Investigation on the Integrity of the Reinforced Concrete Slab at the Former Civil Engineering Laboratory Building

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ABSTRACT

Reinforced concrete slab is an important structure component in a building. Reinforced concrete that has been used for a long time should be evaluated to determine the current strength and durability. Reinforced concrete of poor quality that has a reduced strength will not only cause discomfort to customers but also affect their safety. If the problem is not monitored and no improvement is made, the reinforced concrete will fail and eventually collapse. The former civil engineering laboratory building that had been used for 10 years from 2000 to 2010 was investigated for its integrity. In this study, the soil mechanics laboratory was prepared and assessed. The testing instruments used in this study were rebound hammer test and pundit test. The rebound hammer test was used to determine the current strength while the pundit test was used to investigate the pulse velocity, presence of crack and also properties of concrete. From the data, it was found that the laboratory's concrete slab achieved a 30-40 MPa for current compressive strength whereas the Pundit Test showed that the quality of concrete in the laboratory still had a good condition but doubtful in concrete quality. The reinforced concrete slab for this laboratory also showed consistent strength and no large or medium cracks were detected. Thus, the reinforced concrete slab at the former civil engineering laboratory was safe and had moderate integrity.

Keywords: *integrity, reinforced concrete slab, rebound hammer, pundit test, strength*

Introduction

In Malaysia, there are a lot of material structures used in construction for example, steel structure, timber structure and reinforced concrete structure. Reinforced concrete structure is used the most often in construction because it has many advantages when compared to other material structures. One of the advantages is that it can withstand when loaded in compression or tension, thermal compactibility, ductile and durability. Reinforced concrete structure maintains its strength after 28 days and it can fail due to a reduction in strength, durability failure and mechanical failure. When reinforced steel corrodes, the rust will expand and spread resulting in cracks, flakes and loose bonding of steel and concrete. Cracks allow water to seep into the concrete making the reinforced steel seriously corrodes. Besides that, poor design and inadequate reinforced steel will cause the concrete to crack when under excess load or internal effects. The reinforced concrete structure can be tested to determine its quality, uniformity and the presence and location of voids or defects.

However, if the reinforced concrete structure strength decreases, it will show the presence of voids, cracks or other defects. The defect is occurs near the end of the life of concrete. This defect can become big and more serious and it is important to detect it at a very early stage. If this problem is not taken care of, the building or construction will damage or collapse. To prevent this problem, preliminary investigation must be done to determine the initial void or small crack. Failure and defects due to certain problems will eventually cause the concrete structure to lose its integrity.

The former building of civil engineering laboratory that had used for 10 years from 2000 to 2010 was investigated for its integrity, quality and uniformity. There were seven laboratories in the civil engineering laboratory building namely, soil mechanics lab, structure lab, water lab, building services lab, concrete lab, hydrology lab and survey lab. In this study, only soil mechanics laboratory was prepared and assessed.

Non destructive test (NDT) is an analysis instrument used in civil, structural and forensic engineering. NDT is widely used to evaluate and determine the properties of a material, system or component. This test can save time and money as it assesses the material properties without causing damage. Examples of NDT are Pundit test, rebound hammer, impact echo, strain measurement and penetration resistance.

Rebound hammer is a piece of equipment used to determine the strength of material such as concrete and rock. It measures the rebound of a spring loaded mass impacting the surface of the material. The equipment will hit the surface of a material and it is dependent on the hardness of the material. When conducting the test, the equipment should be placed perpendicular to the surface. The surface must be clean, clear, smooth, flat and not moist.

The ultrasonic pulse velocity (UPV) technique as shown in Figure 1 is used to evaluate the quality of concrete structure, concrete uniformity and properties of concrete. Besides that, UPV can also measure the transit time, presence of voids, path length, perpendicular crack depth and elastic modulus. UPV can be used not only for concrete but also for timber, ceramics, cast iron, geological specimens and other materials. UPV is classified into three categories of reading: direct test, indirect test and semi direct test. The schematic diagram of these 3 categories of reading is illustrated in Figure 2. UPV is used to assess the concrete quality for different structural components like roof beams, crane girders, shell beams, columns, shell roof and etc (Sahu and Jain, 1998). According to Whitehurst (1951), concrete with a density of 2400 kg/m^3 is considered to be excellent for 4500 m/s and above, good for 3500 – 4500 m/s, doubtful for 3000 – 3500 m/s, poor for 2000 – 3000 m/s and very poor for 2000 m/s and below. Besides that, the lower limit for good quality concrete is between 4100 – 4700 m/s (Jones, 1955). As per IS: 13311 (Part 1) – 1992, concrete quality can be classified according to Table 1.

