Measurement and Documentation for Structural Integrity Assessment of an In-Service School

Building at Risk

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ABSTRACT

- The primary aim of carrying out structural integrity assessment of an in-service building is to determine the extent of damage or extent of distress at any point in time.
- This paper examines the methods adopted for damage detection in a school building in Benin City Nigeria.
- The methods adopted included visual inspection, measuring, photographing, probing and sampling.
- Bearing capacity of soil at the foundation of columns were examined using Dynamic Cone Penetrometer Tests along with normal boring with bearing capacity estimated from results of laboratory tests.
- Position, direction, width and extent of cracks in various parts of the building were measured.
- An As-Built plan of the building was prepared from total station survey of the building.
- Elevation within the building area were measured to determine the direction of slope in order to estimate the effect of wetting on the building foundation
- The results of the tests were used to build a database for the development of remedial measures which will increase the service life and safety of the building structure.

INTRODUCTION

- Structural integrity assessment is a process by which we determine how reliable an existing structure is able to carry current and future loads
- and fulfil the task for a given time period.
- In structural monitoring, periodic measurement of displacement, strains, stresses, damage evaluation (e.g. crack width) and vibration characteristics are carried out
- with the sole objective of either detecting the changes that have taken place in the structure or
- where the structure appears to be at risk to plan for its evacuation.

- When there are noticeable defects in the structure such as visible cracks in a building,
- a study to determine the condition of the building is carried out.
- Such investigation should identify the type of defect such as cracking and subsidence, settlement or movement of the structure.
- Technical expertise and an understanding of building construction is essential to correctly identify the cause of building defects and
- the remedial measures required to put the defects right.

- Building inspection is a general surface examination of those parts of a property which are accessible.
- In order to carry out the inspection,
- the surveyor requires some basic equipment to be used during the survey.
- In general four types of inspection are distinguishable:
- these include visual inspection, concealed object inspection, Dampness inspection,
- stress and strain survey.

- In visual inspection, the equipment include
  - digital camera, binoculars, magnifying glass, video recorder etc.
- Concealed object inspection may be carried out by the use of
  - cover meter, fibrescope, endoscope etc.
  - Dampness inspection may be carried out using digital thermometer, hygro test kit, wheel etc.

- Stress and strain tests are carried out to test the structural integrity of various component of the building structure.
- They enable for the detection of sources of bending, cracks and displacement in the structures.
- Some of the equipments for this test include
  - strain gauge,
  - ultrasound and
  - Geodetic survey methods.

- Cracks develop in a building or sections of a building whenever stress in the component exceeds its strength.
- Stress in the building component may be caused by externally applied forces such as
  - dead and live load or foundation settlement or
  - it could be induced internally by thermal variation, moisture changes, chemical actions etc.
- A proper understanding of the type of movement that has caused the crack, and the rate at which this movement is to be expected in the future,
- is a key step in analysing and providing specifications for the repairs of the cracks.
- Buildings can move in several directions and this movement can be in various forms.

- It could be the building moving itself,
- or a small portion of it,
- or it could be the soil on which the building is built, or a small portion of it.
- Thus, crack is not the cause, but rather the sign that shows that the building is undergoing movement.
- There are two major reasons why buildings move, and they include:
  - Movement as a result of conditions below ground; and
  - Movement as a result of conditions above ground.

SITE DESCRIPTION

- St. Mary dedication international school is located along Sapele road in Benin City
- at a distance of about 0.75Km from the city centre.
- The school consist of blocks of classrooms, offices and dormitories.
  - The layout of the building at the school is shown in Fig 1
  - while the attribute descriptions of the building are shown in Table 1.

