The aspect role of building maintenance on architectural design works (case study: a College Building in West Jakarta)

J Rilatupa$^{1,2}$

$^1$Christian University of Indonesia, Jl. Mayjen Sutoyo, Jakarta 13630, Indonesia
$^2$Tarumanagara University, Jl. Letjen S. Parman No. 1, Jakarta 11440, Indonesia

E-mail: jedrilatupa@gmail.com

Abstract. Architecture design needs to be completed with design criteria and standard knowledge of building maintenance in order to estimate a design quality related to shape and building materials selection. Similarly, a design criterion needs knowledge of building operations, including its maintenance aspects. Building maintenance needs to be done, in order to building lifetime can be extended by making periodic repairs, because utilization of each building component is not the same. Generally after building implementation, began to emerge problems with degradation in quality function of each component, utility and utilization of maintenance costs that were not proportional to the building lifetime. This research was conducted at one of the college buildings in Jakarta. This study aims to observe changes in building structures conditions, determine failure location, both in terms of architecture and maintenance; and an improvements inquiry that have been made to construction components. The method used based on BRE Digest 268. Based on an investigation obtained category value reliability and condition of college building is 86.9 with good treatment condition.

1. Introduction

At the phase of planning and designing a building, a consideration of building structure in high-rise buildings play an important role. Although many building developments are not concerned with building maintenance issues since the planning and design period, maintenance aspects must be considered when building is utilized. Good design not only notice to user necessity, but also should observe to facilitate a building operation, including its maintenance [10]. Meanwhile, the Republic of Indonesia Law (UU RI) No. 28 of 2002 on Building contains regarding services, maintenance and buildings periodic inspections and development requirements for a steady and solid capability in supporting load including those emerging from natural behavior [16].

In addition, a guidelines on the buildings maintenance management are also described in the Regulation from Minister of Public Works number 45/PRT/M/2007 [17] explains that aspect of building maintenance necessary to be done, because a building utilization can be extended with improvements periodically (lifetime of any building components are different). Building maintenance activities are often ignored by building owners/managers, because they see that maintenance aspects are not important and even tend to increase the routine costs that should be incurred [3, 6]. As a result, many buildings are only repaired if severe damage is found, thus requiring more funds than routine and planned maintenance [2]. Costs incurred to make repairs due to unplanned maintenance are enormous [13].
Based on this, the building maintenance department requires regular planning and inspection to inspect a building condition. Then, the damage/failure identification data is calculated to obtain a prediction model of building conditions through a method of BRE Digest 268 1988 [18]. The prediction model of building conditions is very helpful for building managers in the maintenance department to keep optimizing a condition and performance of building. Identification of failure to each building component requires to be done to see a failure consequences to the building and its causes [7].

The problem causes are: the influence of local climate and vegetation that directly affect an outer wall surface elements of building [12]. Other problem causes are a mechanical effect on the structure and inner space construction elements, the material selection impact on building construction elements and the decline condition in operational function of building utility. Similarly, non material issues are proportional maintenance cost control related to the age/lifetime of building [8, 9].

This research aims to estimate a value of building construction condition and to know the management system of campus building maintenance which located in West Jakarta. The benefits of this research are as a suggestion to architects to know the environment condition (local climate) that affect to an architecture work. In this case, the architectural work in question is the form and utilization of material types. In addition, a work of architecture requires aspects of maintenance building more efficient and effective.

2. Research Method

The material used in this research is a master plan of 10-storey College building in West Jakarta; and visual data of its building. Meanwhile, the tool used is a visual recorder and inspection form for data exciting. Research method is done by:

- observations of building structure (upper structure), floor by floor, both on the interior and exterior areas
- determining the location of the damage by identifying the damage types, both in terms of architecture, construction management and maintenance
- investigations on improvements already made to the construction component which has been repaired.

