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Adama Science & Technology University

School of civil and Architecture Construction Technology and Management Program Construction Management Post Graduate Program:

A Project Submitted in partial fulfillment of the requirement for the Degree master of Engineering in construction technology and management.

An assessment of building defect the case : of National meteorological Agency head office Building .

Submitted APERIL /2017

Advisor Yashasvi Raj

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An assessment of Building defect: the case of the National meteorological Agency HQ Building

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ACKNOWLEDGEMENTS

My sincere gratitude shall goes to my advisor Mr. yashasvi Raj for his dedication, support he has given me throughout my project in general and Dr.Girmaye for his support and comments he has provided me to work my project on this title, Defect investigation & identification of building at National meteorological Agency head office in relation to the geological nature of the site in particular.

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KEY TERMS

Expansive soil, Geotechnical investigations

Abstract

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1. Introduction

National Metrological Agency that was constructed in Addis Ababa around Bole Airport in 1992 has four three G+1blocks and one G+0 Buildings which show very severe failure on its whole parts of the building that may result in building collapse suddenly.

The investigation is devoted to examination of the nature and magnitude of the failure, of the relationship of such failures to the building foundation soil.

Buildings, like all structures, are designed to support certain loads without deforming excessively. The loads are

- The dead loads of the building itself
- The weight of the people and objects, and
- Live loads; the pressure of the wind / or earth quake

The causes of failure on buildings can be

- Bad design,
- Faulty construction ,
- Foundation failure ,
- Extraordinary loads ,
- Unexpected failure modes ,or
- Combination of the above causes.

1. Bad design does not mean only errors of computation, but a failure to take in to account the loads the structure will be called up on to carry, reliance on inaccurate data, ignorance of the effects of repeated or impulsive stresses, and improper choice of materials or misunderstanding of their properties.
2. Extraordinary loads are often natural, such as the shaking of an earth quick. A building that is intended to stand for some years should be able to meet these challenges.
3. Faulty construction is also the most important cause of structural failure. This includes the use of poor quality construction materials to cast concrete, poor work man ship and other practices well known to the construction workers.

Although the structures carry its loads, the earth beneath it may not. The displacement due to bad foundation may alter the stress distribution significantly.

CAUSES OF FOUNDATION FAILURE IN BUILDINGS

There are many causes of foundation failure; here are the six main ones.

1. Soil type – especially expansive clay soil
2. Poorly compacted fill material
3. Slope failure, mass wasting
4. Erosion
5. Poor construction, and
6. Transpiration

1. Soil Type – Expansive Clay Soil

The most common kind of expansive clay can absorb so much water that it can swell by several hundred percent. The pressure from this degree of swelling can easily lift or "heave" most residential homes. Soils expand with moisture and they contract with desiccation, causing up and down movements known as differential settlement. To preserve structural integrity of the building, we have to provide underpinning for the foundation.

Foundation failure is caused by the movement of expansive and highly plastic soils beneath different sections of the foundation footings. This movement can be in the form of shrinkage, which causes settlement, or expansion, which causes heave. When dry conditions prevail, soils consistently lose moisture and shrink. When moisture levels are high, soils swell. Regardless of the nature of the movement, it will most likely manifest itself in the form of visible cracks in the foundation walls, exterior brick walls, or interior sheetrock or plaster walls. Officially, any structure movement is known as differential settlement.

In addition to expansive soils, subsurface peat, which has a low bearing capacity and deteriorates over time, can also cause differential settlement.

2. Poorly Compacted Fill Material

If the fill material on a lot is not sufficiently compacted to support the weight of the structure above it, there will be foundation problems. The problem can be from the mix of odd fill materials, and from poorly compacted fill, or both.

This building developed a wide crumbling crack in the lowest corner of the foundation. It sits on a hillside, and there is a water drainage area on the other side of the house.

3. Slope Failure / Mass Wasting

Geologists use the term “mass wasting” to describe the movement of earth downhill. It could be “creep” which is slow, or “landslides” which are sudden. Slope failure as we use it refers to “creep”.

Underpinnings can act as a barrier to “creep”, but the power of gravity is such that unless the underpinnings were specifically designed to stop slope failure, warranties can’t usually cover this in sites exposed to slope failure.

4. Erosion

Erosion may be the most straight forward cause of settlement issues. It can come from Poor drainage from yard run-off and gutter downspouts discharging at the base of the foundation. If not identified early, erosion can wear away the soil around foundations, creating a new need for underpinning. Excess moisture around the foundation can cause the soils to become over-saturated and lose “bearing pressure,” or the strength to support weight. When this happens, structures “settle” or sink into the ground

5. Poor Construction

Most towns and cities now have building codes that require soil testing and engineer certification before and during the building process, so poor construction is less and less the cause of foundation failure.

6. Transpiration

Transpiration is a fancy word for the process of trees and large plantings absorbing the water from the soils beneath and around the home. During an active season, roots extending beneath and around the footings of the house can remove moisture from the soil, causing it to become desiccated. Again, where expansive soils exists this removal of moisture will cause soil shrinkage and settlement.

CAUSES OF DEFECTS

Defects are caused by natural consequences that developed over the period of time such as aging and typical uses. However, many premature defects occur due to the fact that improper skills and care are assigned on the building. The study by building research Establishment concludes that over 90 per cent of the building defects are caused by the promptly diagnosable faults in design or construction which could be foreseen beforehand and prevented.

Generally the causes of defects are stated as the followings: (Lee, 1987)

Insufficient brief

Defects are often interpreted as originated from the strokes of designer or on the drawing board in many instances but in some cases they can be attributed as occurring at an even earlier stage. For instance, client may lay down unrealistic cost limits or fail to give clear indication about the functional requirement of the building. Normally, there is no clear information about the intended building life-cycle or maintenance requirements.

