Rare Foundation Failure of a Building in Shanghai, China

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Introduction

The nature of civil engineering construction differs from that of almost all other manufacturing processes in that, most often, the product that is produced is unique. Very rarely a building that is identical to the one that is already built is constructed. Even if an identical building is again constructed, the environment may change; for example, the soil on which it is located, the wind or seismic load acting on the structure, etc. may change. Hence the opportunity to build a series of mock-ups and to improve progressively till a perfect solution is obtained is not available to a civil/structural engineer. Moreover, the nature of the exposure of constructed facilities to often unpredictable natural hazards provides several uncertainties and difficulties. These factors present several challenges to those involved in the design, construction, and operation of constructed facilities.

In this scenario, it is beneficial for the civil/structural engineer to learn from past failures. Although failures are not frequent, the impact is often devastating especially for those involved in the project. An awareness of the past mistakes and the lessons learnt will make engineers better equipped to adopt safe and successful procedures and to avoid mistakes of the past.

It is unfortunate that many failures in India are neither reported nor analyzed and are often buried under bureaucratic procedures. However, it is heartening to note that there is an increasing literature on failures, the study of which will result in better and safer structures[1-13]. It is important to consider failures as important lessons and engineers should ensure that they do not happen again.

Foundation failures are rare, unless the building is located on expansive soils. It is because the factor of safety adopted in foundation is often more than that adopted for structural components. The well–known foundation failure is the tilting of the tower at Pisa, Italy[5,12]. This failure is unique for a number of reasons, as the unequal settlement of its foundation is occurring continuously for the past 800 years! Even though extensive investigations and analyses have

been carried out in the past 70 years, there is no consensus on the cause of this failure! However, several remedial measures have been undertaken in the past to keep the tower serviceable till now.

This article is concerned with another unique foundation failure of a building in China and the lessons learnt from this rare failure.

Rare Foundation Failure in Shanghai, China

At around 5:30am on June 27, 2009, an unoccupied 13-storey block of flat building, still under construction, at Lianhuanan Road in the Minhang district of Shanghai city toppled over and ended up lying on its side in a muddy construction field (see Fig.1). One worker was killed. The official Xinhua News Agency said that a 28-year-old worker, surnamed Xiao, had gone into the building to get his tools and tried to jump out the window when the building fell. He was from Anhui province in eastern China.

Construction work on the block appeared to have been nearly completed, with windows fitted and a tiled facade. Other identical blocks in the same property development were still standing nearby (see Fig.1).

Initially, it was thought that a 70 m section of the flood prevention wall in the nearby Dianpu River might have triggered this building collapse.

China's official news agency, Xinhua, reported that officials were taking appropriate control measures against nine people, including the developer, construction contractor and supervisor of the project after it was found that the company's construction license had expired in 2004.

Cause of Failure

The cause of the building collapse in Shanghai was due to a pressure difference on two sides of the structure, according to an investigation report released at a government press conference. Improper construction methods are believed to be the reason of the building collapse in Shanghai, according to a report from the investigation team. The investigation team's report said that workers dug an underground garage on one side of the building while on the other side earth was heaped up to 10m high, which was apparently an error in construction, according to a report on eastday.com, Shanghai's official news website.

There were also reports saying that cracks on the flood-prevention wall near the building, as well as the special geological condition in the water bank area, may be part of the reason for the collapse. However, these factors were not found to be the basic reason of this accident. An official investigation has said that the accident was due to the construction company's ignorance, rather than flaws in the design or building materials. However, the report stopped short of apportioning blame, and has been criticized for failing to address key issues.

The report said the collapse was caused by earth, excavated along the building on one side with a depth of 4.6 m, for an underground car park, and piled up to depths of up to 10 m on the other side of the structure (see Fig. 2). The weight of overburden earth created a pressure differential, which led to a shift in the soil structure, eventually weakening the foundations and causing them to fail. This situation might have been aggravated by several days of heavy rain leading up to the collapse, but investigators did not site this as a crucial factor. The report said the construction company - Shanghai Zhongxin Construction did not anticipate that

Figure 1: Two views of a toppled 13-storey apartment building that buried one worker in Shanghai on 27th June 09. Photo: Reuters

the overburden created by the earth could have such a devastating effect.

Investigations did not point out whether the company's errors were negligent or easily avoidable. However, they stressed that the building's foundations and construction materials all complied with the city's building regulations.

