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EXECUTIVE SUMMARY

The Ghana Institution of Engineers has constituted a committee to investigate the collapse of the MELCOM building at Achimota on the morning of the 7th November, 2012. The building was a five storey framed reinforced concrete structure, which was being used as a supermarket. The work of the Committee started on November 8, 2012 and an interim report was issued on Wednesday November 14, 2012, followed by a press conference held by the GhIE President on the following day.

The objective of the investigation was to gather all relevant on-site and off-site information to conduct an investigation into the collapse of the building, come out with the possible causes of the failure and advise the President of the Institution, for him to present a statement to the Government.

The methodology applied in the investigation was:

1. Visual assessment of failures and structural behaviour of the various structural members of the building

2. Tests on the various materials and structural members of the building, including soil, and make comparison with the design specifications. Test results also formed an input in the structural analysis of the building

3. Structural analysis of the building and comparison with the as-built situation of the collapsed building. This was based on the Finite Element Model created with the help of observed member sizes and layout drawings received from the users of the building.

On the basis of the above methods applied, the state of the materials of the structural elements of the building were assessed. The following main summary observations were made:

1. Geotechnical investigations undertaken at the site suggested that reasonably high bearing capacities pertain at the site and following careful observation and examination of the available data we concluded that the collapse was not a result of a foundation failure.

2. The concrete used for the columns, beams and slabs had strength range between 12N/mm^2 to 14N/mm^2 as measured with a digital Schmidt Hammer on site. Core samples taken from the site indicated strength of 9N/mm^2 for the floor slab and 11N/mm^2 for columns. The indicated figures were below the minimum allowable by the standards used in Ghana.

3. It was not possible for the committee to have access to the structural drawings for the structure. Discussions with the Accra Metropolitan Authority indicate that a building permit was not issued for the construction.

4. Generally the concrete appeared to be of poor quality.

5. The aggregate size of the structural concrete was generally found to be much more than 20mm, and some were hand-broken aggregates.

6. There were honey-comb on many of the beams and columns

7. The 150mm reinforced concrete slab had in all places an extra 100mm thick cement screed.

8. The longitudinal bars used in the columns ranged from 14mm to 18mm, and the quantity per column ranged from 6 to 8.

9. The links and stirrups in the columns and beams respectively were of the diameter 6mm, and were spaced at 300mm centers on the columns and 200mm centers on the beams.

10. Structural simulation using the Finite Element Method of analysis revealed that the shear and crushing capacity of the columns became very sensitive to loading. In the scenario of the building being loaded with only its self weight, using the minimum allowable concrete strength, some of the middle columns reached between 70% and 90% of their structural capacity. Considering the scenario of the building being loaded with its self-weight and a screed thickness of 100mm, as observed on site, most of those columns have slightly exceeded the limit of their structural capacity. At this stage, the building will rely on the available factors of safety, and when this is depleted cracks and failure will set in. In the scenario of adding an office live load to the first lower 3 floors (ground, first and second floors), those columns at the middle of the building in the ground floor, have reached over 150% of their structural capacity. Substantial non-repairable cracks have developed at this stage. It is worthy to note that the design of structures considers this stage to be a total failure, although the building might still be standing, because at this stage it is NO MORE PREDICTABLE when the structure will physically collapse.

After critical observations and study of site information, remodeling and performing structural analysis including verification on the collapsed building, the following combination of factors, were found to be the reasons for the collapse of the building:

1. The strength of the concrete used was below the minimum allowable by the standards used in Ghana (e.g. BS 8110)
2. The spacing and sizes of links in the columns was inadequate, and hence could not hold concrete in confinement at the fatigue critical parts of the columns.
3. The longitudinal reinforcement was also inadequate for the columns of such a building
4. From the analysis conducted, the poor quality of the materials used made the structural elements (e.g. columns) very sensitive to loading. The load applied when the structure was in service was more than the original design load. This caused some of the middle columns on the ground floor to fail in shear and crushing. This sort of failure is sudden. Since the failed columns were around the middle portion of the building, it caved inwards, thereby causing all the upper floor columns to fail likewise, leaving some of the outer columns that were ‘pulled’ inwards by the collapse mechanism.

From the foregoing our conclusion is that the structure failed as a result of a combination of factors, chiefly among which are:

- Poor structural design lacking diligence and care that will normally be expected for an engineered facility.

- Poor construction practice and inadequate construction supervision, allowing substandard materials to be utilized for a building of this magnitude.

We therefore make the following recommendations:

Recommendations

A: Recommendations for Metropolitan/Municipal/District Assemblies

- Metropolitan/Municipal/District Planning Authorities should take steps to fill all vacant positions related to the permit system and should ensure that the positions are filled with the required expertise. For example, engineering positions must be filled with experienced engineers capable of reviewing and approving engineering designs and not allied professions.

- Planning Authorities should find innovative ways of securing the services of private sector practitioners to undertake certain aspects of the functions contained in LI1630 for which they do not have the manpower resources. This would include the use of certified architects, structural engineers, electromechanical and other experts to check designs submitted by developers. This will among other things ensure:

  (a) That the design of structures particularly high rise buildings, are carried out by experts certified in accordance with the Engineering Council Act, 2011 (Act 819).

  (b) That the District Planning Authorities insist on peer review of designs and investigation reports as part of the approval process for high rise buildings and other important infrastructure.

  (c) Building permit is not issued for the development of a building particularly high rise building without the stamped approval of the various certified experts.

- Buildings have become far more complex and it is completely unrealistic to expect all district, municipal and metropolitan authorities to have the capability to determine whether the design they are presented with is adequate or not. These Authorities must therefore collaborate with the Ghana Institution of Engineers to direct them to competent practitioners, who can be retained to support the permit process.

- Construction of public buildings and high-rise structures must be supervised by qualified technicians, technologists or professional engineers. Currently a building permit is issued when appropriately certified designs are presented but there is no requirement for qualified persons to supervise the construction. One is expected to inform the district and metropolitan authorities at various stages of the construction process so that they inspect and certify. This is clearly an impossible task which must be addressed by the permit process.

- Noncompliance of the building permit process should be viewed as a serious breach of the law.

- Building use and performance must be monitored**.** In much the same way that financial audits are carried out, systems must be put in place for the regular audit of all public and other commercial buildings by qualified engineering professionals. This should among other things monitor changes in use, alterations made to the structure, alterations to electrical design, etc. In the audit, structural members must also be examined for signs of distress. Occupants of buildings will also have a responsibility to ensure that they use buildings as intended. A clean audit report made at intervals of at least five years can be made a requirement for issuance of an insurance certificate.

B: **Recommendations for the Central Government**

- We call on Government to establish serious dialogue with the Ghana Institution of Engineers to address institutional weaknesses inherent in the construction industry. Such weaknesses are to be addressed in a holistic manner. And would therefore require funding for studies to expose the underlying causes.

- The new Engineering Council Act, 2011 (ACT 819) which was meant to address many of the issues that have been raised by this disaster must be put into effect. The Act will require anyone seeking to practice engineering in Ghana to be registered. This includes craftsmen, technicians, technologists and engineers. The Engineering Council will also register engineering firms. Clear boundaries of operation are to be set for both individuals and firms depending on their capabilities. Unfortunately, even though this ACT is now more than a year old, a Council is yet to be inaugurated to begin work.

- The Engineering Council has been mandated among other things to regulate activities and processes in the construction industry. To achieve this objective collaboration between Metropolitan/Municipal/District Assemblies (who are also empowered by law to plan and regulate development in their localities) and the Council is urgently needed. **In this regard we call for the immediate inauguration of the Engineering Council and to put in place steps to make the ACT operational to regulate the practice of Engineering in Ghana**

- Non-compliance with the building regulations must be made a criminal offense.

C: Recommendations for the General Public

- The public must be encouraged to report signs of building failure such as cracks, uncomfortable vibrations, leakages, sinking, sagging and leanings to the relevant Metropolitan/Municipal/District Assembly.

- Corporate Ghana must take responsibility for conducting structural and safety integrity audits for high rise building they are occupying or intend to occupy. The good news is most short comings arising from such audits can be fixed by trained and certified engineers currently practicing in Ghana.

D: Recommendations for Professional Bodies

- The design of structures particularly high rise buildings must be carried out by Certified Engineers. The Institution of Engineers must act on the powers conferred on them by the Act 819 to sanitize and regulate the practice.

- The Ghana Institution of Engineers must facilitate peer review of designs for high rise buildings and other important infrastructure facilities among Certified Engineers, and this must be incorporated in the constitution of the Association of Consulting Engineers.

- It is recommended that the foundation design of high rise structures be checked for adequate anchorage to resist potential overturning forces that could act on the building. Such forces can be easily triggered by earthquakes, unforeseen ground settlement and excessive wind gusts. As previously stated, this was not a contributing factor in this subject matter; however it draws attention to a flaw that needs to be addressed.

- Engineers, Architects and other professional of the Built Environment must collaborate more effectively to ensure safety of design, construction and usage of buildings.

- The implementation agencies, such as the Metro/Municipal/ District Assemblies must be strengthened with **Competent Engineers**, certified by the Ghana Institution of Engineers and the Engineering Council, to ensure that **Permitting Processes** as outlined in the building regulations are strictly complied with. In connection with this the Institution must maintain a register of Engineering Positions in all Metropolitan/Municipal/District Assemblies and participate in the selection of suitable candidates for these positions.

1 INTRODUCTION

On the early morning of the 7th of November 2012, the 6 Storey building occupied by the MELCOM Supermarket at Achimota in Accra collapsed, causing damage to life and property. This incident has raised a lot of concerns in the Government and people of Ghana.

Various questions have been asked concerning the Safety of the Building Structures and Infrastructure Facilities in general, whether there are adequate laws in Ghana governing the Construction Industry, and whether these laws are being enforced properly.

The questions being raised bring to the fore the critical role of the Engineer in ensuring the safety of our Structures and also being in a position to investigate and provide answers to why and how some of these mishaps happen.

In the wake of this event, the Ghana Institution of Engineers as part of it obligation to the people of Ghana constituted a team to conduct an immediate investigation into the case and come out with the probable cause or causes of the collapse of the building.

The Ghana Institution of Engineers formed an 11-man committee of Engineers, led by the Chairman of the Civil Technical Division to conduct this investigation to determine what went wrong.

The team of Engineers comprises experts in such areas as materials behavior, foundations, testing and instrumentation, special load effects and special analysis techniques. The composition of the Team is given in Appendix D.

2 PROJECT INITIATION

Project Initiation required establishing at least the preliminary objective of the work and establishing the investigative plan. Following an initial site visit on November 8th 2012, a number of meetings were held in the Conference Room of the Ghana Institution of Engineers to deliberate on the assignment. Some of the key issues from these deliberations are discussed below.

2.1 Project Objective

The objective of this assignment was to visit the site of the incident, gather as much information as possible, analyze the information objectively, and come out with the possible causes of the collapse of the building. And how to avoid similar incidents and also to ensure safety of engineering structures throughout the country. This will advise the President of the Ghana Institution of Engineers to make a presentation to Government. The result of the investigations could also inform what lessons may be learnt from such failures. The Committee was given one week to complete the assignment, after which a press conference would be called to present the findings.

2.2 This Report

An interim report was issued on November 14, 2012 which formed the basis for a Press Conference held by the President of the Ghana Institution of Engineers on

November 15, 2012 at the Engineers Center. This report is the **Final Report** which takes into consideration additional information obtained by the committee in their efforts to meet various stakeholders.

2.3 Establishing the Investigative Plan

To determine the technical causes of failure, the goals of the investigation were to establish:

1. The mode and sequence of the failure
2. The demands (loads) acting on the structure at the time of failure , and
3. The capacity of the structure at the time of failure.

The process usually involved developing hypotheses regarding the causes of failure and then analyzing and testing those hypotheses. With effort, certain failure theories are eliminated and in the end the facts would support one theory. For instance the investigation may reveal that the demand on a certain part of the structure exceeded its capacity for one failure mechanism and if that mechanism is consistent with the evidence of the mode and sequence of the failure the result is largely conclusive.

3 FIELD INVESTIGATION AND LABORATORY ANALYSIS

3.1 General

The process of this investigation was basically one of analysis requiring a structural approach and data collection as well as the development and scrutiny of failure hypotheses.

3.1.1 Access and Control of the Site

Members of the Committee arrived at the incident site at 10.21 am on the Thursday, 8th November, 2012. At the time of the visit, security agencies have brought order to the site such that access to the site was not impeded by spectators. There was full control of the site by the security agencies and the rescue operation was proceeding orderly.

3.1.2 Site Safety

The NADMO and the security agencies were all equipped with safety gear. Construction machinery helping to remove debris and failed construction elements from the collapsed building were under the full control of the rescue operation handlers. There was adequate safety at the site.

3.1.3 Field Observations and Documentation

The team on arrival was led round the site by the security agencies to get a firsthand view of the site. After that the team took time in observing the collapsed structure. Note was also taken of the nature of construction materials used in putting up the building. The team went as far as taking measurements of key construction elements of the failed structure. This would help in remodeling and re-analysis of the building. Photographs of these observations were taken and notes were made.

Among the observations made were:

1. Most of the links and stirrups used in constructing the columns and the beams respectively were 6mm in diameter. The link spacing was 300mm and stirrups spacing was 200mm.

2. The range of reinforcement sizes for the columns was between 14mm and 18mm, and 6 to 8 in number.

3. Generally the concrete just by observation appear to be of poor quality.

4. The aggregate size of the concrete was generally found to be much more than 20mm, and some were hand-broken aggregates.

5. There was 'honey-comb' on many of the columns and the beams.

6. The slabs of thickness 150mm had in all places an extra 100mm thick cement screed on them.

3.1.4 Samples

The visiting team took samples of the concrete of various parts of the structure. Also samples of the iron rods used in constructing the building were taken for testing.

3.1.5 Eye Witness Accounts

From one school of Eye witness account the structure had sudden failure. Other school of account indicated that substantial cracks developed in some parts of the structural elements so much that it caused complaints from observers. Prior to the failure, noise of cracking or similar was said to have been heard, indicating warning of structural failure. Our discussions with Melcom did not confirm these accounts. According to some accounts the developer stacked significant amount of building tiles on the third floor of the building, and that at the time of the collapse there was a tile-layer working on the third floor. Some of these tiles were identified in the pictures taken, however we were unable to meet the developer for confirmation of this assertion and therefore did not consider the extra load associated with it in our analysis.

3.1.6 Stakeholders Accounts

The committee held meetings with key Stakeholders, mainly the Accra Metropolitan Assembly and its Metropolitan Planning Commission. A meeting was also held with M/S MELCOM the company, which rented the building for use as a Supermarket. The Minutes of these meetings are given in the Appendix E. It was not possible for the committee to meet the developer and designers as well as contractors for the building. Our enquiries revealed that the developer was also the contractor for the project. However the identity of the designer is shrouded in obscurity.

3.2 Field Tests

On the various members of the failed structure, tests were conducted to assess their approximate strengths to ascertain their quality. For example the Schmidt Hammer was used to determine the approximate strength of the failed columns and beams. It was realized that the maximum of such approximated strengths was 14N/mm^2. Other values, especially for the slab, showed a figure as low as 12N/mm^2.

3.3 Geotechnical Investigation

3.3.1 Geology of the Site

The site was underlain by quartz schist of the Togo rock series. It was observed the rock was weathered to various degrees at the different test pit locations (shown in Table 1).

LOCATION	ASSESSMENT METHOD	DEPTH TO ROCK LAYER
South Western Corner	Test Pit	1.2m
North Western Corner	Test Pit	1.75m
North Eastern Corner	Test Pit / DCP	1.8m
South Eastern Corner	DCP	2.6m

Table 1: Rock layer levels as measured relative to existing ground levels

The rock layer was overlain by clayey silt with traces of sand and laterite. We believe this is a result of the decomposition of the rock formation. It was further observed that the fill material used above the footing levels, approximately 0.4m to 0.6m thick, and was not indigenous to the site as it consisted of a mixture of foreign material including concrete waste, laterite, broken cement blocks etc.

3.3.2 Seismic Activities of the Project Area

The history of seismic activity in Southern Ghana dates back to 1862. Most of the earthquakes in Ghana occur in the western part of Accra at the junction of the two major fault systems namely, the Coastal boundary fault and Akwapim fault zone which are believed to intersect at Nyanyanu near Kasoa. According to seismologists, most of the epicenters are located south of Weija in Accra, suggesting that there is little activity north-east along the Akwapim range and westward along the Coastal boundary fault. Most earth tremors in Ghana are related to the level of activity of the faults. According to the records a major earthquake in 1939 flattened Accra and was felt in Eastern Ghana and Togo. The maximum intensity of the shocks was estimated to be 6.5 on the Richter scale. Between 1987 and 1990, over eight seismic events with magnitude ranging from 2.5 to 4 on the Ritcher scale have occurred with epicenters in the Accra – Tema area; (Kato, 1990). The site is some distance from the two major fault-lines and there had been no evidence of geological instability within the area.

3.3.3 Topography of the Area

At the time of this site investigation, it was observed that the site had a gentle downward slope from the west to the east. The site is not located in close proximity to any watercourse.

3.3.4 Field Work

This preliminary geotechnical assessment was carried out on the 10th November, 2012. This consisted primarily of sub-surface exploration.

3.3.5 Sub-Surface Exploration

The sub-surface exploration programme consisted of:

- Dynamic Cone Penetrometer test
- Excavation of Test Pits (to obtain soil sample and partial expose foundation elements for observations.)

