Rapid material estimation for reinforced concrete construction utilizing a parametric tool for Aceh's post-disaster case

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Abstract. This paper offered a new open-source parametric tool for reinforced-concrete construction estimation for post-disaster based on Aceh's case. The tool aimed at introducing and providing an innovative solution of estimation for building materials more dynamically and rapidly. The tool was initiated by the fact that the delay of relief shelter deployment in 2004 post-tsunami in Aceh of Indonesia was caused by the inability to provide a rapid calculation for building materials as a result of a massive request [1]. Further, the reinforced-concrete constructions had become a positive preference by the Acehnese [2]. In order to offer a new tool for rapid and dynamic estimation specifically for reinforced-concrete construction, the authors utilized visual scripting of Grasshopper with GHPython extension for optimization of the proposed tool. The tool introduced in this paper was the improvement of previously explored workflows by the authors and ended up with an innovative tool for modeling, visualizing, and estimating. Furthermore, the tool enhanced users' experiences to construct a workflow based on users' specific logic. The tool allowed alterations in the design without comprising time for estimation. In this way, the specific need of the victims in post-disaster was accommodated without obstruction to an estimation of building materials, thus, improved quality and management of the relief shelters for a post-disaster.

Keywords: Reinforced-concrete Construction, Relief Shelter, Parametric Estimation, Aceh Post-Disaster, GHPython, Grasshopper, Visual Scripting.

1. Introduction
Aceh, an Indonesian province, was the second-worst affected by natural disasters. It was recorded more than 5 million people affected by the disaster from 2000 to 2017 [3]. The immediate need for the aftereffect of a disaster was the availability of shelter for the victims. A shelter was a very important entity that must be rapidly fulfilled for a disaster besides foods, water, and medicines. A good shelter ensured the victims appropriate safety and health. Therefore, the immediate availability of the shelter was a significant aspect in a post-disaster setting such as in Aceh.

Reinforced concrete construction had become a positive preference for post-disaster relief shelters in Aceh. This was confirmed by the author's survey conducted in 2017 for the type of relief shelters available for post-disaster in Banda Aceh, Pidie Jaya, North Aceh, and East Aceh. The main reason for the preference was its durability. Moreover, the role of government regulation, instructed by the Bureau of Reconstruction and Rehabilitation Aceh-Nias, was an important aspect in shaping reinforced-concrete construction for the shelter preferences [2]. For the 2004 post-tsunami, the type of construction with bricks infill as its wall was widely available after ten months of the disaster [1]. It was not an appropriate timeframe for relief shelters. One of the problems that liable for the delay of the relief shelter was the ability to quantify construction materials as the result of a massive request of
the shelter [1]. The positive preference toward the reinforced-concrete shelter, in a post-disaster setting, was not supported by the ability for a rapid material estimation to fulfill the shelter demands.

Building material estimation was a crucial aspect for the success of construction, particularly, for an emergency case such as a post-disaster situation where rapidity was a requirement. Şener & Torus [4] advised rapidity as one important factor for post-disaster relief shelter. A parametric framework that puts attention to building estimation was showed in the work of Yeung & Harkins for Solomon Island's post-earthquake disaster [5]. However, they focused on timber-structured buildings. Furthermore, it was necessary to invent a better way in order to upgrade the current building estimation culture. Besides, this paper was highly related to the author's previous works [6] and [7] since it had significantly contributed and directed this study as discussed in this paper. In this study, we developed the previously explored workflows into a parametric tool.

This tool was aimed at the optimization of algorithms and allowed a more dynamic framework to be constructed. The tool allowed for future development in a more organized and simple way. Also, we extended the ability of our previous workflows, therefore, it was able to handle rather complex construction. These features were missing in our previous papers. In addition, we utilized GHPython to create a parametric tool for dynamic and rapid material estimation for reinforced-concrete shelters to suit a post-disaster condition such as in Aceh's post-disaster relief shelter. Moreover, the tool that we proposed was adaptable to every reinforced-concrete structure in the Indonesia-wide construction industry.

2. Methods

Our parametric framework was under the Grasshopper platform. Grasshopper defined as a visual node-based add-ons editor for Rhinoceros that was invented by David Rutten in 2007 initially known as explicit history [8]. Further, it visual-based scripting made it easy to be comprehended by people with no prior programming skills, particularly, for architect alike. Moreover, GHPython was utilized to develop the estimation tool, thus, it extended the Grasshopper components’ capabilities. The improved capabilities were related to the ability of the component to model, organize the data and calculate the reinforced-concrete construction material. GHPython defined as an additional Grasshopper component that performed as an IronPython translator [9]. It allowed access for Rhinoceros or Grasshopper functionalities within GHPython component. In addition, we utilized the Grasshopper list component for calculation coefficients and yKTools for data streaming into a spreadsheet in our workflows.