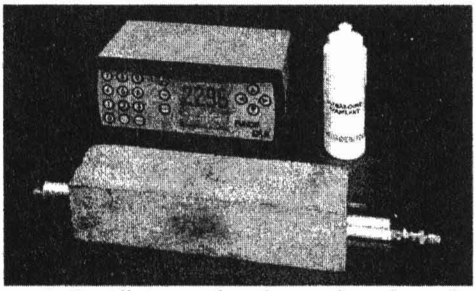


Figure 1: Pundit tester for ultrasonic pulse velocity

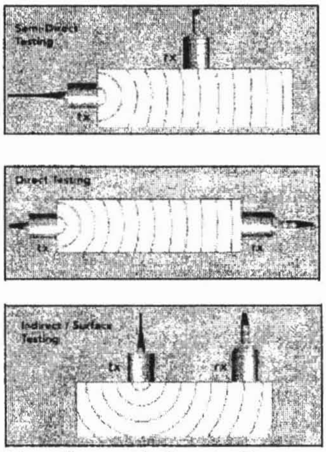


Figure 2: UPV test for semi-direct, direct and indirect test

Table 1: Concrete quality and pulse velocity classification according to IS: 13311 (Part 1) – 1992

Pulse Velocity (km/second)	Concrete Quality (Grading)
Above 4.5	Excellent
3.5 to 4.5	Good
3.0 to 3.5	Medium
Below 3.0	Doubtful

There are many studies adopting the UPV and rebound hammer tests for example, R. Demirboga et al. (2004) who studied the ultrasonic velocity for high-volume mineral-admixture concrete and Yang et al. (2009) who evaluated the residual compressive strength of concrete subjected to evaluated temperature. Other examples include Mohammed et al. (2010) who evaluated the concrete containing crumb rubber (rubbercrete) as a fine aggregate replacement and Hobbs and Kebir (2007) who conducted a correlational study in compressive strengths in Algeria.

Methodology

A reinforced concrete slab is a type of structural element with a thickness of between 10 and 50 cm. It is used to construct floors and provide support to foundations or directly to the soil. Firstly, a grid was drawn on the soil mechanics laboratory's reinforced concrete slab and black points were marked on each grid. These grid lines were measured 0.5 m from the wall. The grid points were 0.5 m apart. Figures 3 and Figure 4 show the grid line and point of the laboratory. Every grid point was marked with letters and numbers to differentiate each grid. The distance of 0.5 m between the grid points was to ensure accuracy in the reading as shown in Figure 5. Besides, voids and cracks would be easily detected when the transmitter and receiver were not far from one another.