3.3.5.1 Dynamic Cone Penetrometer (DCP) Test

Due to ongoing recovery activities at the site, we were only able to safely perform a total of two (2) dynamic cone penetrometer tests. The DCP tests were conducted using light Dynamic Cone Penetrometer (DIN 4094, German Specification). The tests were conducted in close proximity to the north-eastern and south-eastern corners of the structure. This was done in order to adequately conclude on the bearing capacities of the sub-soil on which the foundation pads were placed. The penetration tests at both locations were terminated when over 50 blows were achieved without further penetration.

The results of the DCP tests have been used to estimate and illustrate the variation of the allowable soil bearing capacity relative to depth. The penetration tests results have been included in Appendix B.

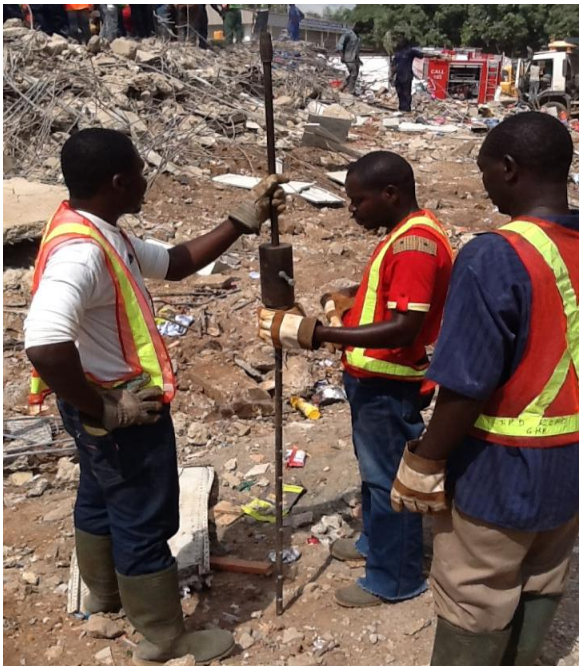

Figure 1: Conduction of DCP test at one of the test locations at the site

The DCP test equipment assembly is as follows:

Weight of hammer (m)	--------	10kg
Weight of anvil	--------	6kg
Height of fall of hammer	--------	50.0cm
Cone Diameter	--------	2.4cm
Cone Surface Area	--------	5cm^2
Apex Angle of Cone	--------	60°

For the purpose of determining the soil's bearing capacity, (q_a), the number of blows required for the cone to penetrate 100mm into the soil during testing was noted for various depths up to the point where there was obvious refusal.

3.3.5.2 Estimation of Soil Bearing Capacity

The strength characteristics of granular soils may be evaluated by converting the unit resistance of the ground into either allowable bearing capacity or standard penetration (N) blow- counts.

In the dynamic cone penetration test method, the parameter "r" is defined as the counted number of blows required to advance 10cm. This data can be converted into unit resistance R_D of the ground in kN/m^2 or kPa using the formula

$$R_D = \frac{m^2 H}{Ae(m+P)}$$

For shallow foundations, the allowable bearing capacity, q_a, may be obtained from the unit R_D by the following relationship

$$q_a = \frac{R_D}{20}(kPa)$$

Thus from further computations, the allowable bearing capacity is obtained from the simplified relationship:

$$q_a = 30r(kPa)$$

"The allowable bearing capacity, q_a , of soil is the net load intensity at which no failure occurs."

The Dynamic Cone Penetrometer test results indicated a fairly consistent subsoil strength characteristic across the project site. The maximum depth at which refusal encountered was at a depth of 2.6m at the south-eastern corner of the structure. See test results in the Appendix B.

3.3.5.3 Excavation of Test Pits

Test pits were excavated in order to obtain soil samples, and to partially expose foundation elements for observations.

- Information collected during this preliminary investigation indicated that, a pad footing type of foundation was adopted for this site.
- During the excavation of test pit #1 (south-western corner) we encountered a concrete ground beam at a depth of approximately 1.45m below the existing ground level. The dimensions of this beam were approximately 510mm wide and 250mm thick.

Figure 2: Foundation beam

- At test pit #2 (north-western corner), we encountered sound rock layer at an approximate depth of 1.75m below ground level. It was observed that the foundation pad at this location was poorly constructed .i.e. a 50mm thick reinforced concrete pad was cast directly on sound rock formations.
- At test pit #3 (north-eastern corner), it was observed that a foundation pad measuring approximately 450mm thick was utilized. It was noted that unlike test pit #2, the foundation pad was not bearing directly on sound rock. See DCP #1 test result.

3.3.6 Laboratory Testing

Routine laboratory testing was undertaken to identify and classify the foundation soil. Classification test revealed that the foundation soil could be described as clayey sandy silt SC/ sandy silt with some clay with low to intermediate plasticity. Chemical analysis on aqueous extract of the soil revealed sulphate (as So_4) content of less than 0.30g/l and chloride ion also less than 0.04% with pH of 7.2. The foundation soil could therefore be said to contain no chemical constituent that would be injurious to the foundation concrete. [Note - the limiting values of the chemical constituent in the soil are based on (British Reclamation Establishment - BRE digest 330)].

3.3.7 Ground Water Condition

No ground water was encountered in the excavated trial pits during the field investigation.

3.3.8 Geotechnical Engineering Conclusions

During our investigations we found the foundation that was constructed for this building was not appropriate. The depth of foundation placement was not adequate with some of the footings rested on solid rock while others were located on the soil. In situations where one footing rests on rock while another rests on soil without being tied, there is the possibility of experiencing differential settlement – which can result in a failure, however such failures are characterized by severe cracking of the structure.

The field testing and visual inspection of sub-surface soils suggests that reasonably high allowable bearing capacity pertain at the site as evident from the DCP #1 test location in which bearing capacity of 450KPa was deduced at the soil supporting the footing at a depth of 1.2m. From the field observations and our engineering analysis of the data collected from the immediate and surrounding ground we concluded that the possibility of the collapsed building being as a result of foundation failure was very remote.

4 STRUCTURAL ANALYSIS

4.1 General

The structural analysis was conducted using the Finite Element Method Software ETABS. This software makes it possible to model the building and analyze it 3 dimensionally. The material properties, the topology and geometry of all structural elements and the sizes of the reinforcement used in the collapsed building were re-modeled by the programme. The software makes it possible for the analysis and results of various in-plane sub-frames to be read. Apart from designing the various structural elements, ETAB allows the selections of materials, members, specifying dimensions, reinforcement and checking for their adequacy.

4.2 Hypothesis for Analysis

Three scenarios of the structural analysis were created in order to study the building under various loading situations.

- In scenario 1, only the dead load (self-weight) of the building was used in the analysis.
- In scenario 2, the self-weight plus a screed thickness of 100mm as observed at the site was applied over the slab.
- In scenario 3, the self-weight, plus the 100mm thick screed plus an office live load.

The following are the sizes of various elements of the model used.

- Columns, b/d = 300mm/300mm
- Slab thickness = 150mm
- Beams b/d = 300mm/450mm
- Main bars 14/16/20mm
- Stirrups and links 6mm

The strength of the materials used is as follows:

- Concrete C25 (25 N/mm^2)
- Iron Rods Mild steel 250N/mm^2

4.3 Analysis Verification

The Consultants undertook verification of the soft analysis outputs. The imposed loads were compared with total reactions. The analysis of a typical beam and a typical column were carried out manually and the results compared with the software output. The verification confirmed that the software output were accurate.

4.4 Finite Element Model

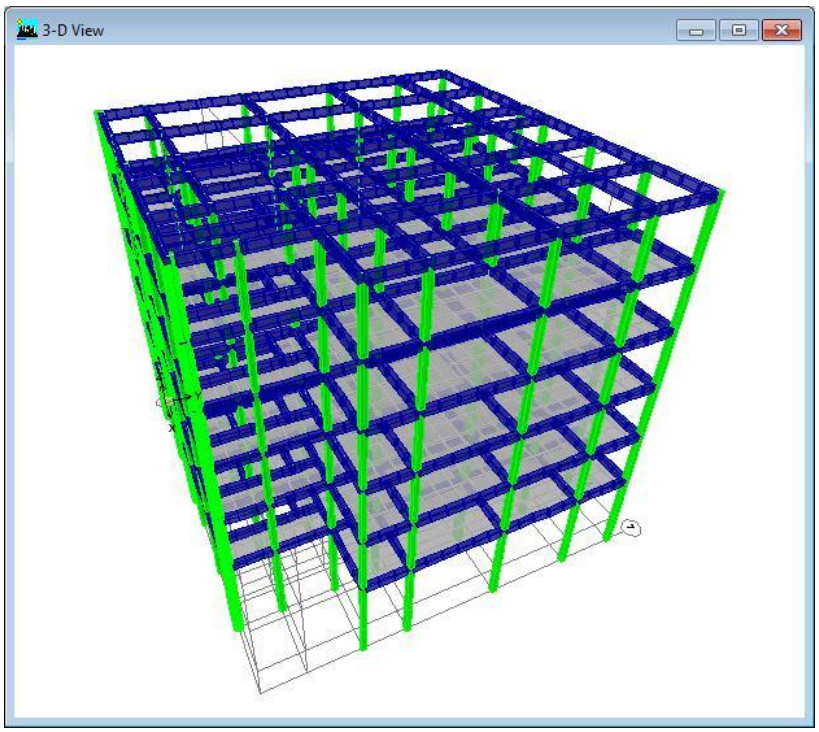

Figure 3: ETAB Model of the Building in isometric view

Figure 4: Typical Floor Plan

4.5 Analysis of Results

Scenario 1 – Building's Dead Load Only

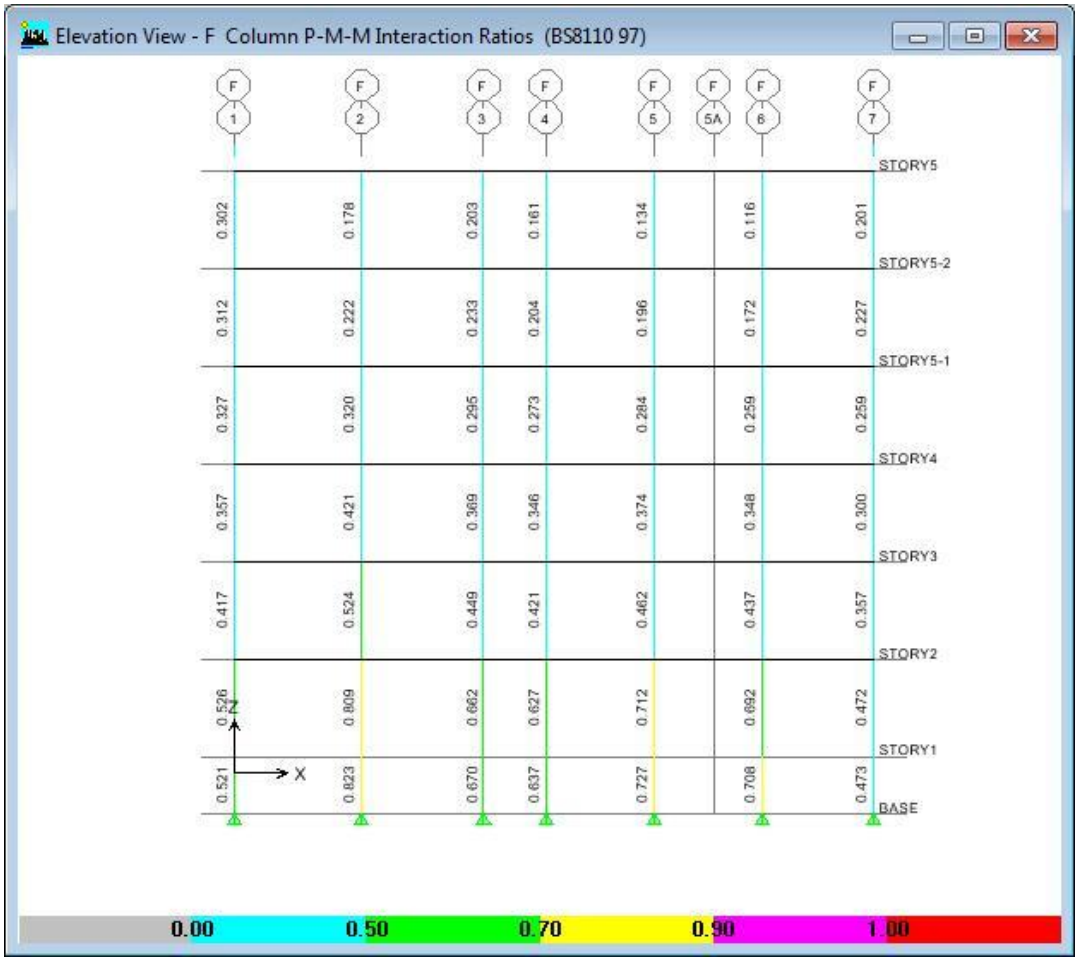

Figure 5: Structural capacity ratio on Gridline F under load scenario 1

Under a solely dead load from the building only, it is seen from the above diagram, showing the structures along gridline F, that the columns on gridlines 2 and 5 were intact (colour yellow) but significantly strained. They have reached about 70% of their structural capacity (see legend below diagram). The structural integrity is already compromised under normal basic condition of material requirement.

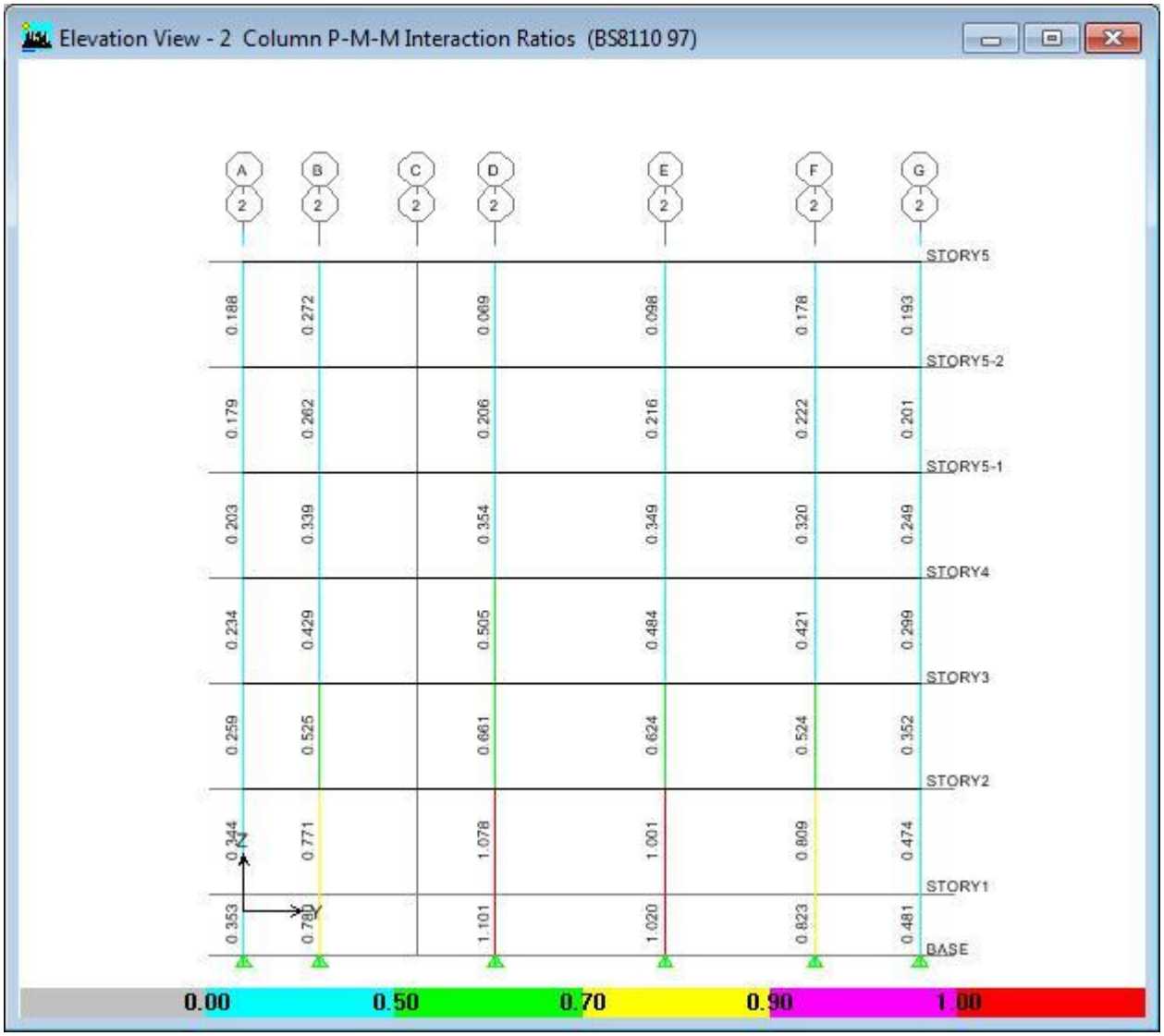

Figure 6: Structural capacity ratio on Gridline 2 under load scenario 1

However along gridline 2, columns on gridlines D and E at the ground floor and first floor have already reached their maximum structural capacity. In this situation extra load on such structures may make their structural integrity unpredictable. Slabs and beams were ok. Some columns, especially in middle had overstretched capacity up to 110%. This is indication of collapse of the members, and hence the trigger of collapse of building.

