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Development of Modular Outdoor Furniture Product Using Lightweight Concrete for Public Parks in Surabaya

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Abstract. The development of public parks into green city facilities in Surabaya has triggered the need of outdoor furniture designs that can resist the tropical wet and dry weather conditions while also having a certain mobility to support flexible park arrangement. However, present furniture designs made of concrete material are generally heavy and immovable. Flexible designs are needed for various activities that can take place at the same time such as sitting and playing, and to support changes in arrangement to keep the green open spaces attractive from time to time. This research develops the idea of a modular outdoor furniture design using cellular lightweight concrete (CLC) as the main material as a result from observing its resistance towards weather change and its relative light weight. It starts with analysis of problems, formulation of design concept, creation of design alternatives, selection of design, calculation of mouldings, adaptation of design to the mouldings and production of a scaled mock-up using CLC. Findings of this research reveal that the modular design along with the CLC material used not only support the flexibility of change in function and arrangement but also make these furniture resistant to the hot and humid weather of Surabaya.

1. Introduction

The development of public parks into recreational areas in Surabaya has triggered a need for new physical facilities, such as outdoor furniture, to attract people towards the green open spaces. As stated in the *Raperda RTRWP Jawa Timur* (the Indonesian Regional Land Use Regulation Draft of East Java) year 2011-2031, green open spaces need to be maximized as an attempt to achieve the local vision of Surabaya as a 'green city' [1]. Healthy planning of the spaces and its facilities such as furniture and equipment should include a place to improve the health conditions of the elderly, youth, and lower socioeconomic status groups [2]. The designs of the outdoor furniture must be able to resist the wet and dry tropical climate of Surabaya, and can be used for a long period of time. Apart from that, these furniture should be flexible in arrangement, use and management such that they can not only bring variety and interest both architecturally and functionally, but also support the dynamic activities that can take place in public parks, such as sitting, socializing and playing. The growth and development of the city has also changed the meaning of the park in daily life [3]. Hence, in this research, modular multi-functional systems of outdoor furniture, using light weight concrete as the main material, are proposed in order to meet those needs.



The background problem in this research is how to produce designs of modular outdoor furniture that are climate-resistant in the public parks of Surabaya city. Parks and green spaces are of significance at the present time as key elements of individual and social life quality and as supporters of a sustainable city [4]. Through various analysis of outdoor materials, lightweight concrete has been chosen as the main material because of its light weight as well as its resistance towards ultraviolet rays, climate, termites, rust and impact force such that it is relatively safe for both adults and children. Lightweight concrete can be moulded into various shapes and finished with many kinds of coats such that it promotes many possibilities of design in terms of form and visual appearance.

Conventionally, the designs using ordinary concrete as outdoor furniture are usually heavy in weight and thus are mostly attached to the ground or wall, inflexible and cannot be easily moved. By using light weight concrete, the furniture can be arranged and moved by the local park managers according to the needs. The basic material used in this research is cellular lightweight concrete (CLC) that is produced by mixing fine form of air bubbles into concrete mortar [5]. CLC is used because it can be moulded easily, is water resistant, have a relatively high durability, relatively cheap to produce and hence suitable for use in public spaces.

2. Research method

The several steps conducted in developing modular outdoor furniture designs using lightweight concrete are as follows:

- Analysing various conditions of green open spaces and adapting functions and anthropometry to the potential users (children and adults). The design factors of the urban furniture includes colour, harmony with the environment, shape, form, ergonomics and its convenience, has had the highest impact on the citizens' perceptive [6].
- Formulating a solution to address the problems observed in the field through a design concept and applying it in the design alternatives. The module design must be formed together with the formulation of concept so that in the design process, the representation of design would become more distinct [7].
- Selecting the most appropriate design from the design alternatives according to the needs and the production process. The moulding technique, volume and weight were calculated in order to create the flexibility of modular design. From that calculation, the design form was again adapted. A scaled mock-up was produced to form and test the modular system [8].

In the production process, the researchers explored the material mixture, as well as the moulding and finishing techniques that could be used. Through the application of the selected module, feedbacks were drawn in order to evaluate its effectiveness in answering the design objectives and problems determined prior to the design process.

