STUDY ON STRUCTURAL COLLAPSE BEHAVIOUR OF REINFORCED CONCRETE BUILDING COLLAPSE STUDY

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Abstract

In this study, the collapse of a reinforced concrete tribune structure was analyzed in order to determine the next steps for repair. Both qualitative and quantitative methods were used, including visual observation, Hammer Test, and computational modeling with Staad Pro v8i. The results showed that the collapse occurred in the beams and floor, leading to the conclusion that they should be demolished, while the columns could be repaired with minor modifications. The Hammer Test revealed a range of concrete quality, with the critical stress occurring at the same location as the collapse. The computational modeling with Staad Pro v8i confirmed that the reinforcement beam design was inadequate and the scaffolding used was too weak. It was concluded that the collapse was due to a combination of factors, including insufficient reinforcement design, unhardened beams and concrete, and inadequate scaffolding support during the concrete hardening process.

Keywords: reinforced concrete**, reinforced concrete, rebound value, tribune**

1. INTRODUCTION

Reinforced concrete construction is still the most widely used type of construction, this is due to the various advantages possessed by reinforced concrete. The structural advantages possessed by reinforced concrete are the combination of concrete and reinforcing steel that provide compressive strength as well as large tensile strength, In addition, this construction is easier to implement. This has led to reinforced concrete being widely used in construction projects that are of value or small value such as buildings, road pavements, bridges, dams , channels irrigation, ports, terminals, and so on.

In the implementation of a building construction, there is often a failure of failure due to damage that occurs to the structure or parts of the structure at the time of its implementation stage or after completion worked on. This incident is partly caused by factors that were not previously taken into account, such as errors in planning and implementation and a burden overload due to changes functions of the building [1].

To obtain the causative factors of construction failure is not easy, sometimes the source of the failure itself is the accumulation of various factors. The source of construction failures is often influenced by natural factors and human behavior [2].

There are several test methods that can be used to investigate building structures including local non-destructive tests such as *ultrasonic* testing and *hammer tests* and are half damage or damage to the overall components of the building tested in the form of *load testing*.

To further examine the collapse or failure of construction, this study will examine the case study of the collapse of reinforced concrete structure. The objectives of this study are:

1) To identify damage to the components of the building structure;
2) To know the capabilities of each element of the building structure;
3) To find out the cause of the collapse of the beams and floor of the Tribune;

2. RESEARCH METHODS

2.1. Literature Study

Literature studies are carried out by exploring material relevant to research, which includes various textbooks, scientific journals, regulations and National and International Standards.

2.2. Research Method / Design

The design of the research that will be carried out is as follows:

a. Measurement of the degree of damage to the structure

Measurement of the degree of damage to the structure can be divided into 2 parts, namely:

1) Qualitative Measurement, carried out by visual observation in the field This observation is a reference to the data collection of the structure which includes:

   a) Technical specifications, contract documents

   b) Measurement of the dimensions of the structure and elements of the structure

   c) Working drawings and as built drawings

   d) Notes / implementation reports

   e) Photos of the implementation

   f) Recent photos of structures' locations, cracks, and faults

   g) Building usage report if the building is completed

   h) Material control quality report

   i) Events during construction: source of material, weather, change of image, etc.

   j) Repairs (if any) after completion of construction

2) Quantitative Measurement, carried out by testing a concrete hammer (Hammer Test).

This measurement of the uniformity and quality of concrete is carried out against structural elements such as beams, columns , and floor slabs.

b. Observation Data Processing

The data that has been obtained from the results of visual observation, and the strength testing of each element of the structure will be analyzed to determine the degree of damage to the structure, so that the cause of the collapse of the building can be known.

c. Recommendations for Analysis Results

After knowing the category of the level of structural damage, a recommendation is made to repair a damage that occurs or maybe if the level of damage is very severe, it cannot be done repair again.

