STRENGTHENING OF A FLAT PLATE SLAB -CASE STUDY

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Abstract-Flat Plate Slab is a popular structural floor system. The popularity of this structural system is due to the speed of construction, which has become a critical consideration in many projects. The slab could be deficient because of under-design or lack of quality control. Strengthening of reinforced concrete slab for flexural is crucial to enhance the capacity of the deficient slab. This study describes the strengthening methodology for a badly designed-story building having Flat Plate slab flooring system. A visual and detailed inspection of the building was carried out, and the bottom and top cracks on the flooring system were inspected thoroughly. The deflection on each floor panel was observed in detail. The pattern of the cracks was noted in the soffit of each slab panel and at the top and in the middle and column strips. The cracks were measured using a digital vernier caliper. The deflections were measured using auto level and inverted staff rod. The whole building was modeled in ETABS software considering all the in-situ parameters. The design was reviewed and found that the slab was under-designed in flexural and shear reinforcement. This paper deals with the flexural strengthening of reinforced concrete (RC) slab which is deficient in flexural steel. This work conducted a detailed field investigation and modeling to control slab deflection and crack using several strategies such as column jacketing, drop panels, creation of beams. This study suggested the best economical and safer solution for a badly designed plate slab flooring system. The innovation of this case study is real big scale commercial building where in literature small scale structures have been discussed.

Keywords- Flat Plate slab, Strengthening, Flexural capacity, Column Jacketing, Drops panels

1 Introduction

Flat plate structures are flat slab constructions without drop panels. Flat Plate slab constructions are commonly found in commercial and residential structures. Flat plate buildings have several advantages, including simple formwork, lower construction costs, ease of installation, greater flexibility in interior arrangement, ease of future restoration, and more clear space. Increased architectural design freedom will also help to reduce maintenance and building costs[1]. Since this structural method was implemented, flat slab strengthening approaches have emerged. Depending on the breadth of the strengthening solution chosen, it could range from a simple extension of the column that supports the slab to more complex solutions involving composite materials[2]. Over several decades, external bonding (EB) technology has been widely employed in civil engineering to strengthen reinforced concrete (RC) structures[3]. EB-bonded steel plates can successfully raise the ultimate flexural capacity and stiffness of the reinforced structure, delay the emergence of the first crack, and lower the crack breadth of RC structures[4]. The major drawbacks of EB-steel plate technique are the corrosion of the steel plate and the premature failure due to plate end debonding of steel plate and shear, which prevent the strengthened member to obtain higher flexural capacities[5],[2]. The corrosion of the steel plate and premature failure owing to plate end debonding of steel plate and shear are the key downsides of the EB-steel plate technology, which prohibit the reinforced member from achieving larger flexural capabilities[6], [7]. The most frequent materials used to reinforce RC structures are steel and fiber-reinforced polymers (FRP). Although each material has its own set of benefits for EB applications, it also has its own set of drawbacks. Steel plates are heavy and have poor corrosion resistance, and their thickness is limited for strengthening RC structures due to a lack of shape flexibility[3], [8]. This research study uses steel and concrete to strengthen a Flat Plate Slab. Finding existing strength of selected structure & expected future life at present condition. Strengthening of a plate slab. Safe and economical solutions for strengthening a flat slab have less reinforcement than required.