Analysis of data obtained through weighting of each component of building construction to determine the priority scale of the 10-storey college building element in West Jakarta, based on BRE Digest 268 of 1988 [18], as seen in Table 1. After obtaining weighting, building reliability testing with scoring and weighting system to obtain reliability of construction and building components based on BRE Digest 268 of 1988, as shown in Table 2.

| Construction components | Assessment of relationship with | Total | Weight (%) |
|-------------------------|--------------------------------|-------|-----------|
|                         | 1     | 2     | 3     | 4     | ....... | ....... | 10 |

*value 3: close relationship value 2: medium relation value 1: less relationship

The assessment factors are related to (1) resilience, (2) stability tolerance, (3) weather/climate impact, (4) maintenance, (5) fire prevention, (6) noise prevention, (7) building system, (8) air conditioning circulation, (9) earthquake resistance, (10) others
Table 2. Assessment of building condition

| Construction components | Weight | Forensic* | Investigation result | Weight x value |
|-------------------------|--------|-----------|----------------------|---------------|
|                         |        | a         | good, medium, broken |               |
|                         |        | b         | slight, moderate, severe |               |
|                         |        | g         |                      |               |
| The outside wall        |        |           |                      |               |
| Rooftop                |        |           |                      |               |
| Doors and windows       |        |           |                      |               |
| Etc                    |        |           |                      |               |
|                        |        |           | 3 2 1                |               |

*Forensic factors observed are (a) sun and light, (b) temperature, wind and air movement, (c) rain, (d) sand and dust, (e) strong winds and storms, (f) earthquakes, (g) biological destroyers

To get the value of the buildings reliability acquired by the equation:

\[
\text{Building reliability} = \frac{\text{total weight x value}}{500} \times 100 \quad \ldots \ldots (1) \quad [18]
\]

Meanwhile, for the category of building maintenance conditions obtained based on the reliability value that has been calculated before. Category of building maintenance conditions assessed based on the results of building reliability calculations [15] can be seen in Table 3.

Table 3. Building reliability and maintenance condition (Uzarski, et.al., 1997).

| Building reliability | Maintenance condition |
|----------------------|-----------------------|
| 81 – 100             | Good                  |
| 61 – 80              | Medium                |
| 41 – 60              | Slightly damaged      |
| 21 – 40              | Moderately damaged    |
| 0 – 20               | Severely damaged      |

3. Results and Discussion

3.1. Investigation results at College Building in West Jakarta

On the 1st floor of this building, found minor damage in the stairs and lobby. Damages sought are a broken tile on the floor and in lobby staircase. The stairs and lobby conditions included in minor damage. In addition, there is a renovation of electrical installations on the 1st floor. The condition of other components on the 1st floor is still included in the medium category (doors, corridors, outer walls and toilets) and good (e.g. elevator) in terms of maintenance. On the 2nd floor found moderate damage in its concrete roof components and minor damage on the stairs. The damage found was a wall of stairs that looked dirty and dusty. Meanwhile, on the 2nd floor looks less clean and less tidy.
Treatment on other components on the 2nd floor is included in the moderate category (e.g. ceiling, outer wall, urinal, etc.) and good category (e.g. elevator and sills).

On the 3rd floor found minor damage in wall and pipe components. The damage found is a wall that looks dirty and dusty. Meanwhile, on the pipe on 3rd floor looks less tidy. Treatment on other components on 3rd floor is included in moderate category (e.g. stairs, outer walls, toilets and others) and good categories (e.g. furniture and frames). On the 4th floor only minor damage was found in the stairs component. The damage found was a wall of stairs that looked dirty and dusty. Treatment of other components on the 4th floor is included in medium category (e.g. lobby). Meanwhile, on the 5th floor found minor damage at the door. Damage found is on the wall near the door frame is not tidy, plumber and painting unfinished. Treatments on other components on the 5th floor are included in moderate category (e.g. stairs, toilets, walls, etc.) and good categories (e.g. elevators and frames).

On the 6th floor found minor damage on the stairs, toilets and sills. The damage found was a wall of stairs that looked dirty and dusty, a ceiling loosened on the toilet. Meanwhile on the 6th floor was seen a broken door handle and wood at the door began to peel off. Treatment conditions on other components on the 6th floor are included in the moderate category (e.g. stairs, outer wall, toilet, etc.) and good category (e.g. elevator). On the 7th floor found minor damage in toilets and pipes. Damage found in the toilet is a peeled ceramic, while the pipe looks leak. Treatment conditions on other components on the 7th floor are included in the medium category (e.g. stairs, urinal, concrete roof, etc.).

