World Engineering Congress 2010, 2nd – 5th August 2010, Kuching, Sarawak, Malaysia
Conference on Buildings and Infrastructure Technology

CETE43
FULL-SCALE LOAD TEST ON REINFORCED CONCRETE SLAB

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ABSTRACT

A full-scale load test on a reinforced concrete (RC) slab was carried out to investigate the structural adequacy and performance of a double storey shop office building which was converted to a technical college. The RC slab used for the load test had an existing crack defect. The crack was sealed using epoxy resin grouting before the load test. The RC slab was subjected to two static cycles of uniformly distributed load. In the first cycle, the RC slab was loaded with the characteristics imposed load as recommended in the BS 6399. The static load was increased by 60% in the second cycle. Vertical deflection of the RC slab at five locations and crack development were monitored during the load test. The experimental results were compared to numerical results carried out using LUSAS finite element software. The findings showed that the building is safe to carry a factored design load of 4.8 kN/m^2 which complied to the requirement of a college application in accordance to BS6399.

Keywords: Load test, reinforced concrete slab, structural performance.

INTRODUCTION

The structural safety and performance of a building that has been converted to a different application from its original design is the motivation to this paper. Alternatively, if an existing building experienced signs of cracks and damage, its continual service has to be investigated thoroughly. In all such cases, structural appraisal of the existing structures is required. Structural appraisal is a different activity to structural design. It is aimed at assessing the real condition of an existing structure [1, 2]. Sometimes, structural appraisal are also used to check the ability of a structure to sustain increased loads or alterations, and the structures subjected to signs of distress or deterioration, fire and accidental damage. There are many methods available for the structural appraisal, either non-destructive or destructive tests can be used to predict and verify the materials and structural behaviour of the existing structures.

Static maintained load test is widely used as direct measurements of the pile capacity and its settlement under the applied load. However, static load tests on building structures will usually be adopted only after other approaches based on calculation, survey and local tests on materials have failed to demonstrate an adequate margin of safety of the structure under the loads likely to be imposed on it. This is because of the time and cost associated with such tests. A load test of a complete structure is costly and time-consuming [1]. Usually, the purpose of a static load test is: (1) to check the structural behaviour of the structure; (2) to establish a proven load capacity; and (3) to provide a degree of assurance for its future use [3].

In reality, all structures and loads are dynamic in nature. However, for simplicity, the majority of structures and their loading environments may be treated as static for the purpose of both analysis and testing [3]. The loadings considered in the structural design are usually simplified as static dead and imposed loads [4, 5]. The characteristic loads are multiplied with the partial safety factor based on the types of load combination in accordance to limit state design. Generally, a structure or part of a structure can be considered as behaving statically if its response to a particular loading can be predicted by considering the magnitude of the loads, the properties of the materials and the geometry of the structure alone. For most civil engineering and building structures, loads that occur less frequently than about once per hour and are applied at a uniform rate over a period of more than about a minute will produce a static response [3].

This paper highlights a case study of a double storey shop buildings consisting of 13 numbers of 22’× 70’ unit which was originally designed for office use now intended for use as a technical college. A full-scale static maintained load test was conducted on a reinforced concrete (RC) slab of the said building and its results are presented critically in this paper. The load test was carried out on November 2009 over a period of 2 days to check the structural adequacy of the existing slab and its surrounding structures before the building was handled over to the owner.

METHODS, PROCEDURES AND INSTRUMENTATIONS

A preliminary visual inspection of the aforementioned 22'× 70' cast in-situ concrete double storey shop office buildings and a full-scale static maintained load test on the first floor suspended RC slab were carried out in order to ascertain the suitability of the building to be converted as an academic institution. The objectives of the tests were: (1) to assess the structural adequacy; (2) to determine the level of imposed load that can be sustained; and (3) to verify the appropriate remedial work on the existing cracks.

Visual Inspection

A visual inspection was carried out to inspect the condition of the existing buildings, and to identify the method of loading and the slab to be loaded. From the visual inspection, a crack was found on the first floor slab of an end lot building. However, no significant crack was found on other superstructures. There were no significant signs of settlement in the non-suspended ground floor slabs and on the main road in front of the buildings. The doors and sliding windows of the buildings can be easily opened and closed. Based on the ground profile, most likely, the double storey buildings were built on the original ground. Further visual observations deduced that the cracks found on the first floor slabs were not likely due to the settlement of the building foundations.

