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Structural Strength Evaluation by NDE and Load Test of RC Slab Structure, Case Study: RC Deck Slab of Primary Hospital Building, Faculty of Medicine, Thammasat University, Thailand

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ABSTRACT

The primary hospital building of Faculty of Medicine, Thammasat University, Kukhot district, Pathumthani, Thailand is an RC building and serves the primary treatment for local patients. This building has been constructed in early 2011 and finished in 2014. This building is still not yet opened for used due to rather huge deflections of the deck slabs. Such huge deflections can be seen with the naked eye. Undrained rain-waterlog remaining on the roofslap causes corrosion to the reinforced steel as well. As a result, the physicians feel fear of the unsafe building and ask the engineer to perform both nondestructive evaluation (NDE) and load test in order to learn the strength of the problematic deck slabs. The load test results are analyzed both load and rebound portions. The graphs relationship between the loads and deflections and weights against times are plotted and analyzed. Furthermore, the slab deflections are compared with the allowable deflections that allowed by ACI 318/318R as well.

1. Introduction

This article evaluates and checks both the deflection and strength of a RC deck slab that is a structural member in the primary hospital building, Faculty of Medicine, Thammasat University, Lumlukka district, Pathumthani province, Thailand. This building has been constructed in early 2011 and finished in 2014. The building structure is a two-story reinforced concrete building and still not yet opened for use as it encounters a problem of rather huge deflections of the deck

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slabs. First step, the visual inspection is applied for observation on building damages such as the cracks, deformations (deflections), water leaking, reinforcing steel corrosion, and etc. Then, the other suitable NDE methods and load test are done in order to get the damage causes, structural (slab) strength, and optimal repair method respectively.

There are many kinds of damages that occur in the deck slabs especially the slab deflections. Some deck slab deflections are more than 8 cm. and rain-waterlog add more load on the slab and also causes the steel corrosion. For this investigation, the slab structure evaluation methods are comprised with the NDE methods, which are the visual inspection and Schmidt Hammer or Rebound Hammer methods, and structural load test.

2. Literature Review

Masetti et al. (2006) studied the behavior of one-way reinforced concrete slab. The hydraulics jack was used for loading on the slab and the Linear Variable Displacement Transducers (LVDT) was used to collect the slab deformations. The results were obtained from the analysis of the graph relationship between load and deflection. The maximum deflection should be not more than the allowable deflection from ACI 318 and the rebound (residual) deflection should be not less than the standard residual deflection that has followed ACI 318 as well.

Casadei et al. (2005) studied the structure response of two way slab. The hydraulics jack was used for loading on the slab and the LVDT was used to collect the slab deformations. The results were obtained from the analysis of the graph relationship between statics load and deflection and between cyclic loading and deflection. The conclusion was shown that the statics load gave the clearly results (deflection) than the cyclic load.

Ramana (2013) studied the concrete strength of a two way slab by Schmidt Hammer. The results were obtained from the graph relationship between rebound number and concrete strength.

The dimensions of the tested deck slab is 7.32 x 4.74 m. (length x width) and its thickness is 15 cm. The nine dial gages are installed at the points G1 to G9 and the dial gage no.5 (G5) is located at the middle of the slab as shown in Figure 1.

3. Load Test Protocols

From the American Concrete Institute (ACI) standard, two variables are considered for the principle evaluation and they are :

1) Dead load effect such as weight of slab and
2) Live load effect.

By this way, the total load (weight) that is applied on the tested deck slab can be calculated as suggested by ACI 318/318R

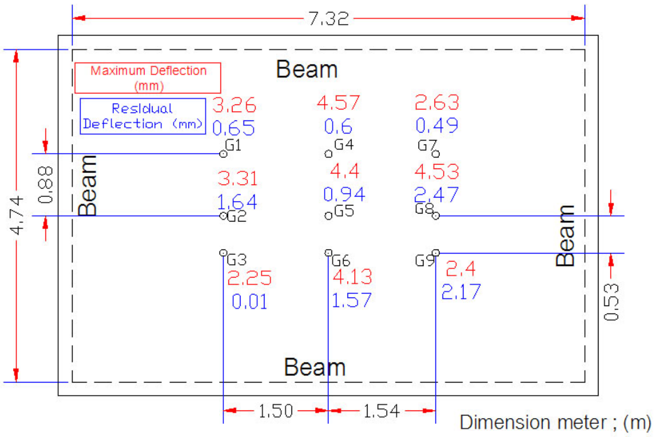

Figure 1: Location of Dial Gauges.

$$\text{Total Load} = 0.85*(1.4*\text{Dead load} + 1.7*\text{Live load}) \quad (1).$$

The ACI requirements and standards for the structural using condition must be considered and limited by two variables that are:

1) Maximum Deflection and
2) Rebound Deflection or Residual Deflection.

According to ACI 318/318R, the maximum deflection and the rebound deflection are

$$\Delta_{max} \leq L^2/20000h \quad (2)$$

$$\Delta_{rebound} \leq \Delta max /4 \quad (3)$$

where
Δ_{max} is the maximum deflection
$\Delta_{rebound}$ is the Rebound deflection or Residual Deflection
L is length of slab on the short side, and
h is thickness of slab.

