Assessment and Rehabilitation of Concrete Buildings

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Abstract - The process of rehabilitating the old structures in a new manner coincides with the modern development of the new uses is one of the things that the countries are urging nowadays because of the technological development in the building materials or the new jobs. The objective of the system for the rehabilitation of enterprises in this case is how old buildings are suited to the new uses of users behavior.

The main objective of this study is to evaluate and rehabilitate the old reinforced concrete buildings in terms of identifying the symptoms and problems of degraded concrete structures and recognizing the importance of restoration in order to increase the load carrying capacity of it in future. Therefore, the assumptions of the inefficiency of the building to withstand the loads may be due to errors in the design stage, or errors in the implementation phase, or due to the problems of deterioration due to environmental conditions surrounding the building. In order to achieve the objective and the hypotheses above, the site was visited several times and tested materials in terms of the form of secondary data as well as checking the integrity of the drawings executed by re-analysis and design. Finally, the state of rehabilitation of the building was verified after the robot structural analysis program was carried out to analyze and design the concrete structures.

Keywords:Assessment, Rehabilitation, Concrete structures, Building materials,Repair, Symptoms,Strengthening, Restoration, Implementation, Deterioration and Structural analysis .

I. INTRODUCTION

A good repair improves the function and performance of structures, restore and increase its strength and stiffness, enhances the appearance of the concrete surface, provide water tightness, preventing ingress of the aggressive species to the steel surface durability. Of course the repairing methods rather than replacement structures should become both environmentally and economically preferable.

Depending upon the state of the structure and the desired post intervention performance level, rehabilitation can be divided into two categories: repair and strengthening.

- Repair is the rehabilitation of a damaged structure or a structural component with the aim of restoring the original capacity of the damaged structure.
- Strengthening, on the other hand, is the process of increasing of the existing capacity of a damage and non-damaged structure (or a structural component) to a specified level [1].

II. CAUSES OF DISTRESS AND DETERIORATION OF CONCRETE

The list of potential causes of distress and deterioration of concrete is a long one. A few examples include accidental loadings, design mistakes, chemical reactions, construction defects, deterioration caused by cyclic freezing and thawing, cavitations, structural overloads, foundation movement and settlement of soil, growth of vegetation, creep, elastic deformation, poorworkmanship, abrasion, plastic cracking, fire damages and poor quality construction [2] [3] [4].

III. CONDITION AND METHODOLOGY OF ASSESSMENT BUILDINGS

(A)*The main steps of condition assessment willbe;*

a) To record the damage if any, and find out the causes for distress.

b) To assess the extent of distress and to estimate the residual strengths of structural components and the system including the foundation.

c) To plan the rehabilitation, retrofitting and strengthening of the building [5].

(B)*Inspection steps:*

1. Visual Inspection [6].

2. Inspection for Equipment: included Schmidt Rebound Hammer Test , Core Test and Ultrasonic Pulse Velocity [7] [8] [9].

3. Autodesk Robot Structural Analysis Professional software.

IV. CASE STUDY

(A) Building data:

- Address : Omdurman Almohandsein

- The history of construction: 1992.
- Type of building: Implementation (skeleton).
- Number of stories: One plus three.
- The system of floor storey implementation (flat slab).
- Construction materials used (reinforced concrete, mild steel with diameters; 16 mm, 12 mm and 6 mm for stirrups).
- Area of building: 308 m^2.

(B) Building Investigation:

During the building investigation and inspection, the findings were as follows:

1. Foundations:

Many foundationswere eccentrically loaded in isolated footing as shown in Fig. 1.

Fig. 1: Eccentrically loaded footing.

2. Grade beams State:

This resulting some cracks at the soffit of grade beams which is led concrete cover to fall as well as minimization the nominal diameter of main bars and shear stirrups as shown in Fig. 2.

Fig. 2: Severe corrosion on grade beam reinforcement.

3. Column State:

Which resulting in some cracks that led discontinuity of column reinforcement into foundation as shown in Fig. 3.

Fig. 3: Severe corrosion on steel bars ofeccentrically loaded columns.

4. Slab state:

All slabs on all floors are established as flat slab with depth ranges between 17 cm to 20 cm as shown in Fig. 4.

Fig. 4: Measuring depth of flat slab.

V. AUTODESK ROBOT PROGRAM ANALYSIS AND DESIGN RESULTS FOR CASE STUDY

- *Presentation of Results:*

In this investigation results were presented as percentages from the ultimate results and discussed all hypothesis of the research to make sure that the process is answered the Hypothesis.