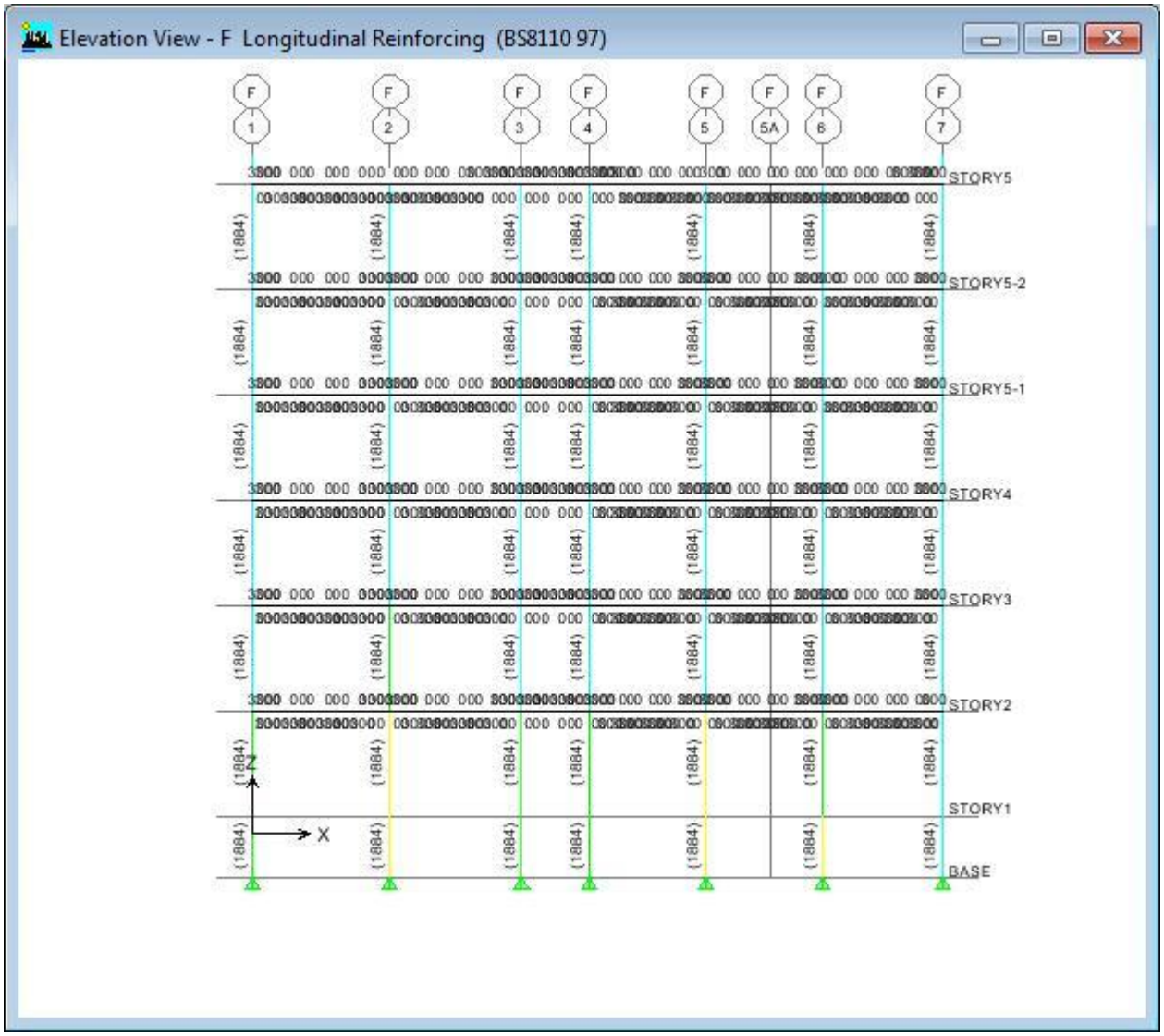

Figure 7: Amount of longitudinal reinforcement in columns on Gridline F under load scenario 1

The above diagram indicates the assumed area of reinforcement (iron rods) in each column, namely 6 number of the 20mm diameter. It must be noted here that, the amount of iron rods considered in this analysis exceeds that which was really found in the collapsed building (namely 14mm to 18mm in diameter).

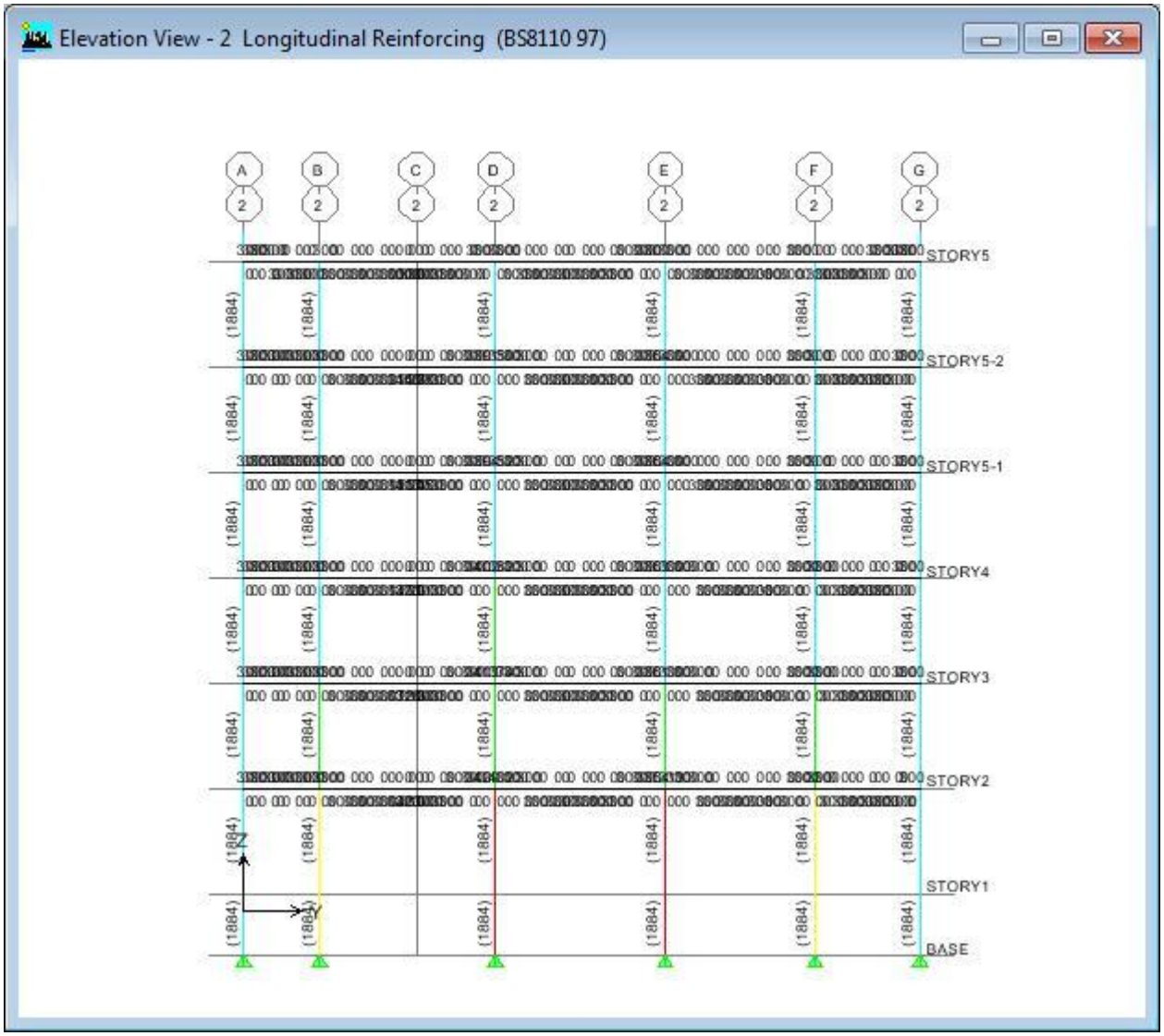

Figure 8: Amount of longitudinal reinforcement in columns on Gridline 2 under load scenario 1

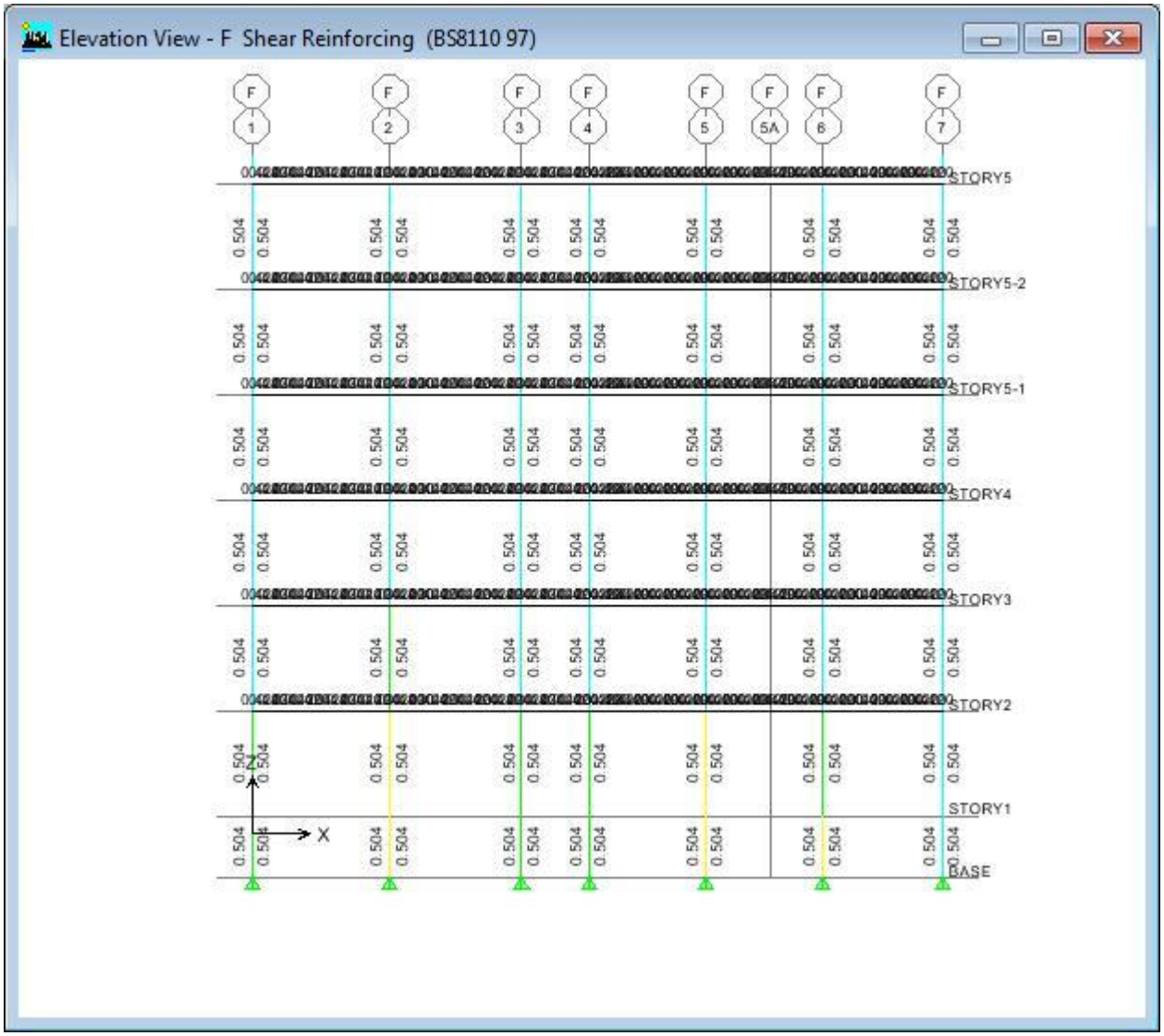

Figure 9: Amount of shear reinforcement on Gridline F under load scenario 1

Along the gridline F, under the sole load of the self-weight of the building, the shear stresses were acceptable on all columns.

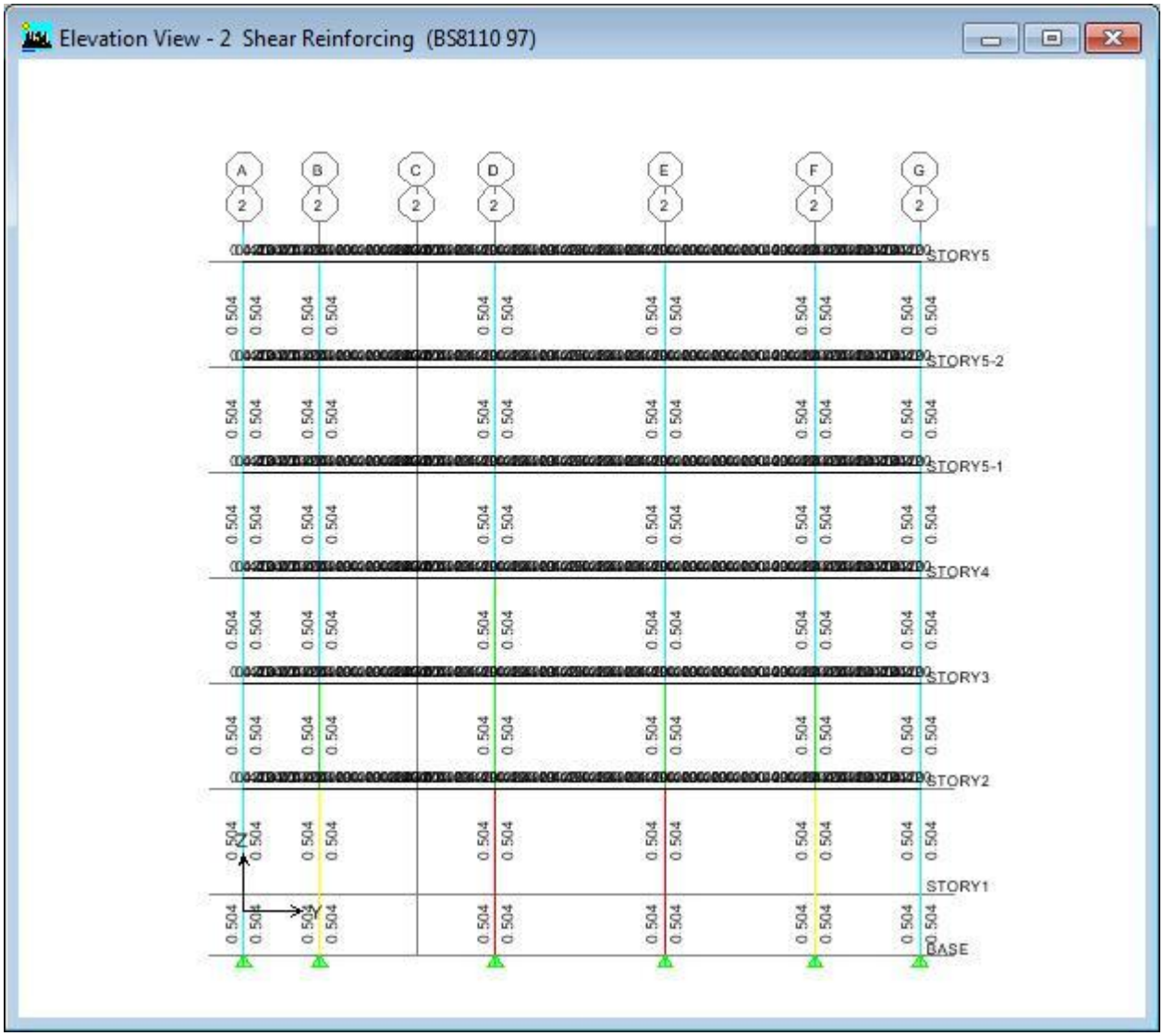

Figure 10: Amount of shear reinforcement on Gridline 2 under load scenario 1

Along gridline 2, similar situation is found that the shear stresses were within acceptable limit.

Scenario 2 – Dead load plus Screeding

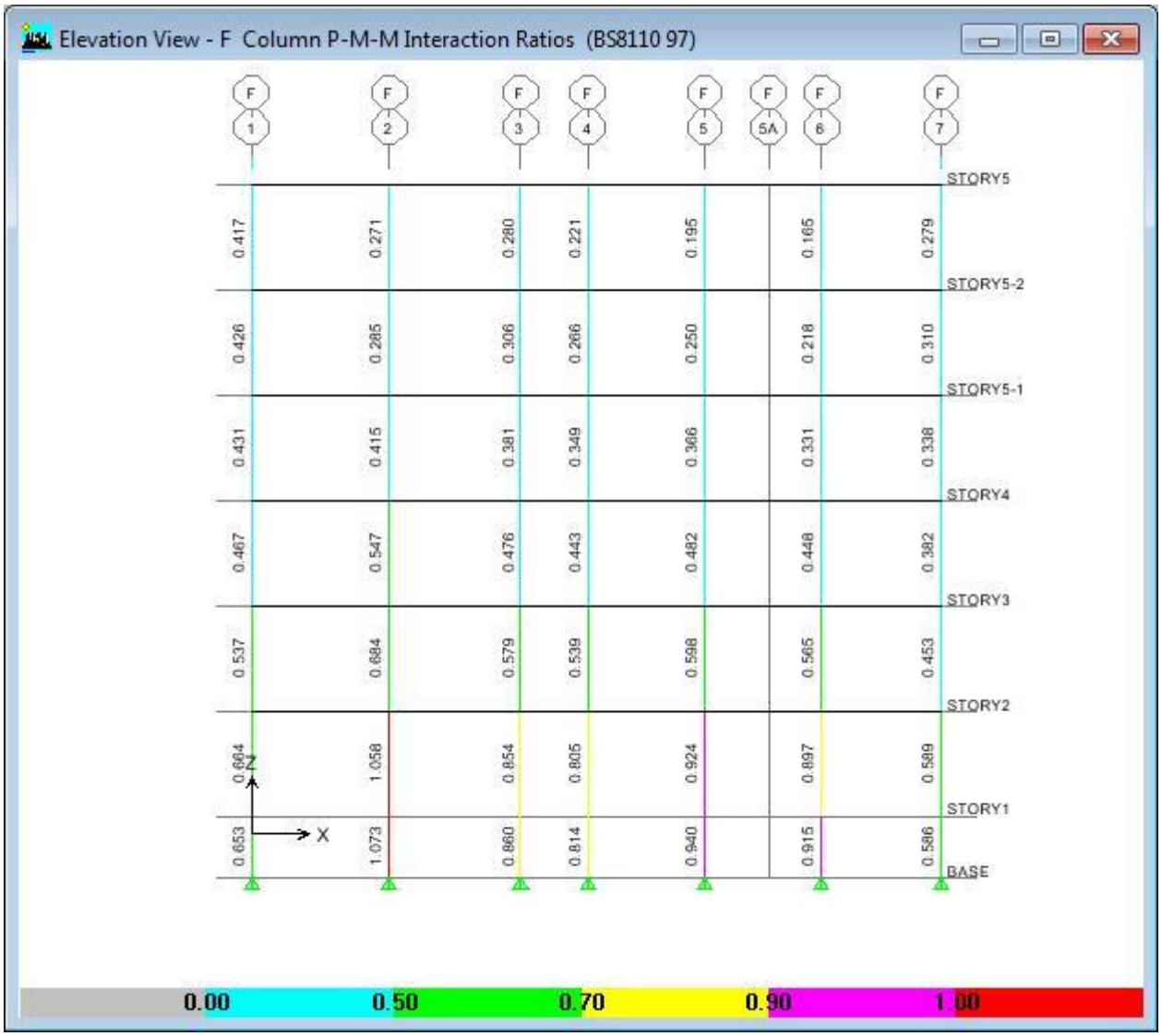

Figure 11: Structural capacity ratio on Gridline F under load scenario 2

In the scenario of adding screed to the self-weight of the structure, the very columns that were structurally sound in the previous scenario, are now found wanting. For example columns in ground and first floor on gridline 2 and 5 have got to their maximum structural capacity (indicated red). Those along gridlines 3 and 4 have changed from green in the previous scenario to yellow. From the legend it is seen that the structural capacity of those columns have got to between 70% to 90%.