3.1 Load Testing Procedure

Procedure for load testing

1. Test the concrete strength by Schmidt Hammer (Rebound Hammer) that is an NDE testing-- before Load Test
2. Install the dial gauges no.1 to 9 (G1- G9) onto the deck slab structure for nine points that are located as shown in Figure 1 and the dial gage no.5 (G5) is installed at the middle of the

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slab. The dial gage installation is used the magnetic base (shown in Figures 2) and shown in Figure 3 as well.

3. Record all initial deflections and the temperature prior the testing
4. Increase the load (water weight) step by step from 0%, 25%, 50%, 75%, and 100% of the maximum test load and each load step is held for 1 hour (for this deck slab structure, the design maximum live load equals 200 kg/m2)
5. Except the maximum test load (100%) that has to maintain 24 hours (shown in Figure 4)
6. After 24 hours, the test load is decreased step by step from 0%, 50%, and 100% of the maximum test and each released load step is held for 1 hour.
7. After release all test load, it is maintained for 24 hours.

Figure 2: Dial Gauge and Magnetic Holder.

Figure 3: Dial Gauges installation.

Figure 4: Loading by Water.

4. Testing Results

The testing results from Schmidt Hammer (NDE) are reported in Table 1 and the results from the load test are shown by the table and graph as Table 2 and Figure 5 respectively.

5. Analysis of Load Test Results

The results from the testing (both the maximum and rebound deflections) must be compared with the allowable maximum and rebound deflections (that are calculate from Equation (2) and (3) respectively as shown in Table 3.

Table 1: Schmidt Hammer Testing Results.

(The average concrete strength from Schmidt hammer is 214 ksc.)

Rebound No.	f'_c (ksc)	Rebound No.	f'_c (ksc)	Rebound No.	f'_c (ksc)
32	194	32	194	36	261
33	211	36	261	38	296
33	183	35	246	35	246
31	183	33	211	35	246
29	155	31	183	34	225
32	194	32	194	33	211
33	211	36	261	32	194
30	158	33	211	38	296
32	194	33	211	36	261
32	194	30	158	36	261
31	183	30	158	35	246
34	225	36	261	38	296
32	194	36	261	33	211
33	211	32	194	32	194
31	183	31	183	36	261
31	183	31	183	32	194
29	155	32	194	35	246
33	211	33	211	32	194
33	211	36	261	38	296
32	194	34	225	36	261
32	194	36	261	35	246
32	194	30	158	33	211
33	211	30	158	32	194
33	211	31	183	32	194

Table 2: Dial Gauges Readings.

Dial Gauge Reading (mm)	G1	G2	G3	G4	G5	G6	G7	G8	G9
Load 0%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Load 25% (Step 1)	1.25	1.25	0.55	1.25	1.13	1.14	1	2.96	0.89
Load 50% (Step 2)	1.86	1.85	1.05	1.96	2.60	2.70	1.48	3.41	1.27
Load 75% (Step 3)	2.57	2.6	1.72	3.83	3.62	3.44	2.12	4.03	1.83
Load 100% (Step 4)	3.05	3.07	2.11	4.29	4.11	3.94	2.48	4.35	2.12
Load 100% held for 24 hours	3.26	3.31	2.25	4.57	4.4	4.13	2.63	4.53	2.4
Released Load 50%	2.36	2.39	1.48	3.52	3.35	3.22	1.91	3.81	2.36
Released Load 100%	0.72	0.71	0.07	0.68	1.47	1.68	0.59	2.57	2.33
Released Load 100% held for 24 hours	0.65	1.64	0.01	0.60	0.94	1.57	0.49	2.47	2.17

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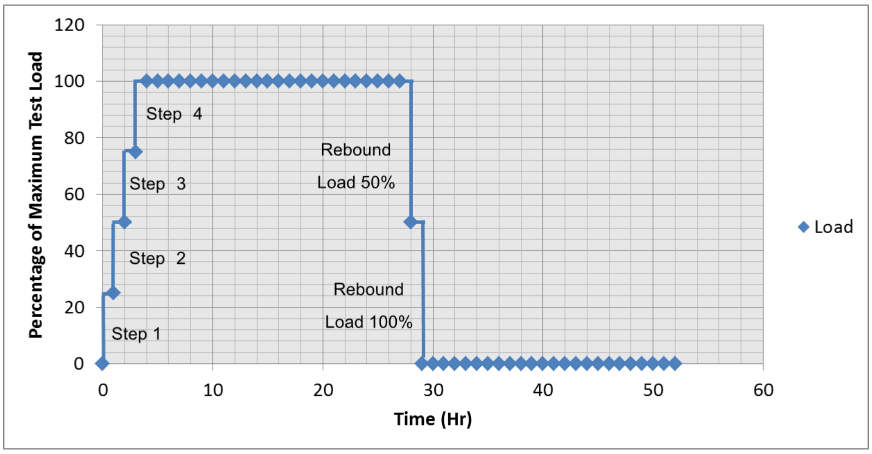

Figure 5: Graph Relationship between Time and Loading Percentage.