3. RESULTS AND DISCUSSION

3.1. Analysis and Results of Visual Observations in the Field

The structural components reviewed in the field by visual observation are:

a) Ground Floor Concrete Beams and Foundations

- The quality of concrete is not tested.
- The entire beam and foundation are still in good condition without any cracks.
- The dimensions of the beam that are carried out have been in accordance with the working drawings.

b) 1st Floor Concrete Blocks

- The quality of concrete was not tested because the beam structure collapsed.
- All beams on the 1st floor have undergone deflection that exceeds the allowable deflection (L/180), and cracks that are paraph on the pedestal and field (middle of the span) so that they are categorized collapsed (see Figure 1).
- No concrete blanket should be seen by at least 40 mm, this can reduce the durability of the concrete (see Figure 2.a).
- The steel reinforcement that is fixed on the pedestal of the beam is too small (only 2 visible pull reinforcement) (see Figure 2.b).
- The dimensions of the beam, the number of bending and sliding reinforcement attached have corresponded to the working drawing.

c) Concrete Floor Slabs

- The quality of concrete was not tested because the floor slab structure collapsed.
- All concrete slabs on the 1st floor have undergone deflection that exceeds the allowable deflection (L/180), and severe cracks in the pedestal and field (middle of the span) so that categorized collapsed (see Figure 1).
- No visible concrete blanket should be at least 20 mm, this can reduce the durability of the concrete (see Figure 1).
- The suitability of the dimensions of the floor slab, the number of bending reinforcements that is attached has matched the working drawing.

d) Concrete Columns

- The concrete quality of each column is tested with the Hammer Test tool.
- There were 4 columns that experienced a slope due to being pulled by concrete floor blocks and slabs that had collapsed.
- The upper concrete at the confluence of beams and columns is severely cracked and crushed (see Figure 3.a), while the concrete in the middle and lower parts is still good not to have cracks (see Figure 3.b).
- The dimensions of the column, the number of bending and sliding reinforcement attached have corresponded to the working drawing.

Figure 1. Structure of concrete beams and floor slabs-1

Figure 2. a. 1st floor concrete block concrete blanket does not exist, b. The number of reinforcements of the upper beam pedestal is visible only.

Figure 3. a. Concrete Column Structure the top cracks and crumbles, b. Concrete Column Structure central section and the bottom is still good not to have cracks

3.2 Analysis and Test Results of Concrete Quality in the Field

Testing the quality of concrete in the field is carried out using the Hammer Test tool. The result of the rebound value was 33,355 and the quality of concrete ranged from 116,640 kg / cm 2 sd. 229,780 kg / cm^2, this means that the quality uniformity of concrete quality on the column can be is estimated to be quite good according to the K225 (225 kg/cm^2) (see Table 1 and Figure 4) [4]. For concrete on beams and floor slabs, hammer test is not carried out .

Table 1. Concrete Quality Test Results **Resume with Hammer Test Tool**

TEST OBJECT CODE	**Rebound**	**Cube (kg/cm^2)**	
		Z_{min}	**Z_{max}**
	(R)	109.729	220.144
K2	32.60	109.254	219.458
K3	33.10	114.043	226.318
K4a	34.80	130.904	249.536
K4b	34.50	127.866	245.448

K5	32.40	107.361	216.709
K6	32.70	110.205	220.831
K7	32.65	109.729	220.144
K8	35.10	133.968	253.620
K9	33.05	113.561	225.632
K10	33.35	116.467	229.742
Average	**33.355**	**116.644**	**229.780**
Resume	**Good Enough**	**Quality concrete K-225 meets**	