On the basis of the visual inspection, a slab with a 4 m length crack was selected for a static load test. The crack was found to be from the top to the bottom soffit of the slab. The thickness of the slab was 125 mm and was designed in accordance with BS 8110 [4] by the previous engineer. Part of the first floor plan for the building is shown in Figure 1.

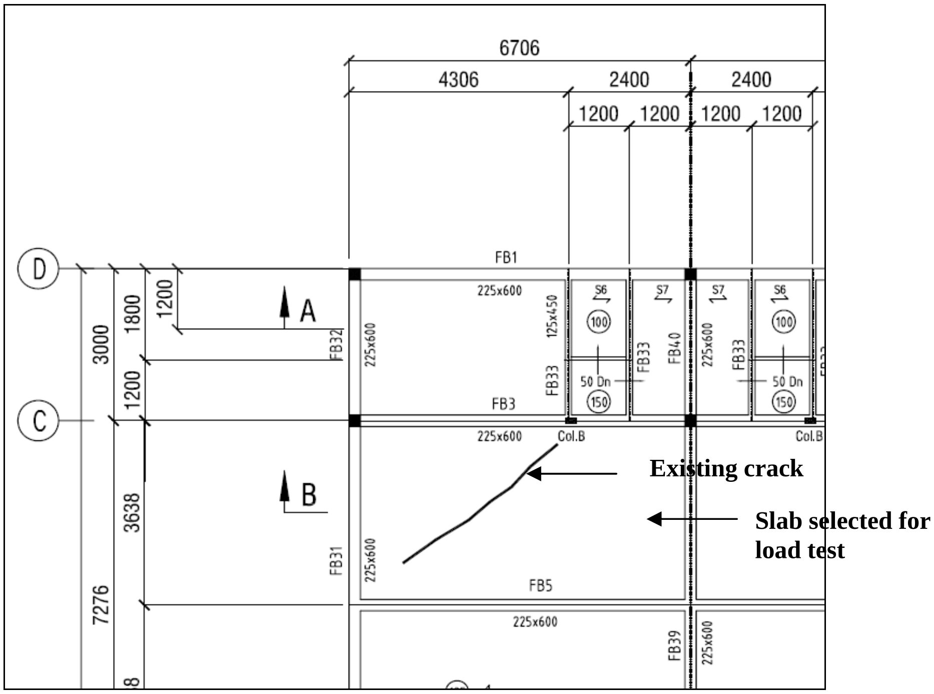

Figure 1: Structural Layout Plan

Load Test

The cracks on the selected slab were first repaired using epoxy resin pressure grouting and then painted with white colour at the bottom soffit. A static load test on this was conducted after 14 days. The applied load was defined as uniformly distributed imposed load (UDL) with a minimum UDL of 3.0 kN/m^2 as recommended in BS 6399-1:1996 [6] for classrooms application. The test load was applied in 2 stages using cement bags of 50 kg/bag. In the first cycle, the slab was loaded to a minimum UDL of 3.0 kN/m^2 and maintained for 8 hours. The total cement bags used for the first cycle numbered 161 bags equivalent to 8050 kg. After the first cycle of maintained load, the test load was increased 60% to 4.8 kN/m^2 and maintained for 24 hours. The total cement bags used for the second cycle were 250 bags equivalent to 12,500 kg. Figure 2 shows the reinforced concrete slab subjected to the static maintained load using cement bags.

Figure 2: Cement bags used as the test load

Measurement of Displacement

Five dial indicators with the accuracy up to 0.01 mm were installed at the bottom soffit of the slab to measure the vertical displacement. Figure 3 shows the points where vertical displacement were measured in the slab. It was assumed that the maximum displacement occurred at the centre of the slab.

