

Design and Modelling the Dynamic Structure of Bundaran Hang Nadim Landmark

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ABSTRACT

This study aims to discuss the form-finding process of a dynamic architectural object design in Batam city through parametric design. The parameters include geometry, material specifications and data based on the site context. This research has two stages, geometry analysis in the design phase and geometric rationalization to become a reference material for the construction process. This paper elaborates the different challenges for the designers to simplify the construction process and outlines the stages of construction with the help of model analysis and algorithmic framework to handle them in a project workflow efficiently. Furthermore, this study can be used as a design guide for research based on the architecture design and provide the potential to build the plan following the initial setup.

Keywords: *Dynamic structure, Computational design, Design workflow, Construction.*

1. INTRODUCTION

This project started with an architectural competition organized by the Batam city government to look for ideas for the design of the Hang Nadim Airport roundabout, which could become a landmark that represents the character and culture of the dynamic Batam community. The project location, right in front of the Batam Hang Nadim Airport entrance, makes this project a crucial welcoming area before entering Batam city. Inspired by the principle of a boat's sail in response to the wind, the landmark "Sail Flourishes" moves dynamically when exposed to a wind breeze.

The use of computational design in the design process opens up opportunities to develop dynamic, interactive and responsive architectures [1]. Dynamic architecture refers to the architecture's flexibility in moving or changing shape in response to environmental conditions to create a more environmentally friendly environment and interact with users [2]. In this project, we take advantage of the flexibility of the pillar material properties as a medium in achieving a dynamic architecture, which can later be developed as a sensor for environmental conditions or as a renewable energy generator. This article aims to describe the workflow of the dynamic architecture from the design process to the process of preparing construction drawings with the help of computational design.

2. RELATED WORKS

Several projects become references by using dynamic pillars as architectural elements that produce a shape's silhouette. Some of these projects include Breeze of Innovation (SMAR Architecture Studio) and *Considering the Quake* (SoftLAB), both of which utilize the elasticity of the material on the pillars to convey information on the condition of the surrounding environment. See figure 1 below.



Figure 1 Proposed design of Bundaran Hang Nadim Landmark.

3. METHODOLOGY - GENERATING FORM

The landmark structure design process consists of several stages, each of which resolves different design constraints. With the help of parametric modelling, all steps are linked into a single iterative process.

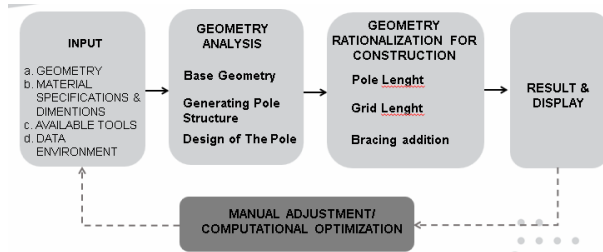


Figure 2 The phase of the research.

3.1. Base Geometry

At the massing stage, exploring the shape of the silhouetted object from the landmark is carried out with Subdivision Surface Modeling using spline-based SubD on Rhinoceros software. This technique is used to quickly and accurately produce design iterations on double-curvature objects [2]. The design goal at this stage is to get the shape of a landmark that represents the maritime culture of the Batam people through a form such as sailcloth. In contrast, the design constraint at this stage is the maximum allowable height regarding flight safety and comfort from the observer's point of view. See figure 3 below.

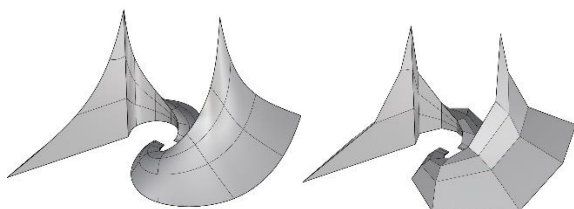


Figure 3 SubD modeling for base geometry: box (left) and smooth mode (right).

