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Parametric estimation for reinforced concrete relief shelter for Aceh cases

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Parametric estimation for reinforced concrete relief shelter for Aceh cases

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Abstract. This paper was a work in progress (WIP) to discover a rapid parametric framework for post-disaster permanent shelter's materials estimation. The intended shelters were reinforced concrete construction with bricks as its wall. Inevitably, in post-disaster cases, design variations were needed to help suited victims condition. It seemed impossible to satisfy a beneficiary with a satisfactory design utilizing the conventional method. This study offered a parametric framework to overcome slow construction-materials estimation issue against design variations. Further, this work integrated parametric tool, which was Grasshopper to establish algorithms that simultaneously model, visualize, calculate and write the calculated data to a spreadsheet in a real-time. Some customized Grasshopper components were created using GHPython scripting for a more optimized algorithm. The result from this study was a partial framework that successfully performed modeling, visualization, calculation and writing the calculated data simultaneously. It meant design alterations did not escalate time needed for modeling, visualization, and material estimation. Further, the future development of the parametric framework will be made open source.

1. Introduction

The development of the parametric method was found very limited in low-tech society, particularly, in developing world and countries vulnerable to disaster. The minimum amount of literature found discussing adoption and implementation of the parametric method in low-tech society was a reason for the situation. Furthermore, The availability of infrastructure which supported the existence of digital technology was considered a major challenge in an area susceptible to disaster. Some earlier examples implemented digital technology combined with conventional one, in a low-tech environment, were the case of Solomon Island's earthquake and tsunami back in 2007 by Emergency Architect Australia shown in the work of Yeung and Harkins and Benros, Granadeiro, Duarte, & Knight in Haiti's earthquake for transitional relief shelters [1] [2]. Even though limited implementation discovered, parametric method, at the same time, offered a wide array of potential as well as challenges for exploration in a low-tech environment.

This research attempted to explore a rapid estimation framework for building materials using the algorithm with a parametric method. Exploration of this study applied to every simple single story reinforced concrete shelter, house or building with brick infills as its wall. This work invented a system that corresponded to design revisions without compromising time due to recalculation for building materials. The intended flexibility was required in a post-disaster reconstruction where time and accuracy need to be fulfilled simultaneously. The reinforced concrete shelter with brick infill for its wall, for Acehnese, was more than just a shelter, yet it was also a dignity to whom it belongs to. For this reason, the researchers believed that the existence of this particular construction would be available for a prolonged time. As a consequence, result from this research benefited every actor in reinforced concrete construction for an extended amount of time.

As a response to the earlier mentioned situation, it was urgently required to invent an effective, efficient and simultaneous framework. A simultaneous framework was required by a designer or an architect to accurately inform and satisfy clients regarding the questions of the material required for construction, even at a preliminary stage. These were another reasons for the immediate needs of this research to be conducted.

2. Limitation

As has been noted previously, this research mainly based on observation toward permanent relief shelters available in the Province of Aceh, Indonesia. At this stage, this study was still a work in progress (WIP) which only intended to perform the calculation for the above-ground structure elements, bricks wall and excluding roof part, doors and windows. Due to some technical problems, rendering and molding materials were omitted at this stage. Furthermore, this study only performed the calculation for building materials required and omitted fee for builders and workers.

3. Definition of Terminologies

The simple reinforced concrete construction determined within this research was a two ways grid structure which used beams and columns made of reinforced concrete and its wall from bricks. A beam was a rigid structure component which beared transversal forces into vertical element called columns. Meanwhile, a column was a rigid component which took axial loads from the beam then transferred it to foundation system of construction [3]. Furthermore, Ching and Adams defined beam as a rigid bearing element which was designed to bear and transfer load into columns [4]. Within a reinforced concrete construction, a beam positioned above foundation was called *Sloof*. The most top beam was called *Rengbalk*. These terminologies were applicable in Indonesia wide construction industry. Beams and columns that were intended made out of reinforced concrete material. Walls at our case study was a brick wall which rendered/plastered both on its inside and outside.

In our algorithm, structural components were considered to be firstly erected followed by non-structural components. Besides, the method of erecting brick walls at first hand followed by structural columns was considered obsolete due to corrosive of the reinforced steel bars as a result of prolonged exposure of structural steel bars to weathering [5]. Furthermore, the method failed to comply with proper concrete covering for beams and columns as regulated. Therefore, it escalated the risk of corrosive of steel bars. It weakened the structural system of construction [6].

