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Heritage building condition assessment: a case study from Johor Bahru, Malaysia

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Abstract: Building condition assessment (BCA) is an assessment that provides the information of deficiencies of the property to support the decision-making and management of its maintenance and rehabilitation. This paper presents the execution of BCA on heritage building, namely Balai Zaharah in Johor Bharu to obtain its rating. The BCA was conducted based on the structural and architectural elements’ maintainability, security, functionality and the sustainability of the construction material’s originality. Therefore, the main objective of this study is to identify the rating of each defect according to its condition and maintenance priority. From each defect, the overall rating from 1 to 5 of the building was determined. A systematic recording of the building systems is one of the methods used in this study by visual inspection and technical notes of each defects and deficiencies existed. As for the material suitability, energy-dispersive X-ray spectroscopy (EDX) was performed on the element samples to identify the chemical composition of the construction materials used so that the originality can be sustained during the rehabilitation and maintenance works. In conclusion, from the building assessment and matrix analysis, it was found that Balai Zaharah was rated to require major maintenance and rehabilitation to reestablish to its original state.

1. Introduction
Knowing that every building constructed was designed for a certain period of design life, Building Condition Assessment (BCA) has to be carried out periodically in furtherance of assessing the current condition of a building to avoid any structural deficiencies or failures. BCA is an assessment to identify whether the structural components in a building are in good condition or need any maintenance or replacement. Each defects and deficiencies of the architectural and structural elements will be rated according to its severity and level of consequences, which could help the authorities or person in charge to clarify the ideal actions that should be taken to dodge with the major defects or structural failures. Developing an area with vast construction has gaining the attention of developers and contractors. However, BCA is rarely been taken into account in the contract and this may risk the safety of the building users as the defects were not identified earlier.

Looking into heritage or historical buildings, certain aspects should be considered as they involved physical and proper actions to preserve the fabric and material originality of the buildings. They had been preserved and will be inherited for the future generations as a knowledge defined within social, political and cultural context [1]. Old and historical buildings, such as monuments, buildings, streets
and landscape act as proof through physical evidence to an ancient histories and knowledge. Therefore, it is very important to ensure that any activities like renovations, conservations or even assessments do not affect the original materials and look of the buildings.

Therefore, this research is aimed to study the originality of the materials used to construct the studied heritage building and its historical value before carrying out the Building Condition Assessment. Hence, from the assessment of the building, an overall rating was concluded according to its current physical condition. As highlighted in Garis Panduan Pemuliharaan Bangunan Warisan by Jabatan Warisan Negara, this study is compulsory before rehabilitation work can be taken place as purpose to sustain the originality and the cultural value of the building [2].

2. Building Condition Assessment

BCA has grown to be an important element in the context of Built Environment and Asset Management in Malaysia according to Syamila Yacob et al [3]. BCA is an assessment to identify whether the structural components in a building are in good condition or bad. Vanier, D. J. et al stated that it gives valuable and necessary information regarding the performance of building materials and for future planning of maintenance work [4]. The purpose of conducting BCA is to determine the condition of major building elements such as columns, beams, slab etc. and also to quantify the defects and deterioration of each element. Besides, BCA provides the information, which may be used to prepare a budget outlining deficiencies and maintenance cost.

Typically, BCA includes a review of all available documents, for instance the architectural and engineering drawings of the structure including warranties and service contracts. However, there are few cases where design drawings are no longer exist and commonly observed to very old or heritage buildings. Furthermore, BCA should come out with a building condition assessment report, which includes all the structural and architectural defects and their ratings of severity and also the overall rating of the building, as the preliminary method to estimate the capital spending for maintenance and spending over 5 to 10 years according to the current contractor’s quotations.

In addition, data gathering by inspection of buildings in use, rather than from models under experimental conditions, is an important means of learning about durability and the need for maintenance [4]. Building condition assessment reflects the original quality, age, environmental influences and any maintenance previously performed.

One of the three objectives for Agenda 21 for Sustainable Construction is “to create a global framework and terminology.” Central to the achievement of this objective is the development and consistent interpretation of common terminology, especially for performance measurement, such as condition assessment ratings. A quick review of international practice reveals a great number of rating systems and interpretations of condition assessments. With the exception of roads and bridges, historical performance data in the built environment is scarce and inconsistent due to a number of reasons. One being the lack of common condition assessment rating systems, which complicates benchmarking and data mining unnecessarily [5].