(1) Foundation Results:

The foundation results presented in this section include dimension [TABLE 1], enlargement percentage [TABLE 2 and Fig. 5], loading capacity of foundation at serviceability limit state [TABLE 3 and Fig. 6] and reinforcement area of foundation [TABLE 4 and Fig. 7].

TABLE 1: Foundations dimension.

Items	Old section	Depth	New section	Depth
F1	1.2×1.2 m	45 cm	2.4×2.4 m	45 cm
F2	1.5×1.5 m	45 cm	2.4×2.4 m	45 cm
F3	1.8×1.8 m	45 cm	3.4×3.4 m	55 cm

TABLE 2: Enlargement Percentage of Foundation.

Items	Old section	New section	Enlargement Percentage
F1	1.2×1.2 m	2.4×2.4 m	100%
F2	1.5×1.5 m	2.4×2.4 m	60%
F3	1.8×1.8 m	3.4×3.4 m	88.89%

From above tables, we evaluate that the enlargement percentage for (F1) is 100% from old section, also the enlargement percentages for (F3) and (F2) are 88.89% and 60%,respectively from old sections.

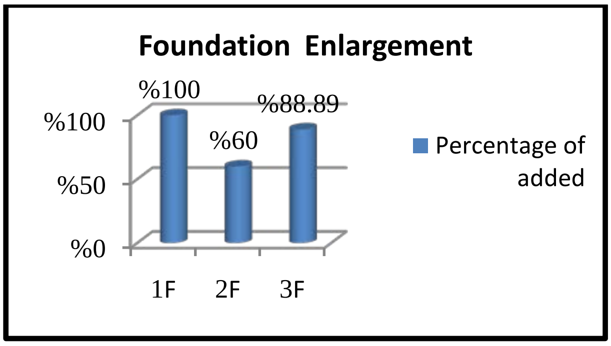

Fig. 5: Enlargement Percentage of Foundation.

TABLE 3: Loading capacity of Foundation at serviceability limit State.

Items	Old SLS capacity	New SLS capacity	Increased Percentage
F1	0.5065 < 1	1.37 > 1	170.48%
F2	0.4542 < 1	1.017 > 1	123.9%
F3	0.3169 < 1	1.018 > 1	221.24%

From TABLE 3 that evaluate SLS loading capacity, the increased percentage for (F3) is 221.24% from the old loading capacity, also the increased percentages for (F1) and (F2) are 170.48% and 123.9%,respectively from the old SLS loading capacity.

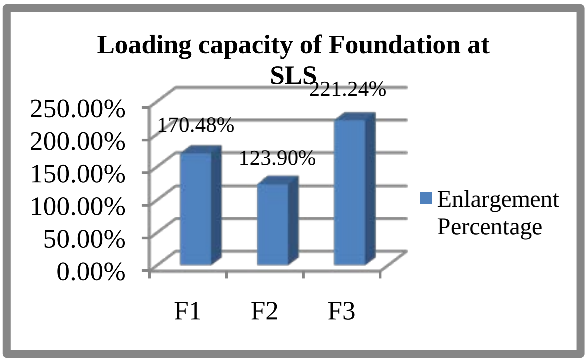

Fig. 6: Loading capacity of Foundation at serviceability limit State.

TABLE 4: Reinforcement Area of Foundation.

Items	Old area of reinforcement (mm^2)	New area of reinforcement (mm^2)	Increased Percentage
F1	1,608	2,300	43.03%
F2	2,010	2,300	14.43%
F3	2,412	3,400	40.96%

From upper table we evaluate that the increased percentage of reinforcement area for (F1) is 43.03% from the old reinforcement area , also the increased percentages of reinforcement area for (F3) and (F2) are 40.96% and 14.43%,respectively from the old reinforcement area.

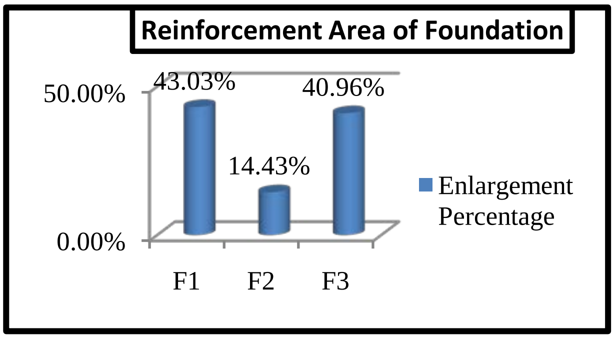

Fig. 7: Reinforcement Area of Foundation.