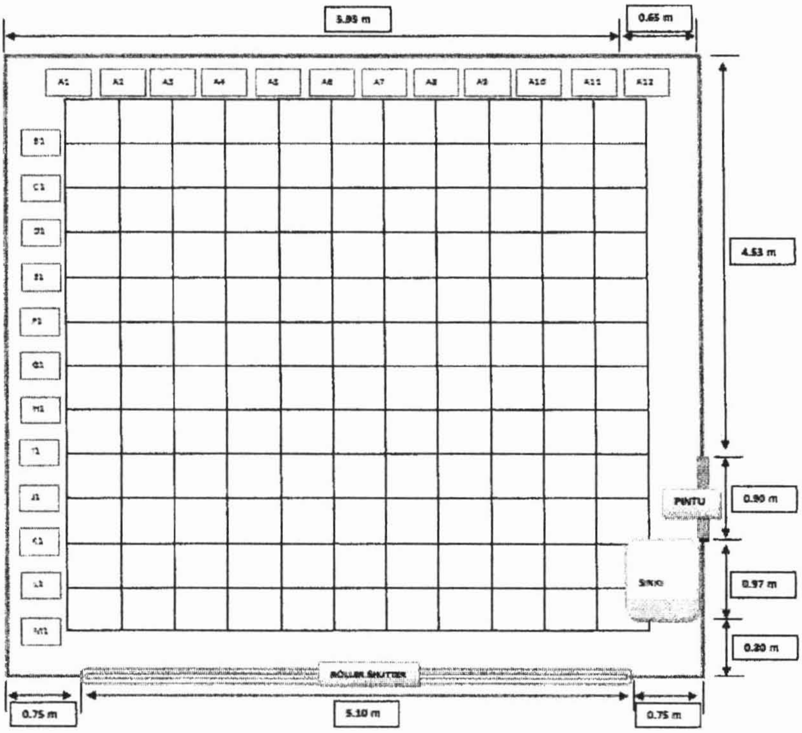


Figure 3: Grid line and grid point of the former soil mechanic laboratory

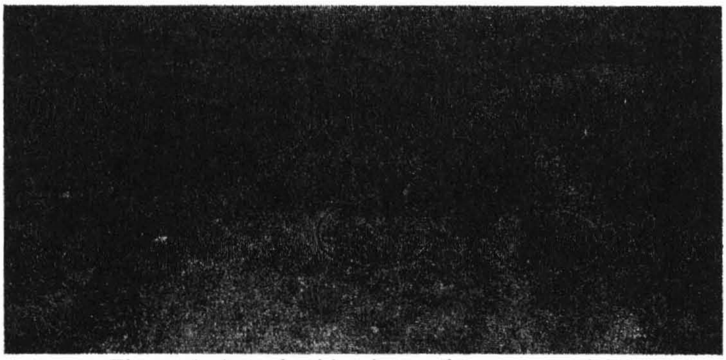
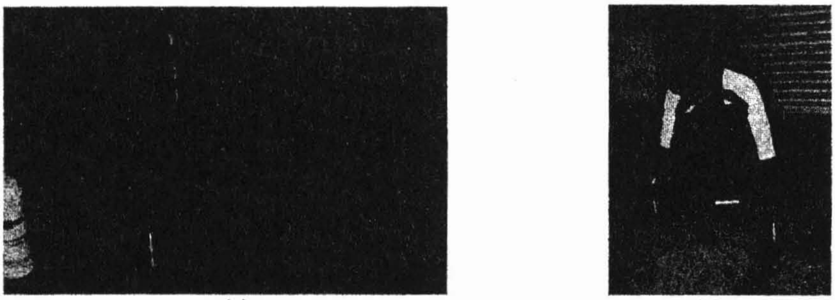


Figure 4: Actual grid point on the concrete slab



(a) (b)

Figure 5(a) & (b): Distance between transmitter and receiver on concrete slab

The ultrasonic test equipment used in this study was PUNDIT (Portable Ultrasonic Non-destructive digital Indicating Tester) test following the BS 1881-203 standard. The UPV method was based on measuring the velocity of compression wave and the velocity of traveling in a solid material and depended on the density and elastic properties of material. The equipment consisted of a transducer for transmitter and a transducer for receiver. The transducer for transmitter transmitted wave or pulses while the transducer for receiver received the wave and directly indicated the time of travel. Concrete surface must be smooth and clear from any particles so that the transducers would be easily placed. The data were obtained by using the method specified in BS 1881-203. In this study, the UPV data for the reinforced concrete slab was conducted using the indirect testing. This was because the slab surface was only in one layer horizontally. Data of pulse velocity, path length, transit time and elastic modulus were taken directly from the UPV equipment.

The rebound hammer or Schmidt hammer used in this study is simple and provides a quick reading as shown in Figure 6. According to BS 1881-202, the equipment is conducted to assess the general quality, uniformity and strength of concrete. Before the start of the test, the equipment was tested for its reliability by using the test anvil. Then, the equipment was applied and pressed by keeping it perpendicular to the surface. It was pressed until the hammer impacted and the button on it was also pressed to note the reading. An average of three readings for every grid point was taken. In this study, the equipment measured the compressive strength of the concrete slab. The quality of the concrete can be determined based on the MPa reading as shown in Table 2.

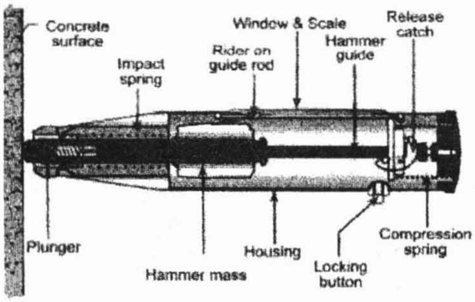


Figure 6: Schematic diagram of rebound hammer (Spectro Analytical Labs Ltd)

Table 2: Average rebound reading with condition of concrete (BS 1881-202)

Average Rebound Hammer (MPa)	Quality of Concrete
>40	Very good hard layer
30 to 40	Good layer
20 to 30	Fair
<20	Poor concrete
0	Delaminated

