IOP Conf. Series: Materials Science and Engineering **849** (2020) 012075 doi:10.1088/1757-899X/849/1/012075

Building Condition Assessment (BCA) on school building in Sabah, Malaysia

Syahirah Mohd Noor[1*], Hazel Kiddo Richard[1], Izni Syahrizal Ibrahim[1], Noor Nabilah Sarbini[1], Lee Hanseung[2] and Jitendra Kumar[2]

[1] School of Civil Engineering, Faculty of Engineering, Universiti Teknologi Malaysia, Johor Bharu, Malaysia
[2] School of Architecture and Architectural Engineering, Innovative Durable Building and Infrastructure Research Center, Hanyang University, ERICA, Korea

Email: *syahirahmn12@gmail.com*

Abstract. The standard guideline for Building Condition Assessment (BCA) [7] has been introduced by Public Work Department of Malaysia to manage the government's building in Malaysia especially in Peninsular Malaysia. Whereby, BCA has never been implemented in Public Work Department of Sabah. Since there is so many buildings need to be maintained especially existing school building, it is the right time to introduce a systematic assessment method for managing the maintenance work. Visual inspections for the selected building have been done with reference to Standard guideline for Building Condition Assessment (BCA) [7] by Public Work Department of Malaysia. Building Condition Assessment online system (BCA-OS) by Universiti Teknologi Malaysia Forensic Centre was used to analyse the existing physical condition of the building in order to determine the rating of the buildings. By using this system, the building wil1 be rated 1 (good) to 5 (critical). Material testing will be conducted to building with rating 3, 4 and 5. This paper will discussed the results obtained from Building Condition Assessment online system (BCA-OS) and test result on 2 blocks of a school in Sabah. In this study it is found that Building Condition Assessment online system are convenient to use and useful to rate the actual physical condition of the existing building. The rating from BCA-OS was found to be really representing the actual condition observed from visual inspection.

1. Introduction

The economic developments in Sabah are increasing with a lot of building construction especially school buildings. Even though the construction of new buildings is increasing, the existing building must not be neglected and its physical condition still needs to be assessed. It is high time for Public Work Department to implement a system that can help managing all these existing buildings condition whether still in good condition, need to be repaired or demolish. In this study, Building Condition Assessment online system will be used to rate the existing building condition. The objectives of this study is to identify defects of building through building inspection, to carry out Building Condition Assessment and material testing to identify the concrete condition of the existing building.

IOP Conf. Series: Materials Science and Engineering **849** (2020) 012075 doi:10.1088/1757-899X/849/1/012075

Building Condition Assessment online system (BCA-OS) were used in this study as a tool to rate the building condition and it will only focus on structural and architectural element of the building. Two (2) schools were selected, School A and School B. Both schools are located in Sabah, Malaysia.

The significance of this study is to make sure that all the data gathered from visual inspection can be analysed and rated using Building Condition Assessment to give more detailed and close to accurate assessment on the building. Hopefully with this study, all existing reinforced concrete building in Sabah that is under Public Work Department will be maintained accordingly with a proper method or system.

2. Literature Review

[1] has done a research on inspection of public buildings based on risk assessment system. The key point to their research are to provide the inspection method for assessment of existing buildings, time efficient, simple for use, easy for reporting and clear for society and stakeholder. [1] have stated that for the next stage of research, there are necessary to improve common guidelines for estimation of risk factors for specified essential requirements to reduce the possibility to give different risk factors for common problem.

[2] had conducted a research to review the use of Building Condition Assessment (BCA) practice in government buildings and have developed the Standard Guideline for BCA on Existing Building [7]. The aim of their study is to improve the government service delivery toward effective decision making for building maintenance and the result of their finding are then used in determining the remedial action maintaining building facilities condition. The case study for [2] research has been done for buildings in Peninsular Malaysia which has a slightly different condition of weather and ground condition compare to East Malaysia.

The importance of managing government assets with a good maintenance system have been stressed out by [2]. The implementation of public sector facility and asset management is crucial and important to ensure the government building well managed and can serve the purpose for which it is constructed [2]. In their study, they also mentioned on the involvement of professionals in the asset management. Therefore, it is important to the professionals involved in managing the asset or facility to know and competent in the related field especially building condition assessment (BCA) [2]. The objective of [2] study is to examine the level of consistency data collection so that it can be easily assessed and understood. In their paper, the writer has also concluded that the result of the standard BCA produces a system that the data can be accessed easily and quickly. BCA also set the priority of the planned maintenance works in order to tackle the shortage of maintenance funds problems.