On the 8th floor, found minor damage to the aluminium siding wall. The damage found was a wall that looked dirty and the paint was peeling off. In addition, the glass window cover also looks dirty and cannot function anymore. Treatment conditions on other components on the 8th floor are included in moderate category (e.g. stairs, outer wall, toilet, etc.) and good category (e.g. elevator). On the 9th floor, found no damage. Treatment conditions on components on the 9th floor are included in moderate category (e.g. stairs, outer wall, toilet, etc.) and good category (e.g. elevator). On the 10th floor, no damage was found. Treatment conditions on components on the 10th floor are included in moderate category (e.g. stairs, outer walls, roofs, etc.) and good category (e.g. ceiling).

3.2. The reliability and maintenance condition of College Building in West Jakarta

The reliability and maintenance condition of the college building in West Jakarta is analyzed based on weighted assessment in terms of architecture and maintenance work expressed as a percentage. Architectural weighting aims to obtain a link between the building's construction component and the appearance seen in its design. The weighting is done referring to BRE Digest 268, 1988 [18] adjusted for Indonesia (tropical climates wet/humid). Meanwhile, the weighting of maintenance work aims to obtain a relationship between the construction component and the building appearance after it was completed 30 years ago (1987 - 2017).

The research or investigation at this building is done to get an adjustment and change an order of construction component work importance. A review of matrix relationship between a type of work construction components and their impact on the appearance was an effort of building maintenance. Efforts or modifications are made to prevent shrinkage and damage to construction components, by reducing a replacement/repair of construction components; and can compress all construction component maintenance [1, 14].

Table 4 shows the percentage of weighted component of college building construction in West Jakarta in terms of architectural (design) and maintenance work. In Table 4 it is seen that there is a change of weight percentage from each construction component from architecture to the college building maintenance work. Meanwhile, a reliability of college building construction component is obtained based on the construction component maintenance work investigation. It aims to look at the building condition based maintenance work. Treatment conditions obtained will be compared with conditions that should be achieved based on the architecture (design) work. Each construction
components inspection results is obtained based system score is multiplied by the weight of each component construction [18].

### Table 4. Weighting assessment of College Building construction component

| No. | Construction components       | Weighting (%) |        |        |
|-----|------------------------------|---------------|--------|--------|
|     |                              | Architecture  | Maintenance |       |
| 1   | The outside wall             | 8.3           | 10.2    |        |
| 2   | Rooftop                      | 7.9           | 8.6     |        |
| 3   | Doors and windows            | 4.6           | 6.2     |        |
| 4   | Floor                        | 8.6           | 9.2     |        |
| 5   | The utility room             | 7.9           | 8.2     |        |
| 6   | Foundation                   | 6.2           | -       |        |
| 7   | Massive walls                | 9.2           | 9.4     |        |
| 8   | Flat roof                    | 7.9           | 8.6     |        |
| 9   | Insulating wall (interior)   | 6.6           | 7.0     |        |
| 10  | Wallcovering                 | 6.2           | 6.7     |        |
| 11  | Stairs                       | 6.9           | 7.2     |        |
| 12  | Placement of building facilities | 5.9          | 5.4     |        |
| 13  | Skeletal system structure    | 6.2           | -       |        |
| 14  | Building support (overstek)  | 7.6           | 8.0     |        |
|     |                              | 100           | -       |        |

### Table 5. The investigation results of maintenance work on College Building.

| No. | Construction components       | Reliability (%) | Decrease/ increase (%) |        |        |
|-----|------------------------------|-----------------|------------------------|--------|--------|
|     |                              | Architecture    | Maintenance            |        |        |
| 1   | The outside wall             | 41.5            | 40.8                   | -0.7   |        |
| 2   | Rooftop                      | 39.5            | 34.4                   | -5.1   |        |
| 3   | Doors and windows            | 23.0            | 24.8                   | +1.8   |        |
| 4   | Floor                        | 43.0            | 46.0                   | +3.0   |        |
| 5   | The utility room             | 39.5            | 32.8                   | -6.7   |        |
| 6   | Foundation                   | 31.0            | -                       | -      |        |
| 7   | Massive walls                | 46.0            | 37.6                   | -8.4   |        |
| 8   | Flat roof                    | 39.5            | 34.4                   | -5.1   |        |
| 9   | Insulating wall (interior)   | 33.0            | 28.0                   | -5.0   |        |
| 10  | Wallcovering                 | 31.0            | 26.8                   | -4.2   |        |
| 11  | Stairs                       | 34.5            | 21.6                   | -12.9  |        |
| 12  | Placement of building facilities | 29.5          | 21.6                   | -7.9   |        |
| 13  | Skeletal system structure    | 31.0            | -                       | -      |        |
| 14  | Building support (overstek)  | 38.0            | 32.0                   | -6.0   |        |
The investigation results of the building construction component reliability showed a decrease in the individual construction components quality, except for doors and windows; and floor (Table 5). The largest decrease was found in stairs (-12.9%), massive wall (-8.4%) and building facilities placement (-7.9%). Decrease in the stairs quality is a ceramics presence, that have been broken/cracked in the staircase and wall is less clean. Meanwhile, the massive wall components, generally less clean. On placement component building facilities, deterioration was found leaks in pipes.