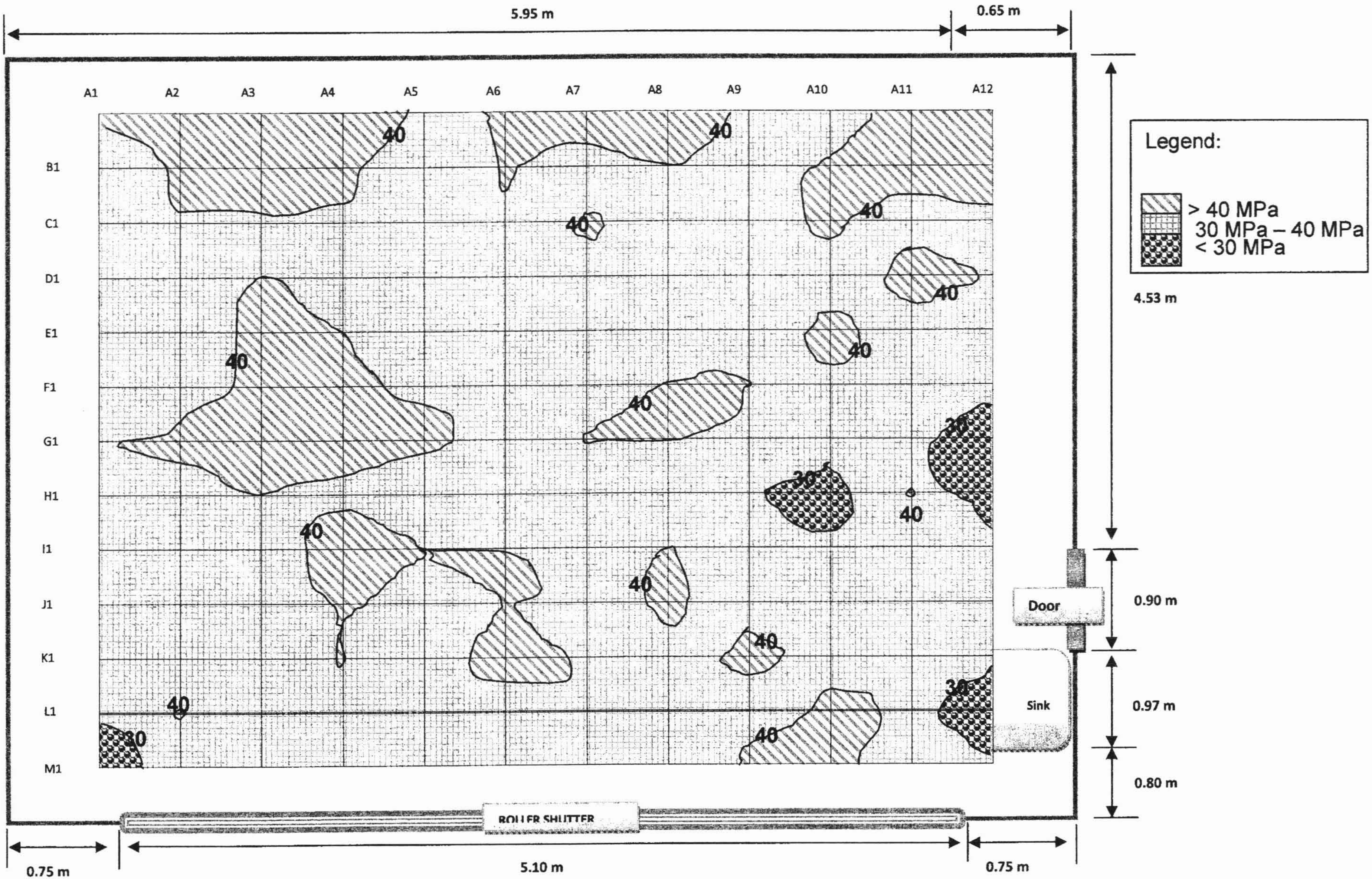
Results and Discussion

Compressive Stress Profile

The results of the pundit test on the slab were analyzed by determining the average value of each point. Table 3 shows the average compressive strength value of each point on the slab. The maximum compressive strength of 45.33 MPa was found at grid A1, while the minimum compressive strength of 24 MPa was found at grid M1. The contour line for 40 MPa and 30 MPa was identified to illustrate the region of concrete condition. It demonstrated the stress profile of the former soil mechanic laboratory UiTM Pahang as shown in Figure 7. It was found that the strength of the laboratory was non uniform across the floor slab. Four big areas located at grids A-C/1-12 had the highest strength of between 32 MPa to 45.33 MPa. This meant that only 1% of the total area in the laboratory could be classified as having fair quality whereas 94% and 5% of the total area could be categorized as good layer and very good hard layer respectively.