3. Design development

3.1. Analysis of data

Through the observation of the user activities, it was found that the furniture should be able to accommodate the various activities that could take place in public parks such as: sitting while chatting, playing, reading, using electronic devices such as tabs, laptops and mobile phones (Figure 1). Playing facilities were limited to children of age 3-12 years. Meanwhile, sitting facilities were used by a variety of people from children to adults. From the measurements taken from twenty adult users and ten children users, along with the data of anthropometric standards according to Dainoff [9] and Mirer [10], two standard measurements were determined and applied in the design.

From all the data collected, the 5P, or the 5th percentile data- the smallest value, was used to ensure that the design could be used by the whole population. The first standard data was the popliteal measurement of adults and children which are 37.8 cm and 19 cm, respectively. The popliteal height was used as the standard measurement of the sitting facility and was maintained even in the development of the module into other functions besides sitting.

The coating or finishing of the material was also an important factor of consideration in this research. Outdoor coats must be used as the furniture coats observed in the public parks currently have mostly exfoliated, disturbing the appearance and safety of the material. The use of concrete, which is hard in nature, is advantageous because it also cuts down the duration of sitting and thus increases the interchange of users, which is suitable for a public facility. A variety of conditions have been observed in the public parks of Surabaya. Among them, it has been found that some are located in limited areas of land among busy urban streets and thus the position of sitting and playing facilities must consider multifunction designs that could not only make good use of the limited space horizontally but also vertically.



Figure 1. Analysis of user activities and atmosphere of Public Parks in Surabaya.

3.2. Programming and concept

From the analysis, a few design concepts have been formulated in this research as solutions to the problems observed:

3.2.1. Form. Geometrical forms were used to produce modular systems with higher flexibility. Apart from that, geometrical forms can balance the generally organic characteristics of the public parks and can also function as visual focal points through the contrast. In designing urban furniture, principles such as discipline, unity, integration and harmony, balance, rhythm and visual strength must be considered [11].

3.2.2. Function. The modular system was adjusted to the functions of sitting and playing.

3.2.3. Dimension. The popliteal dimensions of both adults and children were applied as the standard dimensions of the modular design.

3.2.4. Material. Major principle which have been observed in the design and deployment of urban furniture are to respond to the needs of the environment [12]. Observing all the flaws of the materials that have been used previously in public parks, CLC was chosen as the main material in the design due to its resistance to weather changes and manageable light weight that can support the flexibility of arrangement. The use of this apparently durable material can prolong the use of the furniture and thus reduce the need of repair and maintenance from time to time as have been observed in the current conditions of the furniture in public parks.

4. Modular design for outdoor furniture

4.1. Design Alternatives

From the concept formulated and determined, three design alternatives were produced (Figure 2). The design alternatives were then criticized and analysed in terms of their strengths and weaknesses. From the analysis, the third design alternative was chosen because of the flexibility it could offer in terms of its arrangement into both sitting and playing facilities. The module is also simple in form which is considered advantageous as it can be arranged into a complex form of modular system. From the perspective of design, in terms of form and dimension, this module has the most positive potentials. However, when analysed in terms of production technique and material, this form is not suitable for light weight concrete. The strength obtained from a solid mass form was deemed more favourable as it hinders the need of using frames for construction and stability. Thus, though the third design alternative was chosen, it was further developed into a more bulky solid form in order to strengthen the light weight material used.




No	Design Alternatives	Analysis and Discussion	Conclusion
1		<ul style="list-style-type: none"> The modular system in this design can only be arranged horizontally and hence require larger areas of space. The organic form inhibits possibilities for more variation in terms of modular composition. Each design form can only be used for one function. 	DESIGN DEVELOPMENT
2		<ul style="list-style-type: none"> The design form is more geometric and the modular arrangement can save up more space compared to the first alternative. Vertical arrangement is possible. The modular composition can accommodate multiple functions for both sitting and playing. 	DESIGN DEVELOPMENT
3		<ul style="list-style-type: none"> The design is more geometric, the modular arrangement can save up more space compared to the first alternative. Vertical arrangement is possible. The modular composition can accommodate multiple functions for both sitting and playing. The geometric form is much simpler than the second alternative and hence exhibits possibilities for more variety in modular composition. 	SELECTED DESIGN

Figure 2. Design alternatives produced and the selected design.