3.2. Generating Structural Pattern

At this stage, the structure of the diagrid pattern is applied to the basic geometry to get an effect that resembles the pattern of “pucuk rebung”, the design found in traditional local fabrics. The diagrid pattern is generated based on an isoparametric curve, the value of the base surface's u- and v- curves. Using an isoparametric curve, we get a structural pattern that follows the shape of a landmark and is visually dynamic. Each pillar structure is generated through a point projection from the diagrid structure node to the basic geometry with the direction of the Z-vector. The

design constraint at this stage is the density of the pillar structure, which affects the resulting visual effect. See figure 4 and 5 below.

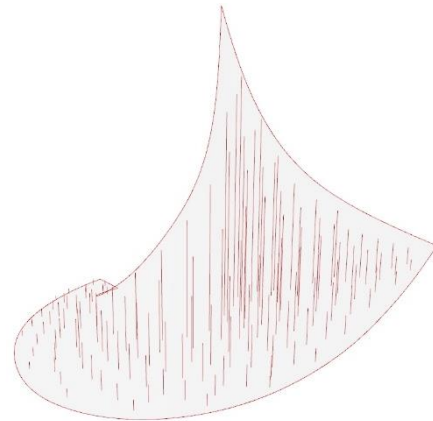


Figure 4 Point projection from structural grid along vector Z to the base surface.

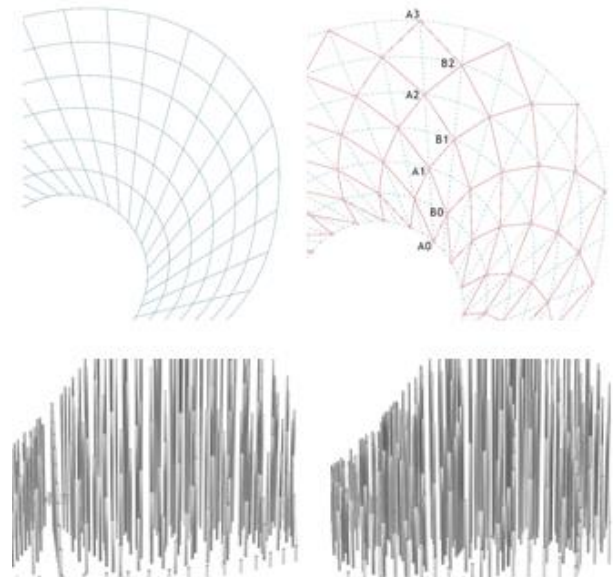


Figure 5 Visual effect using rectangular grid (left) and diagrid pattern (right).

The diagonal grid pattern is obtained by separating the rows on the rectangular grid pattern from isoparametric curves into two groups, row A with the arrangement of points (1-0-1) and row B with a group of points (0-1-0). The two types of point groups are linked crosswise, A0 to B0, B0 to A1, A1 to B1, etc. From the elevation view, we can see the difference in extrusion results between using a rectangular grid and a diagonal grid pattern; at the elevation of the diagonal grid pattern, we can see an effect similar to the pattern of local traditional fabrics.

3.3. Design of The Pole

The design of the pillars takes advantage of the characteristics and material properties of the steel pipe, which will experience deflection when there is a wind load. The flexible pillars will form a volumetric silhouette of the boat sail and become an interactive city landmark that responds to environmental conditions. To align with the swing movement of the pillars, each pillar is connected by horizontal bracing, which simultaneously strengthens the structural strength of each pillar. The movement of these pillars can be developed as a renewable energy generator or can be integrated with sensors that measure the intensity of wind movement or pollution in the surrounding environment.

The dimensions and shape of the pillar profile affect the visual effect produced on the landmark. The length of the pillars will affect the deflection of each pillar, so through structural analysis, we divide the pillars into four types of dimensions according to their height. In addition to controlling the deflection of each pillar, the division of this type of dimension will also minimize construction costs. See figure 6 below.

