

Forensic to the Reinforced Concrete (RC) Structures at Library

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ABSTRACT

This Forensic project has been proposed to investigate the reinforced concrete structure defect at library. There were found 65 points cracks and 20 points spalling in library such as only at reinforced concrete beam and slab part in first floor. The total of cracks which crack width less than 0.25 mm is 63 points and the crack width between 0.25 mm to 5.00 mm is 2 points only. These cracks had categorized as fine cracks because the crack width not more than 5 mm. There was 21 samples Rebound Hammer test was random measured the existing concrete compressive strength of critical structures which six samples at beams, six samples at slabs, six samples at columns and three samples at staircase in library. The Rebound Hammer test shown that average mid-point strength at beam is 33 N/mm², slab is 25 N/mm², column is 38 N/mm² and staircase is 37 N/mm². Based on the Eurocode 2, the minimum grade concrete required is 25N/mm² to do the design for reinforced concrete structures, which all the existing concrete strength were achieved the minimum concrete strength. Finally, the Orion software are used to analysis and determine the size of steel reinforcement, the design found the required bar size of steel reinforcement at the middle span or continuous support is 2T16 & 2T25 or 2T20 & 2T25 but the existing steel reinforcement is 2T12 and 2T20 which the existing steel reinforcement could not be sustained the big loading that applied on the library.

Keywords:

Building forensic; Reinforced Concrete (RC), Rebound Hammer Test, steel reinforcement, Orion Software.

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1. Introduction

Cracks are one kind of universal problem of concrete construction as it affects the building artistic and it also destroys the structures integrity, affects the structure safety even reduce the durability of structure [1]. Some researchers already worked on related topics of causes and remedies of cracks such as an experimental study of crack patterns on reinforced concrete beam found that the different types, nature and effects of cracks in concrete structure are caused by overloading, corrosion, shrinkage or poor workmanship [2]. Causes and evaluation of cracks done in concrete structure research can be used by different technique like Crack Compactor and by Ultrasonic Testing [3]. Research for the crack width evaluation for flexural reinforced concrete members found that the reinforcement detailing or bars distribution is an important factor affecting the crack width and building code equation should limit the value of the mean steel stress as given by Eurocode equation

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to overcome the underestimated values obtained in the case of sections having low steel ratio [4]. Case study on identification, evaluation & repair of cracks in concrete structures found that the repair materials and repair techniques are different, depending upon the forms of cracks according to their positions in structure. Some types of cracks seriously need attention as they are structurally hazardous [5]. A cases study structural investigation into the causes of cracks in building and solutions found that an engineer should have a sound knowledge of causes, effect and types of cracks likely to occur from the behavior of construction materials and construction techniques, which will enable him, proffer the appropriate prevention and remedial measures [6].

However, forensic investigation for sustainability issues in structure found that forensic engineering is the professional engineering investigation works for the structural failure [7]. Apart from judicial or professional necessity, forensic engineering is a systematic study and interdisciplinary in structure failure analysis [8]. According to Lim, building forensic works not only do the visual inspection and materials test but re-evaluated structurally to determine the design adequacy and functionality for use based to the design code BS8110 and loading criteria BS6399 [9]. Hence for better understanding building forensic, this research will be divided into three part such as building defect/ crack inspection by using crack gauge monitoring, strength concrete determination by using rebound hammer test and re-evaluated reinforced concrete structures by using Orion software. Rebound hammer test are used because there are simple and effective method to estimate the compressive strength of concrete [10-11]. It also useful in finding the early strength of concrete [12]. Orion are used for structural integrity and capacity evaluations because there are practical tools and fast solutions in analyses and design for the reinforced concrete structures building based on different building code [13-15].

2. Methodology

Reinforced concrete structures defect/ crack had been investigated at library. A crack gauges are used to monitor horizontal or vertical movement across a crack on a flat reinforced concrete surface as shown in Figure 1. Then, a crack width ruler or transparent gauge are used to determine the width of the crack based on the specified width / range of graded lines [16-18].

Rebound Hammer Test was tested to determine the strength of concrete in library at several reinforced concrete structure parts such as slab, beam, column and staircase to get the average reading of existing concrete strength. Figure 2 shown the procedure of Rebound Hammer Test.