Table 3: Testing Deflection (Δ_{max} and $\Delta_{rebound}$) and Allowable Rebound Deflections from ACI 318

Dial Gauge No.	Δ_{max} (mm.)	$\Delta_{rebound}$ (mm.)	(Δ_{max})/4 (mm.)
G1	3.26	0.65	0.81
G2	3.31	1.64	0.82
G3	2.25	0.01	0.56
G4	4.57	0.60	1.14
G5	4.40	0.94	1.10
G6	4.13	1.57	1.03
G7	2.63	0.49	0.65
G8	4.53	2.47	1.13
G9	2.40	2.17	0.60

Note 1. All maximum deflections (Δ_{max}) from testing must be less than the calculated deflection that equals 8.33 mm. (calculated from Equation (2)).
2. The rebound deflections must be less than the calculated rebound deflections that are shown in the last column of Table 3.

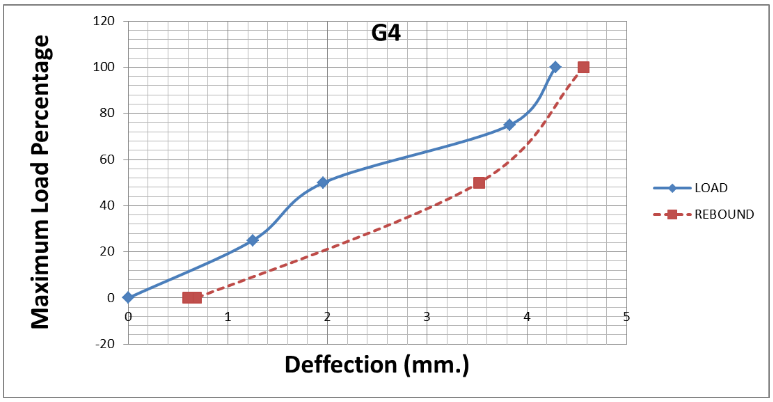

Figure 6: Relationships between Deflection and Maximum Load Percentage for Dial Gage No.4.

For the Rebound Hammer test results, the concrete strength average is 214 ksc as shown in Table 2 that means the slab concrete strength is rather common for the building construction.

The graph, that is shown in Figure 6, show the relationships between the deflection of the maximum slab deflection for the dial gage no.4 (G4) is 4.57 mm and the rebound deflection is to 0.6 mm. For the dial gage no.9 (G9), the maximum slab deflection is 2.4 mm and the rebound deflection is 2.17 mm as shown in Figure 7. From the load test results, all maximum deflections (Δ max) from the testing must be less than the calculated deflection that is 8.33 mm. (calculated from Equation (2)) and the rebound deflections must be less than the calculated rebound deflections that are shown in the last column of Table 3 as well. This building has been suggested for repair because some rebound deflections still exist in the slab structure as shown in Table 3.

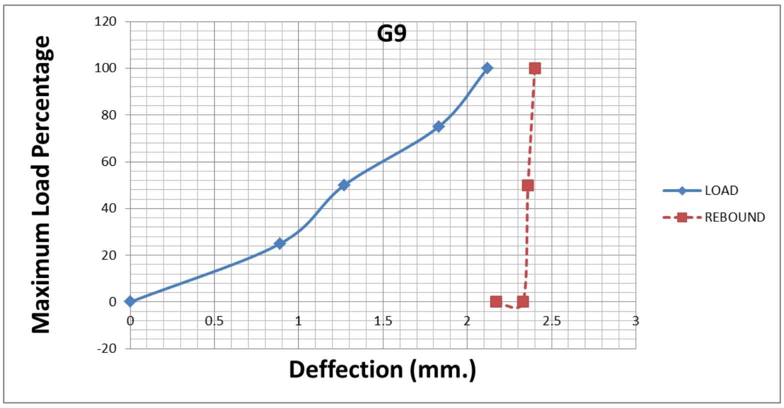

Figure 7: Relationships between Deflection and Maximum Load Percentage for Dial Gage No.9

6. Conclusions

This work investigates structural strength by NDE and load test of RC slab structure of primary hospital building, Faculty of Medicine, Thammasat University, Thailand. After the construction in 2014, the building is still not yet opened for used as rather huge deflections of the deck slabs have been observed with the naked eye. The undrained rain-waterlog remaining on the roof slap causes more load and corrosion to the reinforced steels. This work performs both nondestructive evaluation (NDE) and load test in order to learn the strength of the problematic deck slabs. The load test results are analyzed both load and rebound portions. The plot of relationship between the loads and deflections and weights against times are analyzed. From test observation, greatest deflections do not beyond maximum allowable defection, according to ACI 318. However, the rebounds at some points are fully recovered while at some points are not. Thus, for long term use, it is suggested for proper repair.

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