Table 3: Average compressive strength of the floor slab at each grid point (all in MPa).

	1	2	3	4	5	6	7	8	9	10	11	12
A	45.33	40.67	40.00	41.33	38.67	40.67	41.00	44.00	38.67	38.67	42.00	40.67
B	30.00	43.33	41.33	41.33	32.67	40.67	36.00	40.00	35.33	40.67	41.33	42.00
C	34.00	38.67	39.33	38.67	32.00	32.00	40.67	33.33	34.00	41.33	39.33	36.67
D	30.67	32.00	40.00	38.00	32.67	31.33	32.00	35.33	39.33	35.33	41.33	39.33
E	38.00	32.67	40.67	40.00	32.67	38.67	36.00	31.33	32.67	41.33	34.67	34.67
F	34.67	32.00	40.67	40.67	39.33	34.00	30.67	40.00	40.00	37.33	37.33	33.33
G	39.33	43.33	41.33	43.33	41.33	34.67	40.00	40.00	35.33	37.33	33.33	25.33
H	36.00	36.00	40.00	39.00	31.33	30.00	34.67	32.00	32.67	26.67	40.00	26.00
I	31.33	33.33	36.67	42.67	40.00	40.00	27.33	40.00	35.33	32.00	36.67	36.00
J	40.67	34.00	36.67	40.67	39.33	40.00	34.67	41.33	32.67	32.00	36.00	32.00
K	34.67	34.00	35.33	40.00	38.67	42.00	39.33	37.33	41.00	34.67	36.00	32.67
L	30.67	40.00	38.67	32.67	38.00	34.67	36.00	39.33	37.33	40.67	36.00	22.67
M	24.00	39.33	35.33	39.33	40.67	36.00	35.33	34.67	40.33	42.00	32.67	30.67



5.95 m
0.65 m
A1
A2
A3
A4
A5
A6
A7
A8
A9
A10
A11
A12
B1
C1
D1
E1
F1
G1
H1
I1
J1
K1
L1
M1
40
30
Legend:
> 40 MPa
30 MPa – 40 MPa
< 30 MPa
4.53 m
0.90 m
Door
0.97 m
Sink
0.80 m
ROLLER SHUTTER
0.75 m
5.10 m
0.75 m

Pundit Test

Table 4 shows the results of Pundit test for transit time, path length and velocity. Grid point E displayed the highest transit time and velocity of pulse value while grid points K and J showed the lowest transit time and velocity value with a range of about 220 to 250 usec and 1000 to 1010 m/s respectively. The average for this lab was 341.47 usec for transit time and 1362.69 for pulse velocity. According to IS:13311 (Part 1), this lab can be graded as having doubtful quality of below 3000 m/s. The velocity of pulse in concrete structure decreases if there are any defects such as air voids or cracks. From the results, the integrity of concrete on this lab was classified as moderate. From the observation, the reinforcement in the slab could influence the reading of the pundit test. The pulse velocity measured near the reinforcing steel bars and the amount of steel bars did not represent the true reading (Gupta et al., 2004). On the other hand, the presence of a lot of small voids in this concrete and aggregate size could also affect the pulse velocity reading.

Table 4: Pundit test result for every grid point

Point	Transit time (usec)	Path length (m/mm)	Velocity (m/s)
A	281.5	141	1126
B	412.2	73	1644
C	293.8	169	1176
D	487.5	102	1944
E	537.2	60	1998
F	273.3	110	1088
G	462.0	103	1846
H	271.0	110	1085
I	269.5	111	1077
J	251.7	135	1004
K	225.6	118	1006
L	294.7	98	1220
M	379.1	79	1501
AVERAGE	341.47	108.38	1362.69

Conclusions and Recommendations

From the experimental data, the following conclusions can be drawn:

1. The average of the compressive strength of the concrete slab at the soil mechanics laboratory was 30 – 40 MPa.
2. The average of pulse velocity was 1362.69 m/s; far from the excellent category in concrete quality.
3. The integrity of the concrete structure could be categorized as moderate; the strength was good but the presence of the void or crack was doubtful.

It was not sufficient to use only the rebound hammer and Pundit test in this study. This was because the instruments only provide results for the surface of the concrete structure. Some other NDT methods and instruments should be used to determine the precise data such as pull out tester, half cell potential and strain measurement. The use of combined methods could produce more reliable results (Hobbs and Kebir, 2007).

The following recommendations can be made from the study:

1. The study can be extended by checking the temperature of concrete and minimizing the length of transducers.
2. Other methods of NDT should also be employed to evaluate the concrete structure.

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