Building Condition Assessment is an important process to evaluate a building physical condition and the functionality of the building. Assessing the real condition of building structures is very important for building maintenance programme or building repair works. The condition assessment covers the degree and extent of physical degradation and the work necessary to renovate office buildings including the associated costs [3]. According to [2, 4], building condition is very important to supports decision making and it is also critical to the management in achieving the service standards for maintenance.

Proper building condition assessment can lead to an effective maintenance programme and it will save the cost of repairing the building condition to its serviceability state. [5] had mentioned that BCA may be seen as a way to improvise asset management knowledge and asset monitoring, as well as a method to enhance asset information management. BCA is thus part of the activities aimed to minimise financial and capital costs over the building life cycle while maximising asset value for every stakeholder.

3. Methodology

Figure 1 shows the outline of research methodology for this study.

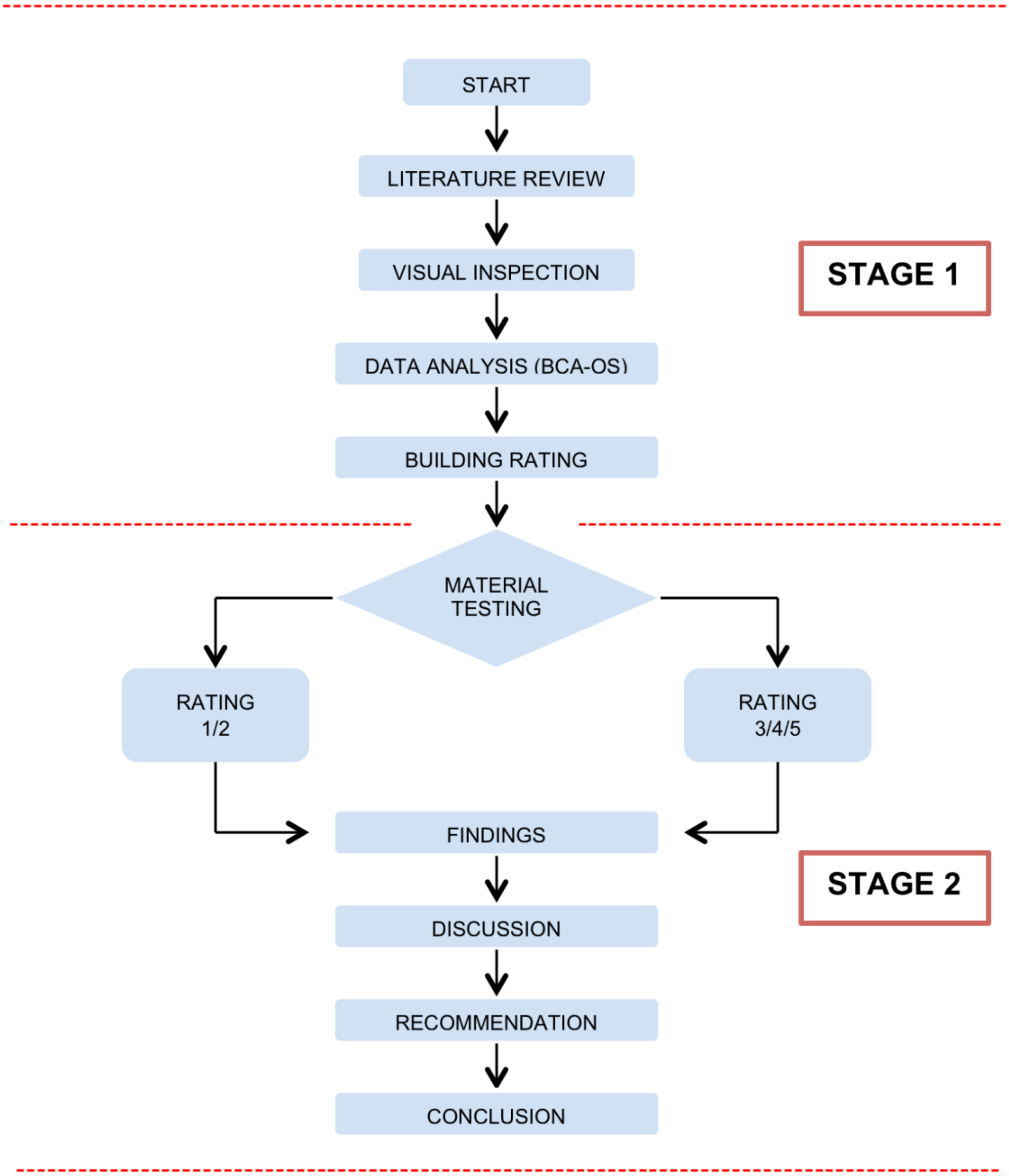

Figure 1. Outline of research methodology.