Inaccurate design decisions

The most common faults can be sorted as follows:-

Failure to follow well established design criteria in the choice of structural system and selection of materials

Ignorance of the basic properties of material. For example, failing to make allowance for the differing thermal and moisture movements of materials used in combination.

Usage of new materials or technologies which have not been thoroughly examined its effectiveness. This is often the result of uncritical reliance on manufacturers' literature quoting stimulated laboratory tests.

Misjudgment of user and climatic conditions under the material will have to perform.

Complex details which have low probability of successful execution on an open building site.

Poor communications between different parties such as design and construction teams.

Construction method

The construction projects normally take place in less ideal conditions and always emphasize on speedy completion due to time constraint which often resulted in careless delivery. Some manufacturers of so-called high technology components have little awareness of the strictness of a building site or the standards of accuracy achievable under such conditions although only a small proportion of defects were attributable to faulty materials. Materials may easily be damaged during transportation, loading and unloading, inappropriate condition of storage on site and placing in position even though the materials may be flawless upon leaving the factory. The defects can be prevented with by taking greater care during all the stages during construction project, providing appropriate training to all the workers and staffs, and ensuring closer supervision.

User Activities

Defects may be caused by unintended misuse due to the lack of knowledge on the correct method of usage or intentional acts of vandalism. This problem can be solved by providing more information such as the degree of severity of use and condition of use to the designer so that a better output can be yield. Besides, some defects may be correlated to the users' financial conditions and also social attitudes. For instance, condensation is affected by the amount of money spent on heating and ventilating, and occupancy pattern.

Maintenance

Incorrect identification of root of the defects may lead to inappropriate remedial work. It won't rectify the original defects but may deteriorate the condition of the building further. Furthermore, negligence during inspection and repair works may lead to defects in previously satisfactory structures or elements. For example, stepping on unprotected felted roof can drive the gravel into the felt which can cause splits and cut and eventually lead to roof leaking.

On the other hand, defects often occur due to the designer's decisions. Designers often do not take into consideration how the materials will behave and react toward other adjoining materials during construction and during the life of the building. For instance, the application of green, rotting or damaged timber for floor joists will result in the floor after completion. It is obvious that a material is often wrongly used even though the material itself is in perfect condition.

Effective communication between designers and construction workers aids in solving problems. Sometimes, construction workers readily implement their own ideas of how to construct rather than discussing with designers when they encounter with messy construction drawings produced by inexperience designers. This is quite common in design-and-build form of contracts as the contractor stands to gain contractual advantage from drawing attention to design defects (Evans, 2005).

Building defects are a matter of concern for a various reasons:

The employer is eligible for what he or she is investing for. The presence of defects means that he or she doesn't get anything proportional of the amount paid for.

Defects might delay the completion of the project and thus affecting the handover of the building. This is because it will take some time to inspect and rectify the defects.

Lot of time and money may also be used up in identifying possible causes of defects, especially to attach blame.

There may be significant disruption and consequential loss if defects are to be corrected in occupied buildings.

Resources spent on defect rectification are not available for use elsewhere.

Defects represent inefficiencies in construction procurement processes.

2- LITERATURE REVIEW

Building defects are always under the spotlight and the grave concern of the construction industry. Different buildings or structures produce different types of defects and require numerous levels and types of quality, which rely on the building functions construction or maintenance systems and also materials adopted.

According to Watt (1999), "a defect may be considered to be a failing or shortcoming in the function, performance, statutory or user requirements of a building and it might manifest itself within the structure, fabric, services or other facilities of the affected building."

Josephson and Hammarlund (1998) quoted from Svensk Standard, SS 020104 (1987) states that defect is defined as 'the non-fulfillment of intended usage requirements' in which requirements are determined by law, regulations, building standards as well as in contract documents, site meeting records and other project documentation. However, not all requirements can be specified as there are many details which are difficult to specify such as non-expressed basic needs of each individual. Therefore, these demands are referred as 'usage' requirements. Opinions and responses from project participants are needed whenever specified requirements are wrong and defects will likely occur if those opinions are not complied.

There is a clear difference between failure and defects. Failure is defined as deviation from original specifications which can or cannot be corrected prior to the handing over of the building. On the other hand, defect is termed as deficiency of the performance which becomes apparent once the building is operational. Failing to differentiate the two terms may lead to inaccurate and incomplete measurements, cost determination and perhaps inappropriate methods to reduce its occurrence (Atkinson, 1987).

Georgiou et al (1999) suggest that defects can be classified as major defect or minor defect. Major defect is considered as those which cause the building to become unsafe, unsuitable for living in and not suitable to be used for the purposes for which the building was designed. On the other hand, minor defects is considered as those originate from poor workmanship or deficient materials used in the construction of the building but do not cause the building to become unsafe, unsuitable for living in and not suitable to be used for the purposes for which the building was designed. Defects which require less than Australian $500 to repair are considered as minor defects. In the meantime, major defects are defects exist after 12 months which need more than Australian $500 to repair and most of them are structural deficiencies (Georgiou et al, 1999).

Georgiou (2010) and, Andi and Minato (2003) state that defects occur if a component has a shortcoming and does not comply its intended functions and acceptable level of quality as required by owners, contractors or regulations.

Oloyede, et al (2010) attributed causes of building collapse as due to man's negligence in some vital areas in construction such as soil investigation, incorporating design for extra loads, stress from winds, earthquakes, uneven terrain, use of substandard building materials, poor monitoring and overall poor workmanship.

Madu, 2005, identified causes of building failure as due to natural occurrences such as earthquakes, tornadoes, flood, etc. Other causes according to him include factors such as omission, carelessness, leading to use of deficient structural drawings, absence of proper supervision of projects, alteration of approved drawings, use of substandard materials, corruption in the Nigerian system, building without approved drawings and translocation of building plans to different sites.

Adebayo, (2000), opined that efficiency in skill and experience is important in creating valuable workmanship in building construction.

