Investigating Materials for Refurbishment Strategies of Heritage Buildings: A Case Study of Soesman Kantoor, Semarang

by Ferry Hermawan

Investigating Materials for Refurbishment Strategies of Heritage Buildings: A Case Study of *Soesman Kantoor*, Semarang

Ferry Hermawan, Didi Wibowo Tjokro Winoto, Ismiyati, Bambang Purwanggono, and Robby Soetanto

Abstract The management of heritage buildings presents complex challenges for local authorities regarding repair methods, the selection of materials and post-repair impacts. Restoring the function of heritage buildings is often still constrained by commercialisation and the problem of maintaining sociocultural values. This raises an important question, what approach strategy is most suitable for maintaining the characteristics of heritage building in the long term? Here, we present a case study with a materials laboratory test strategy for a heritage building in Semarang. The parties involved include local authorities, architects, heritage building experts and academics. Three technical assessments are conducted, namely, materials analysis using X-ray fluorescence spectroscopy and brick compression and paint adhesion tests. This study provides an overview of the strategic approach from the aspects of measuring, interpreting and providing the best solutions for the material elements of heritage buildings in the future. The results promote improving heritage buildings on the basis of stakeholder mapping and building materials improvement strategies. This research contributes to local authorities in arranging heritage buildings with technical considerations in line with the characteristics of the building and development programs that consider local knowledge.

Keywords Strategy · Refurbishment · Heritage

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1 Introduction

1.1 Background

The Old Town area of Semarang (*Kota Lama* Semarang) has high historical value with many buildings from the Dutch colonial era. Some of these heritage buildings are listed as cultural heritage buildings according to Law No. 11 of 2020 on Cultural Heritage [1]. *Soesman Kantoor* is one of these buildings and is located in *Kota Lama* Semarang. According to law, buildings that have existed for at least five decades can be classified as cultural heritage buildings [1]. In addition to this criterion, these buildings are expected to have essential historical, scientific or cultural value.

In the modern era, the attentiveness of cultural heritage buildings is often neglected. The European Charter of Architecture Heritage 1975 Article 6 states that architecture's cultural heritage is being unsettled in Indonesia and around the world [2]. In mid-January and April 2011, two cultural heritage buildings collapsed in Kepodang, *Kota Lama* Semarang. This was caused by the buildings' lifetime and natural factors, such as flooding, seawater intrusion and extreme weather [3]. As reviewed through financial, information and technological aspects, each city's evolution will always be the same from time to time. Cultural heritage buildings have unique features, the significant elements of a culture that reflect an area's identity. Cultural values grow and live within society and have their own uniqueness that makes each stand apart. If these values are maintained, each region will have an identity that differentiates it from others, thus representing its unique charm [4].

The refurbishment and improvement of building function are essential for the aim that cultural heritage can function as a new attraction for tourism and bring an area back to life. The repair of cultural heritage buildings is different from modern buildings. Professionals must handle cultural heritage buildings to avoid irreversible damage. The repair of existing structures must be carried out attentively and by not changing or spoiling any characteristics or details, although changes might be needed [5].

Research on the correct method for cultural heritage building repairs is essential because incorrect action could cause even more damage. The cultural values might be lost if damage to a single component of a cultural heritage building occurs. This research leads to the important question of what is the best method for repairing such buildings?

1.2 Research Method

The refurbishment of cultural heritage buildings in Semarang must be carried out by paying particular attention to the materials and procedures. Laboratory tests can be used to identify the material specification of existing building components. Laboratory test results are used as a benchmark to obtain a better specification of building