3.1 Visual inspection

Visual inspection was done to two schools that are School A and School B. In each school, two buildings were inspected. Classroom Block and Hostel Block was chosen for School A. While for School B, Block A and Block B were chosen. The sizes of the buildings are as shown in Table 1. The structural layout of the building are almost the same, with spacing between columns is 3 m and 7.8 m apart. Concrete beam spanning about 7.8 m long with cantilever about 1.5 m both ends. The size of the biggest concrete slab panel is 7.8 m x 3.0 m, and the slab panel size at the corridor is 1.5 m x 3.0 m.

Table 1. Size of the school's building

SCHOOL	BLOCK	SIZE
School A	Hostel	10.8 m x 63 m
	Classroom	10.8 m x 72 m
School B	Block A	10.8 m x 72 m
	Block B	10.8 m x 72 m

Table 2 shows the number of photos taken for each building. All these photos were uploaded in the Building Condition Assessment online system (BCA-OS) for rating purpose.

Table 2. Numbers of photos taken for each block

Hostel Block	101
Classroom Block	367
Block A	238
Block B	285

Few types of defects were detected on all of the buildings. Table 3 shows the list of defect found in the inspected buildings. There are few defect found especially on the architectural part of the building but it will not be discussed in detailed in this study. There are two types of defects found in the inspected buildings, which is structural defect and non-structural defect. In this study, it is more concern on the structural part defects.

Table 3. List of defect found on the inspected building

1. Pop outs and Spalling	7. Water leak / spot
2. Cracks	8. Algae / Vegetation Growth
3. Contaminated Aggregate	9. Shear Crack
4. Flaking	10. Flexural Crack
5. Corroded Reinforcement	11. Ground Settlement
6. Deflection / Sagging	

Hostel Block in School A has the most concrete spalling problem, with exposed corroded reinforcement bar. Meanwhile, for Block A and Block B of School B, most of the defects found were shear crack and flexural crack. Figure 2, Figure 3, Figure 4 and Figure 5 shows some of the defects photos taken during visual inspection.

Figure 2. Photos of ceiling and column defect.

Figure 3. Photos of settled apron and staircase defect.

Figure 4. Photos of slab defect.

Figure 5. Photos of beam defect.

3.2 Defect mapping

Defect mapping was done to show the location of the photo taken. A draft layout of the building was drawn using AutoCAD software and the output shows the location of each defect. All the photos will be marked accordingly by using numbering system. The number of the photo was marked in the floor layout plan of the respective buildings. This defect mapping is important as reference on the defect location.

3.3 Building condition assessment

All the photos taken from visual inspection were uploaded into Building Condition Assessment online system (BCA-OS) developed by Universiti Teknologi Malaysia (Forensic Engineering Centre). By uploading the photos and identifying the component, defect/deficiency, condition rating and maintenance rating, this system will analyse the rating of the building. Figure 6 shows the uploaded photos in BCA-OS inspection form. The reference number of the defect was written in the remarks section for reference on the location of the defect in the layout plan.

Individual figures should normally be centred but place two figures side-by-side if they will fit comfortably like this as it saves space. Place the figure as close as possible after the point where it is first referenced in the text. If there are a large number of figures it might be necessary to place some before their text citation. Figures should never appear within or after the reference list.