The Shanghai Urban Construction and Communications Council, conducted inspections on the remaining 10 apartment blocks and found that there is no immediate danger to them. However, it may conduct safety inspection of the surrounding buildings again to ascertain their safety and stability.

Another interesting revelation of the investigation is that the construction company did not provide any structure to support the walls of the car park pit, and this had been a key factor contributing to the accident.

From these investigations, it may be concluded that the failure was due to the following causes (see Fig.2):

- An excavation for underground garage was made on the south side, to a depth of 4.6 m, without any support for the earth walls.
- The excavated earth was piled up on the north side, to a height of 10 m.
- The building experienced uneven lateral pressure from south and north. This was due to the overburden pressure and erosion of soil in the pit adjacent to the building, as a result of heavy rain.
- This resulted in a lateral pressure of 3,000 tonnes, which was greater than the capacity of the concrete piles. Thus the building toppled over in the southerly direction.

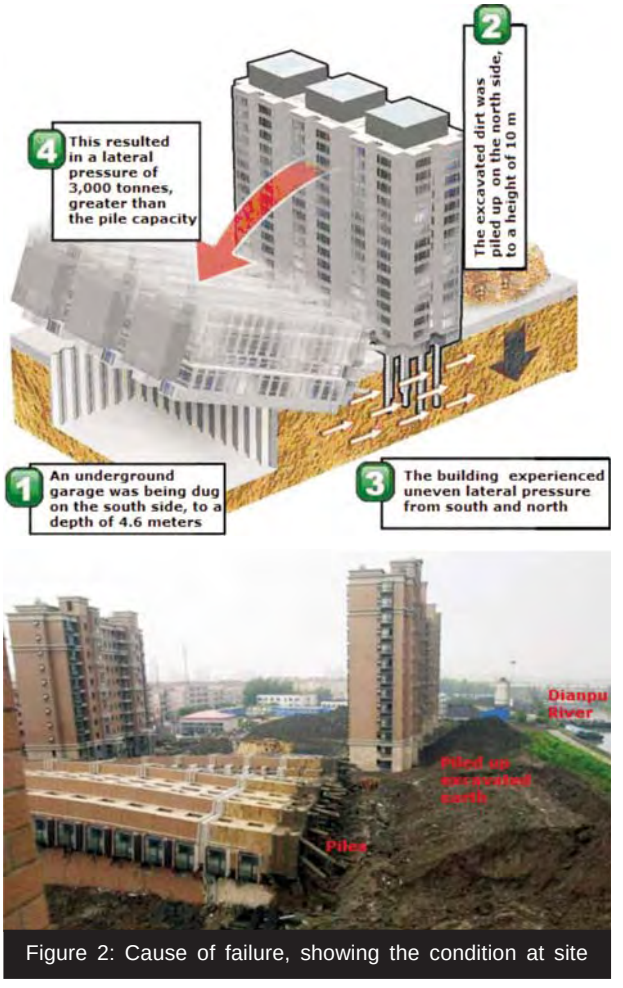
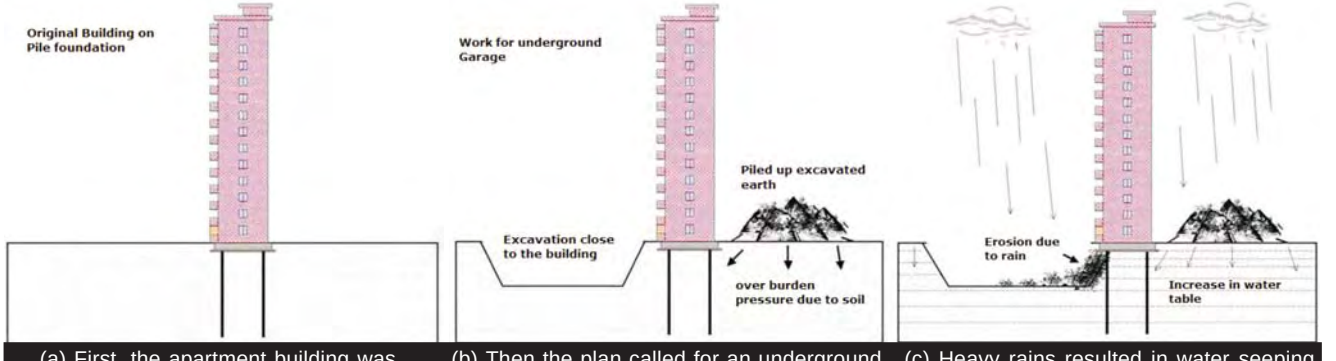