Ayinuola et al, (2004), pointed accusing finger to all parties in the building industry, clients, architects, engineers, town planners in the local authorities and contractors stating that they have contributed to building failures in various dimensions.

Tyagler et al, (2007) traced the causes of building failures to defects or deficiencies at design and construction stages.

Ukpata, (2006), opined that the spate of building collapse in the country can always be traced to unsafe actions of parties involved in building process starting from clients to building consultants, contractors and users.

Adebayo, (2006), opined that building collapse incidences can be controlled or minimized if the client is ready to pay for high quality materials and for expert professional services.

BUILDING COLLAPSE

Building Collapse in Ethiopia


TOYOTA

In the early hours of Wednesday, April 27, a five-storey building collapsed in the Bole district, in an area commonly known as Summit. Fortunately, its construction had not yet been completed and only the ground floor and some of the first floor were occupied.

Two banks, Abyssinia and Dashen, occupied the ground floor, while the floor above was being used as a prayer area. The time of day meant that no one was harmed, but the assets, cash and material of both banks was destroyed.

It may have been a first for Addis Abeba, but it was certainly not a first for Ethiopia, AbebeDinku(PhD), Professor of Civil Engineering at the Addis Abeba Institute of Technology (AAiT), explained, as he displayed slide after slide of collapsed buildings in different regions throughout the country.

This evidently leads to a hypothesis that the increase in revenue recorded in the construction sector has not been accompanied by an increase in quality. During the last fiscal year, the construction industry generated 57 billion Br, while, having noted the good opportunity for business, the role of financing has increased six-fold in the last decade. It was a little over a billion Birr a decade ago, but currently stands at seven billion Br.

The government expenditure, during the same period, has also kept pace with this increase. Being the highest spender, half of the country’s budget was allocated to infrastructure projects –

the majority of which required construction. Construction also accounts for half of the country's industry.

Second building collapse in Summit causes concern

February 20, 2017

Last Tuesday morning around Summit Pepsi Industrial area in Bole Sub City, a three story building, which had been under construction for ten months, collapsed. This is the second time a building has collapsed in the same area while being constructed. No reason has been given for the building's demise and the value of the loss is not known as the incident is still under police investigation.

Experts that Capital interviewed expressed concern that mishaps like this could harm the housing industry. Quality standards and regulations have to be upheld by government offices and the sub city administration. This is even more vital in light of the current construction boom, they said.

"Construction permits are approved by the government only after quality assurance is verified by the contractor, owner and consultant and then the process is closely followed by civil servants in the profession and in addition the project must undergo a soil test," experts said.

They expressed concern that there are unscrupulous relationships between building owners and bureaucrats which can lead to bribes and then unsafe building construction. The owners come out unscathed but the nation's economy and people residing in the building are hurt.

Abera Bekele (Eng), president of Ethiopian Construction Contractors Association, told Capital that lack of evaluation in the early design stage is another problem.

He agreed that the interference of clients or owners of the building is the other major challenge.

The ground floor of the building which collapsed earlier, in April 2016, had been leased by the Bank of Abyssinia and Dashen Bank, who had been working there for a few months, according

to residents of the area.
Immediately after the incident, the Commercial Bank Ethiopia gathered its cash and employees were advised to evacuate the building, owned by the same proprietor and built to similar specifications of the collapsed structure.

Worst High-Rise Building Collapses in History

People and rescuers gather after an eight-story building collapsed near Dhaka, Bangladesh, on April 24.

The substandard construction methods that are suspected of triggering the deadly collapse of an eight-story building in Bangladesh on Wednesday are a common problem in developing countries, where construction materials can be expensive and building inspections infrequent, experts say.

Delhi Building Collapse, New Delhi, India

On November 15, 2010, monsoon rains and a swollen river proved too much for a poorly constructed tenement building in New Delhi, India. Tragically, 67 people died in the collapse and a further 150 were injured.

The multi-story building housed around 400 migrant workers from rural parts of eastern India. With most earning barely enough to cover basic costs, they had turned to living in crowded, illegally built apartment blocks.

Sixty-seven tenants of this New Delhi building paid the price with their lives when the structure crashed to the ground without warning at 8:00 pm. Rescuers used sniffer dogs in an attempt to discover survivors in the wreckage and pounded through large pieces of the building with jackhammers.

Bodies were pulled from the twisted remains all night long, with anxious family members standing by, waiting to hear the news: dead or alive?

Skyline Plaza, Virginia, USA

On March 2, 1973, tragedy struck the Skyline Plaza complex in Bailey's Crossroads, Virginia. One of the complex's towering apartment buildings collapsed, leaving a huge, eerie cloud of dust and debris where it once stood. Perhaps surprisingly, construction hadn't even completed at the time of the disaster. The building was not due to open until August.

Although there was no flaw in the design per se, the forms supporting the concrete columns on the 22nd floor were prematurely removed. The cement hadn't yet hardened completely and couldn't bear the weight of the 24th floor.

The failure of these columns put an increased amount of pressure on the rest of the columns on the 23rd floor until the entire floor buckled and slammed down on the floor below. The building had not been engineered to withstand such a huge increased load, and the tremendous weight proved catastrophic. Each floor gradually succumbed and plummeted onto the story below in a devastating ripple effect.

Fourteen construction workers died and 34 were injured. Michael Hill, 31, ran all the way down the stairs from the 23rd floor when he saw cracks appear in the ceiling. He made it to the fourth floor when he was forced to jump out of a window. He broke both his arms but survived.

Royal Plaza Hotel, NakhonRatchasima, Thailand

On August 13, 1993, at around 10:00 am, the once splendid six-story Royal Plaza Hotel in NakhonRatchasima, Thailand came crashing down in less than 10 seconds, that’s 1.6 seconds per floor! Tragically, 137 people were killed and 227 more were injured in the collapse.