Investigation results on this college building also showed an increase in the construction components quality; as found on door and window components (+ 1.8%); and also at floor component (+ 3.0%) at design phase. This suggests that components of doors and windows and also flooring components well maintained. Meanwhile, based on the investigation results, it was found that the reliability value of the college building was 86.9 with good treatment condition (see Table 3).

Table 6. Forensic factors affecting the construction component of College Building in West Jakarta.

| No. | Construction components | Conditions | Forensic factors* |
|-----|-------------------------|------------|------------------|
| 1   | The outside wall        | medium     | a,b,c,d,e,f,g     |
| 2   | Rooftop                | medium     | a,b,c,d,e,f       |
| 3   | Doors and windows      | medium     | a,b,c,d,e,f       |
| 4   | Floor                  | good       | d,f               |
| 5   | The utility room       | medium     | a,c,e,g           |
| 6   | Foundation              | -          | -                 |
| 7   | Massive walls          | medium     | a,b,c,d,e,f,g     |
| 8   | Flat roof              | medium     | a,b,c,d,f         |
| 9   | Insulating wall (interior) | medium       | b,g              |
| 10  | Wallcovering           | medium     | b,g               |
| 11  | Stairs                 | slightly damaged | f            |
| 12  | Placement of building facilities | medium       | a,b,c,d,e,f,g   |
| 13  | Skeletal system structure | -           | -                 |
| 14  | Building support (overstek) | medium       | a,b,c,d,e,f       |

*Forensic factors observed are: (a) sun and light, (b) temperature, wind and air movement, (c) rain, (d) sand and dust, (e) strong winds and storms, (f) earthquakes, (g) biological destroyer

Forensic factors affecting each component of the building construction are presented in Table 6. Forensic factors affecting exterior wall components, massive walls and placement of building facilities are sun and light, temperature, wind and air movement, rain, sand and dust, strong winds and storms, earthquakes and biological destroyers. While forensic factors that affect components of the building roof, doors and windows, and supporting the building (overstek) is sun and light, temperature, wind and air movement, rain, sand and dust, strong winds and storms, and earthquakes (Table 6).

3.3. Life-cycle cost of College Building

Maintenance can be defined as ease of product maintenance to facilitate future maintenance or overcome environmental changes. Building maintenance is part of the architectural characteristics, thus building maintenance elements become architectural parameters associated with the ease of building maintenance [5].

Social and economic conditions can have a considerable influence on the building lifetime. Thus, when designing buildings it should be noted how to extend the life (economical) of a building by making its structure easy to adapt. The lifetime of a building depends on a number of factors ranging
from the extent to which maintenance factors are included in architecture, the rate at which the owner/occupant performs maintenance work during the service life of the building and also its economic considerations [19, 20].

LCCA (Life-Cycle Cost Analysis) is the lifecycle cost analysis performed which is the process of evaluating an economic performance of a building throughout its life. The LCCA balances the initial monetary investment with the long-term cost of owning and operating the building. Over 30 years of the life of a building, the value of maintenance, operations, and utility costs are now almost as large as the initial project cost [5]. Moreover, in terms of sustainability (sustainability), then designing a building, supposed to make the building more resistant to treatment problems. The purpose of "more resistant" does not mean maintenance free, because the degradation is natural, along with the building lifetime, but has been economically calculated periodic maintenance costs of a building.