Information from the as-built details and existing concrete strength result was reliably used to re-evaluate the reinforced concrete structure. Design was checked against two limit state conditions, such as Serviceability Limit State (SLS) and Ultimate Limit State (ULS). Structural capacity was computed by using Orion software and checked against the maximum load effects under ULS. Structural design, load combinations and load intensities are in accordance with BS8110 or Eurocode 2 and BS6399 [19-21]. For the library or reading rooms with book storage, minimum imposed floor load or uniformity distributed load was 4.0 KN/m^2 and air condition room or plant rooms, fan rooms was 7.5 KN/m^2 [22]. Figure 3 until 5 shown the procedure of design structure library by using Orion software [23].

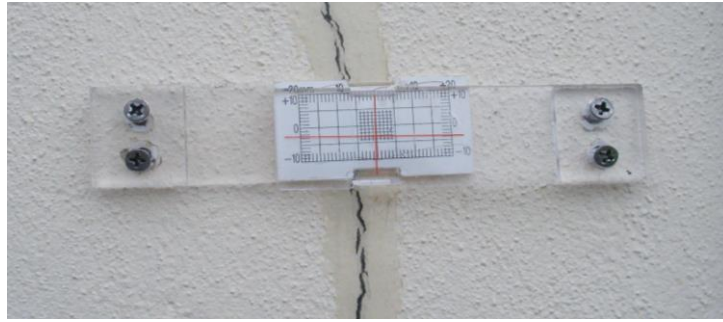


Fig. 1. Standard Crack Gauge to monitor building crack

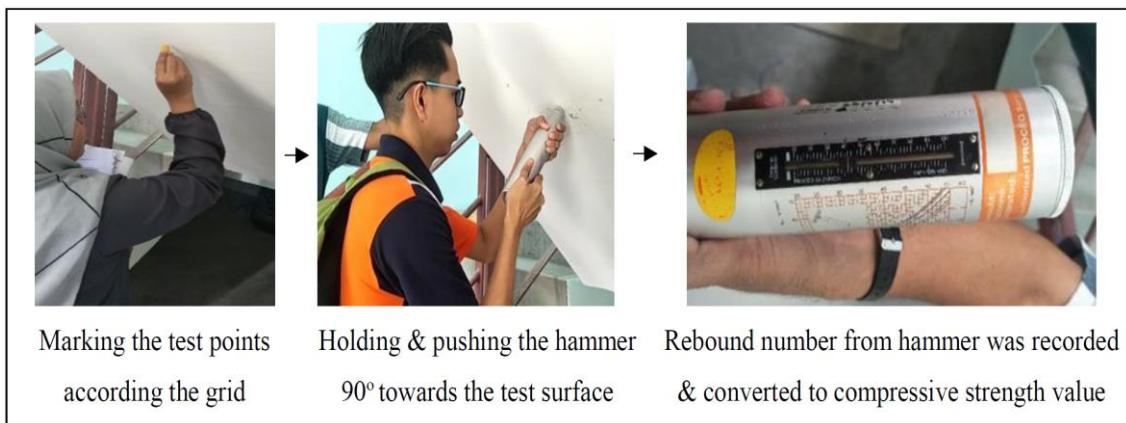


Fig. 2. Rebound Hammer Test procedures

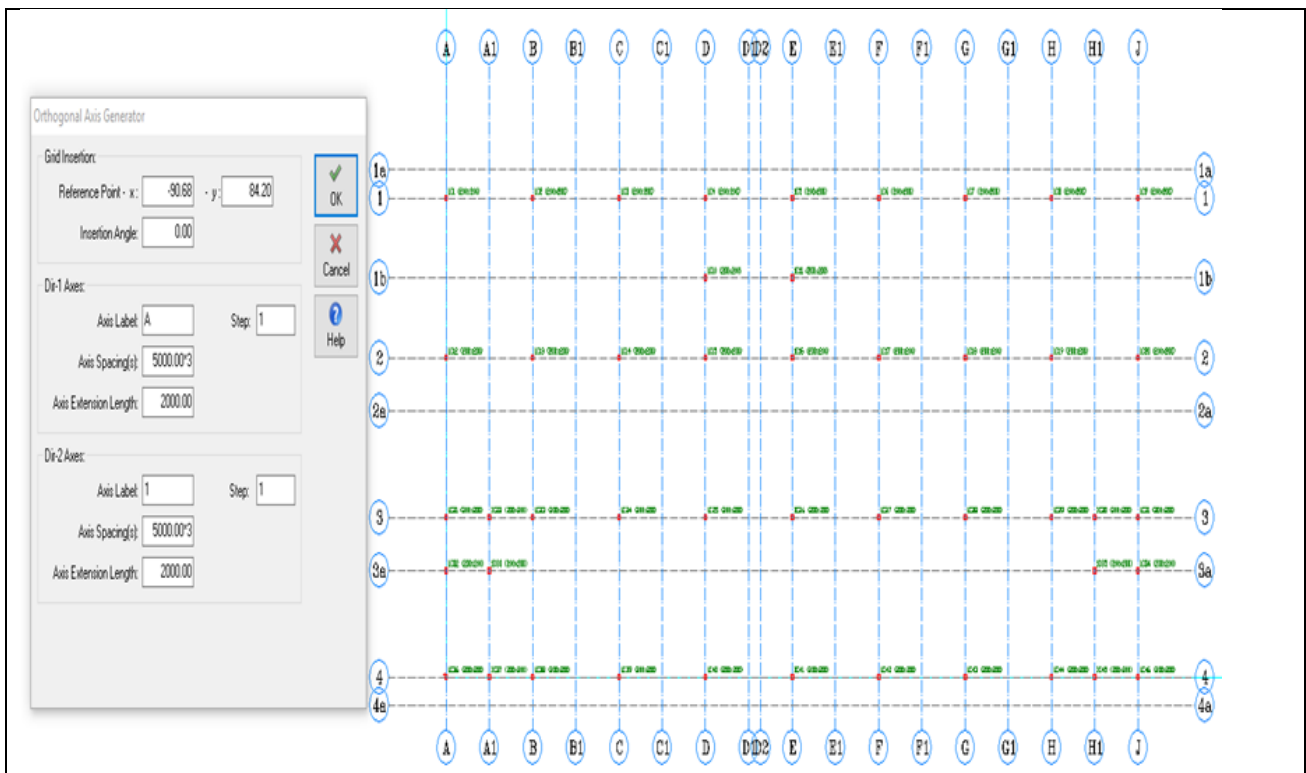


Fig. 3. Orthogonal axis generator

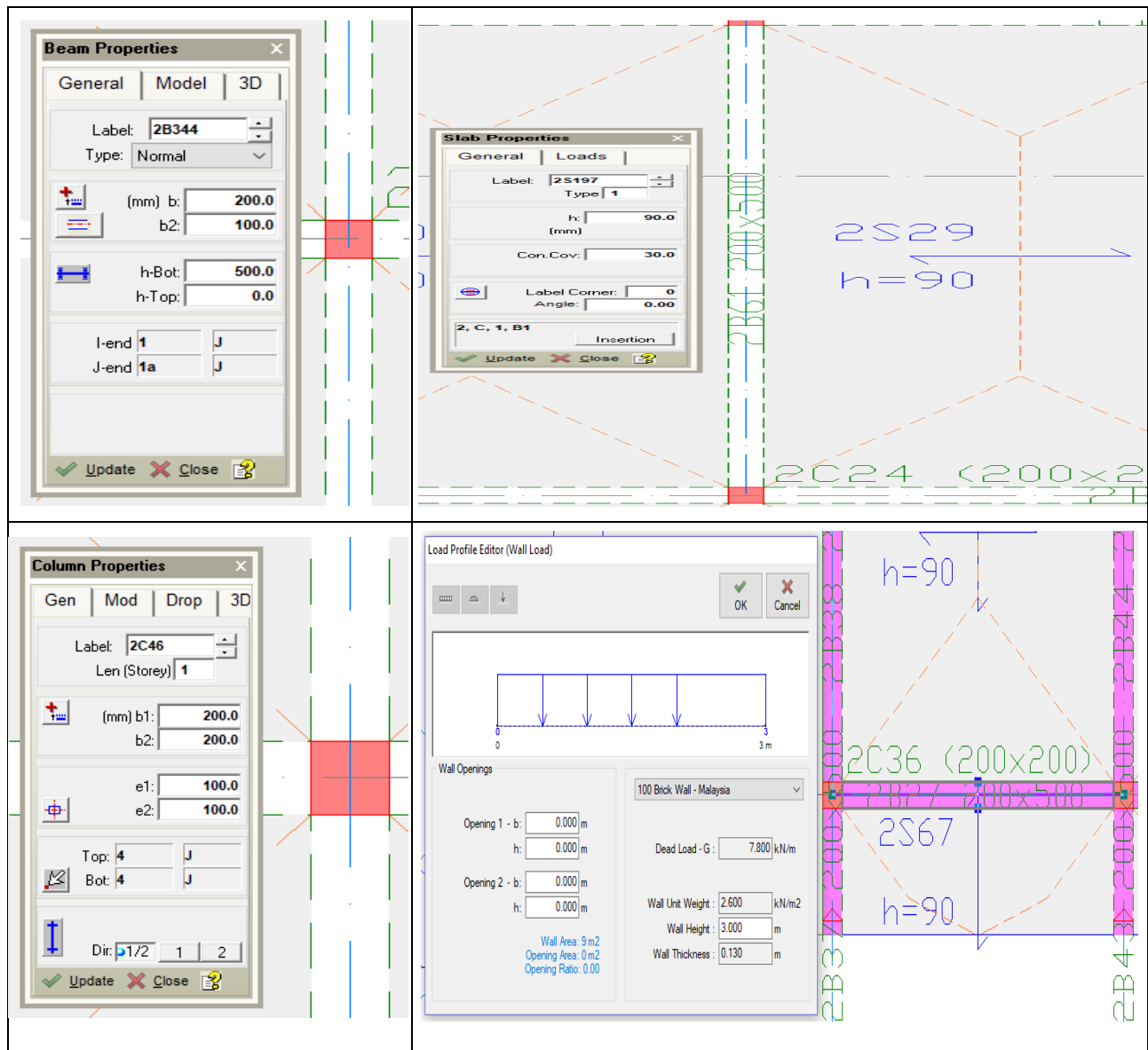


Fig. 4. Creation for Beam, Column, Slab & Wall

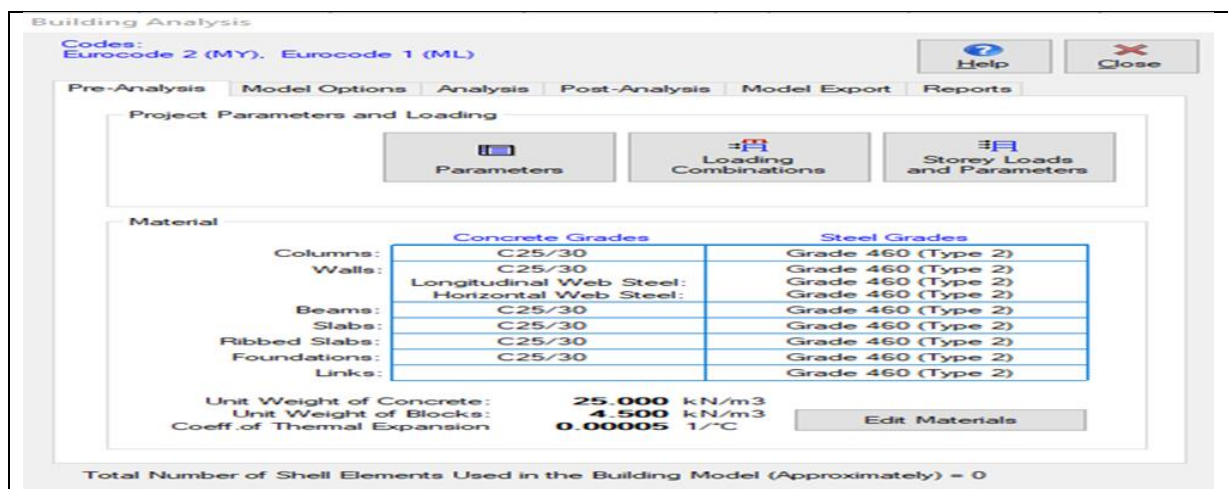


Fig. 5. Building structural analysis