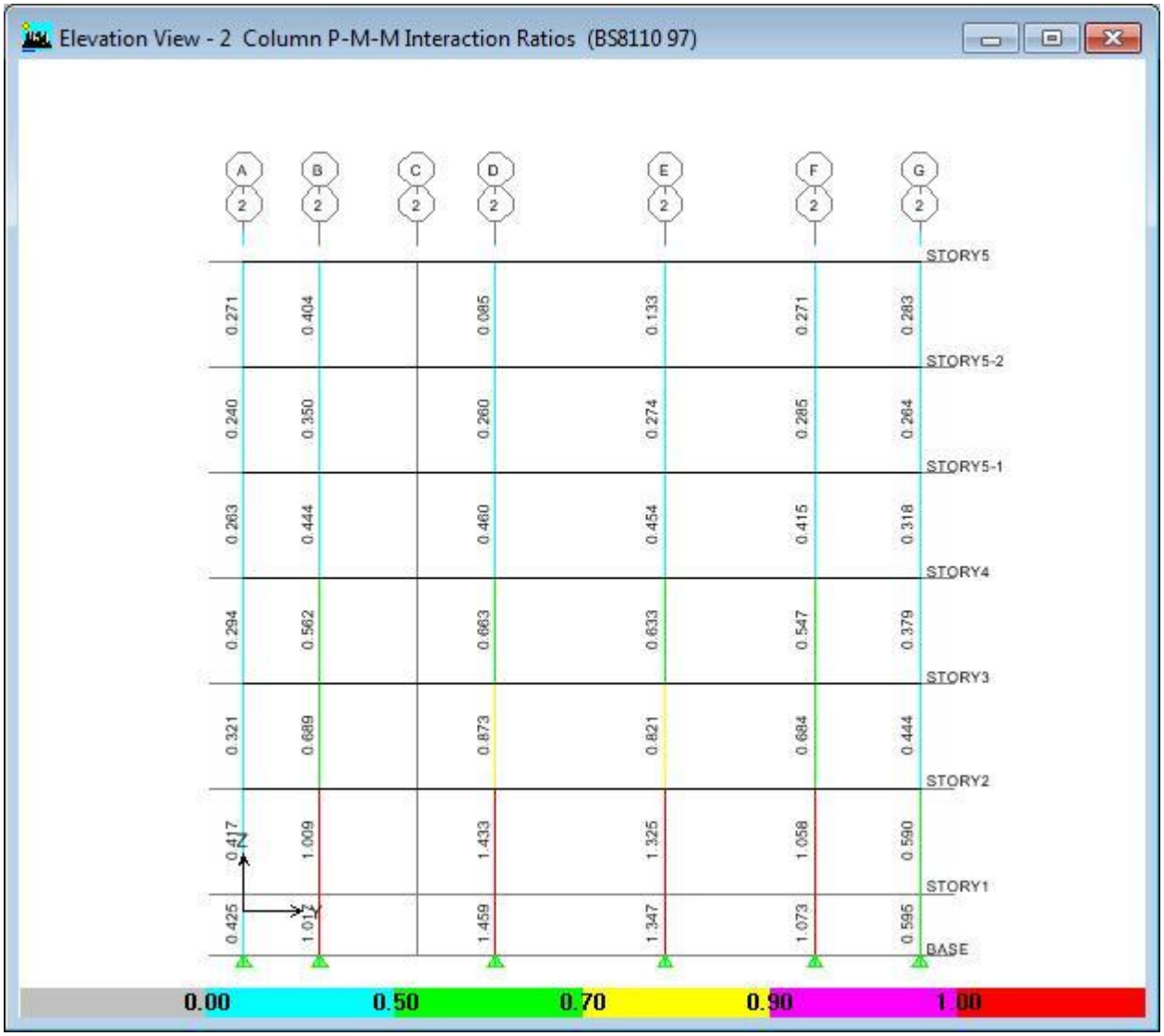

Figure 12: Structural capacity ratio on Gridline 2 under load scenario 2

On gridline 2, more columns have exceeded their structural capacity. For example the column on gridline D has reached over 140% of its capacity. This is a failure. Its tendency of eventual collapse can no more be predicted. It can be seen also that the red colour, showing over 100% use of the structural capacity, is gradually climbing into the first floor and the yellow is getting onto the second floor. This shows that the failure of the columns is moving from the ground floor upwards.

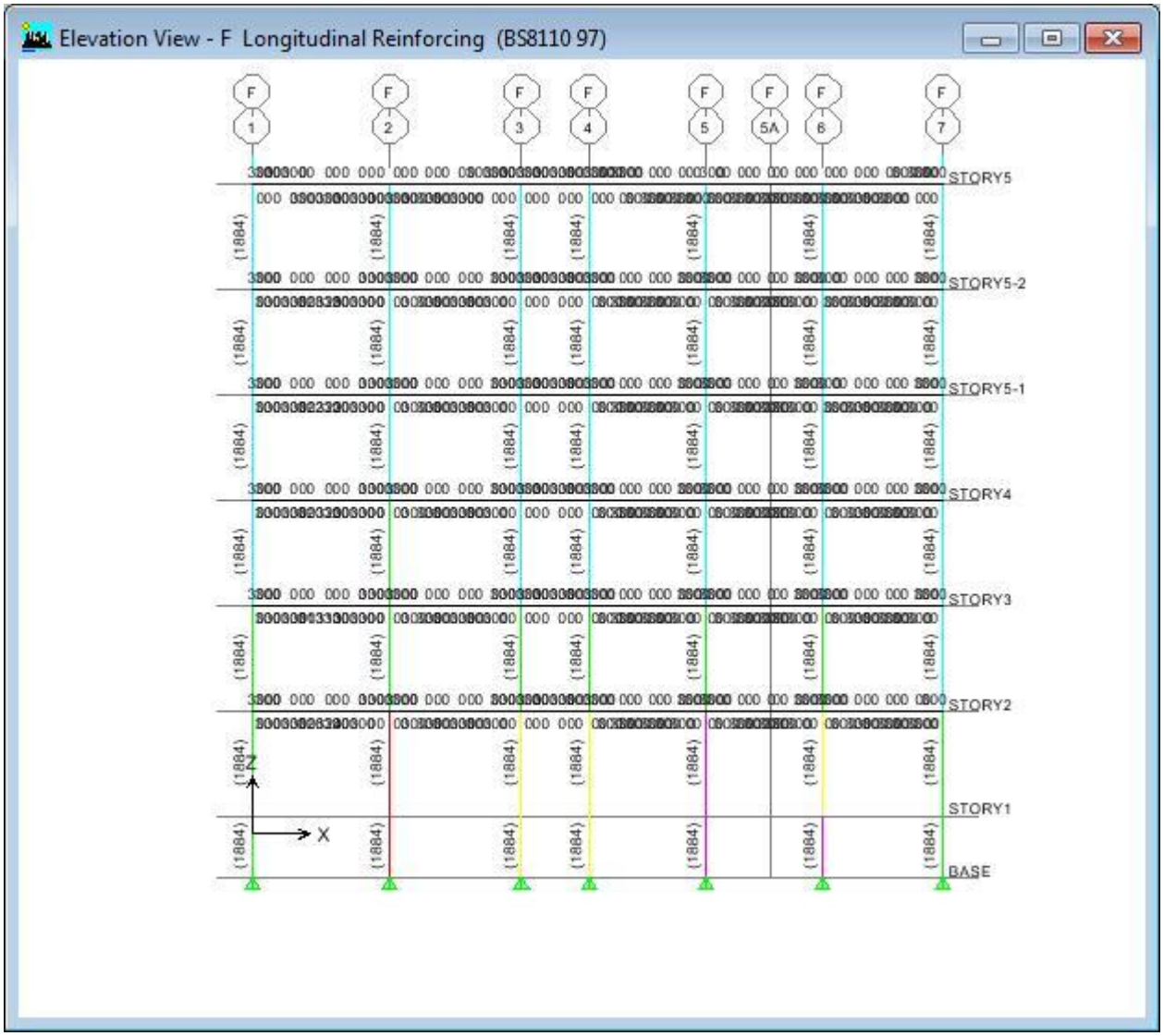

Figure 13: Amount of longitudinal reinforcement in columns on Gridline F under load scenario 2

The same amount of reinforcement is kept in the various structures and analyzed under various loading. This is to enable the study of the effect of various loads on the structure with the same quality of building material. It can however be seen that the columns on gridlines 2, 5 and 6 are inadequately reinforced.

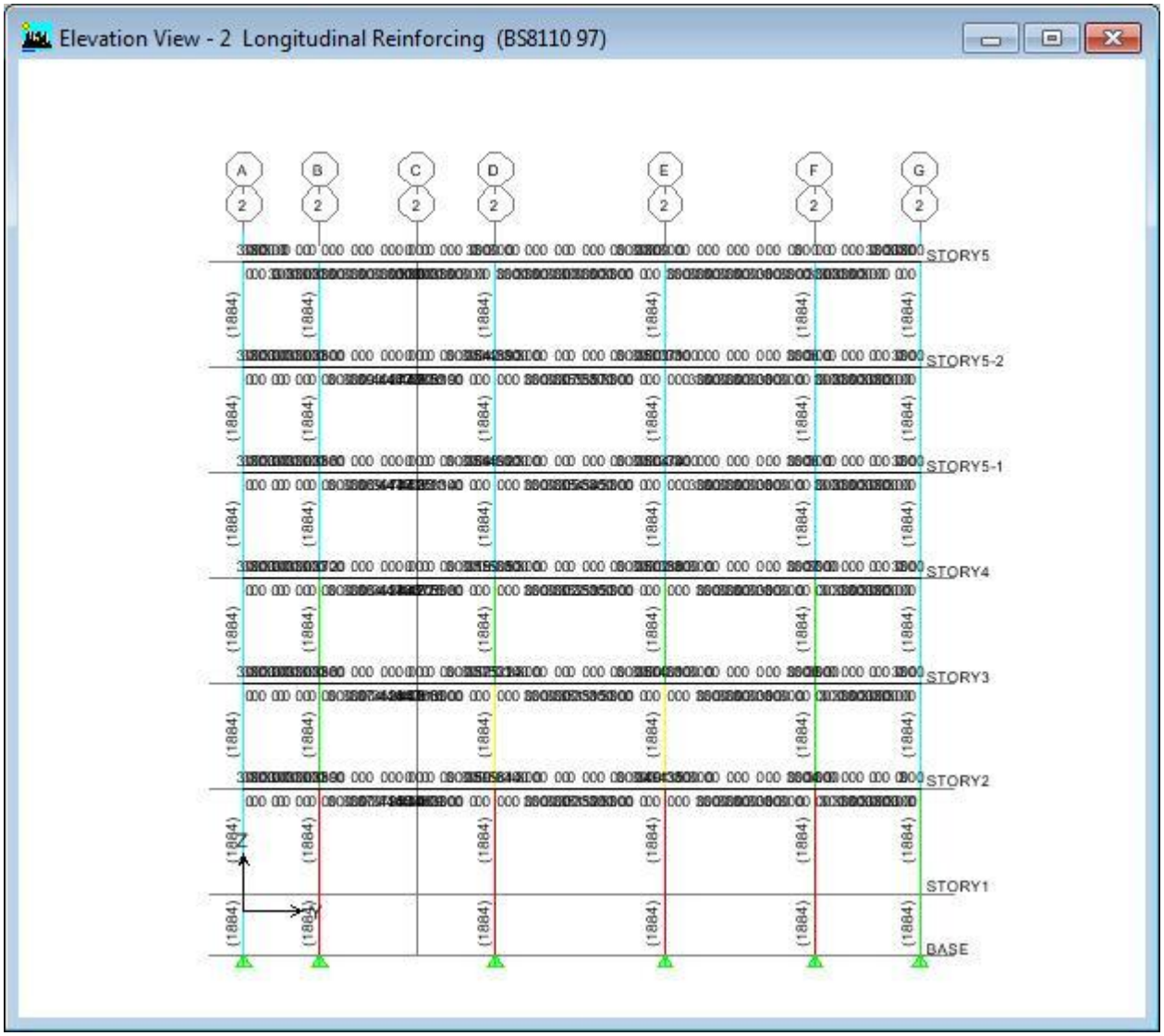

Figure 14: Amount of longitudinal reinforcement in columns on Gridline 2 under load scenario 2

Here on gridline 2, the red colour of the columns shows that the longitudinal reinforcement are inadequate. Those columns have therefore practically failed.

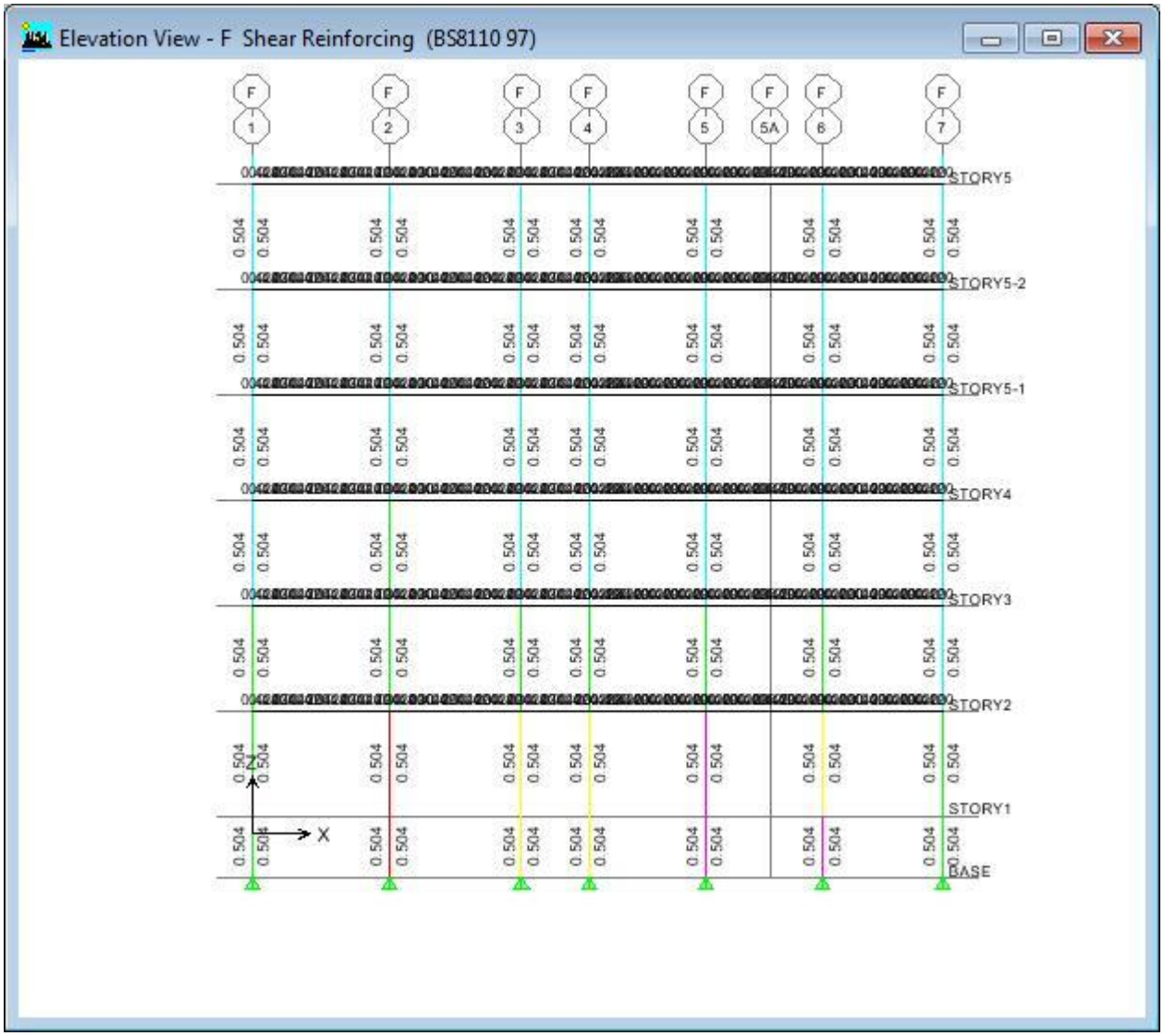

Figure 15: Amount of shear reinforcement in columns on Gridline F under load scenario 2

The shear failure of the columns on gridline F, columns 2 and 5 have increased to the first floor. Column on gridline 6 has also failed in shear.