Figure 2: Cause of failure, showing the condition at site

The sequence of failure of the building is shown in Fig. 3 and some more views of the failure in Fig. 4. Concern on constructed facilities in China[14,15]

China Daily, the state-run newspaper, penned an angry editorial decrying the often corrupt nexus between Chinese property developers and local government officials who depend on property taxes and land sales for a significant proportion of their income. Some construction industry insiders in China have expressed their fear that many buildings designed to have a 70-year lifespan would not stand firm beyond 30 to 40 years- because of corner-cutting during China's rampant construction boom.

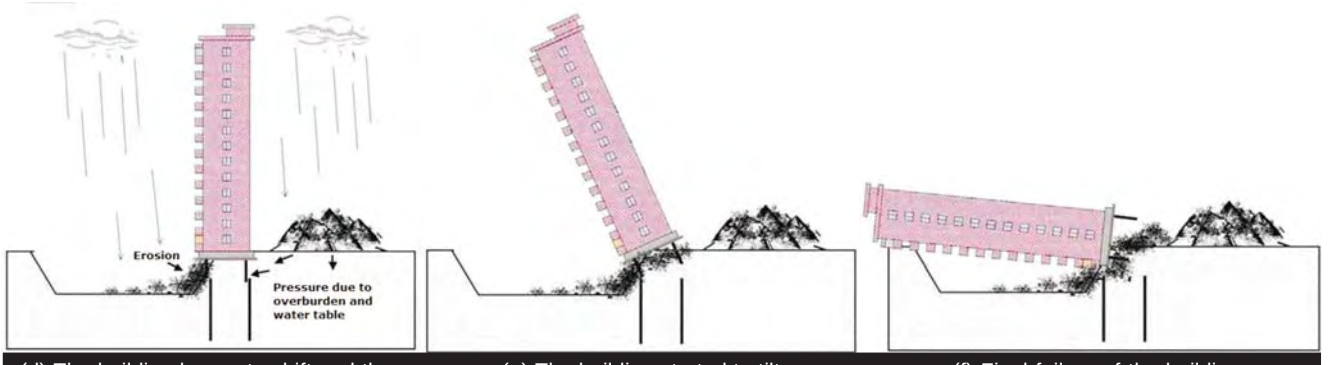
The collapse shocked many in China where construction failures are relatively common in inland areas, but not expected in showcase cities such as Shanghai which will host the 2010 World Expo. On Monday, 29th June 09, just two days after the Shanghai collapse, rescuers were searching a river in northeast China after a section of a road bridge gave way, sending



(a) First, the apartment building was constructed

(b) Then the plan called for an underground garage to be dug out. The excavated soil was piled up on the other side of the building

(c) Heavy rains resulted in water seeping into the ground



(d) The building began to shift and the concrete piles snapped due to the uneven lateral pressures

(e) The building started to tilt

(f) Final failure of the building

Figure 3: Sequence of the failure of the building

seven vehicles into the water below. Local sources said the bridge in Tieli, a city in Heilongjiang province, had been built in 1973 but repaired as recently as 1997.

Substandard workmanship has been a major concern in China's building sector, as the country rolls out enormous city expansions and finishes off vast infrastructure projects to keep pace with fast economic growth. Construction related accidents last year included the collapse of a steel arch on a new railway bridge, which killed at least seven, and a crane which fell on a kindergarten, killing five. The collapse of dozens of schools during last year's Sichuan earthquake also led to a wave of public outrage about corrupt officials and construction firms.

Summary and Conclusions

The rare foundation failure and collapse of the building in China was caused by excavated earth on one side and piled up earth and water table on the other side, exerting differential pressure on the piles. When the pile capacity exceeded, the piles failed and the building toppled en mass, resulting in a rare foundation failure. It was mainly due to the result of careless excavation very near to the building, for the purpose of providing underground car park. Engineers should take a note of the lessons learnt from this failure and avoid such mistakes in future.

Figure 4: A few more views of the failure and close up views of failed piles

Acknowledgment

The author wishes to acknowledge the newspaper reports available in the Net, based on which the material of this paper has been prepared.

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