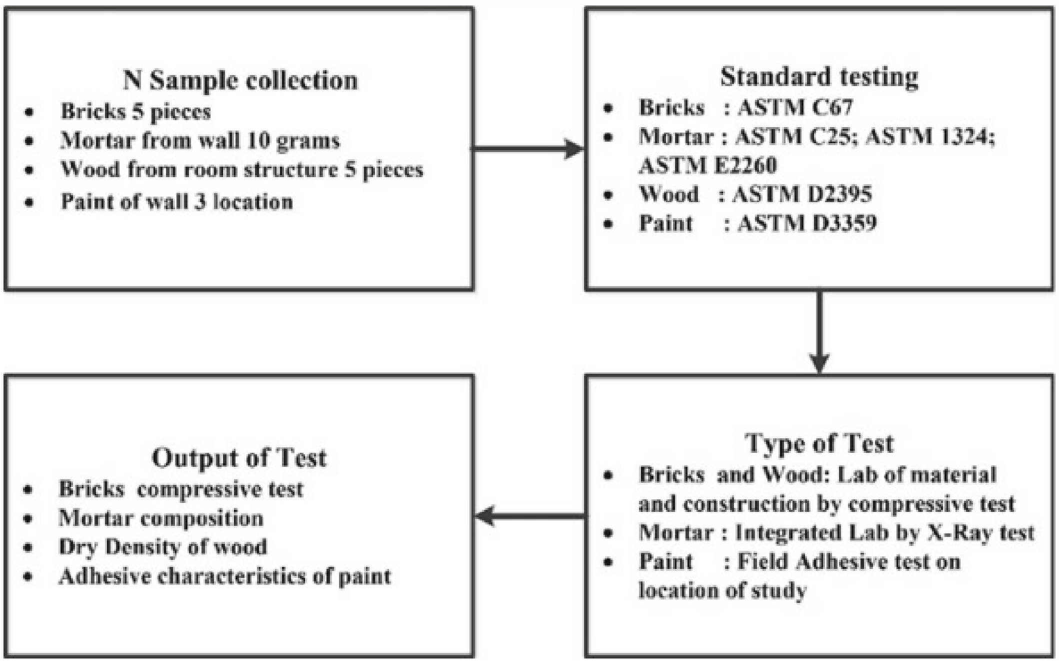

Fig. 1 Laboratory and material test activities

repair or at least at the same grade as the required criteria. The analysis referred to various standards. There are four tested cultural heritage building components, i.e., bricks, mortar, wood and paint.

The source of quantitative data came from the results of the laboratory tests. The tests were conducted on existing building material to obtain information regarding cultural heritage building characteristics. The tests were conducted on materials collected from an existing building, *Soesman Kantoor*.

In the case study building, there are four primary testing materials. i.e., bricks, mortar, wood and paint. The sample collection and testing were conducted by referring to the American Society for Testing and Materials (ASTM). The flow of materials testing activity from materials collection to laboratory tests and the output can be seen in Fig. 1.

2 Results and Discussion

2.1 *Materials Test of* Soesman Kantoor's *Building*

a. Brick Compressive Strength Test Results

The compressive strength of brick samples taken from *Soesman Kantoor* was tested. The compressive strength test aims to acquire the required minimum specifications of brick compressive strength to replace the new bricks during the reparation. The selected bricks should have a greater or equal compressive strength to avoid even greater damage to the existing building. The compressive strength test used automatic cement concrete compression machines with a 3000 kN capacity. The compressive strength test results were obtained from the load-receive brick cross-section area divided by the maximum load from the compression machine. The compressive strength test resulted in the compressive strength of each brick [6].

Older bricks are generally larger than modern ones. The dimensions of the bricks in *Soesman Kantoor* are 25 cm × 12 cm × 5 cm for length, width and height, respectively. Bricks with the same dimensions can preserve the building's aesthetics. In addition to dimensions, colour and texture are also important factors to consider [7]. The bricks in *Soesman Kantoor* are of a rectangular prism shape, with a reddish-orange colour and a smooth surface.

b. Mortar Composition Test Results

Mortar was tested to reveal the composition of the aggregate. The test used a petrographic method to find the chemical content inside the components of the mortar [8, 9]. Petrographic mortar with microscopic and stereoscopic irradiation principles that involved X-ray and electron microscopy was used. The petrographic test could be tested with wavelength dispersive X-ray fluorescence (WDXRF) spectroscopy.