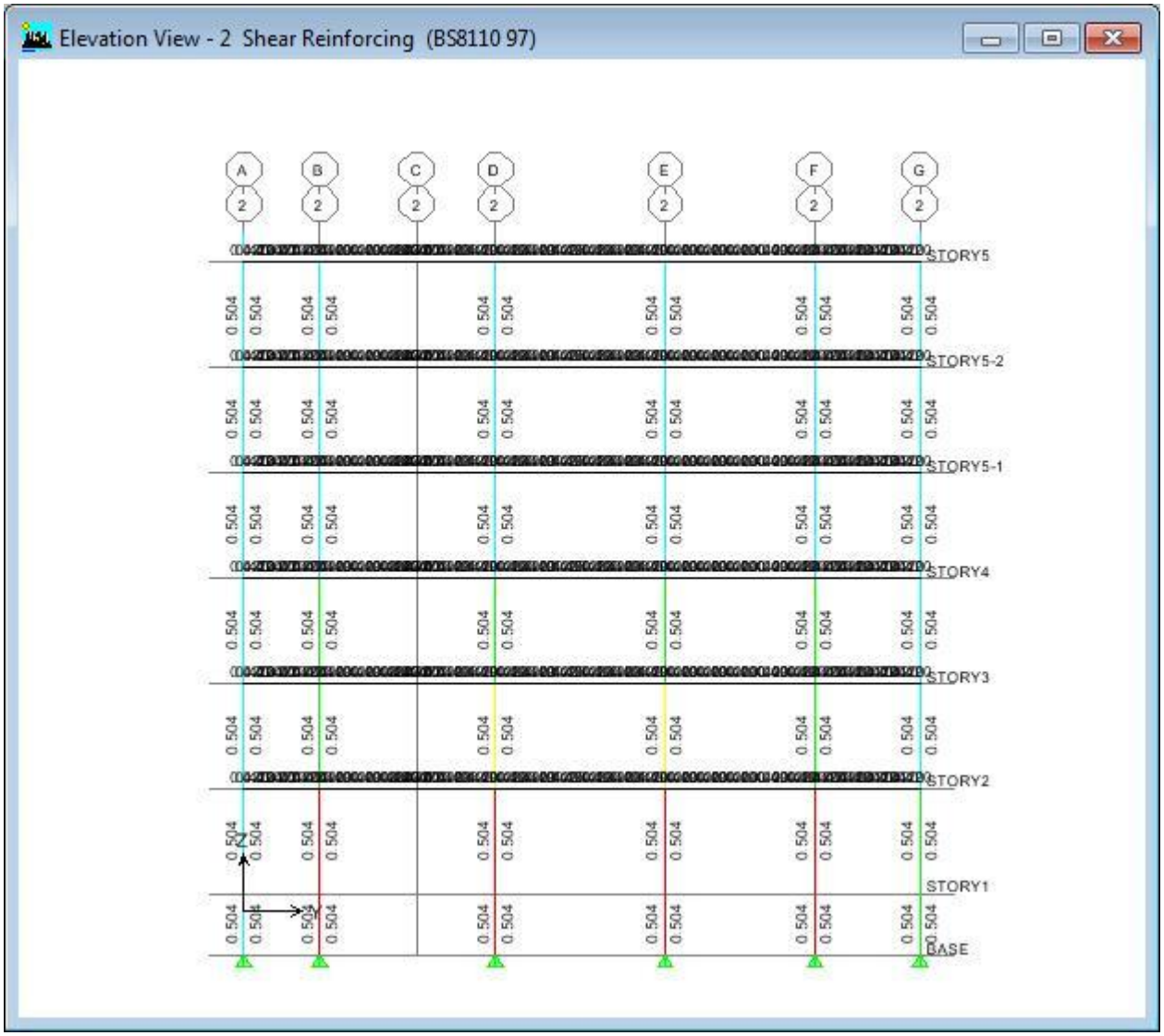

Figure 16: Amount of shear reinforcement in columns on Gridline 2 under load scenario 2

On gridline 2 almost all the columns (except the outer columns) have failed in shear as far as up to the first floor. On the second floor, the middle columns have reached between 70% to 90% of their shear capacity.

Scenario 3 – Dead load plus Screeding plus live load for 3 floors

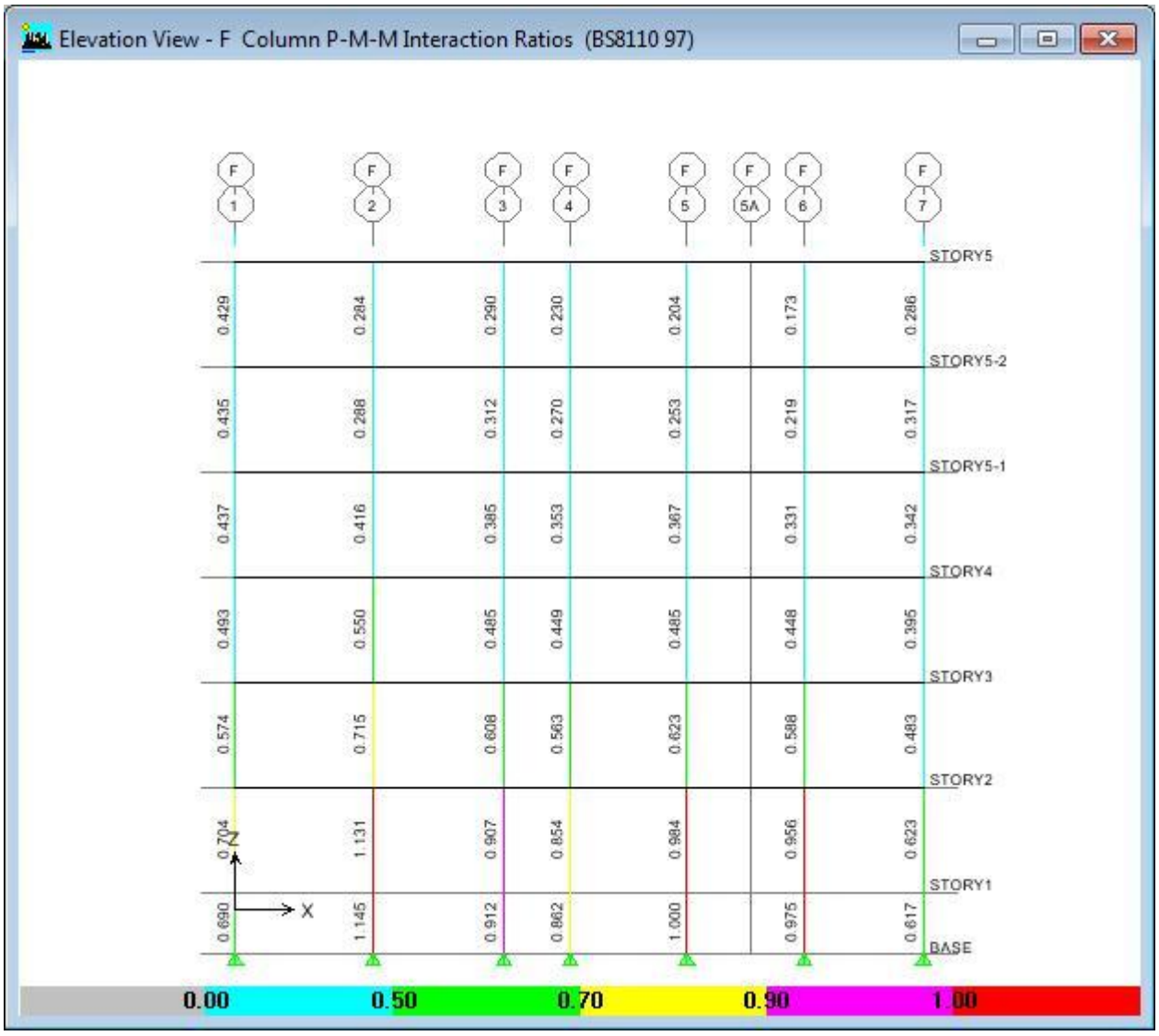

Figure 17: Structural capacity ratio on Gridline F under load scenario 3

Immediately the slightest load was added to all the first 3 floors, almost all the columns in the mid-portion of the building exceed their structural capacity. It is noteworthy that the outer columns still remained stable.

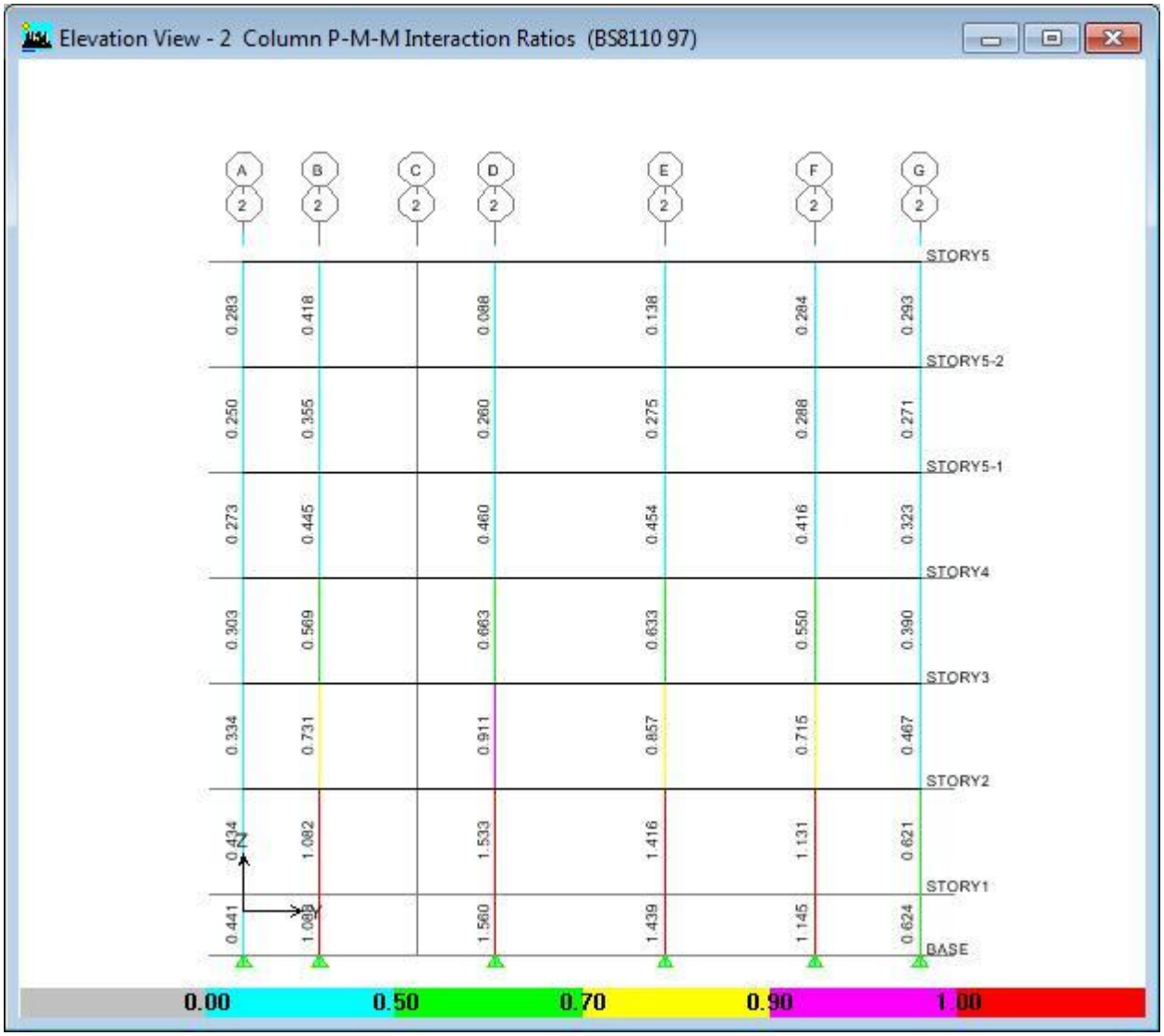

Figure 18: Structural capacity ratio on Gridline 2 under load scenario 3

A much similar situation has happened in the case of columns along gridline 2. Almost all have exceeded their structural capacities, some have reached over 150% of their capacity up to the first floor, and failed further to the second floor (Gridline D). Noteworthy is also that the outer columns remained intact, as may be seen in the pictures in Appendix 1.

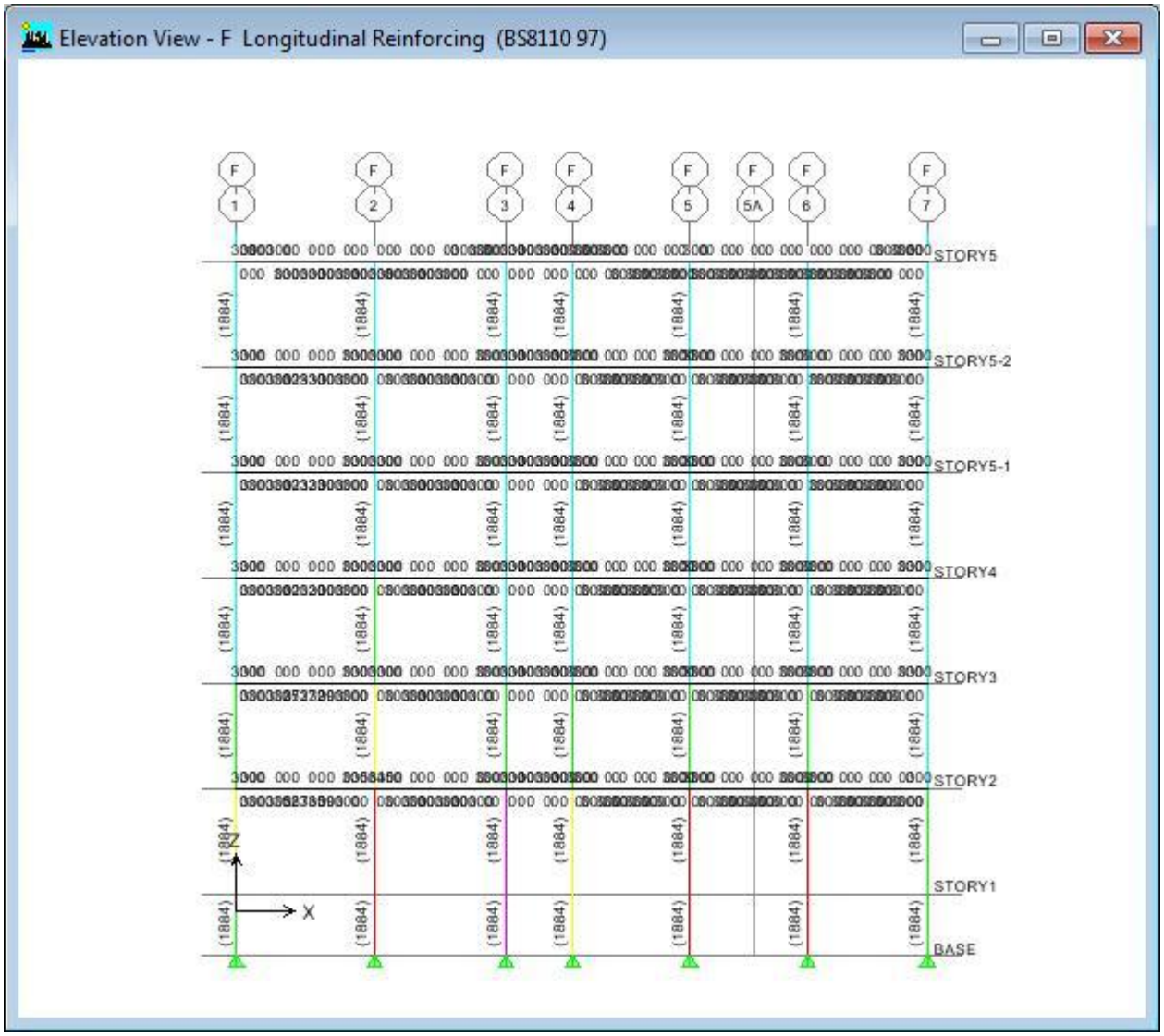

Figure 19: Amount of longitudinal reinforcement in columns on Gridline F under load scenario 3

At this stage the longitudinal reinforcement in all the columns on the ground floor and first floor (apart from the outer columns) have become inadequate. Failure is imminent!

