this area can cause deterioration of concrete as shown in Fig. 14. Further causing to form sinkholes.

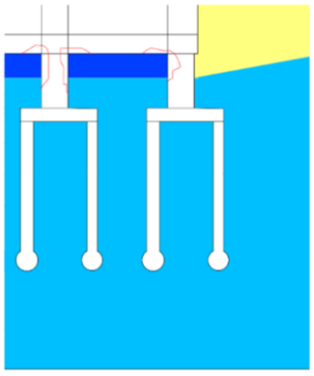


Fig -14: Possible deterioration of concrete.

Fig -15: Waterlogged beneath the floor of the garage.

Columns in this area where water get logged, column pulls water up like sponge cause rusting of reinforcements as shown in Fig. 15 and Fig. 16.

Fig -16: Enhanced image of water pulling into columns.

3.3 Structural Issue

3.3.1 Punching Reinforcements

The tower is constructed in a flat slab construction method. In the collapse of the building, it revealed that there were not any punching rebars present in the building. Punching shear happens when high localized forces on RCC slab, there high proximity for high localized loads on flat slab structure. The failure is due to shear. This type of failure is very dangerous as it cannot be known or seen before failure, so for safety contractors provide punching rebars. The absence of punching rebars is shown in Fig. 17.

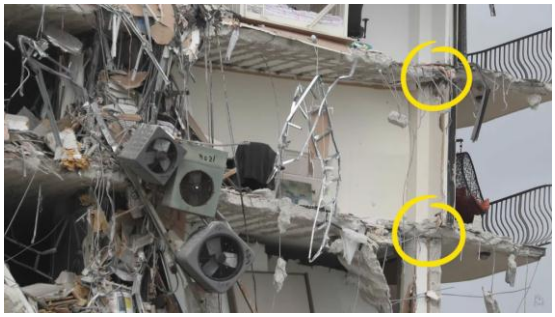


Fig -17: No punching rebars

3.3.2 Columns

Certain column to column-span is very higher than usual standards. It was also pointed out certain columns carried less reinforcement than in the structural drawings.

3.3.3 How it Happened

The first area to collapse is the pool deck. This column punched through the pool deck. This is due to corrosion in the pool deck mentioned in the earlier chapter.

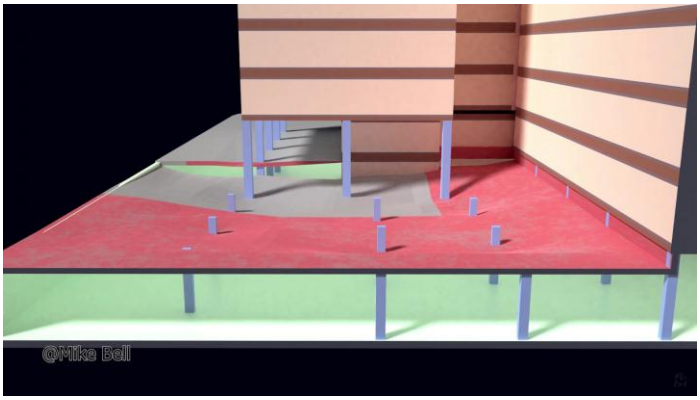


Fig -18: Punching of columns at the pool deck.

This is punching caused the sinking of the pool deck slab along with its beam. Hence pulling a main structural member as shown in Fig. 18.