3. Results

3.1 Building Defect / Crack

Based on the building crack monitoring/ observation, the cracks at the library structures were passive crack. This is because when there had loading in it, the structure started crack. While, when the loading removed, the crack width was statics. Based on the type of concrete crack shown as Figure 6 and the crack mapping shown as Figure 7, the quantity of crack where crack width less than 0.25 mm is the most, which is 63 points occurred only at beam & slab. The quantity of crack width between 0.25 mm to 5 mm is only 2 points. Moreover, the quantity of spalling concrete is 20 points. In general, the overall structure was found in safe condition without apply service/ live / imposed load at library. Therefore, detail material test is required to check the strength of concrete and size of steel reinforcement based on the Serviceability Limit State (SLS) design.





Crack width < 0.25 mm		Crack width 0.25mm -0.50 mm	Concrete Spalling/ honeycomb
Slab = 33 points	Beam = 30 points	Slab = 2 points	20 points
			

Fig. 6. Type of the concrete defects at the slab & beam

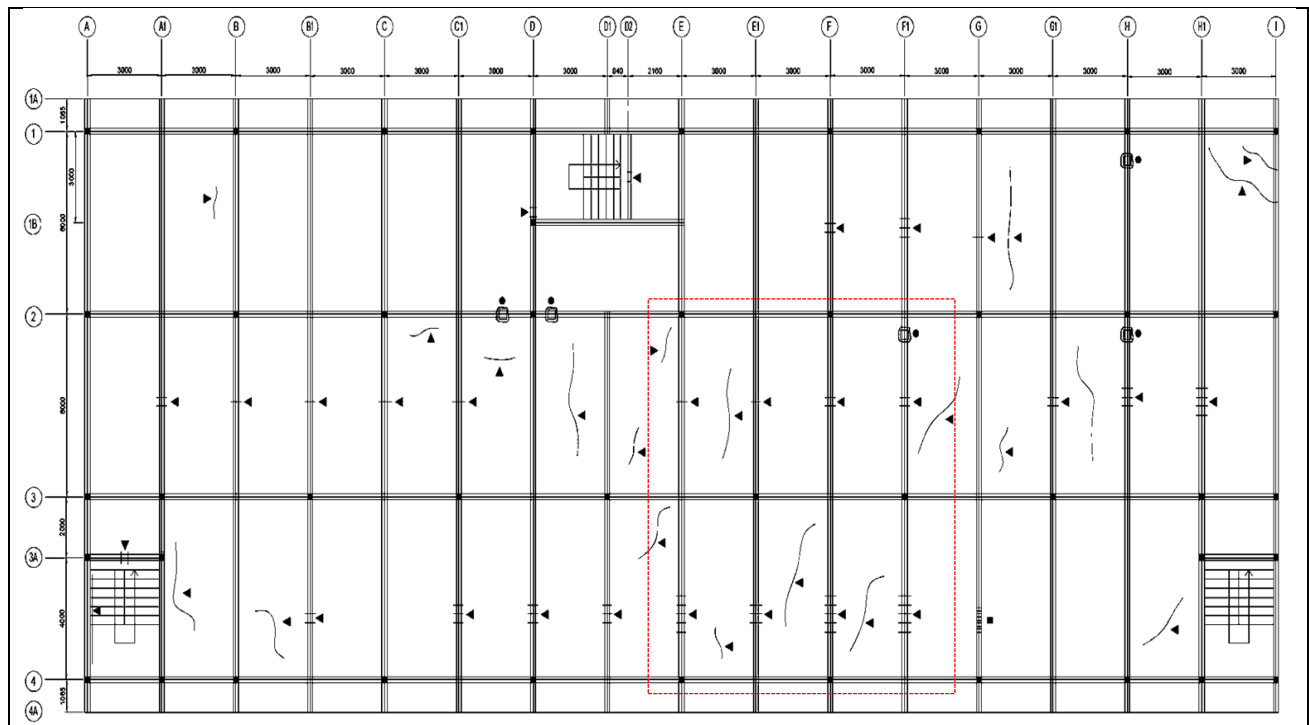


Fig. 7. Library Defect/ Crack Mapping at First Floor Plan (Soffit)