2 Methodology

2.1 Preliminary Data & structure details:

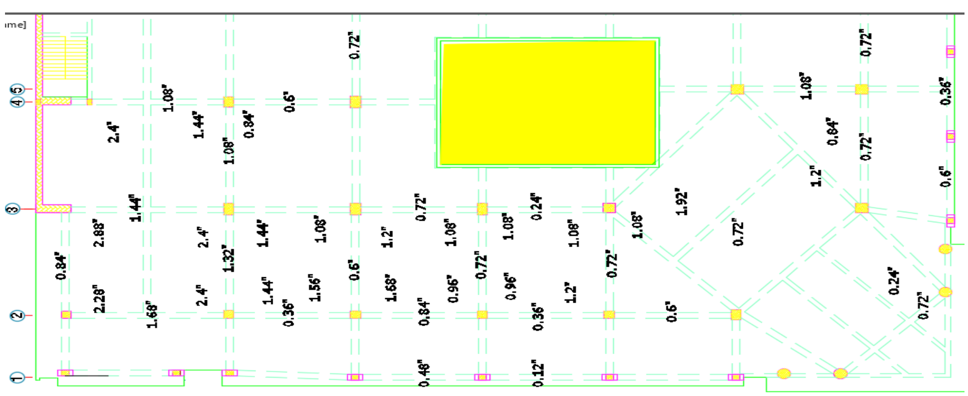
The building is in Rawalpindi Fifth road which occurs in seismic zone 2B according to building code of Pakistan . It' a commercial shopping mall consisting of eight story (three-story basement). The building is constructed in 2018. The slab type is Flat Plate. Span is 25'x25'.

2.2 Preliminary inspection of the building

This structure has been thoroughly inspected from top to bottom, detecting cracks, spells, crazing, seepage, and so f orth. The key areas of inquiry and repair are highlighted on the building's plan. All these cracks are in the middle strip at the bottom of the slab in both x and y direction as shown in figure a and figure b. The pattern and width of the cracks measured digital vernier caliper. Figure F and G represent the cracks at the bottom of the slab, also these cracks and their pattern is noted on plan of the building for each story's slab as shown in figure D. Furthermore, the deflection of slab is found by detailed survey using Auto-level and inverted staff rod and written on building plan in inches as mentioned in figure C. These values of deflection are more than the allowable limit as specified by ACI-318-11 in 9.5(b) . Some cracks are also detected around the column at the top of the slab. these are shown in figure E. The experimentally measured widths of the cracks were found in the range of 0.2mm to 1.64mm at the bottom in the middle strip. The width of the cracks at the top of the slab varies from 0.25mm to 1.18mmm.The middle strip at the bottom of the slab and in the column strip at top of the slab. Deflection and crack's width were measured .The similar pattern of cracks was specialized in middle strip tut the slabs.

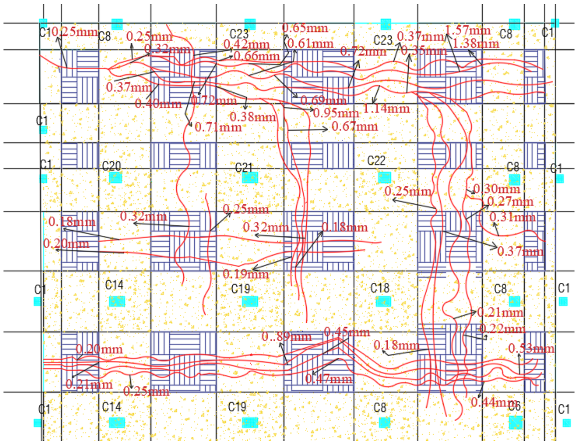
(A) (B)

Figure 1: A. and B. cracks pattern at the bottom of the slab

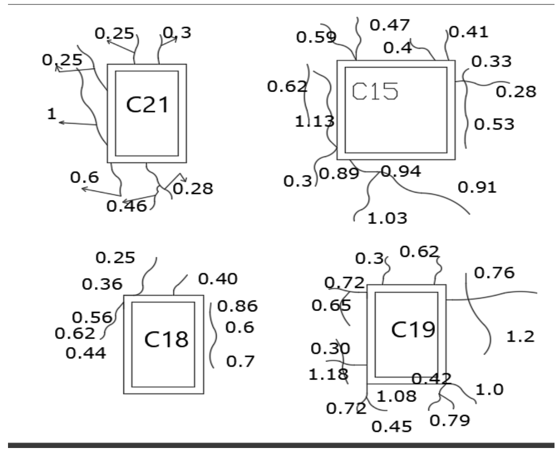


(C)

Figure 2: C. Deflection measured during Visual inspection using auto level and staff rod



(D)



(E)

Figure 3: D. cracks pattern and cracks width measured in millimeters of Ground Floor slab.