According to Juwana [4], to get the basic price of multi-storey building empirical equations are used:

\[ BB_n = BB_o \times (1 + 0.0237)^n \] .......................... (2) [4]

where:
- \( BB_n \): basic price n-floored building
- \( BB_o \): base price for non-storied building
- \( n \): number of storeys

Table 7. The cumulative maintenance costs of College Building until it reaches the initial construction cost.

| Year | Year to- | Cumulative maintenance costs (Rp) |
|------|----------|-----------------------------------|
| 1987 | 0        | 768,329,208,-                     |
| 1988 | 1        | 1,536,658,416,-                   |
| 1989 | 2        | 2,304,987,624,-                   |
| 1990 | 3        | 3,073,316,832,-                   |
| 1991 | 4        | 3,841,646,040,-                   |
| 1992 | 5        | 4,609,975,248,-                   |
| 1993 | 6        | 5,378,304,456,-                   |
| 1994 | 7        | 6,146,633,664,-                   |
| 1995 | 8        | 6,914,962,872,-                   |
| 1996 | 9        | 7,683,292,080,-                   |
| 1997 | 10       | 8,451,621,288,-                   |
| 1998 | 11       | 9,219,950,496,-                   |
| 1999 | 12       | 9,988,279,704,-                   |
| 2000 | 13       | 10,756,608,912,-                  |

Meanwhile, assuming the building cost per square meter is US $ 350 and the exchange rate of 1 US $ is Rp 2,000, in 1987; the College Building, located in West Jakarta (completed in late 1987), cost around Rp 10,671,239,000, - (calculation based on equation 2). Meanwhile, the cost of building maintenance annually is 2% of the cost of the building (Levitt, n.d.). The cost of treatment in 1987 to 1990 was Rp 213,424,780 (two hundred and thirteen million four hundred and twenty-four rupiah) each year (the price of 1 US $ in 1987 - 1990 was Rp 2,000, -). While the average rate of inflation from 1987 to 2017 was 360% with an average value of US $ 1 USD 9211, - from 1987 to 2017 (from
Thus the average cost of maintenance of College Building from 1987 to 2017 is Rp 768,329,208,-/year.

Based on LCCA (Life-Cycle Cost Analysis), the cumulative calculation of maintenance costs has reached the building construction initial cost in the 13th year of the building or in 2000 (see Table 7). According to Khan [5], if the service life of the building has reached more than 30 years, then the maintenance cost has reached the building construction cost (initial cost). Khan's statement, apparently not in accordance with the results obtained in this research. In the maintenance cost calculation, it should take into account an inflation rate or depreciation of a local currency; as happened in Indonesia. Volatility in currency values since 1998, making the rupiah value depreciated, so an inflation rate increased sharply. Thus, the statement of Khan [5] can take effect by considering the inflation rate in Indonesia. With the presence or absence of depreciation against the rupiah, a building maintenance element remains important in extending the building service life.

Maintenance costs due to waste should be reduced in every way. In this case, by minimizing (efficiency) energy can minimize costs for various activities such as artificial refrigeration, natural ventilation and others. This method is a passive way to control the environment which is highly recommended. Thus, during the design and construction process it is necessary to consider that the building can maximize the existing energy source in its environment. This can only be done when the designer (architect) and contractor is knowledgeable and have an idea about the availability and use of green building technologies.

Maintenance has an important role in a production and durability of the architecture, but most architects pay less attention to the elements of building maintenance in its design. In this case, the architects need to learn "maintenance architecture" that offers importance of building maintenance through to have knowledge of building materials. It is time for architects to imagine the maintenance concept in its design, and not only thinking about conception until the buildings realization [11].

4. Conclusions and Recommendations

4.1. Conclusions

In this research, investigation on college building, located in West Jakarta is done on every floor of the building that aims to get right accuracy. In general, an investigation results indicate that the building is quite well maintained, although in some building components and interior equipment shows a damage/failure. Common damage is found on stairs (walls on staircase dirty and dusty, broken ceramics), lobby floor (broken tiles), concrete roof/overstek (less clean), walls that look dirty and dusty, leaking pipes, doors, toilets and sills.

Investigation of the building condition by maintenance and repair section needs to be done to obtain information on the main condition system and public areas: water pipes, electricity, elevators, structural systems, roofs and windows, and others. By conducting periodic investigate, it will be immediately known which improvements should be made to eliminate the damage or the occurrence of an accident (fire hazard); such as repairing a bad electrical connection or faulty equipment, or also to find out which fixes can be delayed.

The reliability investigation results of the college building component construction showed a decline in the quality of each construction components, except for the doors and windows; and also floor. The largest decline found in stairs, massive walls and the placement of building facilities. Decrease in a stairs quality is the presence of ceramics that have been broken in a staircase and walls are less clean. In addition, on massive wall components, generally more to a cleanliness of the wall. In the placement component of building facilities, prominent quality deterioration was found in a pipeline leakage. Meanwhile, based on a results of investigation obtained that the reliability value of a building is 86.9 with good maintenance conditions.