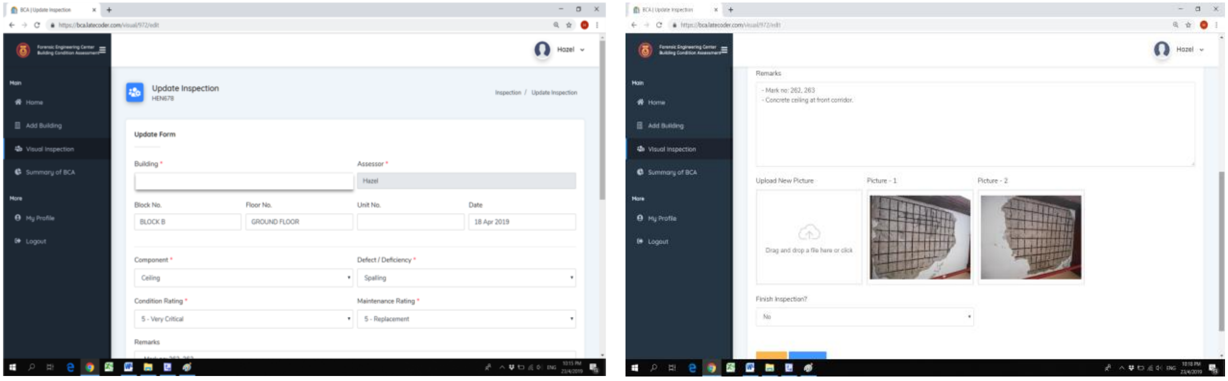

Figure 6. Photos of inspection form in BCA-OS.

The rating scale for the building physical condition will be based on Table 4. It has 5 grade of rating scale and this rating scale is relative to Table 5, which is the maintenance priority for building. The maintenance actions are divided into 5 scale of priority which are normal, routine, repairs, rehabilitation and replacement.

Table 4. Building physical condition level [7]

Grade	Inspection Scale	Description
1	Very Good	. No defect . Good condition . Good functionality
2	Good	. Minor defect . Good condition . Good functionality
3	Fair	. Major defect . Moderate condition . Still can function with supervision / monitoring
4	Poor	. Major / minor defect . Critical condition . Not functioning as agreed service level
5	Very Poor	. Major defect . Critical condition . Not functioning as agreed service level . Risky to safety and health

IOP Conf. Series: Materials Science and Engineering **849** (2020) 012075 doi:10.1088/1757-899X/849/1/012075

Table 5. Maintenance action [7]

Priority	Scale	Description
Normal	1	No defect or damages, element/component well maintained
Routine	2	Minor defects/damages, needs for monitoring, repairs, replaced to prevent serious defect/damages
Repairs	3	Major defects/damages, needs for major repairs and replacement
Rehabilitation	4	Critical/serious defects/damages, needs for urgent and immediate repairs
Replacement	5	Critical/serious defects/damages, needs for urgent replacement, refer to expert detail inspection/expert judgement

Rating score (RS) of building was calculated by dividing the total matrix with total defect (D) found in the respective building. The results from this calculation will be used to determine the rating of the building. Figure 9 shows the condition rating (CR) and the maintenance rating (MR) of each or a group of uploaded photos. The matrix (M) was calculated by multiplying condition rating with maintenance rating.

$$M = CR\ X\ MR \qquad (1.1)$$

Equation (1.1) is the equation used for calculating the matrix.

$$RS = \frac{\sum M}{\sum D} \qquad (1.2)$$

Equation (1.2) is the equation used for calculating the rating score.

In this study, there are four numbers of buildings were inspected and need to be rated. Figure 7 shows the summary of condition rating, maintenance rating and matrix in uploading all the photos and information into BCA-OS. While Figure 8 shows the summary of BCA-OS, it shows that Block A and Block B of School B were in the rating number 2. Classroom Block and Hostel Block of School A were in the rating number 3.

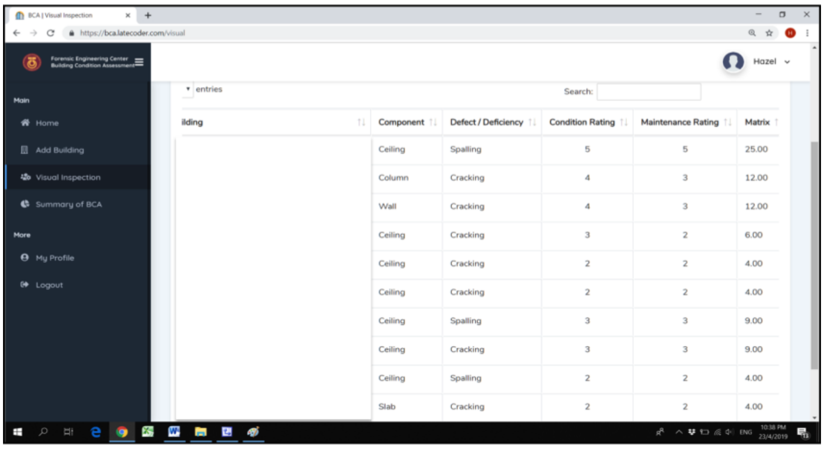

Figure 7. Summary of condition rating and maintenance priority rating.