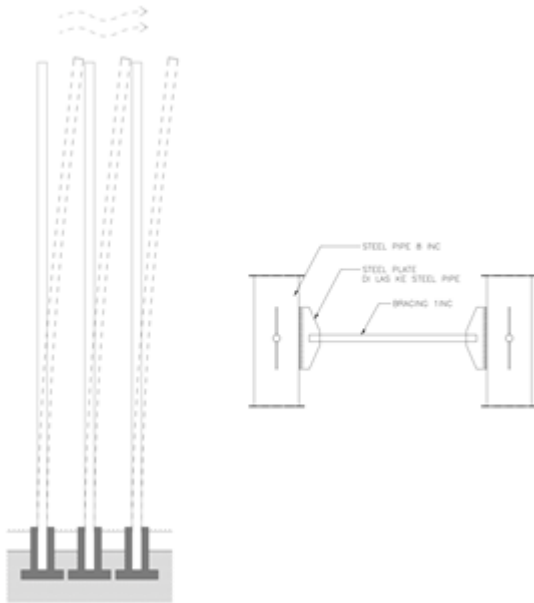


Figure 6 Flexible pole structure responds to the wind.

Forms with many curves will have a more significant drag force against wind loads. In designing the pillars, we tested three types of pillar profiles: circular, oval and cross. The circular shape has a minor drag force based on the wind simulation, while the cross shape has the most significant drag force. Testing the type of profile with wind intensity data at the site location can be a parameter that can be used to control how much sensitivity the pillars have in responding to the wind loads. See figure 7 below.

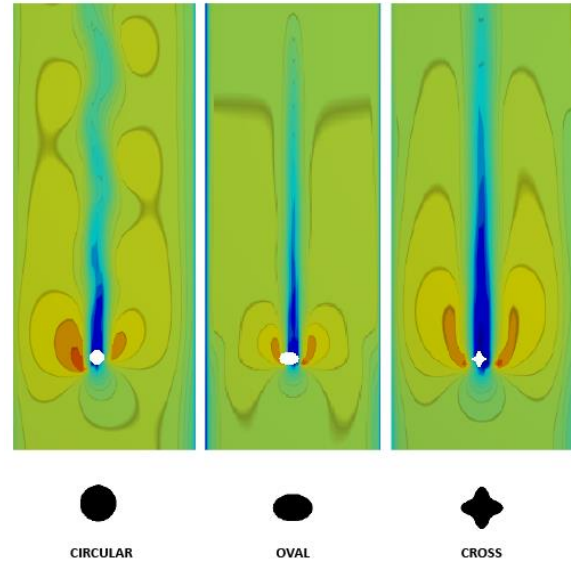


Figure 7 Iteration of the pole profile and their drag force in response to the wind.

4. GEOMETRIC RATIONALIZATION FOR CONSTRUCTION

To facilitate the landmark construction process and adjustments to the fabrication specifications, a dimensional rationalization process for the pillar structure is carried out, which consists of two stages;

4.1. Pole Length

Each pillar component produced by point projection has a different length, complicating the fabrication process using steel pipe materials. These pillar components will be cut manually by referring to the working drawings. To facilitate the fabrication process, it is necessary to standardize the dimensions of the length of the pillars without reducing the visual effect to be achieved. We use modulo operation in multiples of 500 mm on the length of the pillars so that the visual effect achieved is not much different from the original design.

$$l = a - (a \bmod n) \quad (1)$$

Where l is the standard length of the pillar, a is the length of the original pillar, and n is the divisor. After going through the rationalization process, 49 types of pillars with a 500 mm divisor were the most efficient to use without reducing the visual effect. See figure 8 below.