Rescuers dug through the rubble with jackhammers and crowbars, desperately searching for signs of life. According to rescue teams, trapped survivors had been using their cell phones to call for help. On August 15, a pregnant woman was pulled from the mangled pile of steel and debris.

Devastatingly, at the time of the collapse, the hotel was being used for several meetings and seminars, including a large teacher conference and a Thai oil company meeting with more than a hundred attendees. The tragedy also claimed the life of U.S. Air Force sergeant Ramon Canda, who was in town installing telephone lines at the Korat Royal Thai Air Force Base.

Police detained the owner of the Royal Plaza Hotel, the architect, and an engineer over allegations that three stories had been added to the building in 1990 without proper architectural review. Also, a huge amount of water was being stored on the roof of the hotel ahead of an expected water shortage.

Lotus Riverside Compound, Shanghai, China

Image Source

On June 27, 2009, Block 7, one of eleven 13-story apartment buildings making up the Lotus Riverside compound in Shanghai, toppled over, completely intact. The high-rise was still under construction, and luckily, most of the workers were able to evacuate the building when they felt it start to fall over. Unfortunately, one man wasted too many precious seconds collecting his tools. He was then forced to jump out of a window as the building began to go down. He fell to his death.

Block 7 met its demise just one day after 272 feet of a nearby riverbank collapsed, proving the area was unstable and that the soil was loose. Laborers worked through the night to shore up the river, but it was no use. People in the area reported that it felt like an earthquake when the building fell. When they ran outside, they said they saw the massive structure lying flat with its foundation pillars uprooted.

The development company, it turned out, had been working illegally for five years, raising huge concerns over building practices across China. Only the year before, 7,000 schools had collapsed during an earthquake in Central China.

Hotel New World, Singapore

On March 15, 1986, all six stories of Hotel New World collapsed in less than 60 seconds. The building housed a hotel, a bank and a nightclub, all of which disintegrated into piles of rock and twisted metal, burying 50 people inside. It was the worst disaster Singapore had experienced since World War II, and it shocked the nation.

Singapore's newly formed Civil Defense Force launched rescue and recovery efforts immediately, and they continued for seven days. Engineers and other experts from around the world were called in to assist the delicate rescue operation.

At first, they merely removed beams and other remains from the top and sides of the ruins, but not many bodies were recovered. On the second day, assisted by foreign experts who were in Singapore to build a mass transit system, rescuers began to tunnel into the rubble. Sound-detection equipment was used to help locate the 17 lucky survivors.

After intensive research, investigators discovered a terrible error in the original design of the building. The structural engineer had completely left out the building's "dead load," in other words, the weight of the building itself, during the design process. As a result, it wasn't strong enough to hold itself up. Tragically, Hotel New World was doomed from the beginning.

Three High-Rise Office Buildings, Rio, Brazil

On January 26, 2012, a 20-story building in Rio de Janeiro, Brazil spontaneously collapsed. The gigantic high-rise crashed into another ten-story building and a smaller "three or four" story building, reducing all three structures to one huge pile of rubble. The impact sent an enormous wave of dust and detritus through the streets of Cinelandia square, killing at least 17 people.

If the disaster had occurred just a few hours earlier, it would have resulted in mass casualties. Fortunately, the district, home to many office buildings and Brazil's prized Municipal Theater, was pretty desolate due to the late hour of the collapse.

Authorities suggested that illegal construction work had weakened the 20-story building and caused it to fragment, which triggered a chain reaction and brought down the two smaller buildings. This catastrophe has led Brazilian authorities to call for reforms and stricter building and renovation regulations, especially ahead of the 2014 World Cup.

Sampoong Department Store, Seoul, South Korea

On June 29, 1995, in the space of 20 seconds, the Sampoong Department Store in Seoul, South Korea fell to the ground, killing 502 people and injuring 937. Criminal negligence, blatant disregard for ethical engineering practices, and shoddy construction led to the largest peacetime disaster in South Korean history. The problems can be traced almost exclusively to the future chairman of the building, Lee Joon. Under his insistence, the building was changed from being an office building to a department store halfway through its construction.

To install the escalators, several key support columns had to be eliminated. When the contractors refused to continue building after the changes, they were fired, and Joon hired his own company. Later, Joon had a fifth floor added to the building. Despite warnings, Joon once again hired his own company. Not only was the building not meant to support a fifth story, but his extra level was made with a thick, super-heavy, heated floor.

Air conditioning units that were added to the roof quadrupled the load the structure was designed to sustain. To make matters worse, the building was constructed with substandard concrete and had only half the 16 steel reinforcing bars it needed. Also, the concrete columns were thinner than necessary and were reduced even more when fire shields were installed around the escalators.

In April 1995, extensive cracks were spotted, yet nothing was done. These fractures grew exponentially on the day of the disaster, but because management didn't want to lose the day's revenue, they refused to evacuate the building. Top executives, however, left as a precaution. Seven minutes before the collapse, the building began to pop and crack, and employees sounded the alarm, but it was too late to avert disaster, and 1,500 people were trapped inside.

Bonus entry: Katowice Trade Hall, Silesia, Poland

On January 28, 2006, in the midst of a frigid Polish winter, the Katowice Trade Hall was hosting the 56th National Exhibition of Carrier Pigeons. What the 700 people attending didn't know was that the managers of the building had not had the snow and ice removed from the roof. Damningly, the roof had buckled under the winter snow four years earlier and been rebuilt without being properly inspected or tested.

On this fateful day, the accumulation of snow overloaded the roof of the building by 100 percent, and the roof smashed down on the exhibition, trapping hundreds of people beneath its weight, and exposing them to dangerous sub-zero temperatures.

Rescue teams poured in from the surrounding areas, braving the terrible weather. The building, however, was still unstable, and a second section of the roof collapsed during the rescue effort.

The lacerated metals acted like a freezer, further endangering survivors. Still, rescuers couldn't heat the air under the ruins because parts of the building were supported by nothing more than piles of snow.