3.2 Material Test Results

The rebound hammer test result in Table 1 obtained showed that the average concrete strength at beam was 33 N/mm², slab was 25 N/mm², column was 38 N/mm² and staircase was 37 N/mm². Therefore, all the existing concrete strength are achieved the minimum grade concrete required is 25N/mm² based on the building code design. However, the existing concrete strength for the slab are required to do the detail check by core coring test.

Table 1
Summary Result for the Rebound Hammer Test

Location of Test	Beam						Slab						Column						Staircase			
	E/3-4	E/3-4	E/3-4	H1/2-3	H1/2-3	H1/2-3	D-D1 / 2-3	D-D1 / 2-3	E1-F / 3-4	E1-F / 3-4	G1-H / 2-3	G1-H / 2-3	A1/3A	E/2	E/4	E1/3	F/4	H/2	A-A1 / 3A-4	D-D2 / 1-1B	H1-1 / 3A-4	
Position of Hammer	0	+90°	-90°	0	+90°	-90°	+90°	-90°	+90°	-90°	+90°	-90°	0	0	0	0	0	0	+45°	+45°	+45°	
Hammer Readings (stike through highest & lowest reading and any other than obvious error)	1	36	46	32	36	40	34	36	25	34	34	35	34	48	45	48	45	41	44	43	43	47
	2	44	44	34	45	47	36	31	27	42	30	37	33	43	44	44	45	44	43	44	46	45
	3	42	44	34	45	46	34	42	31	34	25	35	31	45	41	46	45	44	44	45	37	44
	4	44	45	39	38	40	35	37	34	40	30	37	25	43	36	37	44	36	36	42	43	45
	5	42	47	37	39	46	35	40	31	40	35	43	32	43	36	44	46	44	45	44	44	38
	6	36	38	35	38	44	38	41	29	39	27	40	25	42	43	44	46	44	43	45	46	43
	7	37	44	36	40	42	38	36	33	34	35	34	34	43	38	38	38	46	46	45	44	46
	8	37	43	39	38	43	37	45	34	42	34	40	28	44	44	38	35	44	44	44	45	45
	9	39	44	31	44	47	34	34	33	42	36	42	34	44	44	43	46	45	45	47	46	42
	10	44	46	35	42	45	34	32	30	36	30	45	28	44	39	40	42	39	38	45	44	38
	11	35	38	33	40	41	36	40	28	35	33	36	26	42	45	40	39	37	44	48	46	44
	12	36	39	34	43	42	37	33	34	42	34	44	25	37	36	44	47	37	45	45	45	43
Average of remaining readings	39	43	35	41	44	36	37	31	38	32	39	30	43	41	42	43	42	43	45	44	43	
Compressive strength Graph, f_{ck} (N/mm ²)	38.0	39.0	37.0	42.0	41.0	39.0	28.0	30.0	30.0	32.0	30.5	29.0	46.0	42.0	44.0	46.0	44.0	46.0	45.0	43.0	41.0	
Field correction factor	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	
Compressive strength, f_{ck} (N/mm ²)	32.3	33.2	31.5	35.7	34.9	33.2	23.8	25.5	25.5	27.2	25.9	24.7	39.1	35.7	37.4	39.1	37.4	39.1	38.3	36.6	34.9	
	fck = 33						fck = 25						fck = 38						fck = 37			

3.2 Design for the Reinforced Concrete Structures

Based on the output obtained in Figure 8 shown that steel reinforcement bar provided at main middle beam/ span for the bottom bar is 2T16, 2T20, 2T25 & 3T32 and the top bar is 2T16, 2T20 & 2T25. While, the steel reinforcement bar provided at continuous edge/ support for the top bar is 2T20, 2T25 & 2T32. But based on as built structures inspection, the existing size of bottom bar is 2T20 and top bar is 2T12 shown as Figure 9. By comparing existing and designed size steel reinforcement, the size of existing steel reinforcement was not enough to support the loading at the beam 2/A-D & 2/F-I or 3/A-D & 3/F-I. But the strength of existing concrete was enough. Thus, the defect was occurred because of the steel reinforcement bar. It could not be sustained the big loading that applied such as library.