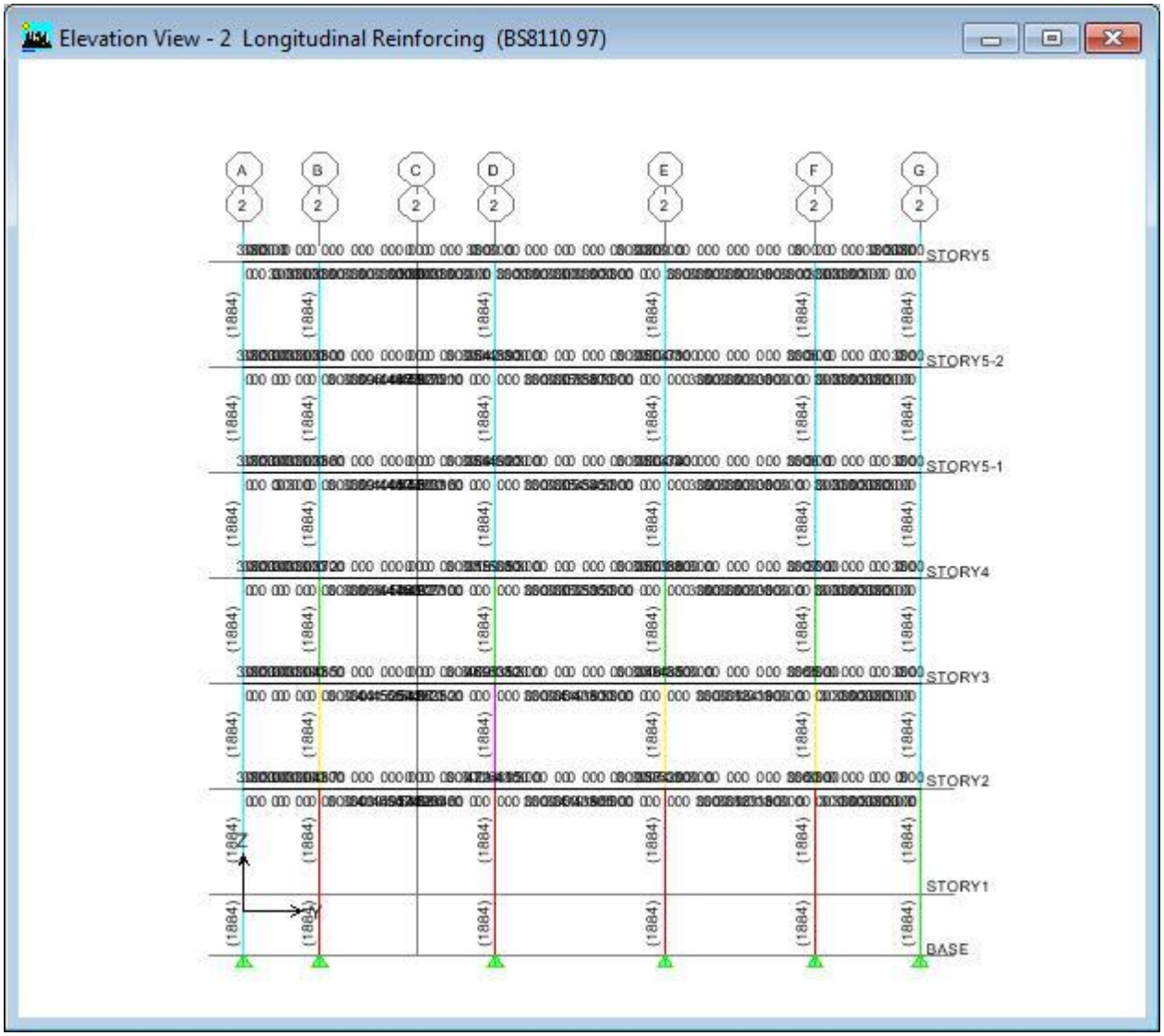

Figure 20: Amount of longitudinal reinforcement in columns on Gridline 2 under load scenario 3

Gridline 2 exhibits the similar situation as along those on gridline F. In this case, even the second floor columns have also failed.

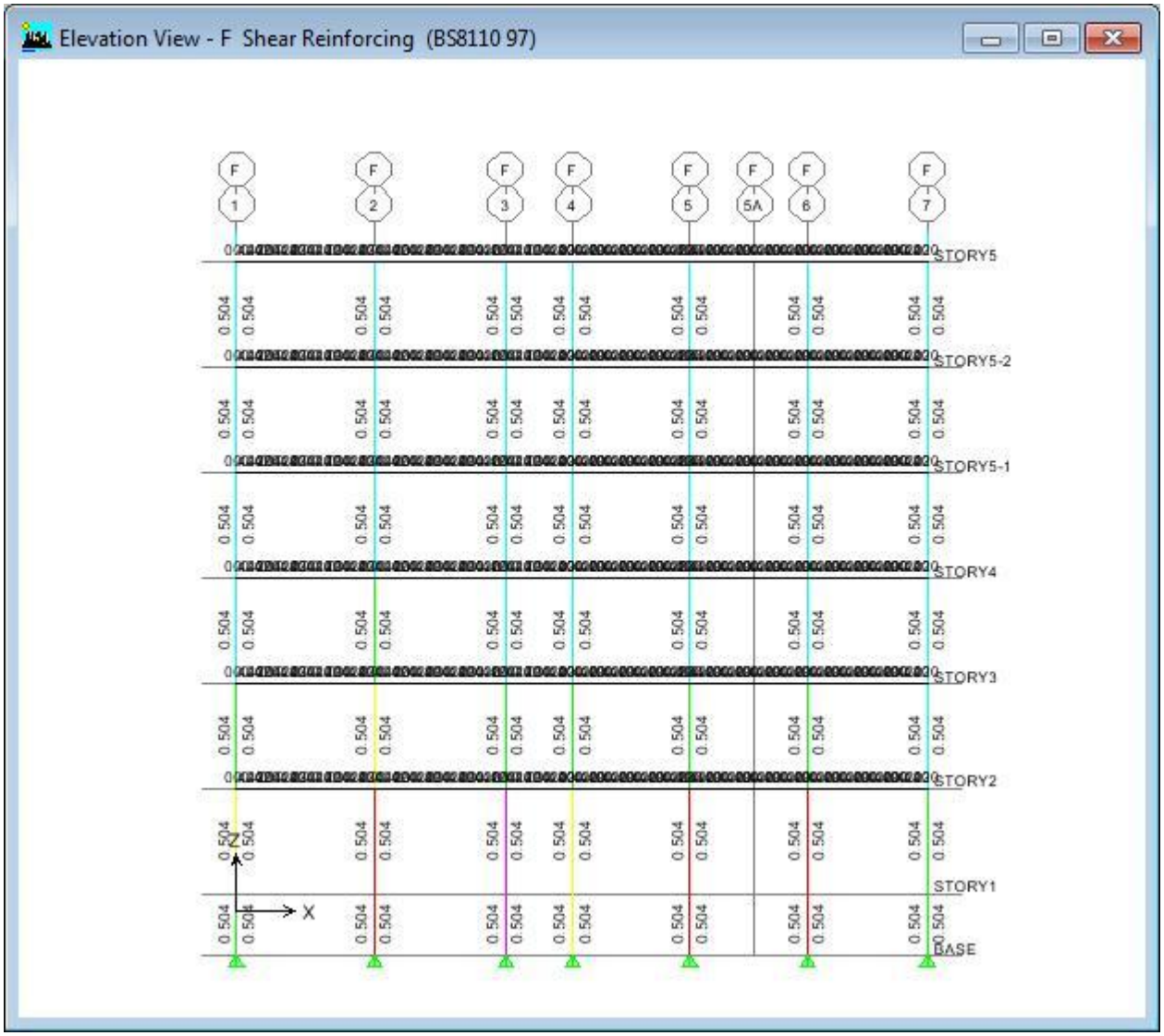

Figure 21: Amount of shear reinforcement in columns on Gridline F under load scenario 3

After the minimum live load was added to the screed and the self-weight of the building, the shear capacity of all columns (except the outer columns) were exceeded up to the first floor along the gridline F.

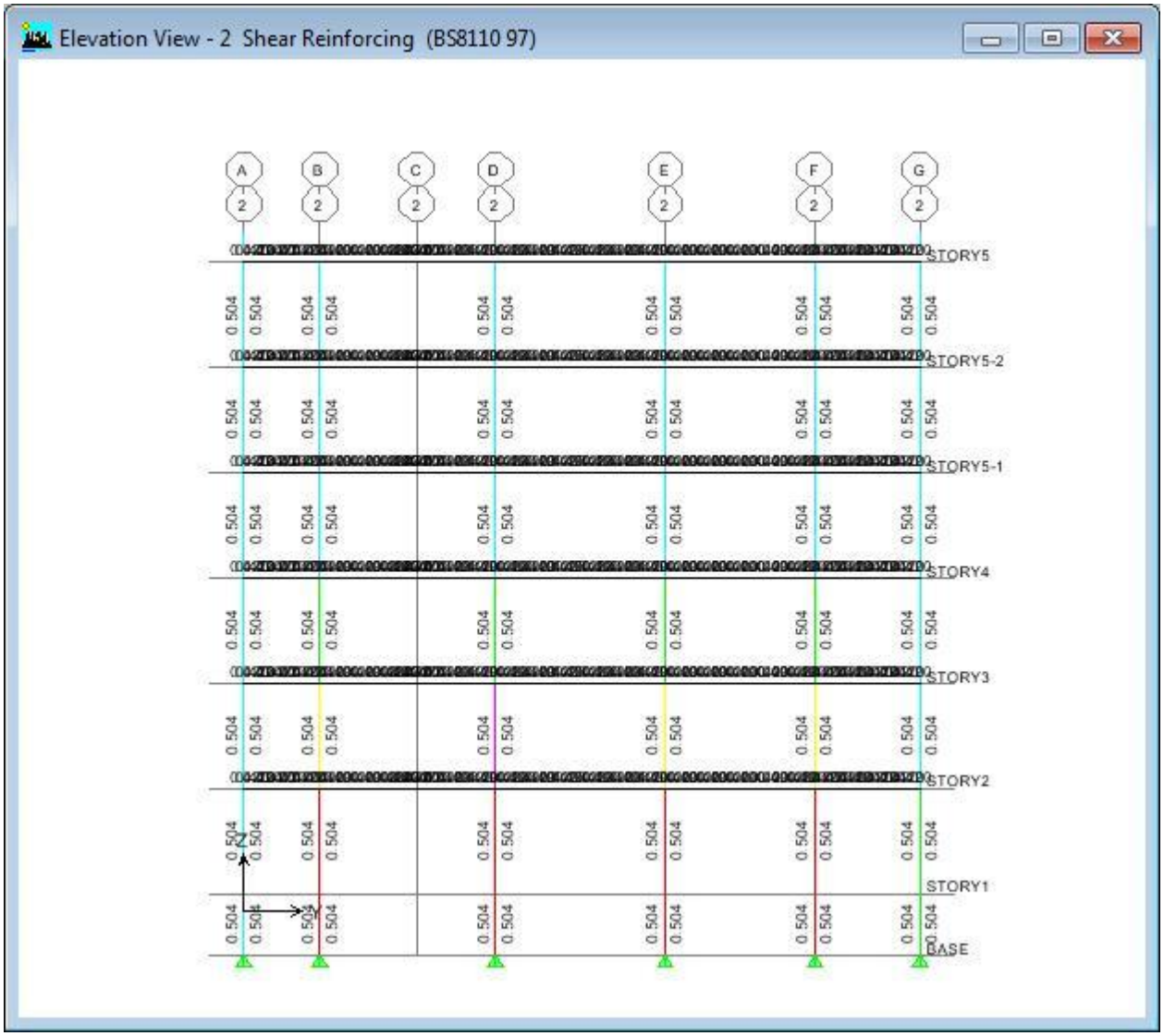

Figure 22: Amount of shear reinforcement in columns on Gridline 2 under load scenario 3

Here along gridline 2, all the columns (with the exception of the outer columns) have failed in shear. Similar shear failures may be seen in pictures in Appendix 1. Exceptional is the column on gridline 2. that failed to the second floor.

4.6 Sensitivity Analysis

This analysis is conducted by keeping all parameters constant and varying the compression strength of the concrete under the 3 scenarios described above. The axial load capacity as computed by the model is compared with axial load capacity of the columns of the building.

Axial load capacity of a column

$N_c = 0.8 * 0.6 * [0.87 * F_{cu} * (A * B – A_s)+F_y * A_s]$

A - length

B - breadth

A_s - area of longitudinal steel

F_{cu} - Concrete strength

F_y - Steel Strength

CASE 1			**CASE 2**			**CASE 3**	
Fcu (N/mm^2)	25		Fcu (N/mm^2)	20		Fcu (N/mm^2)	15
Fy (N/mm^2)	400		Fy (N/mm^2)	400		Fy (N/mm^2)	400
A (mm)	300		A (mm)	300		A (mm)	300
B (mm)	300		B (mm)	300		B (mm)	300
As (mm^2)	1600		As (mm^2)	1600		As (mm^2)	1600
Nc (KN)	**1,230**		**Nc (KN)**	**1,045**		**Nc (KN)**	**860**

Table 2: various scenarios of material quality and corresponding computed axial load capacity

Scenario 1 **(Self-weight only)**	**Scenario 2** **(Self-weight+screed only)**	**Scenario 3** **(Self-weight+screed+min. live load applied to the 3 lower floors)**
1,018 KN	1,228 KN	1,240 KN

Table 3: Axial load in column in gridline 2D on the ground floor

5 REGULATION AND LAWS

The National Building Regulations, 1996 LI 1630 contains the arrangements of regulations guiding the process for application of building permits through to certificate of habitation. The regulation specifies codes of practice for foundations and the super structure.

A general overview of the regulation shows that it is still very relevant if proponents and the Issuing Authority strictly adhere to it.

Between the available British codes and the BRRI Seismic Design Code there is adequate provision for safe design of statically designed buildings as well as wind loading when used in conjunction with the wind loads produced by the Ghana Meteorological Services Department. Various Engineers use different codes when they make allowance for earthquake loading - an Engineering choice based on their experience. The number of floors above which rigid earthquake design is required is also an engineering choice.

An overview of the NATIONAL BUILDING REGULATIONS 1996
The following arrangement is lifted from the regulations. As it stands the regulations relevantly apply currently and when applied in the ideal situation should prevent such occurrence. It is conjectured that the weakness lie in the enforcement of regulations. This is due largely to the following:

- Lack of adequate staffing (professional engineers, building inspectors)
- Lack of skilled staff
- Non-compliance to the laws, rules and regulations

Areas covered by the National Building Regulation 1996, LI 1630

PART I
Regulations

1. Application of Regulations
2. Application for building permit and submission of plans
3. Title of land
4. Exemption from submission of plans
5. Details of building
6. Design of building
7. Building permit
8. Failure of District Planning Authority to process application
9. Use of unconventional materials or methods
10. Notice of commencement and completion of certain states of work
11. Qualified building inspector
12. Compulsory maintenance

PART II – PLOT DEVELOPMENT

Sub-Part I – Location of Building

1. Site requirements
2. Site coverage of buildings
3. Projections beyond building lines
4. Orientation, building lines and improvement lines

5. Boundary lines
6. Building at street corners

Sub-Part II – Spatial Requirements

7. Dimensions, heights and space of rooms and areas in dwelling units

PART III – SITE PREPARATION AND LANDSCAPE

1. Oversite excavation and sub-soil drainage
2. Damp-proof course to substructure
3. Protection of Walls against moisture
4. Weather resistance of external walls
5. Prevention of damp in cavity walls
6. Weather resistance of roofs
7. Landscape development
8. Tree preservation
9. Advertisements

PART IV – MATERIALS FOR BUILDING

1. Suitability of materials
2. Shortlived or otherwise unsuitable materials
3. Testing of materials
4. Materials for buildings
5. Rejection of building application

PART V – STRUCTURAL STABILITY

Sub-Part I – General Application

1. Interpretation of this Part
2. General load requirements
3. Submission of structural design drawing
4. Documentation and inspection of structural calculations
5. Ringbeams or continuous reinforced concrete ties
6. Opening in walls
7. Ornamental projections
8. Earthen construction
9. Soil tests
10. Earthquake loads
11. Requirements in respect of foundations of buildings
12. Structure above foundations

Sub-Part II – Additional structural Requirements for certain Buildings

1. Storey buildings
2. Interpretation of this Sub-Part

Sub-Part III – Beams, scaffolding, roof – General Application

1. General requirements in relation to beams for building
2. Hoarding, scaffolding and temporary structures
3. Roof framing
4. Covering for pitched roofs

5. Weather resistance of external walls, copings, soakers underground structures
6. Underground structures and service ducts
7. Demolition
8. Painting and maintenance of building and structure

PART V – STRUCTURAL STABILITY

Sub-Part I – General Application

6 CONCLUSION AND RECOMMENDATION

6.1 Conclusion

From the foregoing analysis it is evident that:

- The collapse of the building was as a result of structural failure.
- There are all indications that the columns failed due to inadequate resistance to a combination of forces.
- The axial load capacity of the columns were inadequate
- The failure of the middle columns might have produced a P-Delta effect, where extra moments were induced, causing a "DOMINO-EFFECT" of collapse.
- The spacing of the links in the columns was 300mm (instead of 100mm), preventing the column from containing the concrete in confinement.
- Readings from **digital Schmidt Hammer** later confirmed by tests results of core samples show concrete strength ranging from 12N/mm^2 to 14N/mm^2. These values are way below the minimum concrete strength of structural elements of 25N/mm^2 recommended by standard building codes.
- There was no evidence that the building collapsed due to foundation failure.

6.2 Recommendations

6.2.1 Recommendations to Metropolitan/Municipal/District Assemblies

- Metropolitan/Municipal/District Planning Authorities should take steps to fill all vacant positions related to the permit system and should ensure that the positions are filled with the required expertise. For example, engineering positions must be filled with engineers and not allied professions.
- Planning Authorities should find innovative ways of securing the services of private sector practitioners to undertake certain aspects of the functions contained in LI1630 for which they do not have the manpower resources. This would include the use of certified architects, structural engineers, electromechanical and other experts to check designs submitted by developers. This will among other things ensure:

  (d) That the design of structures particularly high rise buildings, are carried out by experts certified in accordance with the Engineering Council Act, 2011 (Act 819).