4.2. Selected Design

The module with a squared form and openings was chosen and further developed into a more solid and bulky form (Figure 3). The geometrical form was maintained in order to promote more variation in the modular arrangement system, while the dimensions adopted the two varying popliteal measurements of adults and children. The higher part of the form could be used for adult sitting while the lower part could be used by children for sitting as well as function as a step for climbing. With the solid module, the design was then developed into various modular arrangements through exploration of forms using scaled models. In the final design, two dimensions were obtained based on the standard of popliteal heights of both adults and children (Figure 4).

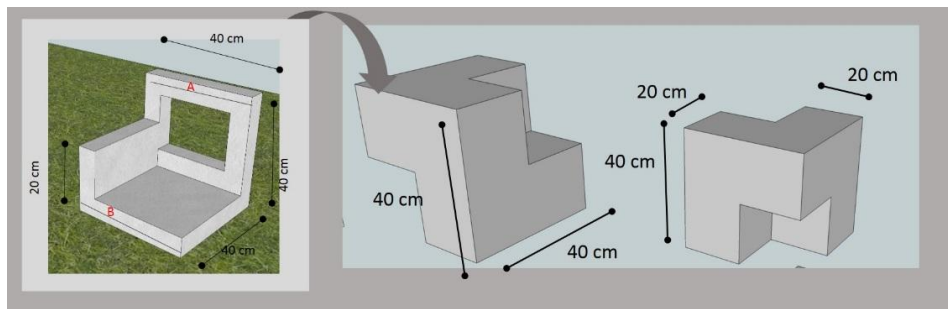


Figure 3. Design development process.

The application of the standard dimensions based on the popliteal dimensions of adults and children, 37.8 cm and 19 cm respectively, resulted in a formulated dimension of 40 × 40 cm in the design. The use of equal dimensions on both sides of the module ease the combination of the modular system. With this dimension, each module weighs about 33.6-38.4 kg. This weight is sufficient and suitable for arrangement change and lifting, and thus is good for mobility, easing the public park managers.

The development of the selected design was then continued with the making of a study mock-up of 1:10 scale using plasticine (Figure 5). The first prototype was made in order to find modular compositions based on form and function. From the various modifications done, several modular systems of sitting and playing facilities were discovered. This prototype provides a limited overview of the effectivity of dimensions and compositions of modular system that can be achieved.

The next step involved the making of a second prototype with light weight concrete with the scale 1:4. Based on the modular compositions obtained in the experimentation done on the first prototype, the second prototype was tested using trial and error in terms of form and material.



Figure 4. Various applications of the selected module.

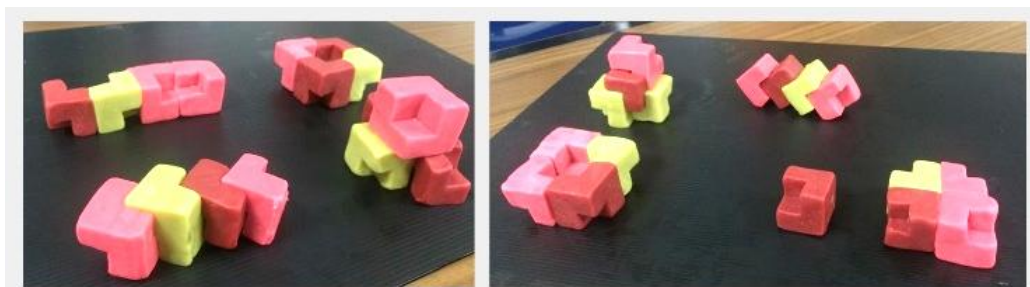


Figure 5. Modular compositions made tested with plasticine.

4.3. Design Evaluation

The design evaluation involved the feasibility study of the product in terms of the modular systems formed, stability and the strength of the design. In this process, it was found that the cavities or openings designed on the upper and lower part of the module ease the interlocking system of the module. However, they cause the outer modules to be unlocked which can trigger the modular composition to collapse. Pressure from one side of the module may cause the unlocked modules to topple down. From the evaluation conducted, at least two modules should be used, in which one module has two cavities while the other module functions as a locking module having only one cavity (Figure 6).