(2) ColumnsResults:

The results of columnspresented in this section include dimensions [TABLE 5], Enlargement percentage [TABLE 6 and Fig. 8], column loading [TABLE 7 and Fig. 9] and reinforcement area of column [TABLE 8 and Fig. 10].

TABLE 5: Columns dimension.

Items	**Type**	**Old section**	**New section**
C7	Center column	250×450 mm	650×900 mm
C21	Corner column	250×250 mm	650×900 mm
C10	Edge column	250×250 mm	650×900 mm

TABLE 6: Columns Enlargement percentage.

Items	Type	Old section (mm)	New section (mm)	Enlargement percentage
C7	Center column	250×450	650×900	160%
C21	Corner column	250×250	650×900	416%
C10	Edge column	250×250	650×900	416%

From TABLE 6, we evaluate that the enlargement percentage for center columns (C7) is 160% from old section, Moreover the enlargement percentage for the corner column (C21) and the edge (C10) is 416% and 416%, respectively from old section.

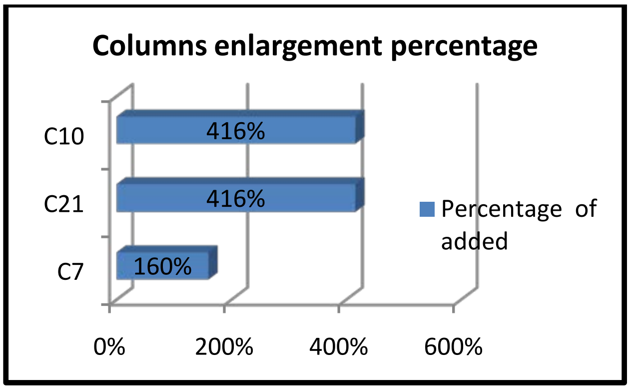

Fig. 8: Columns enlargement percentage.

TABLE 7: Columns Loading.

Items	Old loading (kN)	New loading (kN)	Enlargement Percentage
C7	2396.20	2478.25	3.42%
C21	516.83	638.65	23.57%
C10	1109.42	1234.92	11.31%

From TABLE 7 that evaluate loading enlargement,the percentage for (C21) is 23.57% from the old loading.Moreover, the loading enlargement percentages for (C10) and (C7) are 11.31% and 3.42%, respectively from the old loading.

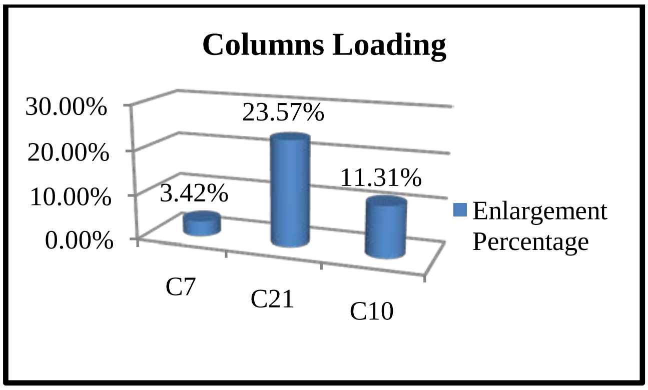

Fig. 9: Columns Loading.

TABLE 8: Reinforcement Area of columns.

Items	Old area of reinforcement (mm^2)	New area of reinforcement (mm^2)	Enlargement Percentage
C7	1,206	3,216	166.67%
C21	1,206	3,216	166.67%
C10	1,206	3,216	166.67%

From above Table, the all evaluation of enlargement percentage for (C7), (C21) and (C10) is 166.67% from old columns reinforcement area.

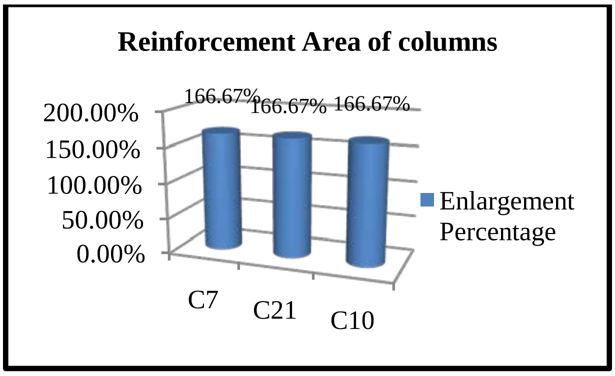

Fig. 10: Reinforcement Area of columns.