3. Historical Building

Harun, S. N stated in “Heritage Building Conservation in Malaysia: Experience and Challenges” that conservation of heritage buildings is a process to prevent decay and is aiming to prolong the life of the buildings [6]. Also the true concept of conserving the heritage buildings is by preserving its authenticity based on the original or historical evident. Authenticity is a process to reveal the true nature of an object, which includes evidence of its origin, its original construction and materials used and also the method applied for the construction. It is not only the physical return of the building but also the emotion, memory and the resulting sense when the building is conserved. The conservation of heritage property should meet the test of authenticity in design, material, workmanship and setting.

Preservation and conservation of heritage buildings have not been taken earnestly until the establishment of National Heritage Department in 2006 and the enforcement of the National Heritage
Heritage buildings conservation is essential as they represent the physical evidence of the ancient environment, which symbolizes the tangible cultural identity and heritage of the nation. Conservation of heritage buildings requires knowledge and understanding of the resources, materials and also the history they represent. However, there are many heritage buildings that had been abandoned and not being maintained.

Heritage satisfies a variety needs such as artistic, earning profits through tourism, aesthetics and recreation, creating positive image of the area and improving the living environment. Heritage building conservation comprises the physical evidence of our environment that symbolizes the tangible cultural identity and heritage of the nation [7]. It is affirming our national heritage and promoting solidarity thus provides the means of satisfying a wide variety of aspirations. However, the public interest in a heritage building conservation depends on its initial state of conservation. The public and stakeholders involved are more likely to neglect buildings in very bad state of which increases the deterioration process of the heritage buildings.

4. Research Methodology

The approach of this research involved both qualitative and quantitative data analysis. The first primary objective in conducting this research is to come out with the overall building rating, which is the preliminary procedure before any rehabilitation or maintenance takes place. The heritage building that was chosen is Balai Zaharah, situated in Johor Bahru. The study on the history of Balai Zaharah and BCA reports of other relevant buildings were first conducted in order to make precautions on the sensitivity of its historical values and to identify each architectural and structural components existed in a building structure for assessment.

4.1 Visual Inspection

Different stages of inspection were performed throughout this research. To fulfill the objective, a visual inspection was carried out throughout the entire building specifically on the architectural and structural components. Each defect of the components was identified and rated according to its condition and maintenance priority. Visual inspection also involved systematic recording with the use of photographs, taking notes, and educational judgement on the defects seen. Observations that were carried out revealed a variety of deficiencies and were rated from 1 to 5, which was indicated in Table 1.

| Rating | Classification |
|--------|----------------|
| 1      | Very good      |
| 2      | Good           |
| 3      | Moderate       |
| 4      | Critical       |
| 5      | Very Critical  |

The physical condition assessments have to link with maintenance priority action to be taken prior defects findings. It is classified as in Table 2. The extent of condition and the maintenance priority combined in a defect score or matrix analysis and it indicates different severity, as shown in Table 3 and Table 4.
Table 2. Maintenance priority ratings.
(Source: JKR 21602-0004-13)

| Rating | Description | Condition |
|--------|-------------|-----------|
| 1      | The defect does not affect the structure and/or structural components and/or other building services | Satisfactory |
| 2      | A minor defect, which there is almost no impact to the structure and/or structural components functionality but still should be maintained | Slight |
| 3      | The structure and/or structural components show unnatural behaviour but the functionality as a whole does not affected | Moderate |
| 4      | The functionality of structure and/or structural components is affected and may cause injury to the occupants | Poor |
| 5      | The defect may cause structural failure and/or services failure if not repaired or maintained | Severe |

Table 3. Matrix analysis.
(Source: JKR 21602-0004-13)

| Condition Rating | Maintenance Priority Rating |
|------------------|----------------------------|
|                  | 5 | 4 | 3 | 2 | 1 |
| 5                | 5 |
| 4                | 25 | 20 | 15 | 10 | 5 |
| 3                | 20 | 16 | 12 | 8 | 4 |
| 2                | 15 | 12 | 9 | 6 | 3 |
| 1                | 10 | 8 | 6 | 4 | 2 |
|                  | 5 | 4 | 3 | 2 | 1 |