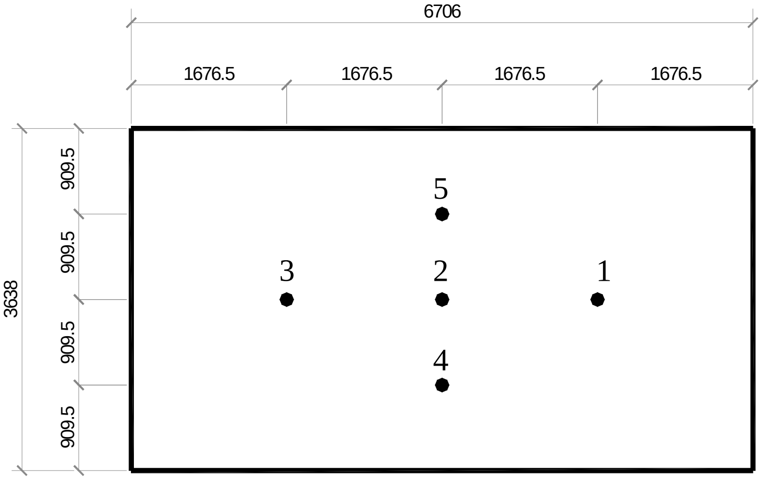

Figure 3: Points of dial indicator installed

The displacements were recorded at the first application of 3.0 kN/m^2 minimum load and subsequently monitored hourly for 8 hours in the first cycle. In the second cycle of load test, displacements were recorded at the first application of 4.8 kN/m^2 maximum load followed by hourly reading for 8 hours and thereafter at 16 and 24 hours after load commencement. Crack detection microscope was used to measure the crack width (if developed) during the load test. Observation of crack propagation and development of the slab and its surrounding structures was monitored during the test.

RESULTS AND DISCUSSION

Visual inspection found a diagonal crack in one of the first floor slab (Figure 1). This slab was located on the first floor of the end shop lot. There was no significant crack found on the RC frames. The diagonal crack on the slab was seen from the top to the bottom soffit of the slab. Further investigation deduced that this crack was not a structural crack but caused by concrete drying shrinkage and improper concrete curing at construction stage. It was observed that this particular slab was exposed to direct sunlight which has likely increased the drying shrinkage process. Drying shrinkage is aggravated especially in thin slab layers. Curing will have a significant beneficial effect on tensile strain capacity and it is for this reason that curing reduces the risk of cracking [7].

Displacement

The dial indicator at point 1 encountered problem during the load test. Therefore, reading for dial indicator at point 1 was not recorded. The displacements at point 2, 3, 4 and 5 are tabulated in Table 1 while the displacements versus time plots are shown in Figure 4 to 7.

Table 3: Displacement reading for the slab

Time (Hour)	Displacement (mm)				Remark
	Point				
	2	3	4	5	
0	0	0	0	0	Before loading
0	0.48	0.38	0.44	0.38	Instantaneous displacement at 3.0 kN/m^2 load application
0.5	0.49	0.38	0.45	0.39	Loaded with 3.0 kN/m^2
1	0.50	0.39	0.46	0.39	
2	0.50	0.39	0.46	0.39	
3	0.48	0.38	0.44	0.37	
4	0.48	0.38	0.44	0.37	
5	0.48	0.38	0.44	0.37	
6	0.48	0.38	0.44	0.37	
7	0.47	0.39	0.43	0.36	
8	0.46	0.39	0.44	0.35	
8	0.76	0.63	0.70	0.55	Instantaneous displacement at 4.8 kN/m^2 load application
8.5	0.75	0.63	0.70	0.54	
9	0.75	0.63	0.70	0.54	Loaded with 4.8 kN/m^2
10	0.75	0.64	0.70	0.54	
11	0.75	0.64	0.70	0.54	
12	0.75	0.64	0.70	0.53	
13	0.75	0.64	0.70	0.53	
14	0.75	0.64	0.69	0.50	
15	0.75	0.64	0.68	0.50	
16	0.75	0.62	0.68	0.49	
24	0.82	0.66	0.75	0.59	
32	0.84	0.67	0.76	0.61	