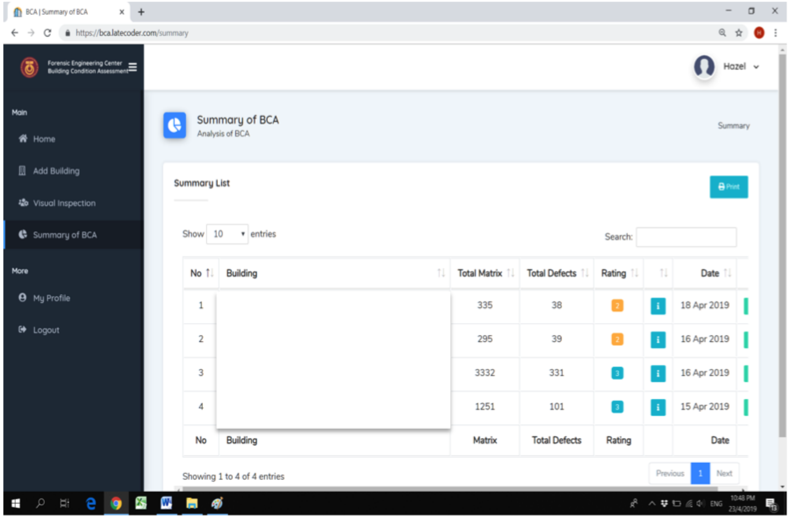

Figure 8. Summary of Building Condition Assessment.

The calculation for the rating of the building is tabulated in Table 6 by using the reference from Figure 8. In BCA-OS, the ratings of the buildings were identified as in Table 7. In Building Condition Assessment online system (BCA-OS), the rating is using numbering system, which is 1 to 5 (very good to very critical). While in Public Work Department manual for building inspection and rating for existing building [7], the rating is using alphabet system. The rating is from A to E (very good to very poor). Table 8 shows the overall conclusion on the rating system in BCA-OS.

Table 6. Calculation for rating identification

Block	Total Matrix	Total Defect	Rating Score (Total Matrix / Total Defect)	Rating (Table 9)
Block B	335	38	9	2
Block A	295	39	8	2
Classroom	3332	331	11	3
Hostel	1251	101	13	3

Table 7. Building Classification Rating (BCA-OS)

Rating	Physical Condition	Action Matrix	Score
1	Very Good	Regular Maintenance	1 to 5
2	Good	Condition Based Maintenance	6 to 10
3	Moderate	Repairs	11 to 15
4	Critical	Recovery	16 to 20
5	Very Critical	Replacement	21 to 25

Table 8. Overall Rating (BCA-OS)

Rating	Descriptions
1	Building functions perfectly as it is
2	Building can be used entirely but require regular maintenance and touch up
3	Building can be used partially but require further investigation
4	Require further investigation
5	Require further investigation

3.4 Material test

Based on the result from BCA-OS, Hostel Block and Classroom Block require further investigation. In this study, material testing was done on both of the buildings as part of the investigation to identify the cause of defect. Listed below are the material tests that have been conducted to the buildings;

(a) Concrete Coring Test (Compressive Strength Test)
(b) In-Situ Carbonation Test
(c) Rebound Hammer

4. Result and analysis

This section shows the result of the material testing done for two blocks of building in School A.

4.1 Concrete Coring Test (Compressive Strength Test)

Figure 9 and Figure 10 shows the result of compressive strength for core sample taken from Classroom Block and Hostel Block. The designed concrete grade is 25 N/mm^2.

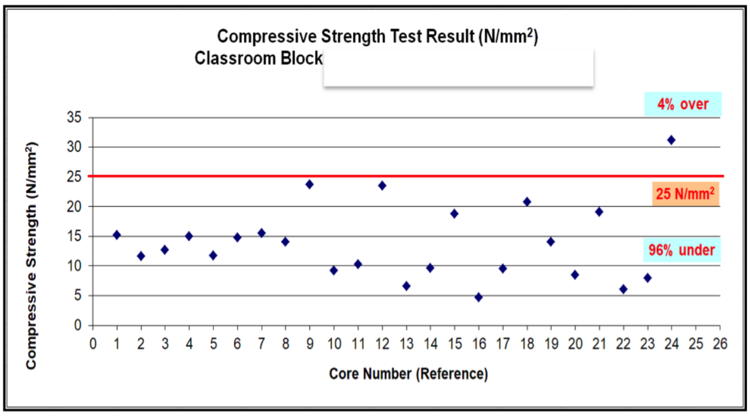

Figure 9. Compressive strength test result for classroom block.