Table I: Attribute Characteristics of School Building

Block – ID	Floors (Nos)	Uses
Block - A	4	Offices, classroom, Laboratories and dormitory
Block - B	3	Offices and classroom
Block - C	2	Ceremonial and Assembly hall
Block - D	3	Offices and classroom
Block - E	3	Kitchen, offices and stores

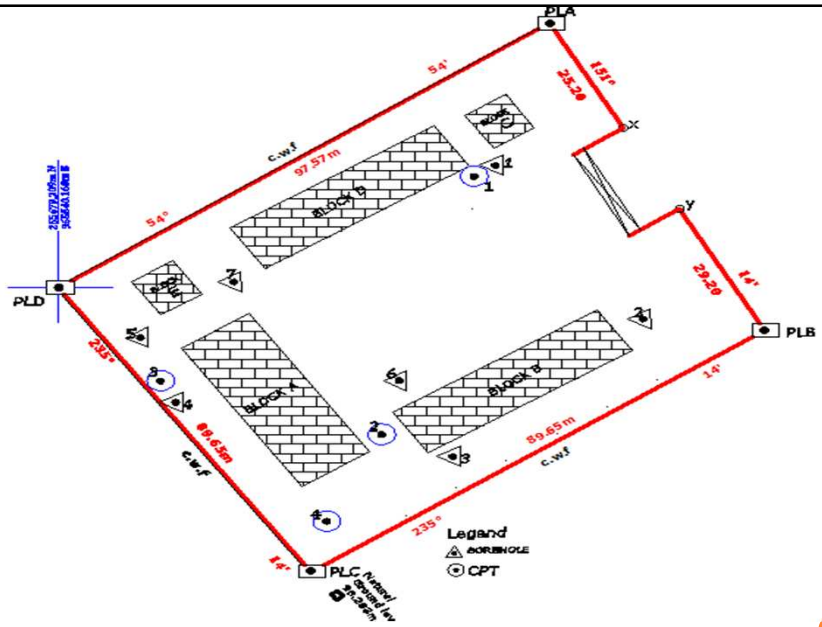


Fig 1: LAYOUT OF BUILDINGS IN SCHOOL

- There are five blocks of buildings within the school compound.
- Shear cracks are noticeable in many of the buildings particularly block A
- which is multi functional block having offices, classrooms, Laboratories and dormitories.
- The cracks are more noticeable on the west wing of the building separated by expansion joint.
- Most of the cracks run from the first floor to the roof.

Data Collection.

- The first phase of work involved a review of the original designs and
- construction documents and drawings with the necessary approval by the Edo Development and Property Authority (EDPA).

These were used to:

- Assess the structural layout of the buildings
- Identify critical areas for inspection
- Identify the specified loads to assess usage and possibility of overloading.
- Verify if unauthorised addition or alteration have been carried out in the building structures.

- ✓ Based on these evaluations, the following field surveys were carried out:

I. Topographical survey of the project site

II. As- Built surveys of the buildings.

III. Geotechnical investigation within the building area and Georeferencing of borehole and CPT locations.

IV. Visual inspection of building

V. Measurement of crack width and length.

VI. Rebound hammer tests on concrete column.

Visual Inspection

- Visual inspection of various parts of the building show that Block A has sufficiently suffered serious structural deterioration.
- Several cracks both longitudinal and transverse were observed particularly in the west wing of the block.
- Many of the cracks run from the ground floor to the roof. Photographic images of many of the cracks are shown in fig 3 to fig 8.

Fig 3: crack in office wall

Fig 4: crack along outside Column D4

Fig 5: Crack around Beams

Fig 6: major crack in wall

Fig 7: diagonal crack on wall

Fig 8: crack in Window

❖**Topographical and As-Built Details**

The total station survey results were used to develop a 3D terrain model of the site
▪in order to determine the direction of runoff.

❖The purpose of the survey was to determine if the percolation of storm water in to the ground at the foundation of the building
❖is responsible for weakening of the soil and creating differential settlement.