In the end, 65 people died and more than 170 were injured. The architects and managers of the building all faced criminal charges.

3. GEOTECHNCAL INVESTIGATION

3.1 INTRODUCTIONS

This report deals with investigating and examining the engineering properties of the foundation material at the buildings site, and interprets the investigation results of the foundation material. Finally, analysis will be made to assess whether the foundation material has any relation with the failure of the buildings and recommendation will be provided.
Failure in this report is to refer the distress caused on the buildings.

The geotechnical investigations comprised of test pitting, collection of representative samples and subsequent laboratory tests on representative samples to determine engineering properties of the soil.

3. 2 LIMITATIONS, SCOPE OF WORK, OBJECTIVES AND METHOD

LIMITATIONS: - the investigation &identification of defect cover only defects in relation to the engineering properties of the foundation material of the site due to time limitation structural plan and cost.

The scope of the investigation includes test pitting, collection of reprehensive samples, and subsequent laboratory testing. In this activity, disturbed soil samples and undisturbed soil samples using Shelby tubes are taken.

MAIN OBJECTIVE: -

To investigate & identify defect of Building at National meteorological Agency head office in relation to engineering properties of the foundation material and to indicate possible remedial measures.

SPECIFIC OBJECTIVES:-

- To assess the degree of damage occurred in the buildings.
- To investigate the cause of the failure.
- To *identify* the possible causes of failure on the buildings.
- To recommend appropriate remedial measures to be taken.

3.3 LOCATION

The project site is located in Addis Ababa, Bole Sub-City, in the compound of National Meteorological Agency, in front of Ethiopian Airlines Aviation Academy. The project area is characterized as flat ground. The Area covered by the agency is 18000 square meter.

3.4 LOCAL /SITE GEOLOGY/

All the material excavated at each test pit site is covered by soft, dark expansive CLAY as presented in the test results attached.

3.5 - METHODES

1. Photos collected in each building and crack identification is done from reference books.
2. Pit Test collected from each block.

Laboratory test conducted to determine the engineering properties of soil following widely accepted and practiced procedures and interpretation of results and data analysis is done.

- Grain size analyses (three samples)
- Unterberg limits (three samples)
- Moisture content (three samples)
- Dry density (three samples)
- Linear shrinkage (three samples)
- Free swell(three samples)
- Swelling pressure (three samples)

4. DESCRIPTION ON THE NATURE AND DEGREE FAILURE

The observation is made on three of the buildings; Block 2-G+1, Block 3-G+1 and Block 4-G+0 which are found in the compound of the National Meteorology Agency, where the failures are very severe which may result in building collapse suddenly. The observations are carried out on each building as listed below:

- Big wall crack which is narrow at bottom around the floor and wider at the top (about30 mm)
- Sever block and brick wall crush
- Cracks on glasses of windows
- Formation of grade separation on the side ditches
- Cracks on walkways around the building (narrow on one end and wider on the other end)
- Separation of building and walkway around the building
- Bending of frames of door and windows
- Vegetation (grass and big trees) is observed all around the building
- Rainwater coming through the down pipes penetrates in to the foundation material under the building through the cracks on the walkway and through separated walkway to side ditch junction and side ditch to side ditch junction.
- Side ditch is not performing the intended purpose
- Level deformation of walkway
- Breaking of the side ditch
- Percolation of rainwater from downpipe through the separation of the grade beam of the building and walkway
- Uneven surface on the ground floor
- Separation of the floor slab and grade beam with the fill (material) underneath

Observations have been shown that the failures might be due to heave and shrink of soil underneath, since the buildings weight is very light which are susceptible to damage caused by expansive soil.

Generally, the damage is alarming and critical.

The soil at the site is also observed visually and found that it is black in color; the wet sample of the soil is sticky and is difficult to clean from the hands.

From the information got from a senior staff of the Agency who has been in the locality for long time, previously, the area at the back yard of Block 3 was always under water (swampy). However, after infrastructures are built around the area, the water disappeared also they mark each year on the crack to see the crack width that increase highly season to season.

Figure 1. Wall crack on Block 2, Right wing

Figure 2. Separation of super structure with the peripheral masonry and Walkway on Block 2, left wing

Figure3. Percolation of rainwater from down pipe through separation of Walkway and non-functional side ditch to underneath of the building on

Block 2, right wing

Figure 4. Severe wall crack and failure on Block 3, right wing

Figure 5. Severe wall crack and failure

Figure 6. Separation of structure and walkway on Block 4

Figure 7. Bending of external stair case on Block 4

Figure 8. Bending of Ceiling Block -4

Figure 9. No selected material is found around the footing

Figure10.Seriouswall crack on multi –purpose hall block -4

Figure11.Serious wall crack around window on multi –purpose hall

Figure 12. Serious wall crack and separation of beam to foundation masonry on multi –purpose hall

Figure 13. Serious wall crack and separation of beam to foundation masonry on multi –purpose hall

Figure 14. Serious wall crack and separation of beam to foundation masonry block-3

4.1 CAUSE OF CRACKS IN BUILDINGS CONSTRUCTED IN EXPANSIVE SOIL AREAS

Cracks caused by swelling soil are wide at the top and narrow at the bottom.
The cause of foundation movement is moisture fluctuation of the foundation soil. Normally, the first sign of foundation movement for a structure founded on expansive soil is the cracking of the floor slab, door binding, window stacking and cracks appearing in the exterior and in the interior walls and even in the ceiling . It is important to differentiate the different types of cracks and their causes in order to know cracks caused by expansive soil heave.

4.2 CRACK IDENTIFICATION ON BUILDINGES

Cracks are more readily noticed on buildings constructed in expansive soil areas. It is a rare case that cracks are caused on light weight buildings due to settlement. Settlement and shrinkage or heave crack can be distinguished by observing the width of the crack as the climate changes from season to season.

If the crack width changes from season to season, the crack is the result of shrinkage and heave (swelling of soil) not settlement.