- *Discussion*
  - *Hypothesis:*

1. Building inaccuracy may be due to design phase.
2. Building inaccuracy may be due to construction phase.
3. Building inaccuracy may be due to deterioration problems.

(1) Foundation:

foundations are constructed upper the existing ones by using a reinforced concrete according to supervisor engineer comments that require F1 from (1.2×1.2) m to (2.4×2.4) m with depth 50cm and with increasing percentage of 100%, F2 constructed from (1.5×1.5) m to (2.4×2.4) m with depth 50cm and with enlargement percentage of 60%, and F3 increased from (1.8×1.8) m to (3.4×3.4) m with depth 55cm and with enlargement percentage of 88.89%.

Design for the severability limit state that concluded the loading capacity evaluation for (F1) is increased from (0.5065<1) to (1.37>1) by anenlargement percentage of 170.48% from the old SLS loading capacity.Moreover, the SLS loading capacity evaluation for (F2) is increased from (0.4542<1) to (1.017>1) by anenlargement percentage of 123.9% from the old SLS loading capacity, and the SLS loading capacity evaluation for (F3) is increased from (0.3169<1) to (1.018>1) by anenlargement percentage of 221.24% from the old loading capacity.

The area of Foundation reinforcement that concluded the evaluation for (F1) is increased from (1,608mm^2) to (2,300 mm^2) by anenlargement percentage of 43.03% from the old reinforcement area.Also the evaluation of foundation reinforcement area for (F3) is increased from (2,010mm^2) to (2,300 mm^2) by anenlargement percentage of 40.96% from the old reinforcement area, and the evaluation for (F3) is increased from (2,412mm^2) to (3,400 mm^2) by anenlargement percentage of 14.43% from the old reinforcement area.

Therefore, we find this enlargement confirms the validity of the first hypothesis provided building inaccuracy might be due to design phase.

Then proofing and protecting all footings from the effect of moisture and corrosion in future by applying membrane sheets and then painted them with short columns by bituminous coating of three layers to the natural ground surface.

Thus, we find this retrofitting confirms the validity of the third hypothesis provided building in accuracy might be due to environmental phase.

(2) Grade beam:

Steel jacketing consists from steel angles and strips 2 inches to tie the old beam in order to strengthen its sectors in accordance to comments of supervisor engineer and graphics, inserting steel jacketing for new columns then made a concrete cover of thickness 10 cm around perimeter of the old beam.

At the end, underground grade beam have been painted by bituminous coating to protect it from corrosion in future.

Then, we find this increasing confirms the validity of the third hypothesis provided building in accuracy might be due to environmental phase.

(3) Columns:

All columns were constructed by using reinforced concrete according to supervisor engineer comments who is required C7 center column to be increased from old section (250×450 mm) to new section (650×900 mm) with anincreasing percentage of 160%. Also columns(C21) corner column and (C10)edge columnwere constructed from old section (250×250) mm to new section (650×900) mm with anenlargement percentage of 416%.

Design for the severability limit state that concluded the loading evaluation for (C7) is increased from (2396.20 kN) to (2478.25 kN) by anenlargement percentage of 3.42% from the old SLS loading.Moreover, the SLS loading evaluation for (C21) is increased from (516.83 kN) to (638.65 kN) by anenlargement percentage of 23.57% from the old SLS loading, and the loading evaluation for (C10) is increased from (1109.42 kN) to (1234.92 kN) by anenlargement percentage of 11.31% from the old loading.

The evaluation of Foundationsreinforcement area for (C7, C21 and C10) are increased from (1,206mm^2) to (3,216mm^2) by anenlargement percentage of 166.67% from the old reinforcement area.

Therefore, we find this increasing confirms the validity of the first hypothesis provided building inaccuracy might be due to design phase. Also, confirms the validity of the third hypothesis provided building in accuracy might be due to environmental phase.

The new column is inserted on the second floor and reinforced by eight (8) bars 16 mm with shear stirrups 8mm atevery 20 cm in accordance to comments of supervisor engineer and graphics.

Thus, we find this increase confirms the validity of the second hypothesis provided building inaccuracy might be due to construction phase.

VI. CONCLUSION

Thispaper concluded that a good study of the causes of damage and cracking of concrete structures increases the possibility of preservation.Operational problems are the most common causes of damage and cracking of concrete structures that may lead to their collapse and it is very important to assess the size of the deterioration in the building to make the appropriate decision on how to deal with it, by either removal or treatment or strengthening.Eventually, do not increase the number of floors on a building without studying the design constraints.

VII. REFERENCES

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