Figure 3:E. cracks in middle strip of columns at the top of slab

(F)

(G)

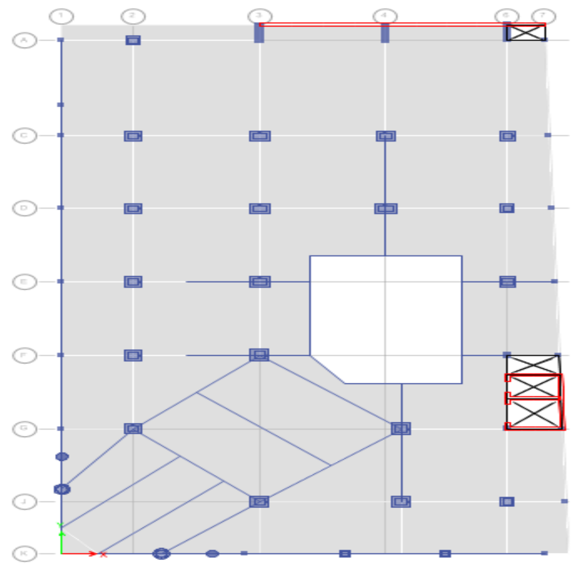
Figure 4: F. and G. width of the cracks measured by Digital Vernier Caliper

3 SOFTWARE MODELLING & ANALYSIS

This work conducted a detailed field investigation and modelling to control slab deflection and crack using several strategies such as column jacketing, drop panels, creation of beams. The flexural strengthening of RC slab-type elements with concrete and steel to control the deflection of the slab.

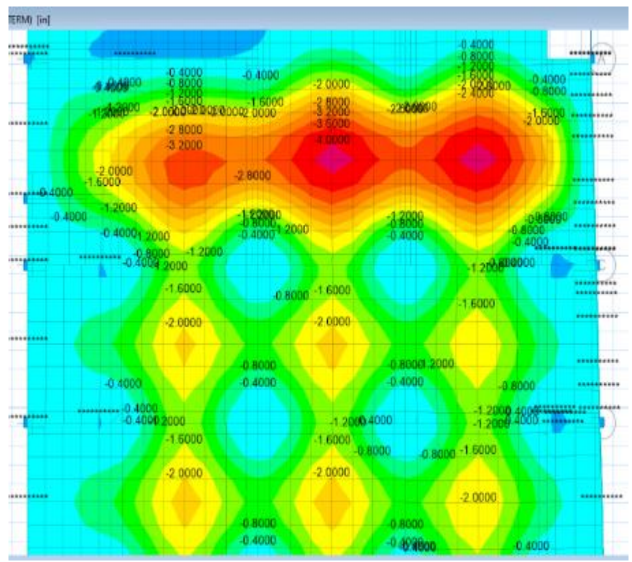
The building is modeled in ETABS according to the drawings. Gravity and seismic loads are applied to the structure. The slab is exported to CSI-SAFE-16 with all defined loads combinations also a new load combination Long Term Deflection is defined, and deflection checked against this combination as shown in figure 9.
Materials are defined in software as Concrete of strength 4000psi and 5000psi and Steel of grade 60,then
Frame sections are defined as Column of 18”x18”,24”x24”,30”x30”,30”x24”,36”x36” and beams are defined 12”x18”,12”x24”,12”x30”,15”x24”,18”x24”,18”x27”,18”x36” also is defined as slab 10” thick and shear wall 9” thick is defined. Load patterns are defined as live load<100, live>100, partition wall load (pw), flooring load (fcd) self-dead load, water load, HVAC and laterals loads EQX and EQY both negative and positive are defined. Seismic loads are defined according to UBC-97 code. Total 38 loads combinations are defined according to ACI-318 code. After defining the materials and frame sizes the model is analyzed and then one story is exported to CSI-SAFE, where long term deflection load combination is also defined. After checking the deflection against long-term load combination, the value of deflection was greater than the allowable limit as shown in figure .Figure 5 H shows the original structure modeled in ETABS-16 .There are peripheral beams on the edges of the slab. The lines represent shear walls .The figure 5 I show the long-term deflection, values vary from 0.4 inches to 3.5 inches. These values