Buildings with slab foundation are affected by the climate change and it is influenced by changes in soil water. If the soil under the slab is wetter than the soil outside the slab, the moisture moves from under the slab towards the slab perimeter .The opposite happens if the soil beneath the slab is drier than the soil outside the slab. In the latter situation, water moves from the wetter soil outside the perimeter of the slab to the slab beneath the interior of the slab.

Cracks in concrete can scar a building's architectural appearance. They can be the cause of leaks from rain or groundwater or they can be the first telltale signs of a potential wall collapse. Thus, no crack should go unexamined.

For every crack, a trained investigator should record, with photographs and sketches, the following information:-

- Location on the building
    - Pattern (horizontal, vertical, and diagonal, eggshell)
    - Length
    - Width (uniform or tapered; if tapered note how)
- Depth (through paint, plaster, entire wall)
    - Age (clean crack indicates new; coated with paint or dirt indicates old)
    - Active (moving) or dormant

Based on this information, an investigator can assess the cause of the crack, how harmful the crack is, and how best to repair it, if repair is deemed necessary. The location and pattern of cracks are the most important factors in determining their cause.

STRUCTURAL CRACKS

Some cracks visible in the plaster may result from cracking of the wall. This can be caused by differential movement of the foundations, moisture expansion or drying shrinkage of masonry units, or thermal movement of the roof. This type of crack often forms in straight vertical or horizontal lines, or in stepped diagonal lines, and may be quite unsightly. The crack width will often vary with the seasons.

Because these cracks originate in the wall and not in the plaster, repairing the plaster is ineffective.

NON-STRUCTURAL CRACKS

Crazing is a network of fine cracks, usually in a hexagonal pattern, which measures between 5 and 75 mm across each hexagon. Craze cracks are usually very fine and shallow and do not extend through the whole depth of the plaster.

They are usually the result of over trowel ling a rich mix (one with high cement content) or using sand containing an excessive amount of dust (more than 15% by mass passing a 0,075 mm sieve). Crazing often occurs within a few hours of the plaster being applied to the wall and cracks may hardly be visible until dust or moisture makes them noticeable.

Craze cracks are of little importance, do not open and close with time, and can be covered using reasonable quality paint. If necessary, glass fiber tissue can be applied during the painting operation.

Map cracking is similar to crazing except that it is usually deeper (sometimes going through the plaster) and the hexagons of the pattern may measure up to 200 mm across. These cracks normally occur when a plaster mix with high cement content is used or the plaster is allowed to dry too quickly.

- **Causes of excessive early moisture loss are:**

• Evaporation, if the wall is not protected from sun and wind.

• Suction in to the walls, if the masonry units are absorbent and they have not been dampened.

• Use of sand that is badly graded and lacks fine material (less than 5% by mass passing the 0,075 mm sieve).

• Not using building lime or a masonry cement when the sand lacks fine material.

When the cracks are noticed while the plaster is still plastic, they are often floated closed, only to reappear some time later. These cracks can be filled with proprietary filler and be painted over. Glass fiber tissue can also be applied during painting.

Cracking which results when an excessive amount of water is lost from the plaster in the first hours after application is known as plastic shrinkage cracking. Map cracking can be due to plastic shrinkage as can the horizontal cracks which form at corners and between windows
Drying shrinkage cracks are the result of moisture loss after the plaster has hardened. Plaster will always shrink and crack so it is desirable that is should develop a large number of fine, unnoticeable cracks at close spacing's. Plasters with very high cement contents and those which are made with poor quality sands having a high water requirement will tend to develop a few, widely-spaced cracks. Plaster applied in layers that are too thick will also tend to crack in this way. These cracks are normally stable and can be filled with a proprietary filler and be painted over.

4.3 CRACK DUE TO SURFACE DRAINAGE

Buildings lack proper drainage system the surface water easily percolates to the foundation and hence disturbs the soils equilibrium moisture. The other factors that might be reasons for the cause of damage include vegetations around the building, leaking of pipes, splashing of down pipes to the foundation soil and new adjacent construction. These factors also contribute for disturbance of soils equilibrium moisture.

4 DATA COLLECTION AND RESULTS

Test Pitting

Test pits with surface area of 1.0 m x 1.0 m were manually dug to a depth of 1.5 m at each block site and one test pit with 1.5 m x 1.5 m dug to a depth of 2.5 m inside the compound. The test pits were dug by equipment such as, pick axle, and shovel. Representative disturbed soil samples are collected from depth of 1.5 to 2.0 m from each test pit for Atterberg Limit, grain size analyses (that is, Sieve Analyses), moisture content, dry density, free swell and linear shrinkage to be tested at laboratory. Representative undisturbed soil samples are also collected at 1.5 to 2.0 m depth from each test pit for swelling pressure test.

Laboratory Tests

The following laboratory tests were performed to determine the engineeringproperties of soils collected during the site investigation, following widelyaccepted and practiced procedures such as

- Grain size analyses (three samples)
- Atterberg limit (three samples)
- Moisture content (three samples)
- Dry density (three samples)
- Linear shrinkage (three samples)
- Free swell (three samples)
- Swelling pressure (three samples)

Moisture Content

There will be no volume change if the moisture content of the clay element is unchanged. When the moisture content of the clay is changed, volume expansion in the vertical and the horizontal direction will take place. Complete saturation is not necessary to initiate swelling. Slight change in moisture content in the magnitude of 1% to 2% is sufficient to cause detrimental swelling.

Dry Density

The dry density of the clay is another index of expansive soils. Soils with higher dry density will show high swelling potential than lower density soils. Soils whose dry densities in excess of 1.76 g/cm3 generally exhibit high swelling potential.