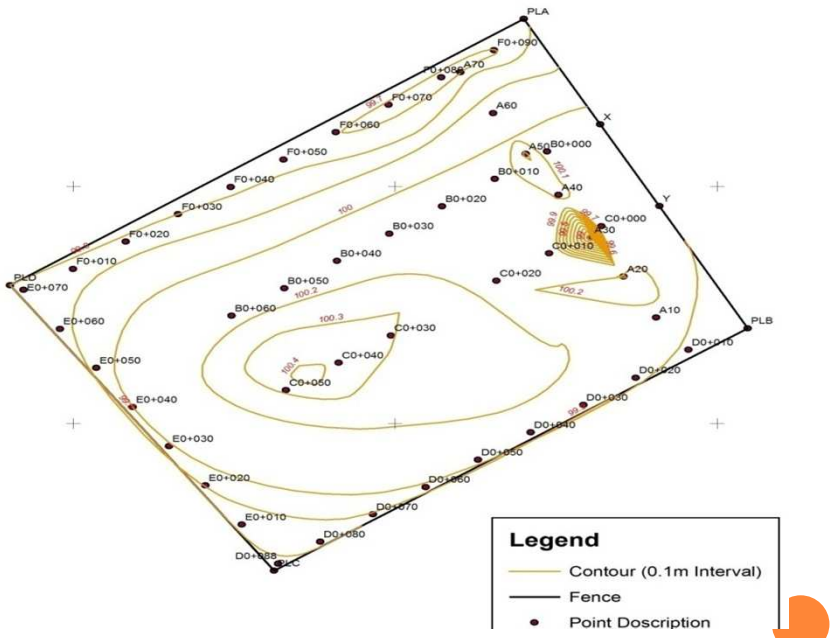


Fig 9: Contour Plan of Site.

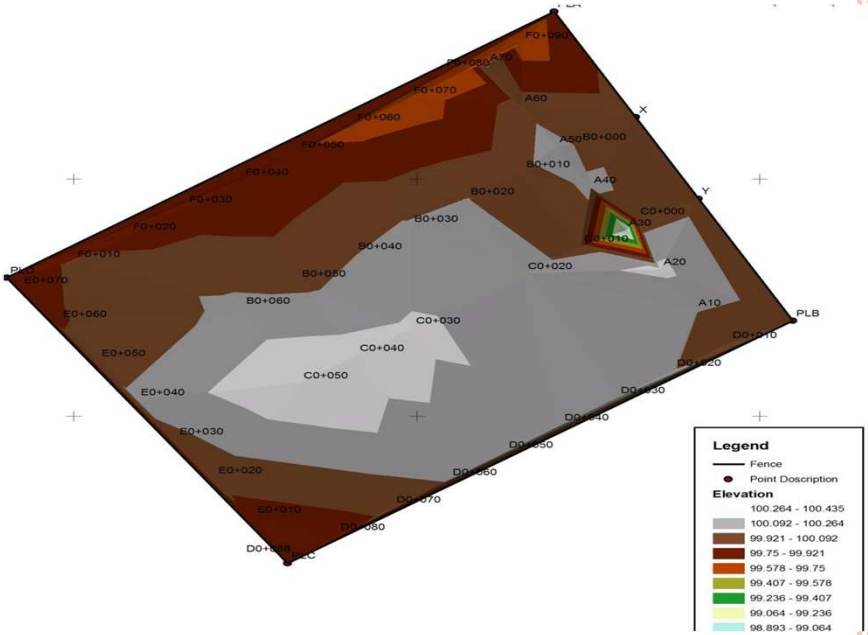


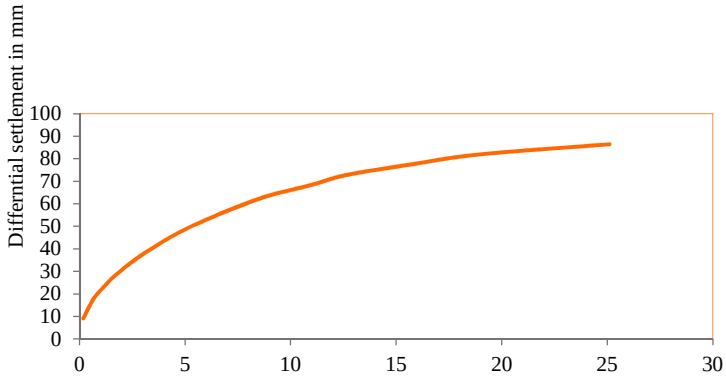
Fig 10: 3D model of the Project Site.