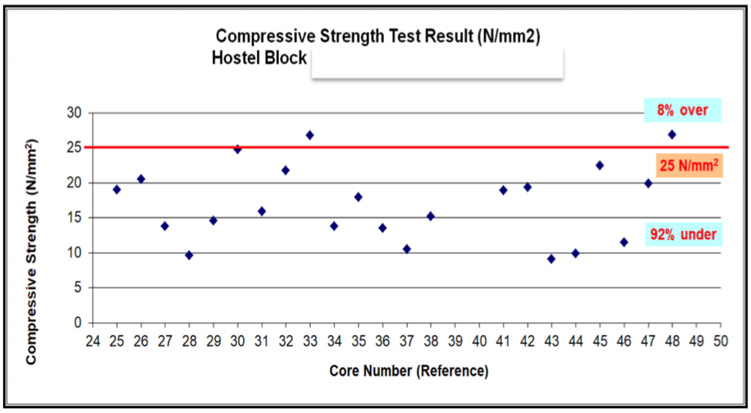

Figure 10. Compressive strength test result for Hostel Block.

IOP Conf. Series: Materials Science and Engineering **849** (2020) 012075 doi:10.1088/1757-899X/849/1/012075

The core compressive strength ranges from 4.7 N/mm^2 to 31.2 N/mm^2 obtained from the results shown in Figure 9 and 9.1 N/mm^2 to 26.9 N/mm^2 in Figure 10. The average cube strength is 13.9 N/mm^2 for Block Classroom and 17.1 N/mm^2 for Block Hostel. Only one (1) sample was found to have concrete strength above 25 N/mm^2 for Classroom Block and two (2) samples for Hostel Block. It is core number S-24, S-33 and S-48. The values are 31.2 N/mm^2, 26.8 N/mm^2 and 26.9 N/mm^2.

4.2 In-Situ Carbonation Test

Figure 11 and Figure 12 shows the result of carbonation test for core sample taken from Classroom Block and Hostel Block. The designed concrete grade is 25 N/mm^2.

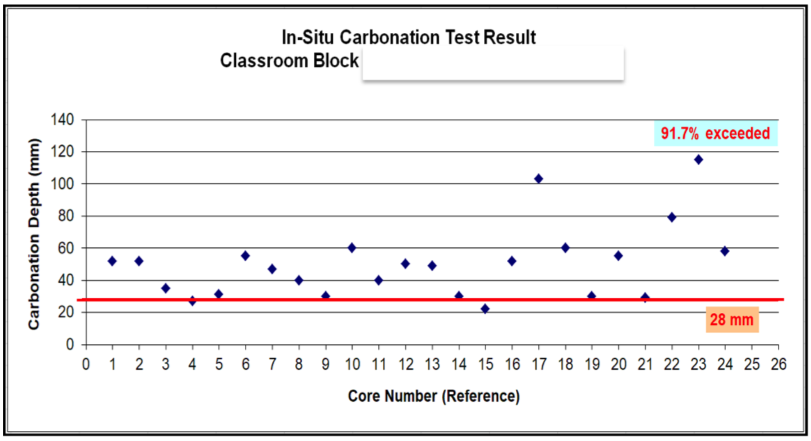

Figure 11. In-situ carbonation test result for Classroom Block.

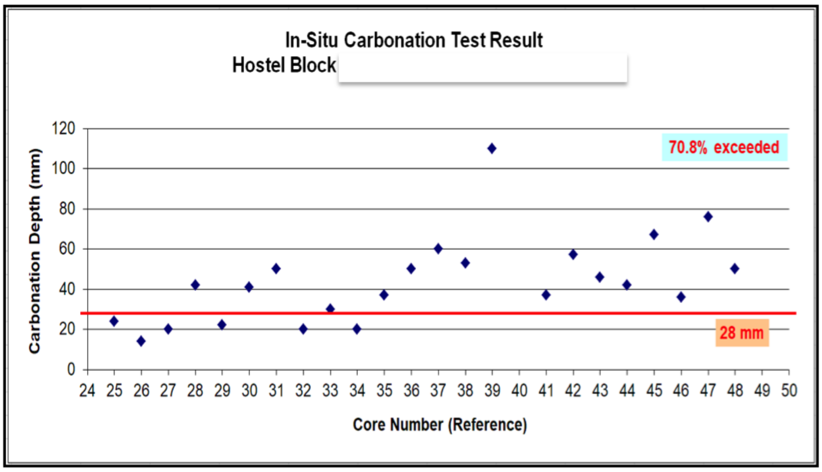

Figure 12. In-situ carbonation test result for Hostel Block.