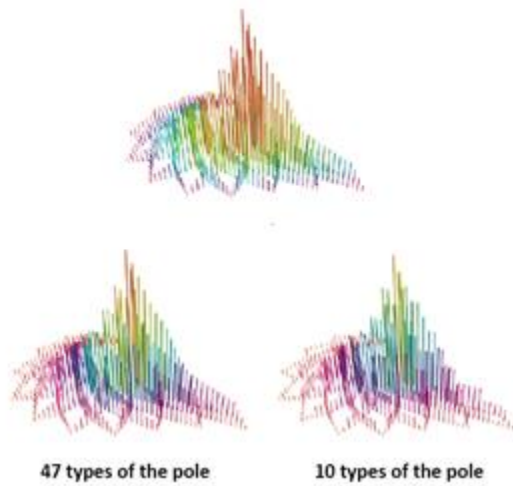


Figure 8 Optimization of the height of the pole types makes fabrication process faster but it can significantly reduces the perception of the object.

4.2. Grid Length

The length of the grid using the diagonal grid pattern in the original design has different sizes. To minimize the variation in the size of the grid spacing, optimization is carried out using Kangaroo (physic simulation) on Rhinoceros Grasshopper. Each meeting point on the diagrid is connected by a centerline that equates with the spring law.

We used the modulo operation to standardize the length between grids with a 500 mm divisor similar to the previous approach. See figures 9-11 bellow.

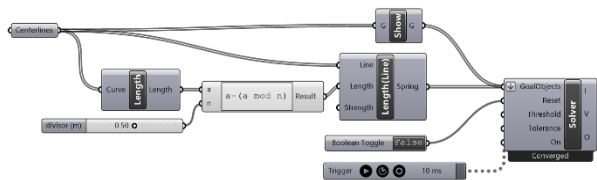


Figure 9 Script to minimize the difference length between the pole structures.

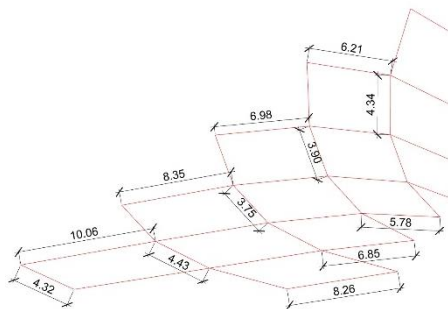


Figure 10 The original grid.

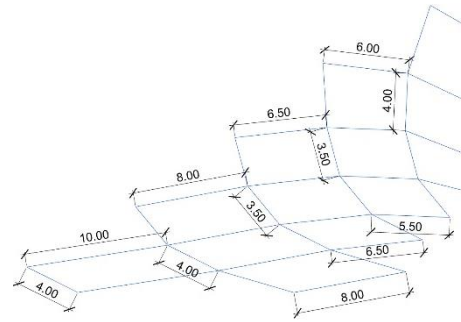


Figure 11 The optimized grid length.

After optimizing the distance between the pillars, the results obtained are entirely satisfactory, from the previous size of each varying distance between the pillars being grouped into several types with a multiplication of 500 mm.

5. CONCLUSION

We have outlined the development of the form-finding process of a dynamic architectural object through parametric design. The main contribution of the suggested method is in providing architects with a parametric design approach to show an alternative way to simplify the geometry for construction purposes. See figure 12 bellow.

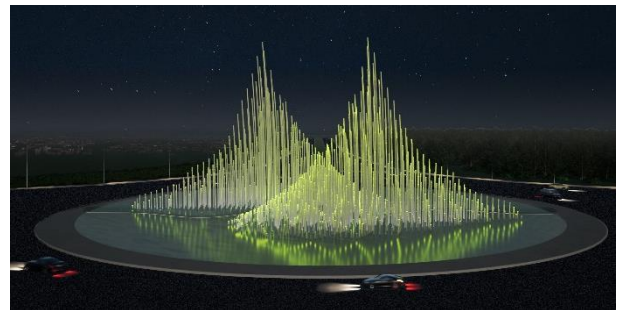


Figure 12 The final impression of the dynamic landmark at night.

REFERENCES

- [1] M. Fox and M. Kemp, *Interactive Architecture Vol.1*. New York: Princenton Architectural Press, 2009
- [2] P. Beesley, S. , Hirose, J. Ruxton, M. Trankle, and C. Turner, *Responsive Architectures: Subtle Technologies*. Riverside Architectural Press, 2006.