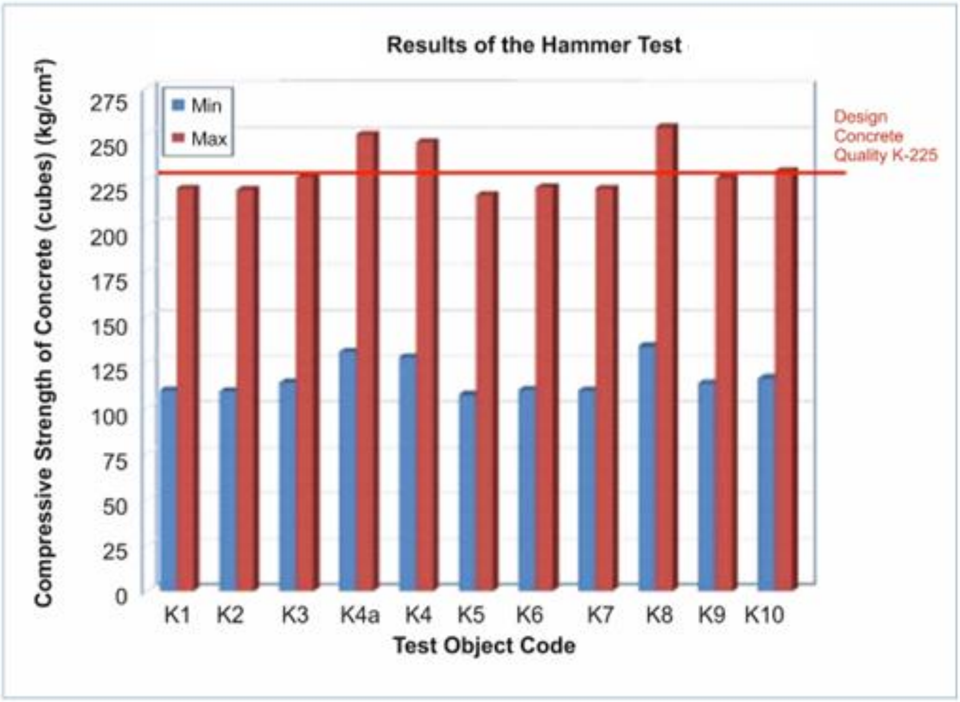

Figure 4. Concrete Hammer Test Results

3.3 Collapse Analysis of Tribune Concrete Structure

Based on visual observations, it can be analyzed the possible factors causing the collapse as follows: **a) Concrete Quality Factor**

The quality of concrete column test results with the Hammer Test tool obtained a bounce value (Rebound) of 33,355 and the quality of concrete ranged from 116.64 kg / cm 2 sd. 229,780 kg / cm^2, this means the quality The uniformity of concrete quality in Kolom can be estimated quite well according to the K-225 plan (225 kg/cm^2).

b) Concrete Hardening Factor (concrete age)

According to regulation it is said that the determination of the quality of concrete $\sqrt{f_c'}$ must be based on testing concrete that has been nutty28 days [5].

This can be predicted by looking at the conditions in the field that only the upper column is severely damaged (cracked crumbly) while the columns in the middle and bottom no damage (cracks) (see Figures 4.a and 4.b), this means that there is no full-load channeling from floor slabs to beams and from beams to columns because the relationship between the concrete beam and column still does not have enough strength (the concrete is not old enough), while the scaffolding is opened too quickly so that the beam and plate suffered a collapse first.

c) Target Time Factor

Target time is the thing that most often makes workers, supervisors and implementers do a lot of carelessness. By looking at the contract the fairly short completion time of the work is as long as 120 days it is very likely to cause the release of scaffolding and formwork of concrete work too quickly, the impact is that the structure experiences construction failure because the concrete still does not have enough strength and strength to withstand its own weight.

d) Concrete Column Strength Design Factor [6]

This can be seen with the condition of the concrete column at the bottom which is still good (minor damage only occurs to the top of the column due to being pulled by beams and slabs collapsed concrete) (see Figure 3.a and 3.b), and the dimensions of the concrete columns that meet the minimum size t (30 /30) in withstanding a load of 2 floors with a minimum capability Pu = 86,160 tons per column, so with 10 parts. The total load that the Column can withstand is 861,600 tons compared to the total weight of the building of 186 tons.

e) Beam and Column Rebar Design Factors

This can be seen from the condition of the concrete and the lack of the main reinforcement of the beam pedestal (only 2D10 pull reinforcement is visible) in the relationship of the column beams that are unable to withstand load beams and floor plates (see Figure 2.b).

To further examine the collapse of the Tribune structure design, modeling was carried out using Staad Pro V8i Software (see Gambar 6), with the following results:

Figure 5. Concrete Tribune Structure Modeling with Staad Pro V8i Software

1) Block Looping Design

The maximum moment that occurs in the beam from the Staad Pro structure analysis only due to dead loads can be seen in Figure 6. The location of the beam's maximum moment was also the location of the collapse that occurred.