WDXRF spectroscopy is an analytical technique used to detect chemical elements in solid and liquid materials. X-ray fluorescence (XRF) is a "secondary" characteristic X-ray emission (or fluorescence) of materials excited through high-energy X- or gamma rays. WDXRF is known for its high accuracy, precision, and reliability.

The mortar test sample was taken from the indoor wall of *Soesman Kantoor*. The minimum mass of samples tested was 10 g. The mortar composition test was conducted with a petrographic examination utilising WDXRF spectroscopy to analyse the metal contents in solid and liquid materials, both metal elemental and metal oxide. Generally, lime mortar consists of several primary chemical compositions, including CaO, MgO, SiO_2, Fe_2O_3, Al_2O_3 and CO_2 [10].

c. Wood Specific Gravity Test Results

The testing of wood samples was completed using a wood specific gravity test. This test aims to discover the minimum wood specific gravity that is to be used in the building component repair of the existing cultural heritage building. Wood specific gravity is generally proportional to wood strength or its mechanical properties [11]. The greater the wood specific gravity, the stronger the wood. Wood specific gravity compares the oven dry wood weight at 105 °C and the weight of water with a volume equal to that of the wood. The specifications of new materials must be better or equal to avoid further damage.

After being weighed, the wood sample was dried in a laboratory bench oven and with digital control to eliminate moisture from the wood samples. The final wood sample gravity was obtained from the weighing after being dried in an oven under 103 ± 2 °C for 24 hours The results of wood specific gravity were obtained from the wood sample dry weight divided by moisture level and volume. The mean specific gravity from the five wood samples was 0.571 gr/cm^3.

d. Paint Adhesive Power Test Results
The paint adhesive power test was directly conducted on the *Soesman Kantoor* exterior wall utilising a cross cut tape test method. The test was completed on three walls in different locations of *Soesman Kantoor*. The part of the wall to be tested must be smooth and clean. It was then cut longitudinally and circularly, each with six lines of a 2 cm length and a 2 mm gap between each line. We observed the test area surface on the cutting line area. Sticky tape with a 1-inch width was then applied until the whole area was closed and the tape was flattened with fingers or additional tape. The tape was taken off with a near 180° direction, with constant speed and at once. The condition of the paint surface was observed [12]. In location 1 (old wall), the test result showed that the paint's grade was zero because more than 65% of the paint surface was peeled. For the side wall (location 2), the test result showed a grade 2 paint indicated from the peeled paint at the side of the cutting line and some parts of the square area. The peeled paint area was ~15–35%. For the third location (front wall), the test result showed a grade 5 paint, as seen from the zero-peeled paint on the test area where the cutting edge also remained intact.

2.2 *Refurbishment Strategy Formulation for* Soesman Kantoor

Brick Repair

The repair was completed by first determining the correct replacement materials. The criterion for alternative brick materials was materials with a minimum compressive strength of 100.63 kg/cm^2. Brick wall repair that included an area of more than 0.19–0.27 m^2 or more than 20% of an existing wall, or exceeding 2.4–3.0 m length, as a required consideration to meet the physical strength criteria of the brick. It needs to meet the physical strength criteria to level the building movements due to the load distribution and expansion and shrinkage of the existing and new bricks. The installation of new bricks with different specifications might cause cracks and fracturing of the bricks.

Another aspect to consider is the appearance of the bricks, which includes their dimensions, colour and texture. The old brick dimensions are different from the size of the contemporary brick. It is suggested to ask the brick manufacturer for the specific brick size to make it more economical. The most crucial must-match dimension is for the brick parts to be exposed [7]. For the other unexposed parts, a variation in size is allowed as long as it does not obstruct the repair. The dimensions of bricks known as the government's model are 26 × 12.4 × 52 cm.

Contemporary bricks with the same colour and texture, but larger than the existing bricks, could be used by cutting it with a wet saw to the desired size. This is an economical way for the small needs of bricks. Using materials other than bricks is not recommended due to the building's visual aspect. Repair work on new brick components must be marked to identify the components that have been repaired.