Figure 1 illustrated the parametric platform for this study. Rhinoceros on the upper left as the main platform for the entire system. Grasshopper on the left as an environment for GHPython. It showed the GHPython component on Grasshopper canvas with its editor was activated as revealed on the bottom left. In addition, Figure 1 illustrated that the GHPython components consisted of amendable input and output parameters. In this case, the authors put the description at the beginning of the GHPython script. All the descriptions for and inside the code were written in Indonesian. Both inputs and outputs took and produced objects, numbers or texts. It depended on the intended codes inside
the GHPython editor. Further, both input and output descriptions were amendable for the clarity of either the input or the output. Besides, the icon for each new component was modifiable. In this way, components for our tool were created. Appreciatively, for the structure of the scripting inside GHPython was inspired by the Ladybug Tools [10].

The intended codes inside GHPython editor for reinforced-concrete construction estimation were written based on Indonesian Standards for reinforced-concrete estimation. Those standards were [11] for concrete, [12] for the wall, [13] for rendering and [14] for foundation works. Steel reinforcement estimation based on the formula (1) explained in [7]. Meanwhile, the roof coefficients were based on the rule of thumbs calculation for metal roofing in Indonesia. Thus, it required re-evaluation and re-validation processes for the coefficients, as authors had not discovered standard for metal roofing calculation.

3. Result

The tool produced in this paper was the result of the author's previous exploration of rapid estimation frameworks. To this stage, we had created twenty-seven components for the tool. The tool was installed by dragging the entire components into the Grasshopper's canvas. In order to create the effectiveness of our tool, we divided it into several categories as showed in figure 2. Firstly, the data consisted of components for sorting out the calculated data in certain order prior to it streamed into a spreadsheet. Secondly, material estimation contained components for material calculation based on SNI. Thirdly, coefficients for the calculation, which were created using Grasshopper’s value, list components. Next, modeling, it involved components for modeling of the intended construction. The aimed of modeling components were for a more efficient of algorithms since some of Grasshopper's default components were coded into a single GHPython component. Finally, extra components for unforeseen functionalities that helped and might be developed in the future for the effectiveness of estimation.

4. Discussion

From the above modeling category, the component for making a roof was missing. This component was in progress for its development. Up to this stage, the roof modeling relied on Grasshopper capability or Rhinoceros model as an input model for calculation for materials using the component presented in this paper. However, the simple ridge and gable roof systems were successfully modeled using Grasshopper algorithms. The roof modeling took inputs from a rectangle assigned to the perimeter of the building and positioned it in its elevation by taking an elevation input as a base from the height of the shelter. The authors aimed at the most optimum roof shape for the limited budget, as budget constraints were an important factor in determining the final shape of the relief shelters.

Furthermore, the components created above had allowed modeling and estimating being optimized and improved the adaptability of a workflow to users' specific senses. For example, to create a column in default Grasshopper, at least, it needed four components, while using GHPython it required one component. Furthermore, the workflow was able to be more dynamic, while it still maintained the rapidity of the calculation, since it open possibilities to adjust to users' specific logic of construction. For instance, if a user needed to directly utilize a 3D model from Rhinoceros, thus, the user was allowed to input the geometry into estimation components. Either way, if a user required inputting centerlines and points as inputs, also, it was allowable. This method needed a user to input to modeling components in our parametric estimation tool as demonstrated in figure 3. In addition, figure 3 exemplified the use of the tool to model and calculate for related construction materials.
this case, columns and foundations materials for concrete structure in Grasshopper canvas. The calculated data had not yet written into a spreadsheet.

By using a similar working method, the components presented in this study were allowable to be organized to users' intended logic for a more complex building system. For example, the visual algorithms in figure 4, is designed to input from centerlines drew in Rhinoceros. The optional inputs, for the workflow, were windows and doors locations. Either these modeled in Rhinoceros or using Grasshopper geometries was acceptable by the algorithm. The algorithm simultaneously performed modeling, visualization, and estimation for the shelter. The calculated data streamed in a real-time to a spreadsheet even the design of the shelter changed or altered to a specific request.