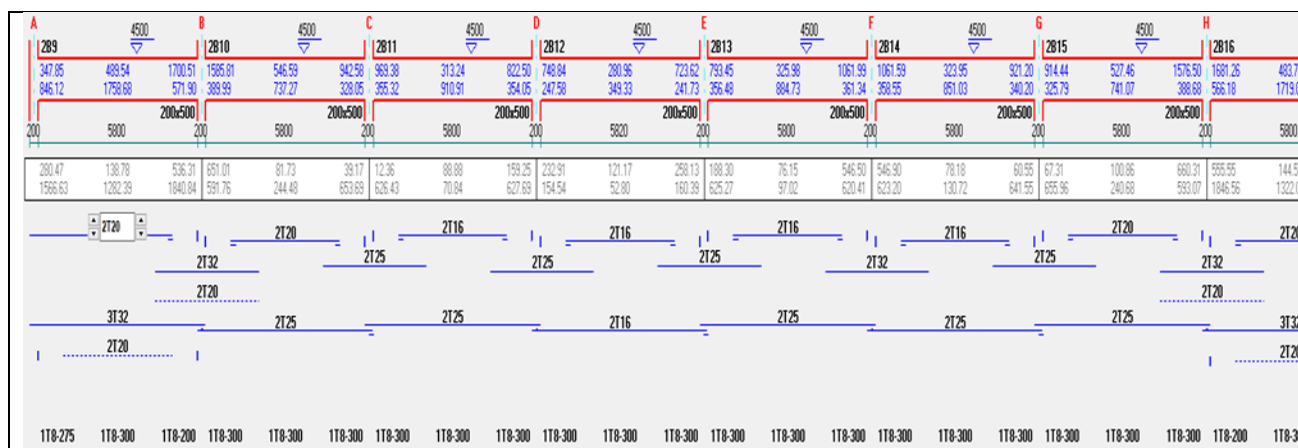


Fig. 8. Library Defect/ Crack Mapping at First Floor Plan (Soffit)

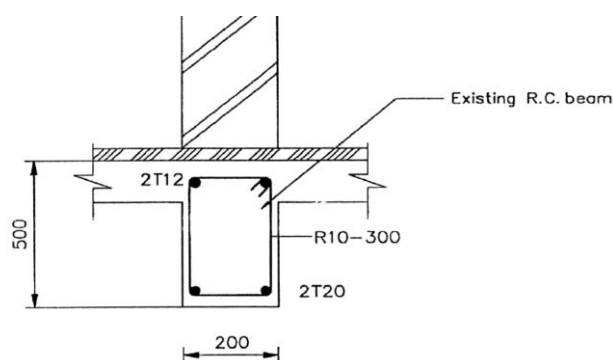


Fig. 9. Detail for the existing Reinforced Concrete beam

4. Conclusions

In conclusion, the concrete strength in library was in standard value which is 25 N/mm². Apart from that, in Orion beam reinforced concrete design, the standard size at middle span of bottom bar and top bar were 2T25 and 2T16 respectively. But the existing size of bottom bar and top bar were only 2T20 and 2T12 respectively. Regarding to the comparison, the size of existing steel reinforcement was too small compare to Orion designed. Thus, the defect was occurred is because of the steel reinforcement. In our opinion, there were many factors that affected the defect / crack at reinforced concrete structures. One of the factors is underestimate the loading to the library structures. Therefore, an engineer forensic required used holistic approaches to the evaluation, design and construction of building. For the recommendation, there are some actions that can be taken to overcome the structure defect issue. This is because when we ignore this problem, structure defect, as time passes, it will become structure failure. If structure failure occurs, it will destroy the whole building even though human life will be affected. Hence, here we list down several ways to overcome this structure defect issue.

- a) Structural repair work to the structure crack.
- b) Structural strengthening work.

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