Table 4. Maintenance Action.
(Source: JKR 21602-0004-13)

| Condition Rating | Action |
|------------------|--------|
| 21-25            | Very severe and require immediate actions |
| 16-20            | Severe and require further detail investigation |
| 11-15            | Major defect and require further detail investigation |
| 6-10             | Minor defect and only require easy redecoration |
| 1-5              | No maintenance required |

4.2 Analysis
The condition of the buildings are assessed and summarized in the preparation of reports based on the following criteria such as functionality, security, maintainability and sustainability. All the findings identified are assessed and recorded in building condition schedule and in defects sheets. The defects
were illustrated with photographs. The details inspections of the defects were to be filled in BCA form. Figure 1 shows the process of building condition assessment.

The analyzed data of defects are summarized and major defective elements were identified. All data were then sorted for the rating and analysis. The score obtained from the building condition schedule determined the level of defects finding. The overall building rating derived from the total mark from sum up matrix analysis divided by total number of defects and classified as in Table 5. This is the same method of calculation research by Hamzah, N. et al [8]. A rating system that minimizes subjective evaluation is repeatable and can be effectively used to predict future condition.

![Figure 1. Condition assessment process (Source: JKR 21602-0004-13, 2013).](image)

| Rating | Condition | Maintenance Action         | Score |
|--------|-----------|-----------------------------|-------|
| 1      | Very good | Preventive maintenance      | 1-5   |
| 2      | Good      | Condition based maintenance | 6-10  |
| 3      | Moderate  | Repair                      | 11-15 |
| 4      | Critical  | Rehabilitation              | 16-20 |
| 5      | Very critical | Replacement               | 21-25 |

### 4.3 Energy-dispersive X-ray Spectroscopy (EDX)

In the matter of construction materials, the Department of National Heritage had highlighted in “Garis Panduan Pemuliharaan Bangunan Warisan, 2012” that the use of the original construction materials for conservation or maintenance of heritage buildings is compulsory. The originality of the materials is the main aspect that should be considered in conserving heritage buildings as it brings along the historical value of the past. Most of the materials used in heritage buildings are from natural sources, such as wood, masonry and lime. Besides that, the original materials are more suitable in the matter of material reactions as there were cases where the wrong usage of materials had cause worse defects occur in heritage buildings. Samples were taken from the building to investigate the chemical composition of the materials using energy-dispersive X-ray spectroscopy test (EDX). Set up as in Figure 2.
EDX makes use of the X-ray spectrum emitted by a solid sample bombarded with a focused beam of electrons to obtain a localized chemical analysis. In principle, all elements from atomic number 4 to 92 can be detected. The qualitative analysis involves the identification of the lines in the spectrum and fairly straightforward owing to the simplicity of X-ray spectra, while the quantitative analysis entails measuring line intensities for each element in the sample. From the scanning of the sample in a television-like raster and displaying the intensity of selected X-ray lines, element distribution images or most commonly known as maps can be produced. The images produced by electrons reveal the surface topography and the atomic number of the elements. The scanning electron microscope (SEM), which is closely related to the electron probe, is designed primarily for producing electron images, but can also be used for element mapping. In this study, energy-dispersive X-ray spectroscopy (EDX) was carried out on three samples, as in Figure 3 from the building to identify the chemical composition of the materials.

5. Findings and Analysis

5.1 Building Rating
The execution of BCA in this study involved all structural and architectural elements in Balai Zaharah. From the tables of rating provided by Jabatan Kerja Raya, the calculation of the matrix of each defects was performed to obtain the overall rating of the building in this study. Table 6 shows the list of defects identified during the visual assessment on site.
**Table 6.** List of defects identified on site.