Atterberg Limits

Plasticity index and the liquid limit are useful indices for determining the swelling characteristic of most clay. Liquid limit and swelling clay both depend on the amount of water absorbed; High swelling soils will manifest high index properties

Linear shrinkage

The shrinkage characteristic of clay should be a consistent and reliable index to the swelling potential. A soil having higher linear shrinkage limit is critical as compared to soils of lower linear shrinkage limit.

Free swell

Free swell is the maximum volume change expressed as percent of initial volume. Expansive soils have generally higher free swell value.

Table 1. Summary of Laboratory test results

TP- ID	Depth (m)	% age pass this sieve (mm)			LL (%)	Pl(%)	Free swell (%)	Unified soil classification
		2.0	.425	.075				
TP-01	1.5-2.0	100	100	99	81	35	180	MH
TP-02	1.5-2.0	99	99	98	92	46	170	MH
TP-03	1.5-2.0	100	100	99	80	35	180	MH

6. INTERPRETATION OF RESULTS AND DATA ANALYSIS

The problem observed on buildings varies from simple crack on walls to severe Structural damages, which may result in distress or collapse of the whole building. The principal causes of building failures include deficiencies in maintenance, use of materials, and/or inadequate consideration of external events, and a combination thereof.

External factors, such as extraordinary loads, heavy rain, earthquakes and defective site, with very unusual ground conditions, like swampy land can cause failure on buildings. A building that is intended to stand for some years should be able to resist all these challenges. This shall be incorporated into the design. Identification of the characteristics of particular site conditions by the engineers/consultants, through suitable geotechnical studies, can help with site selection and site progress that reduce the risk of failure.

- Based on the laboratory test results, degree of expansiveness is made for the soil at site. The plasticity chart developed by casagrande shows the expansive soil at site falls below the A-line for all the samples and shows it is in organic clay SILT of high plasticity.

According to Chen (and Holtz and Gibbs, 1956), classification system relating the swelling potential with the plasticity index, soil which has plasticity index of 35% and above is considered to have very high swelling potential. The soils located around Blocks 2, 3 & 4 have PI of 35%, 35% and 46 %, respectively. This shows they have very high swelling potential, which means the soil is bad with regard to their effect on buildings erected on them.

The swell potential is presumed to be related to the opposite property of linear shrinkage measured in a very simple test. Altmeyer (1955) [1] suggested that soils that have linear shrinkage greater than 8% are considered to have critical degree of expansion. The soils around Block 2, 3 and 4 have linear shrinkage value of 22%, 19% and 14%, respectively. This also shows the soils around the buildings exhibit critical degree of expansion.

Soils having a free swell value as low as 100 percent can cause considerable damage to lightly loaded structures, and considered as expansive soils. The free swell values of soils located around Blocks 2, 3 and 4 respectively are 180,180 and 170. This also shows that the soil around all the buildings considered is expansive soil.

From the above analysis, the soil found at site on which the foundations are placed is expansive clayey SILT.

Expansive soil is a clay soil that changes its volume when the water content of the soil changes. Usually, the soil will shrink when water (or moisture) content is reduced and will swell when the water content increases. The stress caused by alternate heaving and shrinkage, which is an additional stress to be considered quantitatively in design, of the foundation soil creates stress on the structures that causes damage to the buildings.

Light structures, like one or two story buildings, warehouses and fences are more vulnerable to damages because these structures couldn't exert a heavy pressure to counteract the uplift pressure from the expansive soils.

Damages like crack of floors and walls, stacked windows and doors, bulged floors and tilted walls and structures are usually the effects due to alternate heave and shrinkage or differential heave of the foundation soil.

The building is exposed to surface percolated water in all the three buildings due to poor surface drainage condition water. It is clear that the percolated water disturbs the moisture equilibrium of the soil and creates welling pressure which distresses the buildings elements.

6.1. Soil – Moisture relationship of expansive soils

For swelling to take place, the environment of the expansive soil has to be changed. Environmental change can consist of pressure release due to excavation, desiccation caused by temperature increase, and volume increase because of the introduction of moisture. It is the effect of water on expansive soil that plays the major role. Moisture migration depends on the geological formation, climatic condition, topographic features, soil type and ground water level. The most common method of moisture transfer is by gravity. The seepage of surface water and precipitation in to the soil are common examples.

Moisture in the soil varies due to seasonal climatic changes, change of surface conditions and external influences. Climatic change consists of a change in atmospheric temperature, precipitation, evaporation, transpiration and relative humidity. Surface condition (changing of paved area in to garden) and External influence which is resettlement of new houses around the existing building will disturb the moisture content of the foundation soil resulting variation of moisture content which in turn results in the swelling and shrinkage of the soil. This alternate shrinkage and swelling of the foundation soil creates stress on the structures as a result, the structures be faced to additional stress which is not yet considered during the design.

In lightweight structures, the contact pressure is normally much smaller than the swelling pressure of the expansive soil. As a result, the whole building will be lifted differentially and creates stresses, which may not be accounted on the design. This stress creates cracks and through time sudden structure collapse will happen.

7. CONCLUSION AND RECOMMENDATION

7.1 CONCLUSION

As was discussed in this paper and Observations and test results shows that the cause for the failures;

- heave and shrink of soil underneath, since the buildings weight is very light which are *s*usceptible to damage caused by expansive soil, lightweight structures such as the structure investigated are more susceptible to damages because these structures couldn't exert a heavy pressure to counteract the uplift pressure from the expansive soils.

  As a result, the whole building will be lifted differentially and creates stresses, which may not be accounted on the design.
- The other main cause of failure or damage of the buildings observed are also due to poor drainage system, which easily disturbs the equilibrium moisture.

Methods that have commonly been used to prevent building damages due to heave are moisture control, soil stabilization and structural measures. But for this case to give a solution to the soil problems such as controlling moisture fluctuation using horizontal barriers, vertical moisture barriers, subsurface and surface drainage as well minimizing or completely eliminating the moisture; by compacting to a lower density, by replacing the expansive soil with non expansive soil, by stabilizing the expansive soil with chemicals and by isolating the soil it's too late because we can't give a solution to the structural failure which will not be revisable.