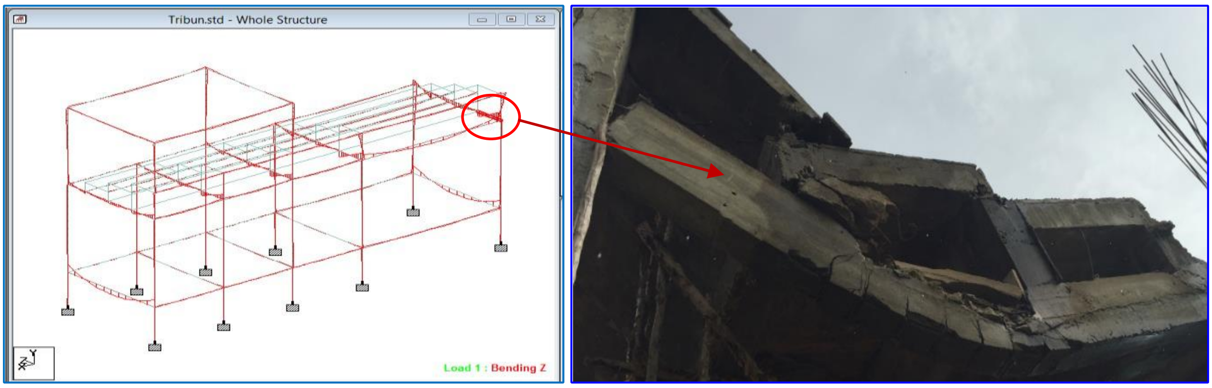

Figure 6. The location of the maximum moment of the Staad Pro V8i software result which is also the location of the collapse of the Tribune beam

The block reinforcement designed by the software to carry the dead load alone is at least 3D12 and 3D16 (see Figure 8), while in the working drawing and installed condition is 2D10 (see Figure 2.d), this means that the rebar of the attached beam does not inflamed so that it can lead to the collapse of the structure.