Building maintenance techniques can consist of reactive maintenance of equipment damage (e.g. electrical equipment), based on equipment operating conditions and based on preventive/predictive maintenance. Research at college building, showed maintenance tends to be implemented with
reactive maintenance ways, like equipment repairs after damage occurs. The percentage of reactive maintenance in college building reaches 50 – 55 percent, while other maintenance techniques are 10 percent of equipment conditions and 40 percent of preventive maintenance. Periodic maintenance required for building M and its components is 1 - 1.5 years for each period.

4.2. Recommendation

Maintenance of buildings is very important and needs to be done after the building is completed built and used. This maintenance will make the building age to be longer, in terms of aspects: strength, security and building performance. The success or failure of a building construction can be seen from a service life (lifetime) of the building in accordance with its design maintenance procedures of the building itself.

Maintenance has an important role in architectural production and durability, but most architects pay less attention to the building maintenance elements in their design. In this case, architects need to learn the "maintenance architecture" that offers the importance of building maintenance through with having knowledge of building materials.

College building maintenance should use predictive/preventive maintenance techniques to obtain detection analysis of the damage causes and find the right problems. Furthermore, modifications and combinations of installation and repair techniques need to be done to avoid the same problems.

References

[1] Chanter B and Swallow P 2008 Building Maintenance Management (2nd ed.) (New York: Wiley Online Library)
[2] Douglas J and Ransom B 2013 Understanding Building Failures (New York: Routledge)
[3] Hackett M and Statham G 2016 The Aqua Group Guide to Procurement, Tendering & Contract Administration (Oxford: Wiley Blackwell)
[4] Juwana J S 2005 Panduan Sistem Bangunan Tinggi (Jakarta: Erlangga)
[5] Khan S 2013 Designing Buildings for Minimum Maintenance to Achieve Sustainability Architecture Research 3(4): 74-78.
[6] Levitt J n.d. Evaluating Real Costs for Building Maintenance Management. http://www.maintenancetraining.com/news_articles/Building-Evaluating%20Real%20Costs%20for%20Building%20Maintenance%20Management.pdf, diakses pada 12 Januari 2018.
[7] Nuswantoro W Juni 2010 Analisis Jenis Kerusakan pada Bangunan Perumahan. Jurnal Rekayasa Rancang Bangun, Vol. 11 No. 1: 1-14.
[8] Randall M 2012 Environmental Science in Building (New York: Palgrave)
[9] Ratay R 2000 Forensic Structural Engineering Handbook (New York: McGraw Hill)
[10] Rostiyanti S 2005 Studi Pengaruh Umur Gedung pada Kualitas Pemeliharaan Sistem Pencegahan Kebakaran Memperingati 25 Tahun Pendidikan MRK di Indonesia. Bandung: Institut Teknologi Bandung.
[11] Sample H 2016 Maintenance Architecture (London: The MIT Press)
[12] Schmid K F 2014 Building Inspection Manual: A Guide for Building Professionals for Maintenance, Safety, and Assessment (New York: Momentum Press)
[13] Stanford H W 2010 Effective Building Maintenance: Protection of Capital Assets (London: The Fairmont Press, Inc)
[14] Talamo C and Bonanomi M 2017 Knowledge Management and Information Tools for Building Maintenance and Facility Management (New York-London: Springer International Publishing)
[15] Uzarski D R, Laurence A, Laurence and Burley 1997 Assessing Building Condition by the Use Condition Indexes in M Saito, Infrastructure Condition Assessment: Art, Sciences and Practices (New York: ASCE)
[16] Umum D P 2002 *Undang-Undang Republik Indonesia No. 28/2002* (Bandung: Citra Umbara)
[17] Umum D P 2007 *Peraturan Menteri Pekerjaan Umum Nomor 45/PRT/M/2007* (Jakarta: Departemen Pekerjaan Umum)
[18] Watt D S 2007 *Building Pathology: Principles and Practices* (Oxford: Blackwell Sciences Ltd)
[19] Wood B 2009 *Building Maintenance* (Oxford: Blackwell Publishing Ltd)
[20] Wordsworth P 2001 *Lee's Building Maintenance Management* (Oxford: Blackwell Science)