| NO. | COMPONENT | DEFECT/DEFICIENCY | CONDITION RATING | MAINTENANCE PRIORITY RATING | MATRIX ANALYSIS |
|-----|-----------|-------------------|------------------|-----------------------------|-----------------|
| 1   | Column    | Cracking          | 2                | 3                           | 6               |
| 2   | Facade    | Spalling          | 5                | 3                           | 15              |
| 3   | Column    | Moss              | 4                | 3                           | 12              |
| 4   | Column    | Dull              | 5                | 3                           | 15              |
| 5   | Painting  | Flaking           | 4                | 3                           | 12              |
| 6   | Column    | Vegetation        | 5                | 5                           | 25              |
| 7   | Painting  | Dull              | 4                | 3                           | 12              |
| 8   | Column    | Vegetation        | 5                | 5                           | 25              |
| 9   | Painting  | Dull              | 5                | 4                           | 20              |
| 10  | Painting  | Flaking           | 4                | 4                           | 16              |
| 11  | Ceiling   | Corrosion         | 5                | 5                           | 25              |
| 12  | Ceiling   | Fungus            | 5                | 5                           | 25              |
| 13  | Column    | Delamination      | 5                | 5                           | 25              |
| 14  | Slab      | Broken            | 5                | 5                           | 25              |
| 15  | Slab      | Rot/Rusting       | 5                | 5                           | 25              |
| 16  | Slab      | Termite attack    | 5                | 5                           | 25              |
| 17  | Joist     | Rot/Rusting       | 5                | 5                           | 25              |
| 18  | Joist     | Termite attack    | 5                | 5                           | 25              |
| 19  | Slab      | Missing           | 5                | 5                           | 25              |
| 20  | Column    | Corrosion         | 5                | 5                           | 25              |
| 21  | Window    | Missing           | 5                | 4                           | 20              |
| 22  | Door      | Broken            | 5                | 4                           | 20              |
| 23  | Wall      | Spalling          | 5                | 4                           | 20              |
| 24  | Slab      | Textural features | 4                | 4                           | 16              |
| 25  | Staircase | Broken            | 5                | 5                           | 25              |
| 26  | Staircase | Missing           | 5                | 5                           | 25              |
| 27  | Staircase | Rot/Rusting       | 5                | 5                           | 25              |
| 28  | Beam      | Corrosion         | 3                | 4                           | 12              |
| 29  | Wall      | Vegetation        | 5                | 5                           | 25              |
| 30  | Column    | Deformation       | 5                | 5                           | 25              |
| 31  | Apron     | Deformation       | 5                | 5                           | 25              |
| 32  | Staircase | Spalling          | 3                | 4                           | 12              |
| 33  | Staircase | Missing           | 5                | 5                           | 25              |
| 34  | Apron     | Deformation       | 4                | 4                           | 16              |

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Figure 4 shows that the highest percentage of the defect level is 21-25, which is the most critical level indicated.

![Pie chart showing the percentage of defect levels](image)

**Figure 4. Percentage of Defect Level.**

Building rating = \( \frac{\sum \text{matrix}}{\sum \text{ defects}} \)  

\[= \frac{699}{34} \]

\[= 20.6 \approx 21 \text{ (Rating 5)} \]

From the data collection and analysis, the overall rating of the building is 5, which indicates the building is in very critical condition and requires major maintenance and replacement as per assessment.

5.2 Chemical Composition

Chemical composition of the construction materials used in the building is identified using energy-dispersive X-ray spectroscopy (EDX) on three samples to obtain more accurate data and results. From the experiment, it was found that the materials contain calcium, silica, carbon, aluminium, sulphur, potassium, titanium, iron, chloride, magnesium and sodium. The materials that should be used for maintenance and rehabilitation should comply with these elements and do not result in chemical reaction that may cause worse defects occur in the building.
Figure 5. Chemical Composition in Sample 1.

Figure 6. Chemical Composition in Sample 2.
Figure 7. Chemical Composition in Sample 3.

Figure 5, Figure 6 and Figure 7 shows the chemical composition of the material from Sample 1, Sample 2 and Sample 3 respectively. From the test, it shows that the material has high content of calcium, carbon and silica. The chemical composition from each sample shows different composition due to different surface analyzed and each surface does not represent every composition existed in the whole sample. Therefore, if the original material used in the building is impossible or hardly can be obtained, the material that can be used to replace the original must comply with the chemical composition identified to prevent any failure or deficiency of the building in future. Material that does not match these chemical compositions should not be proceeded with the maintenance or rehabilitation.

6. Discussion and Conclusion
From the analysis, it can be concluded that the overall rating of the building has been achieved. The rating of the building studied is 5, which requires major maintenance and replacement in order to reestablish the original state of the building. Upon repair and rehabilitation, the materials replaced must be equivalent to the original materials as it was first built. However, if the original materials are no longer existed, other materials used should have a compatible chemical composition as the original materials. Any materials that may lead to unintended chemical reaction must be avoided.

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