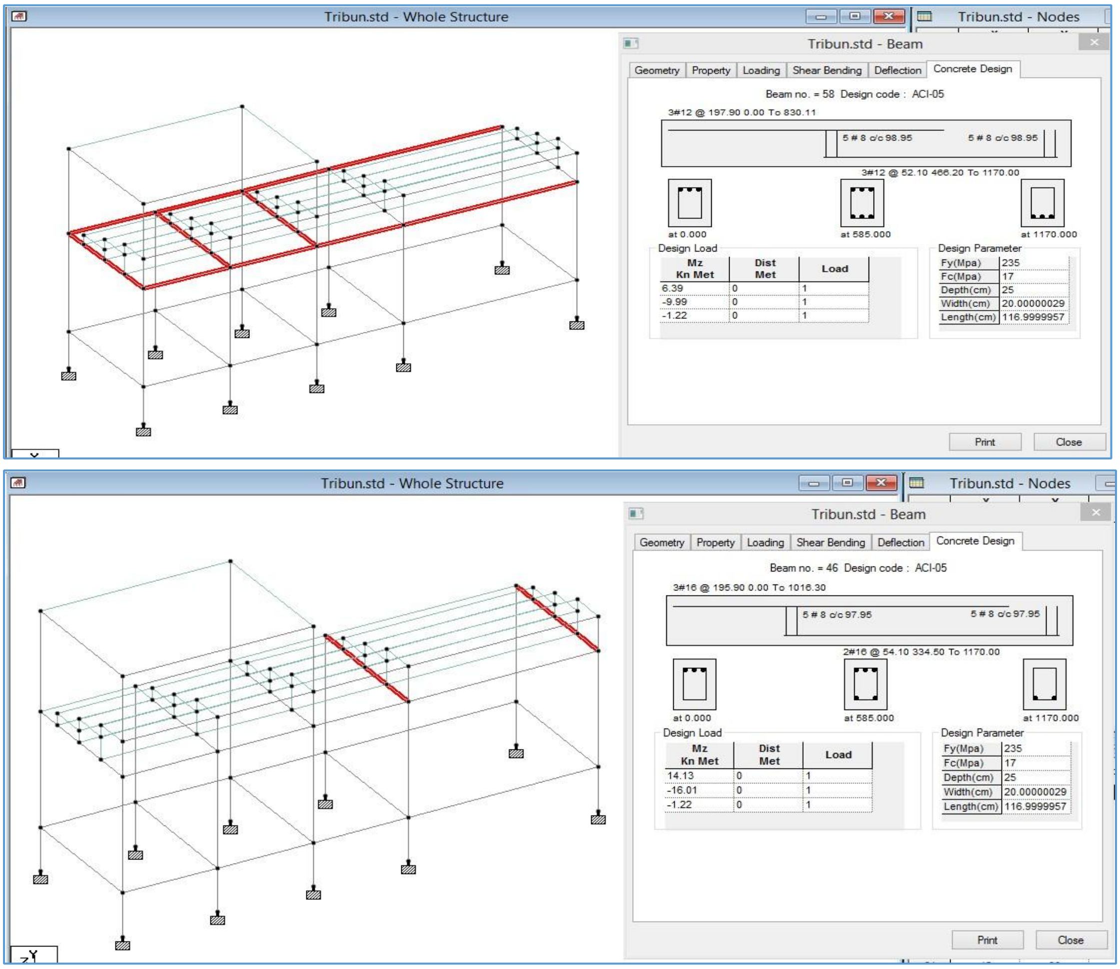

Figure 7. The results of the 3D12 and 3D16 Tribune beam reinforcement using Staad Pro V8i Software

From the results of the analysis of Staad Pro V8i Software, it can be known the contours of the voltage that occurs in the structural elements of the concrete plate, so that the location of the maximum voltage (red color) can be known. potentially cracking to the point of collapse (see Figure 8).

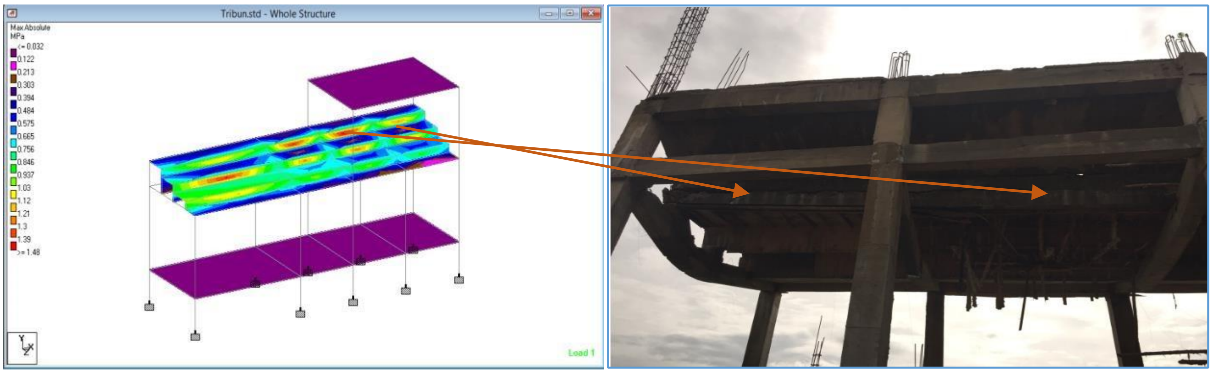

Figure 8. Location of maximum stress of concrete slab elements resulting from potentially Staad Pro V8i Software

In addition, it can also be known the contours of the voltage that occurs in the structural elements of the concrete block, so that it can be known the locations of the maximum voltage (red beam in the Z direction) that has the potential fractured to the point of collapse (see Figure 9). The beams have a tensile stress value exceeding the tensile stress of the concrete permit (f_r = 0.7. $\sqrt{f_c'}$ = 0.7. $\sqrt{17.67}$ = 2,942 MPa).