Tabe II: SAMPLING POINTS COORDINATES

S/N	Borehole No.	NORTHING	EASTING
1	BH 1	255705.126	355611.103
2	BH 2	255672.550	355635.118
3	BH 3	255643.349	355604.164
4	BH 4	255654.869	355559.144
5	BH 5	255668.597	355553.450
6	BH 6	255659.494	355595.450
7	BH 7	255680.397	355568.598
8	CPT 1	255702.777	355607.655
9	CPT 2	255648.049	355592.627
10	CPT 3	255659.595	355556.686
11	CPT 4	255629.595	355583.672

- From the structural analysis point of view,
  - the isolated footings existing in the site are expected to have a maximum settlement varying from
  - 13.88 to 104.89mm with an average of 53.66mm
  - and the maximum differential settlement about 91.01mm
  - in standard practice, allowable differential settlement should be 25mm
  - and the maximum differential settlement is limited to half of the total allowable settlement i.e. 12.50mm.

- A plot of the differential settlement – duration curve is shown in fig 11 below.



Period from Commencement of Construction In Years

Fig :11 Settlement-duration chart for the foundation footing

- In the site under consideration, there is a considerable amount of clay content in the soil
- and the clay is likely to be saturated.
- In such case, settlement is likely to occur over a period of about 25years;
- and within 5years maximum differential settlement would have reached 40mm.
- As a result, structural distress would have become noticeable
- as evidenced from the different types of cracks (both longitudinal and transverse)
- and map shaped cracks noticeable in Block A.

❖From an evaluation of the geotechnical results,

➢ the defects at the site can be said to have resulted from inadequate foundation consideration

➢as the foundation has been designed on a consolidating soil strata

➢with high differential settlement.

Crack Measurement

- From the measurement carried out in block A on the major cracks,
- the longest of the cracks occurred along the column joint with the cracks varying from a minimum of 1.8m to 3.15m.
- The width of the cracks ranged from 1.75mm to 22.25mm.
- Along the walls, the length of the cracks varied from 525mm to 2800mm
- while the width varied from 15.50mm to 31.50mm.
- Diagonal cracking was found to be approximately 1.2m in length
- and initiated at about 0.55m from the support.
- In general, cracks vary in size from 0.75mm to 31.50mm.
- The results of both visual inspection and instrumental measurement
- does show that extensive crack development and propagation occurred on the ground floor slab, columns and walls on every floor in block A.

- **Assessment of Concrete Strength Using Rebound Hammer.**
- Results of non destructive strength assessment of columns, beams and slabs using Schmidt Hammer tests are summarized in table 3 below:

Table 3: summary of Non destructive Tests of structural Elements.

S/N	Structural Element	Member	Mean compressive strength N/mm^2
1	Column	D1	41
2	Column	D2	43
3	Column	D3	42
4	Column	D4	40
5	Beam – first Floor	D14	57
6	Beam – Second Floor	D14	50

- In table 3, the mean compressive strength for each of the structural element was > 25N/mm^2 which is the minimum acceptable compressive strength of concrete.

CONCLUSION

- This study has been carried out using a combination of
- structural, Geotechnical and Geomatics Engineering methods.
- From the investigation carried out,
  - it has been established that inadequate foundation consideration has resulted in differential settlement
  - which is responsible for the various cracks noticeable in building Block A.
- The foundation footing is found to be inducing high bearing pressure on the soil,
  - thus resulting in substantial differential settlement.

The cracks within the building vary in width from 0.75mm to 31.50mm.

- As some of the cracks along the wall are more than 25mm,
- it means that the stability of the building is already being impaired.
- As these cracks taper and extend below doors and windows openings in many cases,
- we can conclude that the cracks has occurred as a result of differential settlement.

THANK YOU FOR LISTENING.