Mortar Repair

Mortar repair on the cultural heritage building wall was completed by stripping the old mortar layer, a process known as repointing [11]. Repointing increases weather resistance, reduces water seepage, maintains structural strength and appearance, and extends the building's lifetime. Field inspection was essential to point the damaged mortar. If the previous mortar repair was not matched to the original mortar, it needed to be stripped. Original mortar identification is crucial to obtain a suitable new mortar. The colour and texture of the original mortar had to be investigated visually, while the mortar composition was observed in the laboratory.

After getting the correct mortar composition, a test must be carried out to compare to the original mortar, in terms of colour, texture and the finishing of the surface. This assessment was carried out once the mortar hardened. The new mortar trial assessment must represent the conditions and surface material to be peeled and have proper lighting and the same environmental condition. The mortar repair must use compositions similar to the existing conditions so it can sufficiently stick. The composition was acquired from the laboratory test results with WDXRF to find the ratio of the correct mortar constituent components. The most dominant component of mortar test results in the laboratory were calcium oxide (CaO), which represents lime material with ~85.2%, ferric oxide (Fe_2O_3)/clay with ~32.4%, silica (SiO_2)/sand with ~16.4% and aluminium oxide (Al_2O_3)/clay with ~3.96%. The composition of the mortar mixture according to the existing test results were lime:clay:sand with a ratio of 8:3:1. The laboratory test results show the composition of the old building mortar, but it is still in the percentage of mass per molecule that significantly involves oxygen and causes the mass to exceed 100%. The mass per element is acquired through the calculation that involves atom mass and molecular weight.

The simple lime mortar process was completed by burning the lime in a furnace to form quicklime. The lime was then mixed with water to form slaked lime, which forms a hydrated lime putty or lime powder. The powder was then mixed with sand and water to form mortar. The type of lime mortar that is known as non-hydraulic has a prolonged setting time through the reaction with carbon dioxide in the air. The setting speed can be increased by using limestone, which is burned in a furnace, to form a hydraulic lime that breaks down if it comes into contact with water. The application of mortar to the gap of the bricks must be compact and should not leave any cavities. The application must consist of double layers, where each is compacted beforehand.

Wood Repair

The wood component repair was carried out by determining the material with a specific gravity that was better or at least equivalent to the existing wood component. The wood specific gravity that must be met is 0.571 gr/cm^3 or equivalent to wood strength grade level II, according to SNI 7973:2013 [12].

Structural reinforcement in cultural heritage buildings was carried out by replacing wood materials with the same quality. There are 17 various types of wood in Indonesia with various specific gravities that can be used as replacements in heritage buildings, including timber (*Lagerstroemia speciosa*), teak tree (*Tectona grandis*), rubber (*Hevea brasiliensis*) and cinnamon (*Cinnamomum purrectum*). Knowledge of the various types of wood would reduce the dependency on a specific type of wood, so that other types of wood that have not been used could increase. Wood material repair for construction elements could use alternative wood types, but it is better to use wood with a better or at least equivalent grade.

In addition to structural strengthening, damages caused by termites must also be replaced by replacing wood materials of the same quality. To avoid termites, maintenance is essential by spraying with anti-termite liquid and traditional cleaning using cloves, tobacco and banana fronds with the ratio of 1:1:1.

Differently coloured wood components could be repaired by means of camouflage, i.e., change the shape and materials to make it look like the original. Maintenance that could be carried out includes monitoring climatological conditions with an extreme thermometer [13].

Paint Repair

Repainting cultural heritage buildings requires special paint that allows water vapor to move freely through walls. Painting with a mixture of cement and regular sand or cement plaster will only cause cracks and will not bond well with the old cement-sand mixture that sticks to the wall. Plaster made of regular sand cement and cement plaster would be too stiff and hard, thereby potentially causing cracks on the wall.