MOISTURE CONTROL

Generally, expansive soil will not be a problem if the moisture content is constant throughout the soil. Moisture fluctuation can be controlled by using horizontal barriers, vertical moisture barriers, subsurface and surface drainage.

Horizontal moisture barriers can be installed around a building in the form membrane, rigid paving or flexible paving. Polyethylene membrane, concrete aprons and asphalts membrane can be used as a horizontal moisture barrier.

Vertical moisture barriers are used around the perimeter of the building to cutoff the source of water that may enter the under slab soils. Vertical barrier is more effective than horizontal barriers in minimizing drying and shrinkage of the perimeter of the foundation soil as well as maintaining long-term uniform moisture conditions beneath the covered areas. Concrete can be used as a vertical moisture barrier.

When such materials are used as a barrier, this depth should be equal to or greater than the depth of moisture fluctuation.

SOIL STABILIZATION

The swelling potential of expansive soil can be minimized or completely eliminated by compacting to a lower density, by replacing the expansive soil with non expansive soil, by stabilizing the expansive soil with chemicals and by isolating the soil so that no moisture change will exist in the foundation soil.

It is discussed that the soil around the buildings is expansive soil with high swelling pressure and potential. The main cause of failure or damage of the buildings observed are also due to poor drainage system, which easily disturbs the equilibrium moisture content of the foundation soil resulting in differential heave.

Organic and inorganic chemicals can be used to stabilize the expansive soil.
The most common chemicals used are lime, cement, sodium chloride and sodium silicate.

Stabilization using lime reduces the plasticity and the swelling potential of the soil by replacing the weaker ion such as sodium on the surface of the clay particle by calcium ions of lime. Cement and other inorganic chemicals reduce the swelling potential, plasticity index and liquid limit and increase the shear strength of the soil.

Proper foundation design and construction may not be enough to solve the problem associated with swelling soil. It should also be careful on the landscaping of the area or the garden plot by

- avoiding grass and shrubs around the building
- avoiding sprinkler system around the building
- avoiding tree plantation around the building
- giving appropriate slope so that the water drained away from the building

Shrubs and grass around building disturbs the moisture equilibrium of the soil, and it disturbs the soil moisture and swelling pressures develops and results in crack.

It is also observed that the soil beneath the floor is subjected to moisture disturbance due to percolation of rainwater from down pipes & side ditches, and surface water.

The peripheral masonry wall under the grade beam is placed near the surface believing that it is not structural.

However, during the dry season the soil near the surface shrinks and the masonry wall placed on surface or in shallow depth settles. This results in detachment of the masonry wall and the grade beam.

In this case the buildings are in great risk due to the following remarks:-

- Deformations or deflections which affect the appearance or effective use of the structure (including the malfunction of machines or services) or cause damage to finishes of non-structural elements.

- Cracking of the concrete which is likely to affect appearance, durability or water tightness adversely.

- Combination of deformation, bending and crack which causes discomfort and fear to people, damage to the building or its contents, or which limits its functional effectiveness.

- Large cracks and deflection has been observed in all blocks.

It is known that any structure is design to resist not only for normal /service loads but also to give good resistance during critical unexpected load occurrence.

Thus, based on our code buildings constructed in Addis Ababa are designed to resist at least an earth quick of having gravitational acceleration of 0.05g in addition to its expected dead and live loads. In contrary to this, the building is not at its full capacity to bear the conventional loads.

From the above result and current actual observation the buildings severity ranked as follows

1- Research center ; it is observed that a lot of crack ,uplift pavement around the building ,sliding happened hence, from laboratory analysis and actual site observation data this blocks leads the degree of severity .
2- Operational center; it is observed that a lot of wall crack, roof leakage, shaking of foundation when large vehicles pass by the near road. Hence from laboratory analysis and actual site observation data degree of severity of this block ranked next to the research center.
3- Mulit – purpose hall ;from the observation wall crack, up lifting of pavement around the building ,sliding ,missing alignments of columns ,broken stairs hence , from laboratory analysis and actual site observation data degree of severity of this block ranked in the third place .
4- Engineering center;-from actual site observation and laboratory analysis that hair cracks around wall, uplifting of pavement around the building, and slab crack hence, severity of this block ranked in the fourth place.

Generally, from laboratory analysis, site observation and functional criteria that the research center, operational center and multi- purpose blocks Research center; hall it is too late to improve the failure since the buildings are at great risk

When we come to engineering center, compare with the other blocks it is stable and less in cracks and other effects. Thus by providing appropriate drainage system prevents extra or further damage of the building.

7.2 RECOMMENDATION

The following remedial measures are recommended to reduce further stress &distress:-

- Provide proper surface, and subsurface drainage which intercepts the percolated water and drains away from the building.

- Clean and make functional ditches around the building to drain water properly

- Provide vertical moisture barrier.

However the above recommendations are feasible only at the early stage of construction but for such projects ageing greater than fifteen years it will not return back the previous alternating stress and distress occurred. This measure only prevents the extra or further damage to the building due to the moisture fluctuation neither it didn't bring the original structural capacity of the building i.e., the building losses its capacity due to repeated fatigue effect.

Finally, Structural engineers can efficiently and accurately design the structural elements required based on the results of the soil test analysis for long term viability and soundness of the project. The result also helps to determine whether there is need for soil stabilization and the foundation depth to attain the required bearing capacity.

Also a building needs good maintenance plane after certain period from its construction completion.

In this project the structural analysis not included. Hence, it would be of highly recommendable for further detailed study of including structural analysis as it will make the result more accurate.

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ANNEXES

ANNEX -1 SOIL TEST

ANNEX- 1 PHOTOS SHOWING BUILDING DEFECTS

ANNEX -1 SOIL TEST

ANNEX- 2 PHOTOS SHOWING BUILDING DEFECTS