are like Figure 2 C which were obtained from site survey. Figure 6 J describes long term deflection when beams were included whose values vary from 0.28 inches to 0.32 inches. Figure 6 k represents deflection of column Jacketed model slab whose values are varies from 0.4 inches to 3.20 inches. Figure 7 I show deflection of slab with Drop Panel values are up to 0.22 inches. Figure 8 H show long term deflection when a middle column is included and a few beams above the ramp region with maximum value of 0.16 inches.



(H)

Figure 5: H. plan view of ETABS Model



(I)

Figure 5: I. deflection of original slab in inches

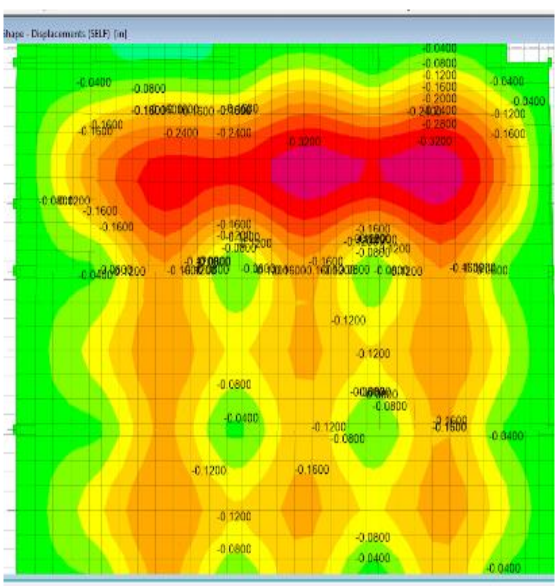


Figure 6: J. Deflection after beams were inserted

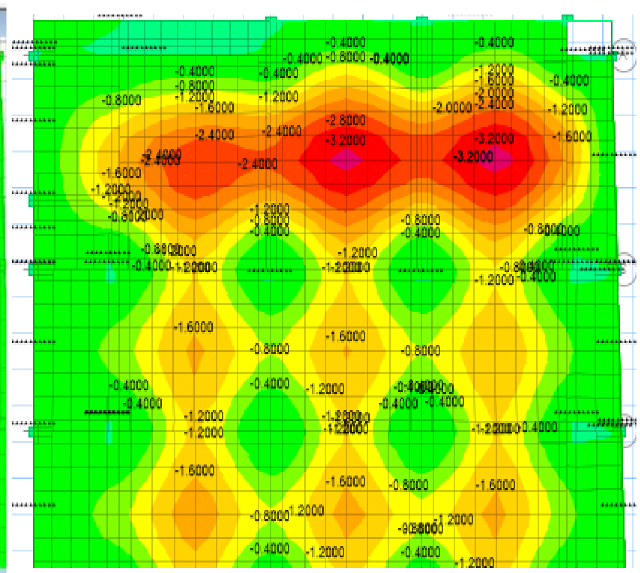
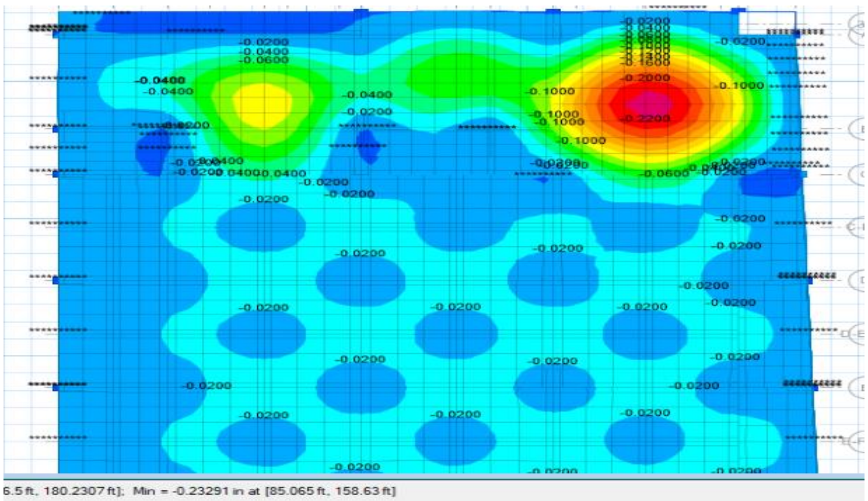
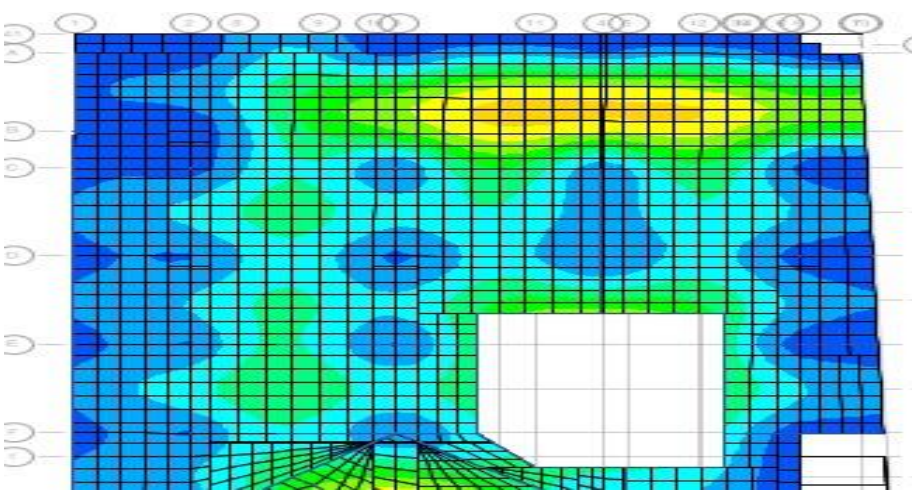


Figure 6: K. Deflection of column Jacketed model slab.



(l)

Figure 7: l. Deflection of slab with Drop Panel



(H)

Figure 8: h. Deflection of the slab when middle column and beams are applied

4 Conclusion

- The collected data of the building was modeled and analyzed in software considering in-situ parameters and the following conclusions were made.
- The cracks and deflection that were present in the building were also confirmed by the software results under the same type of loading which means that the building was under designed.
- Jacketing was applied to the columns, and they were unable to control the deflection of the slab.
- Drops panels were applied to the columns which controlled the deflection.
- Extra Beams were introduced to the model that controlled the deflection of the slab but at the same time it imparts extra weight to the building due to which the building fails in soil bearing pressure.
- A middle column was added to the model and shows the best results for controlling the deflection of slab.
- The best economical is inclusion of the columns in the middle of each slabs' panel throughout the height of the buildings, also a few beams were added to the structure above the ramp region where columns cannot be added to the structure because of access of vehicles to the basements.
- If we apply only beams to all slab ,they increase the weight of the building due to which the building fails in soil bearing pressure. The option of column jacketing cannot control the deflection and cracks of the slab. The method of inserted a middle column and a few beams above ramp area resulted better in term of controlling deflection which can be seen in Figure H and this method can be done easily because above the ramp there are walls where beams can be added. This method is economical because there is no high initial cost of steel and concrete. the span is 25 and 25 feet so middle columns can be added without the compromising the space. The sum up, this method neither creating problems of footing failing nor the issue of cost, so this technique is safer and economical.

5 References

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