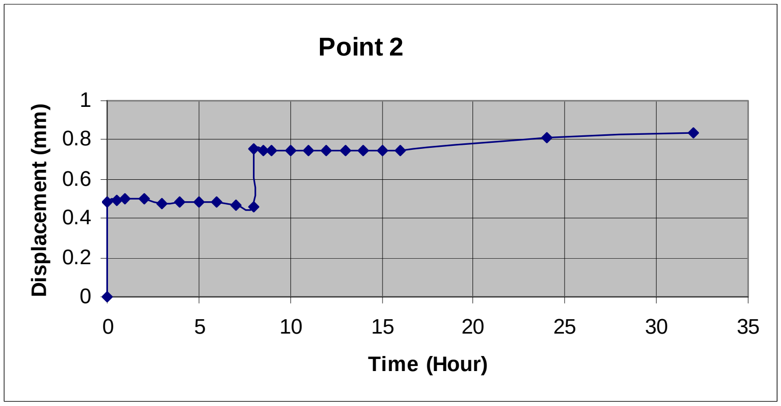

Figure 4: Displacement versus time at point 2

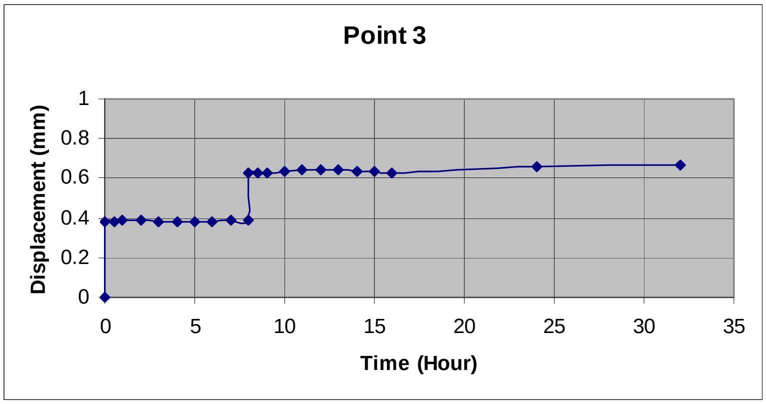

Figure 5: Displacement versus time at point 3

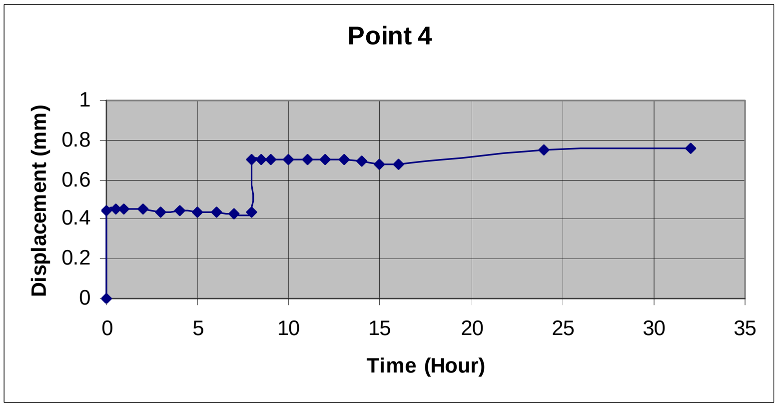

Figure 6: Displacement versus time at point 4

By assuming the displacement at point 1 is equal to point 3 (see Figure 3), the deflection along the mid-span at both directions under load at 8, 16 and 32 hours are shown in Figures 8 and 9 for points 3, 2, 1 (longitudinal direction along 6706 mm length) and points 5, 2, 4 (lateral direction along 3638 mm length), respectively. The displacements at 8 hours were based on minimum load and the displacements at 16 and 32 hours were based on maximum load.