On the other side, regarding the method, there were terminologies such as parametric and algorithm that were utilized in this study. Parametric was defined as a method to solve design problems using algorithms as its workflow [7]. Furthermore, Khabazi explained algorithm was compilation or group of rules and instructions as a certain procedure to calculate, processes data and perform particular works that were already defined [8]. Within this study, we used Grasshopper as an interface for constructing algorithms. There were two objects needed to be understood within Grasshopper. Firstly, a parameter, a Grasshopper object stored or enclosed information or data. Secondly, a component, a Grasshopper object that executed commands or known as an operational object [9].

4. Trend in Literature

Sener and Torus utilized parametric technology, particularly Max Script under 3DSMAX platform, to establish attractive post-disaster refugees camps using container [10]. The work focused on creating the camps that were dynamically arranged for the unknown number of casualties. Another advantage offered was the ability to randomly arrange a camp. Thus, it did not look monotonous as happened in the most of the humanitarian cases. This feature was considered able to enhance the psychological performance of its users. Moreover, advantage used containers that it was easily reused and removed into a different location [10].

Implementation of parametric technology in a real humanitarian available in work Yeung and Harkins at post-earthquake and tsunami relief in Solomon Island [1]. They developed a system that facilitated input data from a spreadsheet which then connected to Grasshopper 3D interface. Data from the spreadsheet as a requirement from the field then translated to produce a latrine design for a public school. Furthermore, all cost estimation was integrated into the system which finally used off-site laser cutting technology to produce building components. In this case, they used wood construction for the building. Another special feature developed within their work was innovative working drawing which was presented as a simple graphics. It was a simplification of each building components which then used to the assembled building as simple as playing with a child's toy. This was significant for transferring building information effectively to everyone in the field, particularly for a humanitarian case.

Meanwhile, at Haiti earthquake back in 2010, Benros, Granadeiro, Duarte, & Knight utilized parametric technology with C# on Revit platform to explore design possibilities based on interpretation of local vernacular architecture [2]. The algorithm was able to generate design multiple variants. This was significant to improve psychological quality due to the capability to suit particular needs of post-disaster users. Also, the possibilities to integrate mass-customization techniques were discussed for Haiti case [2].

Further, Goncalves produced shelter typology design from modular building components. The most intriguing feature of study by Goncalves was the concept of *Do It Yourself* (DIY) [12]. DIY ability was a crucial factor for reconstruction in post-disaster case. The feature was considered to contribute to improvement in the physical and psychological situation of post-disaster users. The feeling of belonging to the building also improved utilizing DIY concept.

The most current integration of parametric technology in the humanitarian case was shown in the work of Daher, Kubicki, and Halin. At the research, exploration was directed to use parametric potentials to help, direct and decision-making for a shelter and camp designs. At the study, they produced a shelter and camp prototype out of parametric design system based on International Red Cross requirements [11]. At work, the material calculation was not its focus.

From the discussions, there was focused on cost estimation shown in the work of Yeung and Harkins in Solomon Island. At the research, cost estimation was only limited to wood construction. For the reasons, the writer considered there was a need for immediate research for calculation of construction materials specifically to reinforced concrete shelter, this was particularly due to its wide availability at humanitarian aids, such as in 2004 Aceh post-earthquake and tsunami relieves. Therefore, this research focused on material estimation for reinforced concrete construction. The material estimation that was produced in the form that was widely understood by people from different backgrounds.

5. Methods

The method of calculation used an algorithm to perform the tasks. The intended algorithm was a visual algorithm in Grasshopper interface. Grasshopper was plug-in works under Rhinoceros platform. Advantage used the visual algorithm that it helped designer comprehending more easily even without a prior programming background. The steps within this research, firstly, prepared a design directly on Rhinoceros platform in the form of center lines. Secondly, organized and put together algorithms on Grasshopper 3D interface. Thirdly, wrote of algorithms for modeling, visualization and volume calculation on Grasshopper. Finally, organized algorithms for writing the result of the calculation into a spreadsheet. We used plug-ins under Grasshopper called ykTools to write the data into Microsoft Excel. Finally, authors used GHPython scripting to customize some modeling, calculation and data organization components. Those components were intended to simplify and optimize the algorithms.

The algorithm was able to simultaneously visualize, calculate and write the result into spreadsheet even as design changes, in a real-time. The changed could be room organizations, opening sizes, or structural element sizes. Flexibility, high accuracy and effectiveness to correspond to design alterations were the innovative way that helped to stimulate and to improve the culture in the practice of cost or material estimation. Thus, it promoted a highly efficient working culture for optimum result.