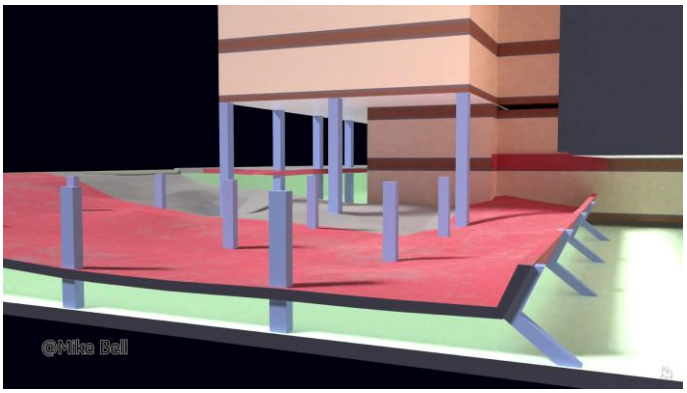
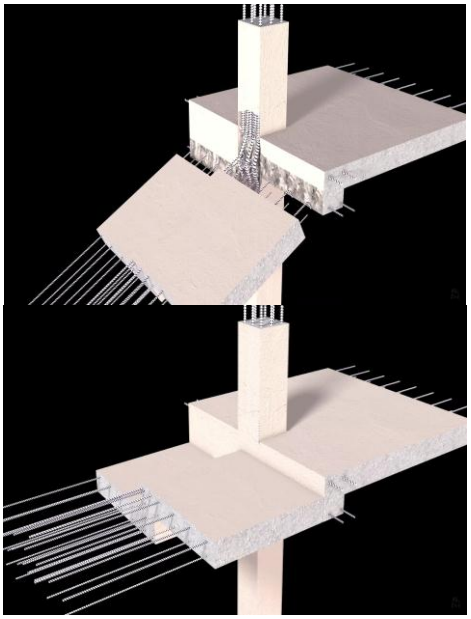


Fig -19: Pulling of slab from the columns.

The corresponding beams connected to columns of the building which already lapped into the columns get pulled off or ripped off the columns, hence causing buckling of columns. The first two columns to collapse is column 13 column 14.Rest of the building collapse like a chain reaction as shown in Fig. 19 and Fig. 20.



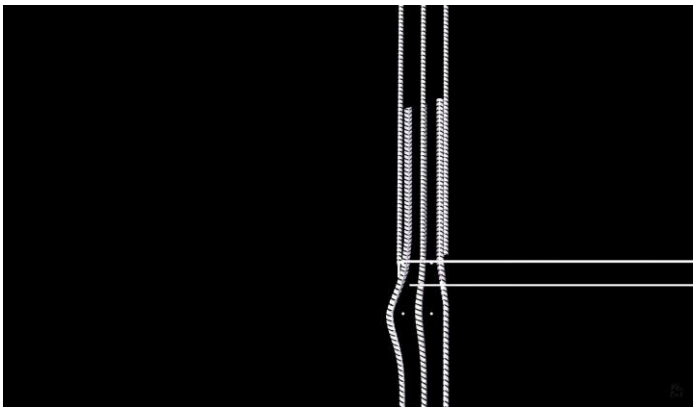


Fig -20: Buckling of column.

Moments before the collapse of the building, a bystander was able to capture a video of the collapsed roof of the garage and a broken pipe with water falling. The extent of the collapse is still unknown as shown in Fig. 21.

Fig -21: Big chunks of concrete on the floor of the garage.

3.3.4 Shear Wall

Shear wall is a structural member in a RCC structure. These structural members are used resist lateral forces such as wind forces and seismic forces. They are used in tall buildings. As height of building increases, the effect of wind forces increases. There codes of practices that limit on horizontal sway.

The main reason why the rest of the building didn't collapse is that the west section of the building consists of shear walls containing the elevator shaft. This wall protected the rest of the building as shown in Fig. 22 This wall is a strong element, when the rest of the building collapses, it is simply torn off from the shear wall.

Fig -22: The shear wall is shaded in red colour in the right picture, the left picture shows the aerial view of the shear wall.

4. CONCLUSION

This paper deals with the collapse of the Champlain tower south building. It brings out the grounds of collapse and triggers which may have caused the collapse. Some of them are leakage issues caused by the improper drainage facilities and ignorance of the management in solving the leakage issue, not providing punching rebars for flat slab construction. Not doing proper quality control and quality assurance. Hence forensic engineering in the civil field is very important.

- This helps us uncover many hidden facts.
- Discoveries in the performance of a building in different service conditions and during construction.
- Forensic engineering bring out mistakes or wrong procedures that may be corrected to aid in constructions of new buildings.
- Providing recommendations for elements to incorporate into the design.It will enhance life-cycle rates, lower maintenance costs, solve immediate problems, cost savings and provide long term efficiencies.
- Forensic engineering will provide a holistic view of building collapse followed by the stressors that may occur in neighbouring buildings.
- This brings out new standards and greater importance in quality control and quality assurance.

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