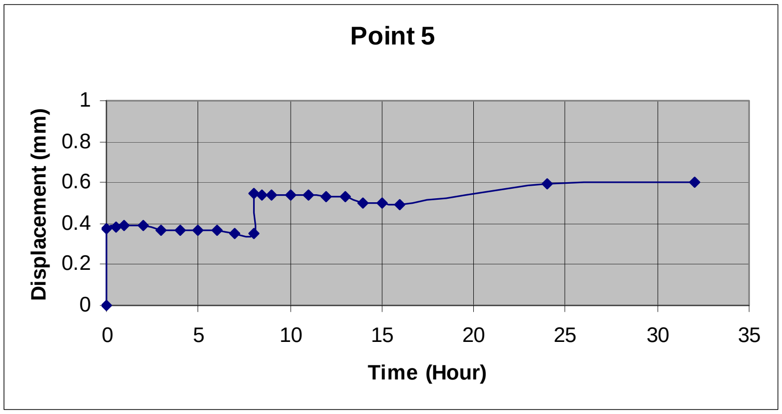

Figure 7: Displacement versus time at point 5

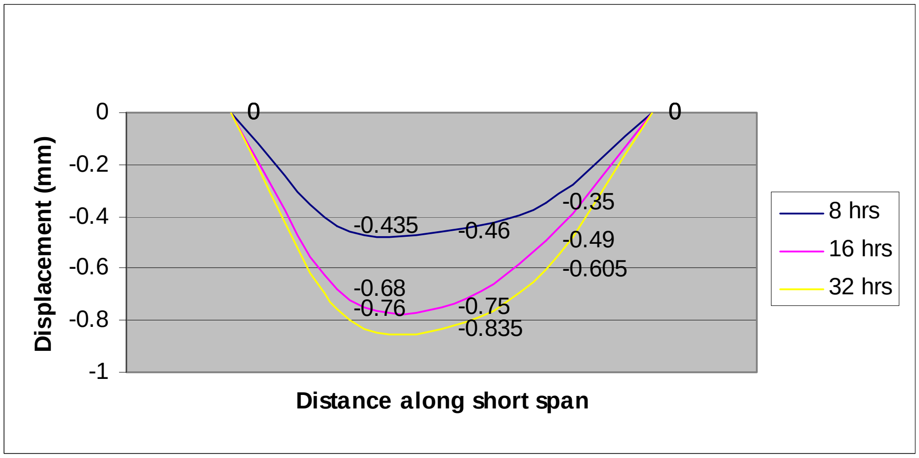

Figure 8: Deflection along short span (point 5-2-4)

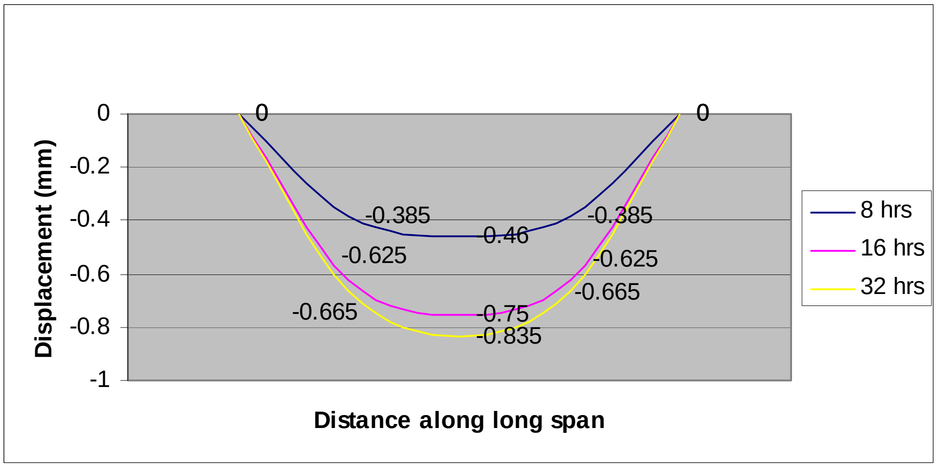

Figure 9: Deflection along long span (point 3-2-1)

The maximum displacement of the slab recorded at point 2 was 0.84 mm at 32 hours under 4.8 kN/m^2 maximum load. Displacements at other points were smaller than point 2 at midspan as expected. The maximum displacements at point 3, 4 and 5 are 0.67 mm, 0.76 mm and 0.61 mm, respectively. A significant increment of the displacements were recorded when the test load was increased from 3.0 kN/m^2 to 4.8 kN/m^2 as the readings shown in Table 1. Referring to Figure 4 to 7, after the slab was loaded, the displacements were almost constant compared to the instantaneous displacement at the application of minimum and maximum loads.

The displacement of the slab shows that the slab behaved as linear elastic. When the test load was increased 60% from 3.0 kN/m^2 to 4.8 kN/m^2, the displacements recorded at point 2, 3, 4 and 5 increased 57%, 64%, 59% and 45%, respectively. This results show that the displacement was increased almost linearly proportional to the load. However, no cracking was observed on the slab and its surrounding structures during the test. This phenomenon can be explained as the concrete stress for the slab under maximum load has not yet achieved the allowable concrete stress and the reinforcements embedded inside the concrete are not yielded.