  (e) That the District Planning Authorities insist on peer review of designs and investigation reports as part of the approval process for high rise buildings and other important infrastructure.

  (f) Building permit is not issued for the development of a building particularly high rise building without the stamped approval of the various certified experts.

- Buildings have become far more complex and it is completely unrealistic to expect all district, municipal and metropolitan authorities to have the capability to determine whether the design they are presented with is adequate or not. These Authorities must therefore collaborate with the Ghana Institution of Engineers to direct them to competent practitioners, who can be retained to support the permit process.

- Construction of public buildings and high-rise structures must be supervised by qualified technicians, technologists or professional engineers. Currently a building permit is issued when appropriately certified designs are presented but there is no requirement for qualified persons to supervise the construction. One is expected to inform the district and metropolitan authorities at various stages of the construction process so that they inspect and certify. This is clearly an impossible task which must be addressed by the permit process.

- Noncompliance of the building permit process should be viewed as a serious breach of law.

- .Building use and performance must be monitored**.** In much the same way that financial audits are carried out, systems must be put in place for the regular audit of all public and other commercial buildings by qualified engineering professionals. This should among other things monitor changes in use, alterations made to the structure, etc. In the audit, structural members must also be examined for signs of distress. Occupants of buildings will also have a responsibility to ensure that they use buildings as intended. A clean audit report can be made a requirement for issuance of an insurance certificate.

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6.2.2 Recommendations to the Central Government

- We call on Government to establish serious dialogue with the Ghana Institution of Engineers to address institutional weaknesses inherent in the construction industry. Such weaknesses are to be addressed in a holistic manner. And would therefore require funding for studies to expose the underlying causes.

- The new Engineering Council Act, 2011 (ACT 819) which was meant to address many of the issues that have been raised by this disaster must be put into effect. The Act will require anyone seeking to practice engineering in Ghana to be registered. This includes craftsmen, technicians, technologists and engineers. The Engineering Council will also register engineering firms. Clear boundaries of operation are to be set for both individuals and firms depending on their capabilities. Unfortunately, even though this ACT is now more than a year old, a Council is yet to be inaugurated to begin work.

- The Engineering Council has been mandated among other things to regulate activities and processes in the construction industry. To achieve this objective collaboration between Metropolitan/Municipal/District Assemblies (who are also empowered by law to plan and regulate development in their localities) and the Council is urgently needed. **In this regard we call for the immediate inauguration of the Engineering Council Bill to regulate the practice of Engineering in Ghana**

- Non-compliance with the building regulations must be made a criminal offense.

6.2.3 Recommendations to the General Public

- The public must be encouraged to report signs of building failure such as cracks, uncomfortable vibrations, leakages, sinking, sagging and leanings to the relevant Metropolitan/Municipal/District Assembly.

- Corporate Ghana must take responsibility for conducting structural and safety integrity audits for high rise building they are occupying or intend to occupy. The good news is most short comings arising from such audits can be fixed by trained and certified engineers currently practicing in Ghana.

6.2.4 Recommendations for Professional Bodies

- The design of structures particularly high rise buildings must be carried out by Certified Engineers. The Institution of Engineers must act on the powers conferred on them by the Act 819 to sanitize and regulate the practice.

- The Ghana Institution of Engineers must facilitate peer review of designs for high rise buildings and other important infrastructure facilities among Certified Engineers, and this must be incorporated in the constitution of the Association of Consulting Engineers.

- It is recommended that the foundation design of high rise structures be checked for adequate anchorage to resist potential overturning forces that could act on the building. Such forces can be easily triggered by earthquakes, unforeseen ground settlement and excessive wind gusts. As previously stated, this was not a contributing factor in this subject matter; however it draws attention to a flaw that needs to be addressed.

- Engineers, Architects and other professional of the Built Environment must collaborate more effectively to ensure both safety of buildings.

- The implementation agencies, such as the Metro/Municipal/ District Assemblies must be strengthened with **Competent Engineers**, Certified by the Ghana Institution of Engineers, to ensure that **Permitting Processes** as outlined in the building regulations are strictly complied with. In connection with this the Institution must maintain a register of Engineering Positions in all Metropolitan/Municipal/District Assemblies and participate in the selection of suitable candidates for these positions.

APPENDICES

APPENDIX 1 – SITE PICTURES

Picture 1: The arrival of the Committee set up by the Ghana Institution of Engineers to Investigate the cause of collapse of the Melcom Building to the site

Picture 2: Construction Machinery to help in the Rescue operations at the incident site

Picture 3: Failed members of the building being removed from the site

Picture 4: Members of various institutions working around the clock during the rescue operation on the second day after the incident

Picture 5: Some parts of the failed slabs cut out in an attempt to reach people who might be trapped in the various floors below

Picture 6: One of the initial observations made: A buckled 300mmx300mm column showing rings of diameter barely 6mm and about 300mm in spacing, main bars of diameter 18mm and 6 in number

Picture 7: The reinforcement in the part of the slab showing here is about 10.5mm in diameter and 200mm in centers

Picture 8: The concrete shown here above looks suspicious of lacking adequate cement with aggregate size well above 20mm. the slab is about 150mm thick. However on the right one sees a screed of about 100mm thick extra over the 150mm thick slab. This is an excessive extra load over the slab that is to carry live load of a supermarket.

Picture 9: A failed column indicating the size of barely 200mm in the width

Picture 10: Also observed was iron rod of size about 5mm in diameter in the failed slab. It cannot be established for what purpose they were used in reinforcing the slab

Picture 11: One of the outer columns that showed failure at the bottom, but more or less upright

Picture 12: Similar failures

Picture 13: Similar failures

Picture 14: Similar failures

Picture 15: Similar failures

APPENDIX B – DETAILED GEOTECHNICAL REPORT

1. Scope of work

As part of the ongoing engineering investigation into the collapse of the Achimota Melcom Shopping Center, it was necessary to conduct a preliminary assessment of the ground conditions on which the building in question was found. This was necessary in order to determine whether or not a foundation failure occurred thus either causing and/or contributing to the total failure of the structure. To achieve this, the following main activities were undertaken:

- Desk top study of the geology, seismic, and drainage condition of the area.
- Estimation of the bearing capacities of the underlying soils.
- Excavation of test pits
- Foundation pad inspections

2. Geology of the Site

A total of three (3) test pits were excavated in close proximity to the south-western, north-western and north-eastern corners of the structure. This was done to expose the underlying soil structure. We discovered that the area was underlain by some quartz schist of the Togo rock series. It was observed the rock was weathered to various degrees at the different test pit locations.

LOCATION	ASSESSMENT METHOD	DEPTH TO ROCK LAYER
SOUTH WESTERN CORNER	**TEST PIT**	**1.2M**
NORTH WESTERN CORNER	**TEST PIT**	**1.75M**
NORTH EASTERN CORNER	**TEST PIT / DCP**	**1.8M**
SOUTH EASTERN CORNER	**DCP**	**2.6M**

Table 1: ***Rock layer levels were measure relative to existing ground levels.***

The rock layer was overlain by clayey silt with traces of sand and laterite. We believe this is a result of the decomposition of the rock formation.

It was further observed that the fill material used above the footing levels, approximately 0.4m to 0.6m thick, was not indigenous to the site as it consisted of a mix of foreign material including concrete waste, laterite, broken cement blocks etc.

3. Seismic Activities of the Project Area

The history of seismic activity in Southern Ghana dates back to 1862. Most of the earthquakes in Ghana occur in the western part of Accra at the junction of the two major fault systems namely, the Coastal boundary fault and Akwapim fault zone which are believed to intersect at Nyanyanu near Kasoa. According to seismologists, most of the epicenters are located south of Weija in Accra, suggesting that there is little activity north-east along the Akwapim range and westward along the Coastal boundary fault. Most earth tremors in Ghana are related to the level of activity of the faults. According to the records a major earthquake in 1939 flattened Accra and was felt in Eastern Ghana and Togo. The maximum intensity of the shocks was estimated to be 6.5 on the Richter scale. Between 1987 and 1990, over eight seismic events with magnitude ranging from 2.5 to 4 on the Ritcher scale have occurred with epicenters in the Accra – Tema area; (Kato, 1990). The site is some distance from the two major fault-lines and there had been no evidence of geological instability within the area.

4. Climate of the Project Area

The project area experiences two climatic seasons in a year – the wet and dry seasons. The wet seasons usually extends from middle of April to early October. Rainfall is bimodal, with a main season reaching its peak in May/June. The minor season normally extends from late August to early October. On average, the rainfall values ranges between 800mm to 1100mm. The degree of saturation of the ground during this period is almost 100%.

The period between October and March is relatively dry. During this time of the year, the area is affected by the North-Eastern Trade winds locally referred to as Hamattan. A value of 25^0 and 30^0 are recorded for the lowest and highest mean temperatures. During this period, the relative humidity is 75% in the afternoon and nearly 90% in the evenings and early mornings.

5. Topography of the Area

At the time of this site investigation, it was observed that the site had a gentle downward slope from the west to the east. The site is not located in close proximity to any watercourse.

6. Field Work

This preliminary geotechnical assessment was carried out on the 10th November, 2012. This consisted primarily of sub-surface exploration.

7. Sub-Surface Exploration

The sub-surface exploration programme consisted of:

- Dynamic Cone Penetrometer test
- Excavation of Test Pits (to obtain soil sample and partial expose foundation elements for observations.)

7.1 Dynamic Cone Penetrometer (DCP) Test

Due to ongoing recovery activities at the site, we were only able to safely perform a total of two (2) dynamic cone penetrometer tests. The DCP tests were conducted using light Dynamic Cone Penetrometer (DIN 4094, German Specification. The tests were conducted in close proximity to the north-eastern and south-eastern corners of the structure. This was done in order to adequately conclude on the bearing capacities of the sub-soil on which the foundation pads were placed. The penetration tests at both locations were terminated when over 50 blows were achieved with further penetration.

The results of the DCP tests have been used to estimate and illustrate the variation of the allowable soil bearing capacity relative to depth. The penetration tests results have been included in the Appendix.

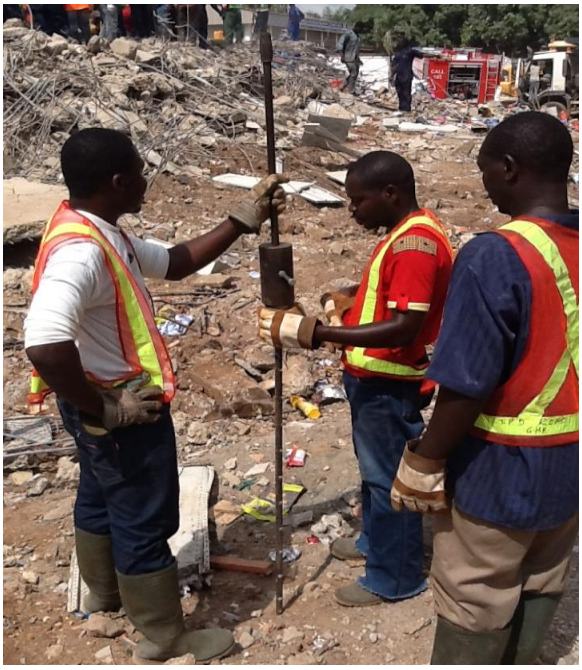


Figure 1 shows the performance of DCP test at one of the test locations at the site.

The DCP test equipment assembly is as follows:

Weight of hammer (m).....10kg

Weight of anvil.....6kg

Height of fall of hammer..... 50.0cm

Cone Diameter.....2.4cm

Cone Surface Area.....5cm^2

Apex Angle of Cone.....60°

For the purpose of determining the soil's bearing capacity, (q_a), the number of blows required for the cone to penetrate 100mm into the soil during testing was noted for various depths up to the point where there was obvious refusal.

7.1.1 Estimation of Soil Bearing Capacity

The strength characteristics of granular soils may be evaluated by converting the unit resistance of the ground into either allowable bearing capacity or standard penetration (N) blow- counts.

In the dynamic cone penetration test method, the parameter "r" is defined as the counted number of blows required to advance 10cm. This data can be converted into unit resistance R_D of the ground in kN/m^2 or kPa using the formula

$$R_D = \frac{m^2 H}{Ae(m+P)}$$

For shallow foundations, the allowable bearing capacity, q_a, may be obtained from the unit R_D by the following relationship

$$q_a = \frac{R_D}{20}(kPa)$$

Thus from further computations, the allowable bearing capacity is obtained from the simplified relationship:

$$q_a = 30r(kPa)$$

"The allowable bearing capacity, q_a , of soil is the net load intensity at which no failure occurs."

The Dynamic Cone Penetrometer test results indicated a fairly consistent subsoil strength characteristic across the project site. The maximum depth at which refusal encountered was at 2.6m at the south-eastern corner of the structure. See test results in the appendix.

7.1.2 Excavation of Test Pits

Test pits were excavated in order to obtain soil samples, and to partial expose foundation elements for observations.

- Information collected during this preliminary investigation suggests that, a spread footing type of foundation was adopted for this site.
- During the excavation of test pit #1 (south-western corner) we encountered a concrete ground beam at a depth of approximately 1.45mm below the existing ground level. The dimensions of this beam were approximately 510mm wide, and 250mm thick.

Figure 2: Ground beam of the Melcom building

- At test pit #2 (north-western corner), we encountered sound rock layer at an approximate depth of 1.75m below ground level. It was observed that the foundation pad at this location was poorly constructed .i.e. a 50mm thick reinforced concrete pad was cast directly on sound rock formations.
- At test pit #3 (north-eastern corner), it was observed that a foundation pad measuring approximately 450mm thick and 1.5m long was utilized. It was noted that unlike test pit #2, the foundation pad was not bearing directly on sound rock. See DCP #1 test result.

8. Laboratory Testing

At the time of this reporting, no laboratory testing has been performed on the sub-soil on which the structure was founded.

9. Ground Water Condition

No ground water was encountered in the excavated trial pits during the field investigation.

10. Engineering Conclusions

The field testing and visual inspection of sub-surface soils suggests that reasonably high allowable bearing stresses pertain at the site. Example, at the DCP #1 test location, the bearing capacity of the soil supporting the footing at a depth of 1.2m was 450KPa. From

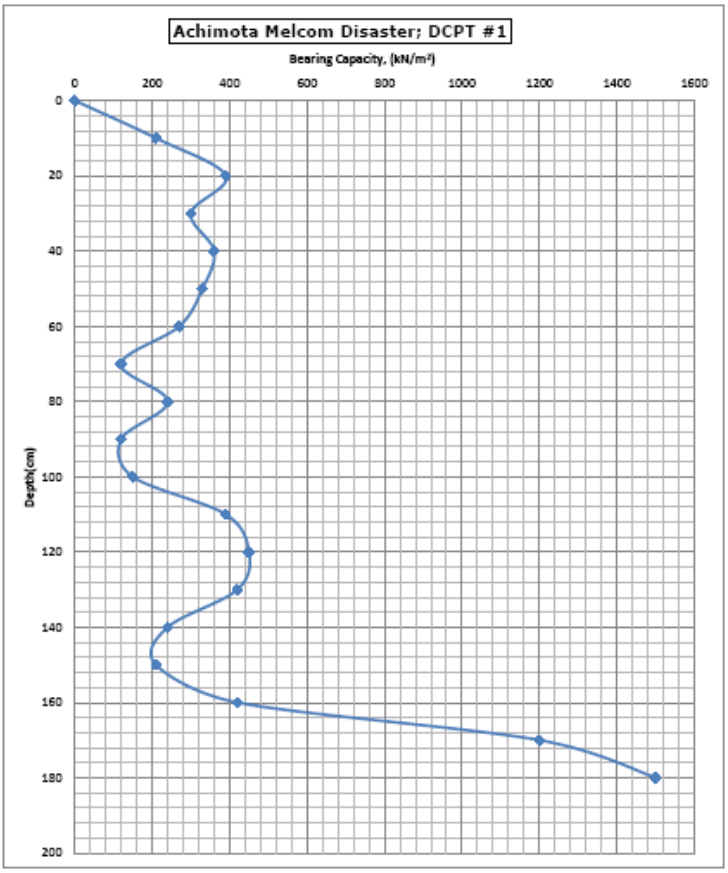
careful observations, and examination of the data collected from the immediate and surrounding ground, we concluded that the collapse of the Melcom shopping building was **NOT** a result of a foundation failure; however, we find the foundation that was constructed for this building not fit for a high rise structure.

11. Engineering Recommendations

With reference to the subject matter, i.e. the collapse of the Achimota Melcom Shopping Center, we recommend that the foundation design of high rise structures should be checked for adequate anchorage to resist potential overturning forces that could potentially act on the building. Such forces can be easily triggered by earthquakes, unforeseen ground settlement and excessive wind gusts. As previously stated, this was not a contributing factor in this subject matter; however it draws attention to a flaw that needs to be addressed.