Paints must be breathable, but it could not be found easily in paint products in the modern era because modern buildings tend to seek waterproof paints to prevent rain from getting into buildings. Coloured mortar could be acquired by adding pigments into the mortar mixture. This method can only be achieved if the desired colour can be achieved using aggregates that can provide that colour. The breathable paint was made from a lime-based mixture. Lime could also provide a white colour if it is the desired one. The paint composition used referred to the BOW analysis. The mixture for a 10 m^2 paint was one part *Tras Muria*, one part limestone and three parts sand.

The pigment added into the mortar must be smooth to be mixed evenly, but it should not cause a reaction that can damage the mortar. This kind of pigment could be achieved through pigments with a metal-oxide nature, i.e., lime (CaO). The pigment addition must be carried out in moderation to maintain the composition and mortar performance. The suggested pigment addition is a maximum of 10% of the total mixture.

The advantage of using lime is its flexibility and its resistance to shrinkage cracking from wall movements. The cracking that occurs due to the structural movement can occasionally "self-heal" with water circulation. The coloured mortar also does not need to worry about adhesion because it is homogeneous with the mortar. The disadvantage of lime is that it requires a long time to harden. It could turn soft and crumble if continuously exposed to water. The summary of refurbishment strategies as presented in Table 1.

Table 1 Summary of refurbishment methods

Component and characteristics	Visual	Repair method
Bricks Dimensions 25 cm × 12 cm × 5 cm Colour Dark orange Compressive Strength	Long rectangular prism brick, flat and no-cracked surface, and angled corners. Dark orange bricks or with as close as possible colour to the existing bricks if it is exposed	Repair using bricks with a minimum compressive strength of 105.03 kg/cm^2. The new brick dimension must be made as close as possible to the old one, i.e., 25 cm × 12 cm × 5 cm The colour and texture of the bricks are adjusted to the existing one to maintain the aesthetic value, i.e., reddish orange with a flat surface Alternative material is not recommended because it might damage the appearance of the new brick wall
Mortar Colour Composition	The colour is dominantly dark white due to the mixture of lime and clay paste	Making mortar with a composition significantly similar to the existing mortar, i.e., the mixture of lime:clay:sand with the ratio of 8:3:1. Application
Wood Dimension Colour Specific gravity	The wood dimension depends on the repaired components The colour of the wood is adjusted to the original condition	The structural wood repair must meet the conditions of minimum wood specific gravity of 0.571 gr/cm^3. The type of wood may vary as long as the specific gravity is sufficient. Joinery could be done if the desired wood dimension is unavailable, by paying attention on the technical guidelines of *SNI* 7973, 2013 Non-structural component repair
Paint Composition Waterproof paint is not allowed Grade 5 is the expected adhesive power, in which no paint is peeled during the tape test	White paint or adjusted to the colour of the original paint	Repair using pigment-coloured mortar. The pigment used could come from one of the aggregates with the desired colour. Lime aggregate works as an adhesive and pro-vide white colour to the paint. The adhesive power in paint is not a problem because the paint itself is the mortar's homogeneous part

3 Conclusions

It is strategic to conduct a comprehensive investigation before repairing cultural heritage buildings to acquire thorough information regarding the buildings. The laboratory test on *Soesman Kantoor* building components is a way to obtain the characteristics of each material. The testing was carried out on the elements with the most damaged materials, i.e., bricks, mortar, wood and paint.

The differences in materials and manufacturing methods of two time periods show the technology development that becomes more efficient each day. However, the material authenticity and work methods must be maintained as the original; thus, modern materials and manufacturing methods cannot be carelessly applied.

There is a wide range of cultural heritage building components, so it could not be generalised. The repair must be done per case because each issue needs a different solution and could not be equated to other building components. The repair guidelines of a cultural heritage building with *Soesman Kantoor* as the case study focuses on brick, mortar, wood and paint components. All components could be repaired by following the minimum criteria for replacement materials. If a material cannot be repaired as well as the original, it can be replaced as long as it is not invasive and reversible.

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