A computational study to predict the displacement of the slab using linear elastic finite element analysis (FEA) was carried out to compare with the full-scale load test result. The slab was modelled as thick shell element and the beams modelled as thick beam using LUSAS FEA package. The slab was subjected to the maximum load of 4.8 kN/m^2. The maximum displacement at the centre of the slab predicted by the FEA is 3.46 mm which was significantly higher than the actual experimental displacement. This was because the slab was modelled as plain concrete structure without considering the embedded reinforcements. The FEA model is shown in Figure 10 and the displacement contour of the slab in Figure 11.

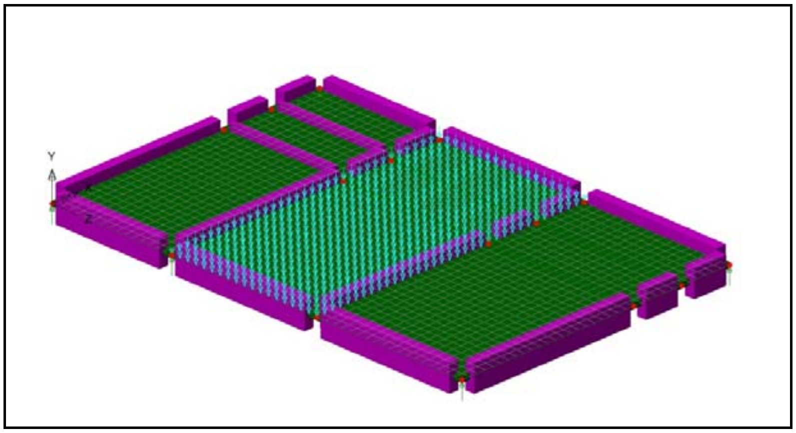

Figure 10: FEA model

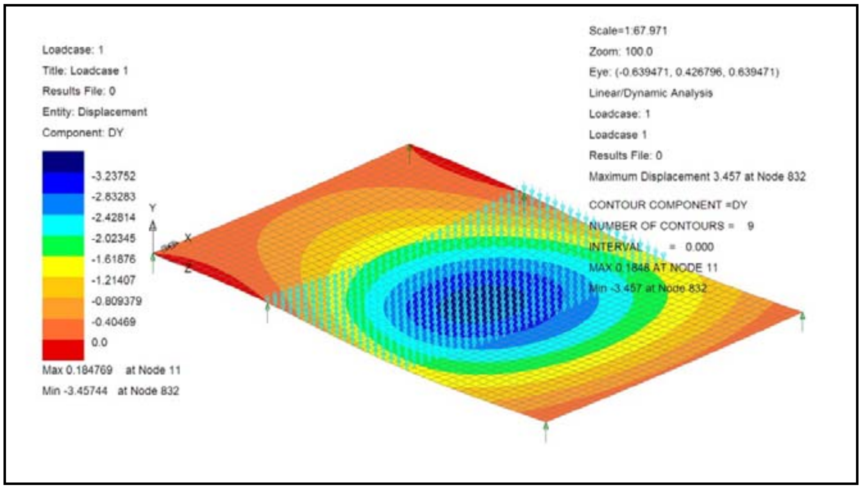

Figure 11: Displacement contour

The tested slab was a two-way slab with the ratio of long span/short span less than 2.0. Therefore, the deflection check should be based on the shorter span of 3.638 m. The maximum deflection obtained from both load test and FEA is within the BS EN 1992 [5] limit of span/500. The deflection limit is 3638/500 = 7.28 mm.

CONCLUSIONS

Based on the results obtained from the full-scale load test, the following conclusions can be derived:

- The RC slab was safe to carry the maximum uniformly distributed load without exceeding the allowable deflection.
- The RC slab behaved linear elastically within the maximum uniformly distributed load. The deflection of the slab was linearly proportional to the applied load.
- Existing crack did not propogate during the test. Therefore, the repaired work done for the existing crack using epoxy resin grouting has effectively sealed up the crack.
- The surrounding structures supporting the slab were adequate to support the design load because they showed no signs of damage and cracking during the test.

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