Equation (1.3) is the equation used for calculating the estimated carbonation depth. In Equation (1.3), d_c = depth of carbonation, K = carbonation coefficient (K-value often 3 or 4 $mm/year^{0.5}$) and t = time exposure (years) [6].

$$d_c = Kt^{1/2} \tag{1.3}$$

These two buildings in School A was built around the year of 1971 so, t = 48 years and K = 4 $mm/year^{0.5}$. The estimated carbonation depth by using Equation 1.3 is 28 mm. Based on Figure 11 and Figure 12, all the core samples carbonation depth have exceeded the estimation carbonation depth of

28 mm. It is found that 91.7% of the core samples of Classroom Block have exceeded the estimated carbonation depth that is 28 mm and 70.8% exceeded in Hostel Block.

4.3 Rebound Hammer Test

Figure 13 and Figure 14 shows the result of rebound hammer test of Classroom Block and Hostel Block. Based on the result, 21% of the total test have rebound value less than 25 N/mm^2 for Classroom Block and 21% of the total test have rebound value less than 25 N/mm^2 for Hostel Block.

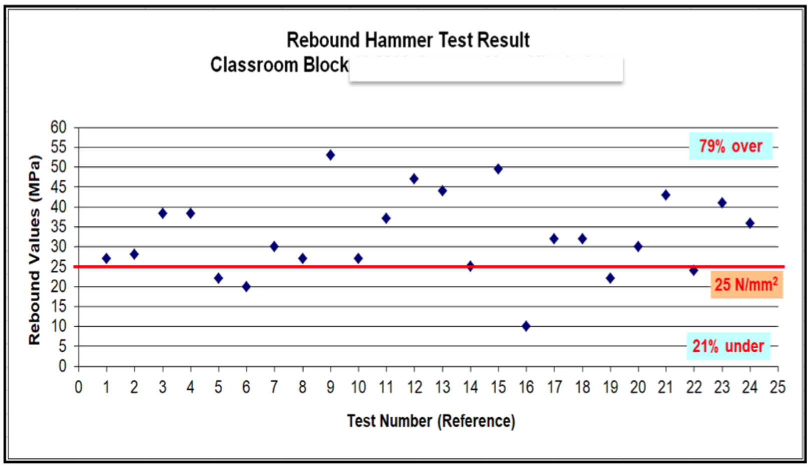

Figure 13. Rebound hammer test result for classroom block.

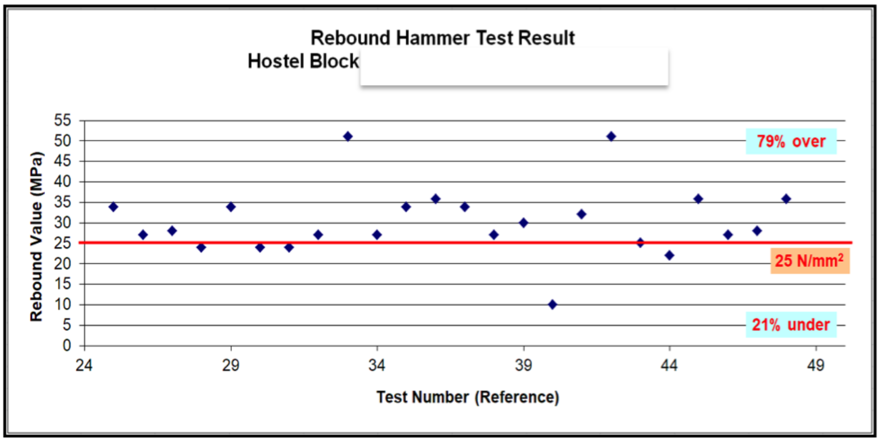

Figure 14. Rebound hammer test result for hostel block.

5. Findings and discussion

Based from the visual inspection and the Building Condition Assessment, the rating of the building in School A is three (3), while for School B is two (2). Buildings with rating three (3) need further investigation and material testing was conducted. In general, from the material testing result, the concrete qualities for the two (2) buildings that are Hostel Block and Classroom Block are very low. The compressive strength test from the core samples shows that the concrete strength of the existing buildings is low.