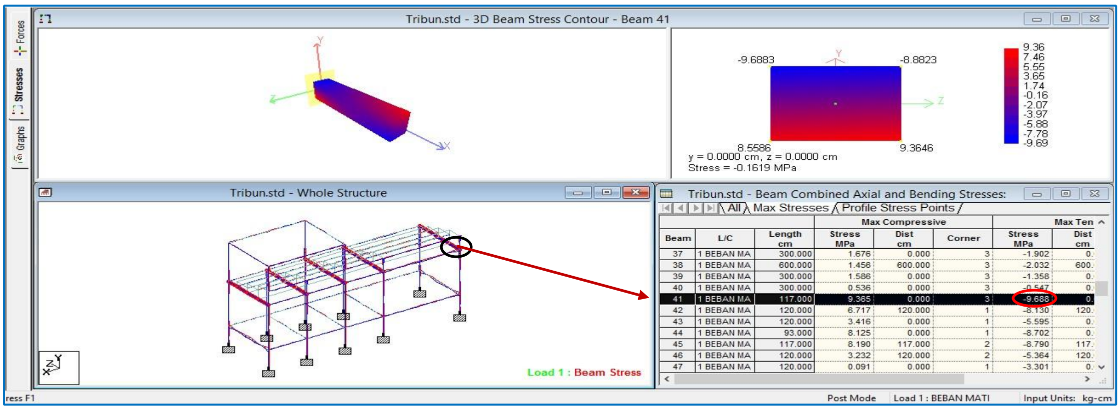

Figure 9. The location of the maximum tensile stress on the beam elements resulting from the Staad Pro V8i Software potentially causing cracking of beam structures

2) Column Looping Design

The column reinforcement from the software design to carry the dead load alone is at least 8D12 (see Figure 10), while in the working drawing and installed condition is 12D12 (see Figure 3.a), this means that the reinforcement of the terracing column is sufficient to carry the dead load of the structure.

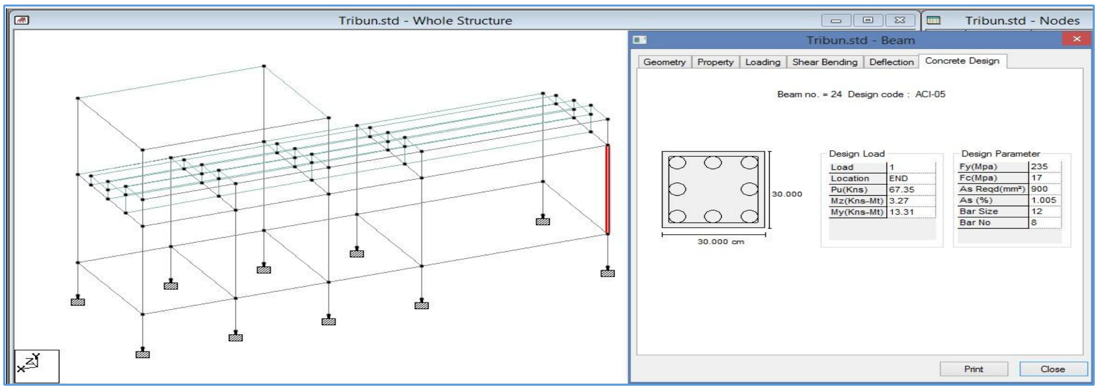

Figure 10. Reinforcement column Tribune results Staad Pro V8i Software

f) Scaffolding and Formwork Strength Factor

Scaffolding and formwork as a buffer, especially during concrete, are very influential on the safety of workmanship. If it is not strong enough, both because of the quantity, distance, and quality of materials, it will cause a decrease in the structure, and the collapse of the structure during the concrete cast work and the process of hardening it.

4. CONCLUSIONS

From the results of the analysis of field examinations and computer model simulations of the condition of the swimming pool concrete stand structure after experiencing a collapse, it can be concluded as follows:

1) Overall the concrete columns are still in good condition (seen from cracks, slopes, and Hammer Test tests), with the exception of the columns that are tilted.

2) The entire 1st floor concrete beams and slabs suffered severe damage and had to be demolished.

3) The approximate compressive strength of concrete on the column is 116.64 kg/cm 2 to 229,780 kg/cm 2, while the quality of concrete plan K-225 ($\surd_{bk}'$= 225 kg/cm ^{2}) (from the hammer test results).

4) The collapse of floor slabs and concrete blocks of the Tribune is more due to 3 factors, namely:

   a) The design factor of repeating beams that are not capable of carrying the load.

   b) Factors hardening blocks and concrete slabs that are still not old enough.

   c) Scaffolding strength factor that is unable to withstand the load of beams and floor slabs during the concrete hardening process.

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