Project Title:	Melcom Disaster
Project Location:	Melcom Shopping Center, Achimota
Client:	-
Architect:	-
Site ID:	North Eastern Corner

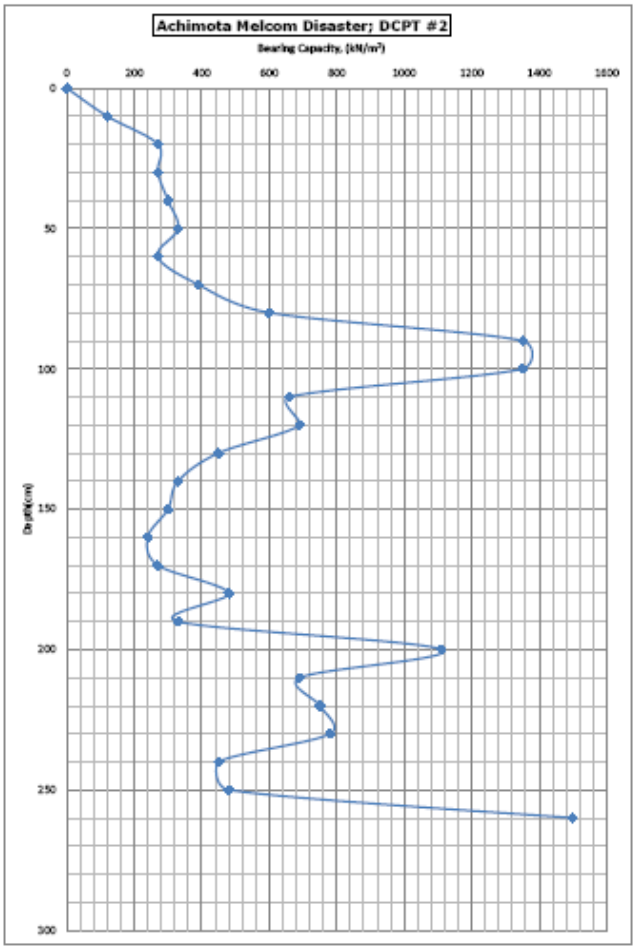
DCPT 1		Bearing Capacity
Depth (cm)	Blows	kN/m²
0	0	0
10	7	210
20	13	390
30	10	300
40	12	360
50	11	330
60	9	270
70	4	120
80	8	240
90	4	120
100	5	150
110	13	390
120	15	450
130	14	420
140	8	240
150	7	210
160	14	420
170	40	1200
180	50	1500



DCP Test results for the North Eastern Corner of the building

Project Title:	Melcom Disaster
Project Location:	Melcom Shopping Center, Achimota
Client:	-
Architect:	-
Site ID:	South Eastern Corner

DCPT 2		Bearing Capacity
Depth (cm)	Blows	kN/m²
0	0	0
10	4	120
20	9	270
30	9	270
40	10	300
50	11	330
60	9	270
70	13	390
80	20	600
90	45	1350
100	45	1350
110	22	660
120	23	690
130	15	450
140	11	330
150	10	300
160	8	240
170	9	270
180	16	480
190	11	330
200	37	1110
210	23	690
220	25	750
230	26	780
240	15	450
250	16	480
260	50	1500



DCP Test results for the South Eastern Corner of the building

APPENDIX C: ANALYSIS OF CONCRETE CORE SAMPLES

ACHIMOTA MELCOM SHOPPING MALL
ANALYSIS OF CONCRETE CORES

DATE: 15/11/12

I.D. No.	Diameter of Core (mm)	Length of Core (mm)	Length/Dia. l/d ratio	Cross x-sectional Area mm^2	Failure Load (kN)	COMPRESSIVE STRENGTH-N/mm^2			% of Characteristic Strength
						Measured Core Strength	Estimated In-situ Cube Strength	Estimated Avg. In-situ Cube Strength	
SLAB	110	110	1.00	9,504.55	94.7	9.96	9.2		
SLAB	110	110	1.00	9,504.55	82.6	8.69	8.0	9.0	
SLAB	110	110	1.00	9,504.55	93.6	9.85	9.1		
COLUMN	110	110	1.00	9,504.55	105.8	11.13	10.2		
COLUMN	110	110	1.00	9,504.55	109.0	11.47	10.6	11.0	
COLUMN	110	110	1.00	9,504.55	134.7	14.17	13.0		

NOTES:

1. Cores were crushed at the GHA Central Materials laboratory
2. Test was done according to BS 1881 : Part 120 : 1983
3. Cores were drilled vertically from broken structural elements

APPENDIX D: COMMITTEE MEMBERS

COMMITTEE MEMBERS

No.	Name	Organization	Contact No.	Email
	Ing. Steve A. Amoaning-Yankson (Chairman)	MDC	0208929889	mdc@ghana.com
	Ing. Magnus L. Quarshie	Delin Consult	0244265431	mquarshie@delincl.com
	Ing. Joshua Allotey	Jukess Consult	0244241295	jnmallotey@homail.com
	Ing. J. Pinkra		0208177938	jofpink@yahoo.com
	Ing. Frank Fiifi Yawson		0272588788	fiifi.yawson@gmail.com
	Ing. Dr. Desmond Aryee-Boi	Bonades Ltd	0244266742	daryeeboi@yahoo.com
	Ing. Ebenezer Laing	ABP Consult	0244364824	laing@abpconsult.com
	Ing. Emmanuel Degbotse	Deoke Consult	0244167462	Edegbotse2@yahoo.com
	Ing. William Dickson	Daovtech Design Group	0208140842	William.dickson@daovtech.com
	Ing. Dr. C.K. Wenyonu	Caad & Cad Consult	0277559999	primmavverra@yahoo.com
	Ing. K. Nyarko Twumasi	HAG Consult	0208133933	twumasi@hotmail.com

Appendix E – Records of Consultations with Stakeholders

I- Interview with City Authorities

MINUTES OF ADHOC COMMITTEE MEETING ON MELCOM DISATER

HELD AT THE ENGINEERS CENTRE, ROMAN RIDGE, ACCRA ON

FEBRUARY 6, 2013

1.0 In Attendance

No.	Name	Organization	Telephone
1.	Ing. Steve Amoaning-Yankson	GhIE	0208 929 889
2.	Ing. Joshua Allotey	GhIE	0244 241 295
3.	Ing. Twumasi – Nyarko	GhIE	0208 133 933
4.	Ing. Dr. Desmond Aryeeboi	GhIE	0244 266 742
5.	Ing. Isaac Justice Mintah	GhIE	0244 208 192
6.	Mr. Yaw Twumasi – Ankrah	Legal Department – A.M.A.	0208 133 443
7.	Mr. Victor Mensah	Metro Works Director – A.M.A.	0233 345 999
8.	Miss Doris Tettey	Town and Country Planning	0244 089 690
9.	Mr. Jacob Sebuafor	Chief Building Inspector, Accra Metro Works – A.M.A.	0244 087 563
10.	Supt. Baffour Appenteng	Ghana Police Service	0242 814 863

2.0 AGENDA

1. Welcome Address
2. Discussion on Melcom Building Disaster
3. Discussion on Challenges confronting development control in the Accra Metropolis
4. AOB

3.0 Discussions

Item	Discussion	Action
3.1	**Introduction** The meeting chaired by the Chairman of the Sub – Committee, Ing. Steve Amoaning – Yankson started at 10:15am. He expressed his gratitude to the Chief Executive and members of the Accra Metropolitan Assembly (A.M.A.) present at the meeting for honoring his invitation.	
3.2	**Welcome Address** The Chairman said the Melcom Disaster Investigation Committee was constituted by the President of the Ghana Institution of Engineers to investigate the failure of the structure and report to the Council of the Institution, to enable them formulate proposal to advise the Government. Terms of Reference include: ○ Determination of the probable causes of the failure ○ Recommendations on policy measures to forestall future occurrence He informed the house that as of now they have completed the technical aspects of the assignment leading to the submission of an interim report. This was followed by a Press Conference. What is outstanding is the completion of a final report. This final report will be submitted to the Government. In finalizing the report it has become necessary to hear from all stakeholders and in particular get their side of the story. They are mindful of the fact that there have been numerous reports from various quarters including eye witnesses and the press. From experience eye witness account may be unreliable. That is not to say eyewitnesses are dishonest but rather, on account of lack of technical training, they may appear to have distorted view of events, particularly when there is a catastrophic failure such as the one under consideration. An exception is where the account is given by construction workers.	

Item	Discussion	Action
3.3	**Interview** **1. What is the permitting process in the Assembly?** Miss Doris Tetteh answered by informing the house that they have a system which they are slightly modifying. In the old system, an applicant submits his or her development proposal to the planning office and completes an application form. The application forms indicates a number of documents to be attached such as Detailed Drawings, Architectural Drawings, Building Permit Form, and any other material deemed to be relevant for the process. With the modified system, in addition to the documents in the old system, Structural Drawings, Structural Computations, Geotechnical Report for three or more storeys are collected. Other reports such as Fire Report, EPA Report etc are collected based on the application type. Upon receipt of these documents, we proceed to carry out an inspection, planning verification and make recommendations to the Technical Sub – Committee of the Planning Committee. The Planning Committee then recommends approval, further investigations, amendments or refusal. These recommendations are then presented to the main committee which is the Accra Metropolitan Planning Committee who gives consent of approval subject to payment of fees and preparation of certificates. When the certificates are prepared, the applicants are made to take copies.	
3.4	***2. How long have you had this modification?*** This has been an on-going modification for the past two to three years.	

Item	Discussion	Action
3.5	***3. Does Melcom Building fall under the old system or the modified system?*** We will be hard pressed to give a clear and definite answer because the owner of the building did not submit any application for a permit to our office. However, with information on when the construction of the building was started, the permitting process would fall under the old system. The owner of the said building started his construction without a document. The assembly deals with buildings which have been started before the owners apply for a permit. For this category, A.M.A. request for structural integrity report and geotechnical report if required from a qualified engineer which the structural engineers of A.M.A. look at and advice the Planning Committee.	
3.6	***4. Did your office receive any application for a permit from the owner of the building?*** The owner of the building did not submit any application for a permit to our office.	
3.7	***5. Did your office issue a permit to the building owner?*** No. The Department of works gave a window of opportunity to people without building permits but were already constructing unauthorized developments to apply. This was however in contradiction to the system being implemented since the application was carried out through the works' department and not through Town and Country Planning. The works department issued letters indicating they have received applications from the applicants without going through the due process. This process was stopped by the Town and Country Planning.	

Item	Discussion	Action
	The owner of the Melcom building might have taken advantage of this window of opportunity put in place by the Works Department, however this could not be confirmed by the AMA Officers at the meeting. The Town and Country planning in regularizing buildings without permit came out with the condition that applicants in such category should produce all necessary documents and also attach structural integrity report, geotechnical report and any other document required. When the documents are presented, they are evaluated and submitted to the Planning committee which makes recommendations for regularization. At this point, the committee imposes a penalty and the applicant is allowed to make payment.	
3.8	***6. Did your building inspectors at any time report of unpermitted activity?*** Yes	
3.9	**7. Do you have any information regarding the drawings for the development?** No	
3.10	***If unpermitted activity was reported, what steps were taken to stop the development?*** For unpermitted structures, the works department issue written notice to the owner of the building to suspend the works and bring all relevant documents on the structure to the Town and Country Planning for a building permit. This is carried out through a written notice as well as a wall notice. When this is exhausted and the people are recalcitrant, the final warning is issued after three to seven days. If this fails, the attention of the Accra Metropolitan Planning Committee is drawn to it. With the Melcom building, the owner was served with written notice to suspend the development. Unfortunately, the inspector was threatened with a gun and chased away from the site. He however managed to leave the written notice at the site.	

Item	Discussion	Action
3.12	**9. What are the challenges confronting development control in the Metropolis?** The following are some of the challenges; • Inadequate technical hands to vet structural integrity. • Obsolescence of the building regulations • Cost to the Assembly for processing the permits • Political interference • Weak prosecution • Municipal Development has not been put on the Governance Agenda and as such violation of Municipal Laws cannot be checked. Even ministries are guilty as evident in the development explosion at the ministries. • Financial and Manpower resources for managing development control is grossly inadequate • Some approved structures change during the implementation stage (approved 5 storey structures become 10 storey) and the building inspectors' protests are ignored with impunity. • Assembly Staff sometimes don't have the will power to carry out their duties due to insecurity. • Development Control – the capacity or ability to stop people from putting up unauthorized structures is minimal • Lack of a law to govern Building Contractors in Ghana • LI 1630, National Building Regulation, should be reviewed • There is a need to define a procedure to be used to declare a building unsafe in the building code. • Necessary to constitute a committee to visit unsafe buildings to recommend demolition.	
	10. Conclusion Ing. Steve Amoaning Yankson thanked the team from Accra Metropolitan Assembly for their contributions and also attending the meeting. The meeting came to an end at 12:30pm.	

Recorder

(Ing Isaac Justice Mintah)

II- Interview with Melcom Management

INTERVIEW WITH MELCOM MANAGEMENT

The meeting was chaired by the Chairman of the Sub – Committee, Ing. Steve Amoaning – Yankson, and started at 14:05pm in the premises of Melcom (Kaneshie). He expressed the sincere condolences of the GhIE to Melcom and the Families of the departed brothers and sisters.

The members of Sub-Committee present at the meeting were

- Ing. Steve Amoaning-Yankson (Chairman)
- Ing. Joshua Allotey
- Ing. Joseph Buckson (Secretary, GhIE)

The members of the Melcom Company present were

- Mr. Ramesh Sadhwani (J. G. M. D.)
- Mr. Mehesh Melwani (J. G. M. D.)
- Mr. Arvinder Singh (C. O. O.)

The chairman said the Melcom Disaster Investigation Committee was constituted by the President of the Ghana Institution of Engineers to investigate the failure of the structure and report to the Council of the Institution, to enable them formulate proposal to advise the Government. Terms of Reference include:

- Determination of the probable causes of the failure
- Recommendations on policy measures to forestall future occurrence

He informed the meeting that technical aspects of the assignment have been completed, leading to the submission of an interim report. This was followed by Press Conference. What is outstanding is the completion of final report.

In finalizing the report it has become necessary to consult all stakeholders and in particular get their side of the story, while being mindful of the fact that there have been numerous reports from various quarters including eye witness and the press. From experience eye witness account may be unreliable. That is not to say eyewitnesses are dishonest but rather, on account of lack of technical training may appear to have distorted view of events, particularly when there is a catastrophic failure such as the one under consideration. An exception is where the account is given by construction workers.

He therefore implored Melcom Management to be truthful in the information given.

B INTERVIEW

1. What is the name and address of the Owner of the Building?
   Ans: Nana Boadu, Director, Kinsadus Co. Ltd., P. O. Box 10919, Accra North.

2. When was the construction of the building completed?
   Ans: Finishing works for the building was being carried out as of I8th November, 2011 when we took possession of the Ground Floor.

3. When was building occupied by your Company?
   Ans: The Company moved into the building in November 18, 2011 and opened the store to the general public in January 2012.

4. What was the condition of occupation (rented for what purpose)?
   Ans: It was for Commercial and Industrial use but Melcom used the building solely for Retailing purposes.

5. Was any modification made to the building?
   Ans: Melcom did not carry out any Structural modification to the existing building. The works carried out by Melcom includes tiling, electrical etc.

6. Can you briefly give an account of your involvement with the property, from the time you obtained it from the owner to the time of its collapse?
   Ans: We had no access to the structural drawings. However a shop layout was prepared by Melcom for our own use. The activities carried out include fixing of lighting and AC fittings, setting up of Display Stand, placing of Merchandises on display, Opening of Shop for the Public and Routine receipt of goods from warehouses.

   A 200kva Generator was installed about 10 – 15feet from the main building on a concrete foundation.

7. How was the structure operated:
   - Indicate functional use of Ground Floor
   - Indicate functional use of 1st Floor
   - Indicate functional use of 2nd Floor

- Indicate functional use of 3rd Floor
- Indicate functional use of 4th Floor
- Indicate functional use of 5th Floor

Ans: Our company occupied the Ground, First and Second Floors and had no access to the Third, Fourth and Fifth Floors. The ground floor was occupied with electrical appliances, electronics, cash counters, impulse counters and IT Equipment. The first floor had garments, clocks, kitchenware and supermarket items whiles the second floor was occupied with furniture, carpets, stationery and sundries.

Melcom did not use any part of the building for storage purposes. The warehouse of the company is operated separately from their shops.

8. Did you receive reports of deformation or cracks in certain parts of the building?
   Ans: No

9. Is it possible to describe the nature of these cracks?
   Ans: N/A

10. Did you have any mechanism for dealing with the report of cracks?
    Ans: N/A. However, if any request for maintenance is required, the shop manager sends an email or communicates with the Operation Department at the headquarters. Usually, this is done for IT related issues, electrical including generators and carpentry etc.

11. Do you have an idea of the address of the Contractor who built the structure or any of the technical people involved in the construction?
    Ans: No

12. As a policy do you take steps to verify the structural integrity of buildings you acquire for use as shops?
    Ans: No. Generally, Melcom obtain AMA Permit, Fire Permit, ECG Clearance Certificate and VAT Registration.

13. Is there any other information you wish to bring to the attention of the committee?
    Ans: Mr. Arvinder Singh informed the meeting of the following;

- He debunked the story being put up by the Landlord that part of the building was being used for storage of goods (warehouse).

- Prior to the collapse of the building, containers of tiles were brought to the site by the Landlord. The tiles were offloaded to the 3rd Floor where tiling works were being carried out.

  Three days after the collapse, stack of tiles were identified at the site between two slabs. Pictures of the stack of tiles were shown to the committee. A sample taken from the site weighs about 5kilos. Melcom however do not sell tiles.

- The rescue team also called the management of Melcom to find out if the building has a basement. According to them four rooms full of televisions and other goods have been found buried in the ground.

  Melcom then informed them that those items were located at their ground floor and they were not aware of any basement for the building. This he said suggests that the foundation was not filled or not filled and compacted properly before the base slab was constructed. Hence a void may have been created beneath the base slab. He therefore asked the sub-committee to also investigate this.

- A single storey building was demolished before the six story building was constructed at the same location. He asked the sub – committee to also investigate if the foundation of the single storey building was demolished and a new foundation for the six storey building was constructed or not.

The leader of the delegation thanked the management of Melcom for the meeting and for the information. The meeting came to an end at 15:05pm.