From the prototype made, several modular systems were then produced that could function as sitting as well as playing facilities. The system was then evaluated in terms of form, joints and suitability of function. As shown in Figure 7, composition no.1-3 dominantly function well as sitting facilities, both for adults and children. Whereas, composition no. 4-5 can function as sitting as well as playing facilities. With the second module (Figure 6) functioning as the locking module, the modular system would be stable and can also be arranged vertically.

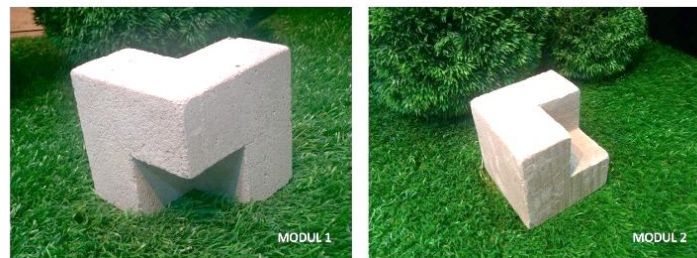


Figure 6. The two basic modules that can be applied in the selected design



Figure 7. Development of modular compositions from the second prototype.

4.4. Material Exploration

Exploration of material mixture were conducted to yield a concrete mixture that is light-weight and not brittle. Cellular Lightweight Concrete (CLC) is a light-weight concrete material that uses foam generator to produce fine air bubbles to be mixed into concrete mortar having advantageous benefits such as high workability, lightweight, use of less material, low water absorption and a good resistance to change in temperature. The air bubble in CLC can be as high as 60-70% by volume and this results in a lightweight material, consequently decreasing its compressive strength [13]. However, consistency in the light weight of the CLC brick can be maintained by adjusting the weight and volume of the foam.

In order to make the CLC, composition of mixture uses about 300 kg/m³ of cement, 300 kg/m³ of fine sand, added with water and foam to yield a wet density of about 800 kg/m³. From the feasibility test of the material, the compressive strength acquired was about 2.5-3 MPa with a water absorption value of 25% of the weight. The more foam used in the mixture, the less the weight of the resulting

CLC. However, if the weight is too light, the concrete would be unusable because it would be brittle and have low strength. This is proven by fact that a light brick with a weight of 500 kg/m^3 , when removed from the formwork, would result in very porous material and can no longer be used. Hence, the ideal weight for lightweight concrete in this design is between $700\text{-}800 \text{ kg/m}^3$.

4.5. Production Technique and Process

Through the evaluation of the material composition conducted, a cast system with wooden boards have been determined as a suitable system for making the mouldings. Wooden boards were chosen because of their low cost compared to iron and silicon mould. The wooded boards must be coated with wax so that they can be detached from the mouldings and used again. For mass production, certainly it will be feasible using steel mould for faster casting cycle and longer mould life time.

The concrete that has dried must be polished to smoothen the surface and to minimize sharp edges so that they could be safely used by adults and children. This is then followed by the finishing process by sealing and polishing the small air bubble that was visible in the surface using cement. Grey colour, the basic colour of the concrete was chosen. The outer surface should then be coated with weather-resistant coat having a doff texture as material protection. The various shades of grey can produce attractive natural tones of composition that complement with the natural settings of the green spaces.

5. Concluding remark

In designing urban outdoor furniture, the activity of its users as well as the durability of the material need to be considered. Designing the furniture as a modular element, improve its usability in adapting with the change of user activity. Lightweight yet sturdy material of CLC was selected as the main material, as it has low economical value which also prevents the loss of properties.

The use of cellular lightweight concrete, which is hard in nature, is advantageous because it cuts down the duration of sitting and thus increases the interchange of users, which is suitable for a public facility. A variety of conditions have been observed in the public parks of Surabaya. Among them, it has been found that some are located in limited areas of land among busy urban streets and thus the position of sitting and playing facilities must consider multifunction designs that could not only make good use of the limited space horizontally but also vertically.

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