Figure 3. Workflow's algorithm using a parametric tool (left), Model produced in Rhinoceros (right)

Figure 4. A parametric workflow using components invented from this study to perform a calculation for shelter materials

Once the algorithm was established, accordingly, to intended shelter design, it required only input processes while the modeling, visualization, and calculation for building materials were performed simultaneously. The authors discovered the process of inputting took one and a half minutes for a beginner. Obviously, this approach was solving the inability to quantify and provide information for shelter material requirements problematic as suggested by Ashmore et al. [1] for Aceh's post-disaster case. Thus, improved rapidity and this a positive situation as this important factor to make a success for the relief shelters in post-disaster as recommended by Şener & Torus [4]. The sample of a relative powerful algorithm to perform materials estimation was showed in figure 4. A completed material calculation was still missing in this paper; however, the most complicated calculator for reinforcement
of concrete was successfully created. Alongside with future development of this parametric estimation tool, the rest of the easier and lighter components for modeling and calculation of the shelter construction materials will be available.

At the most right as presented in figure 4 were components yKTools. It allowed access for writing the data into a spreadsheet, in this case, Microsoft Excel. Using the components helped to stream the calculated data in a real-time into a spreadsheet without having to retype nor copy for the data. Also, along with some other Grasshopper components integrated into the workflow, it had proved the compatibility of the components presented in this paper with either other Grasshopper components or its add-ons. Therefore, the parametric estimation components presented in this paper had extended the capability of Grasshopper for a special task such as intended within this study. Figure 5 illustrated the modeling, visualization and calculation data written into a spreadsheet using the parametric estimation tool. The purpose of writing the data into a spreadsheet was considering that in the post-disaster settings people involved came from different backgrounds. Thus, it allowed for easier communication for relief shelter such as decision making for the shelter design based on a plotted budget. In addition, the roof algorithms were created Grasshopper un-optimized default components as explained earlier.

Figure 6 demonstrated the capability of the parametric components and workflow, as showed in figure 5, for shelter different configurations. The rapidity for modeling, visualization and estimation had allowed for comparison of a more suitable shelter configuration to adjust to a plotted budget. This was an important factor to assist decision making to select a suitable design for a budget scheme by a donor body and at the same time fulfilling victims' needs.

Figure 5. The parametric estimation tool in action. Rhinoceros in the left, Grasshopper in the middle and Microsoft Excel in the right.

Figure 6. Sample of different shelter configurations with the estimated data. The data updated in real-time as the design changed.

In addition, figure 6 showed the calculated material for the rubble stone foundation. Yet, the foundation was not modeled and visualized. For this algorithm, the author used LTrap component to calculate for the construction material. This component had the capability to calculate accurate
information for the rubble stone foundation system without having to model the geometry of the foundation. However, for clarity and for the purpose of easier validation author recommended using the component for modeling the geometry. This was to show the capability of an extra component created in this study.

5. Conclusion
This study had resolved the slow material calculation method using a parametric estimation tool. This tool helped the estimation for reinforced concrete construction shelter more rapidly, accurately and flexibly. Using components introduced in this paper, it allowed the algorithms to be constructed more efficiently. Since it combined separated functionalities into one component using GHPython script. Furthermore, this improved validation of the algorithms more easily, if necessary, thus it reduced the risk of human error. Moreover, the components presented here enhanced the adaptability of workflows to a user-specific logics and needs. This opened an opportunity for the components to adjust for the estimation of more complex reinforced concrete buildings.

With the potentials explained above, the authors convinced, the parametric estimation tool was implementable in a post-disaster. The design alterations, it more likely to happen in a post-disaster as victims' requests, thus, it was not problematic. Obviously, this improved some obstructions explained by Ashmore et al. [1] in 2004 Aceh post-disaster. Further, rapidity as an important factor, as suggested by [4], was enhanced using the parametric estimation tool. The rapidity of information availability, for building materials, was one crucial factor that improved the time for a permanent relief shelter to be decided.

Despite the potentials explained earlier, there were limitations to this tool. Firstly, this work was limited to estimation for a core structural component of a reinforced concrete shelter. The development of the tool was allowable for estimation that was not explained in this paper. The improvements and developments were either for its functionality extensions or alteration for codes and coefficients, for example, the roof material calculator component. Next, the tool was tested and compatible with Rhinoceros 5 and Grasshopper 0.9.0076 above. The authors did not recommend it used in older versions. Also, the tool tab name within Grasshopper still used the first author's name, and this did not follow the common sense of Rhinoceros which used animal names for its add-ons. Apart from this, the tool will be released as an open-source tool. In this way, the authors believe that the development of this tool will be faster. Therefore, it will be usable immediately for implementation in a relevant post-disaster relief shelter.

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