Most of the carbonation depths have exceeded the estimated carbonation depth of 28 mm that was calculated using Equation 1.3. Most of the damages to the building are due to material deterioration / corrosion. Repairs of these concrete structures are required but generally for repairs to aging building that is undergoing carbonation attack and with low compressive strength are very costly and tedious. Routine maintenance after the repairs will be necessary as the corrosion process can only be slowed down but not completely halted.

6. Recommendation and conclusion

The result from visual inspection, Building Condition Assessment online system and material test are summarized below;

1) The outcome from the visual inspection are clearly shows that both school need to be repaired or rehabilitated. Most of the concrete structures in both of the schools have undergone deterioration process and the defects found were concrete spalling (ceiling and beam), corroded reinforcement bar, cracks on beam, slab and column. School B have the least concrete spalling problem but it has shear crack and flexural crack shows on the main beam. Further investigation on the building structure design has to be conducted to identify the root cause of the cracks and the remaining life cycle of the building for safety reason.

2) Result from the Building Condition Assessment online system (BCA-OS) analysis, Block A and B is in Rating 2 while Hostel Block and Classroom Block are in rating 3. By using this result, further investigation was done to Hostel Block and Classroom Block of School A.

3) Core samples were extracted from both of the buildings for compressive strength test of the concrete and carbonation test. In-situ rebound hammer test was also done. The compressive strength result for the coring sample taken from the inspected building was found to be low. It is ranging from 4.7 N/mm^2 to 31.2 N/mm^2 for both blocks; Hostel Block and Classroom Block. The carbonation depth is ranging from 14 mm to 115 mm. Meanwhile, the results of the rebound hammer test are found relatively higher than the core sample compression test but it is still giving a low result on the existing building comparing to the normal fresh concrete grade.

Based on the result of this study, it is found that the buildings in School A and School B need to be repaired and rehabilitated as soon as possible. The most critical structural condition is the buildings in School A and it should be prioritized for repairs and rehabilitate. Result from this study has contributed to the knowledge of building condition assessment on school building in Sabah and the important of the system used to rate the building condition. This Building Condition Assessment system is recommended for the technical government agencies to be implemented on their building inspection procedure.

The result from the Building Condition Assessment online system shows that Block A and Block B of School B is at the rating 2 and no further investigation was proposed. By judging from the observation from visual inspection, it was detected that the respective building's main beam has shear crack and flexure crack that need to be closely monitored and investigate. This kind of crack is the sign shows that the building is under distress. Due to this reason, it is recommended for future study to improve the building assessment system so that any sign of structural crack that can lead to structural failure can be detected in the system even though the user of the system is a layman or have a minimal basic knowledge on structural design.

7. Acknowledgement

This research was funded by the Ministry of Education (MoE) and Research University Grant (RUG COE) No. Q.J130000.2422.04G10 Universiti Teknologi Malaysia (UTM). Invaluable appreciation goes to all staffs and Assistant Engineers in the Structures and Materials Laboratory, School of Civil Engineering, Faculty of Engineering, Universiti Teknologi Malaysia. My sincere appreciation also extends to the principles, all the teachers and staffs of School A and School B for their assistance in supplying all the data and information needed.

8. References

[1] Drukis, P., Gaile, L. and Pakrastins, L. Inspection of Public Buildings Based on Risk Assessment. *Procedia Engineering*. 2017. 172: 247–255.
[2] Yacob, Syamilah; Ali, Azlan Shah; Cheong Peng, A.Y. The Practice of Building Condition Assessment in Public Sector Facility Management. *Journal of Building Performance*. 2018. 9(2): 1–3.
[3] Brandt, E. and Rasmussen, M. H. Assessment of building conditions. *Energy and Buildings*. 2002. 34(2):121–125.
[4] Yacob, S., Ali, A. S. and Peng, A.Y.C. Building Condition Assessment: Lesson Learnt from Pilot Projects. *MATEC Web of Conferences.* IBCC. 2016: 66.
[5] Dejaco, M. C., Re Cecconi, F. and Maltese, S. Key Performance Indicators for Building Condition Assessment. *Journal of Building Engineering*. 2017. 9: 17–28.
[6] Neville, A.M. *Properties of Concrete*. 5th ed. England: Pearson Education Limited. 2011.
[7] Public Work Department. *Garis Panduan Pemeriksaan dan Penilaian Keadaan Bangunan Sedia Ada*. Kuala Lumpur, Malaysia, JKR 21602-0004-13. 2013