6. Validation

Calculation for each building elements based on Standard Nasional Indonesia (SNI), which was Indonesian Standard, of reinforced concrete construction. Those SNIs were as followed:

- SNI 6897 2008, for wall works [13];
- SNI 7394 2008, for concrete and molding's works [14];

For the weight of steel bars per cubic meter will be calculated based on the following formula:

$$The\ weight\ of\ Steel\ Bars\ \ (Kg) = V\ x\ BJ \qquad (1)$$

Whereas**:**

V: Volume of steel bars
BJ: Weight of steel (kg) per cubic meter (7850 Kg/m^3)

The volume of a steel bar was the volume of the cylinder due the profile of steel bar used in the construction was the rounded shape. Using the formula (1) above, the height of steel bars were the accumulative length of some steel consisted of a structural component in a cubic meter. Meanwhile, the radius was half of the size of the steel bar used. Next, the weight obtained was converted into some steel bars by multiplying the total volume of a structural component such as columns. The result then divided the weight of steel bar in length as available in the market. The steel bars were tabulated for steel bar considering 12 meters length of each steel bar.

Next, the need for cement was converted into a unit of Zak with the assumption each Zak contained 40 kg of cement. So with brick that was tabulated into some brick. Sand and aggregate were in cubic meters. Generally, within low-tech environment, when the need for materials were given based on unit mentioned on SNI, most people failed to understand it, such as, the need for steel bars using kilograms as it units within SNI, meanwhile, steel bars available in the market was steel with the length of 12 or 10 meters each bar. This misunderstanding compromised toward the plotted budget. All of this validated data and formula was written in GHPython scripting to perform an optimum calculation.

7. Result and Discussion

The Grasshopper algorithms were structured in five main parts to model, visualize, calculate, organize data and write data into a spreadsheet. It needed one input of multiple curves, which were centerlines. The rest were parameters to control shelter's elements size, position, and elevation. All off controlling parameters were put at the most left side of algorithms for easier controlling of shelter modeling. These controlling parameters were set to the standard of shelter construction; therefore, by default, it did not need to change the input parameters of input centerline curves.

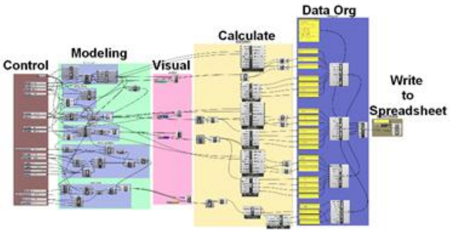


Figure 1. The rapid estimation algorithms

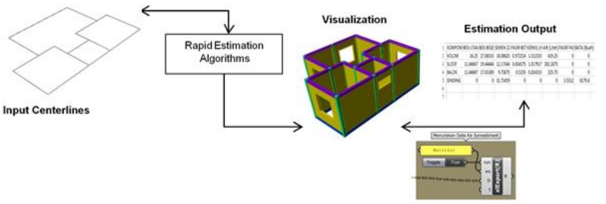
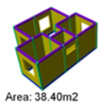


Figure 2. The framework flow

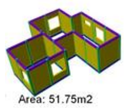
The algorithms took one curve input parameter from Rhinoceros, right clicked on the curve input in Grasshopper then selected the intended centerlines within Rhinoceros. Next, the algorithms performed simultaneous tasks of modeling to writing the estimation data into a spreadsheet. The curve input parameter was able to handle multiple centerline curves. By limiting one input, it had saved a significant amount of time for modeling, visualization and estimated the materials. To write the estimation data to a spreadsheet, it needed Microsoft Excel opened. Through Boolean toggle available within the algorithms, by double-clicking, the estimation data streamed automatically into Microsoft Excel.

Figure 1 demonstrates which one curve input all of the building components were automatically modeled based on reinforced concrete construction system after passing algorithms. For example, columns were automatically modeled by the framework based on the 12m^2 rule of the wall surface; it needed reinforcement. The logic for columns creation, firstly, the component took input curves then generated points for columns positioning. Furthermore, the algorithms evaluated the length of each curve and multiplied it by the height of columns. The height of columns was achieved from slider input of Grasshopper. If multiplication length of each curve with a height of columns was equal or larger than 12m^2, a new column was automatically added. Further, walls, bottom, and top beams were modeled based on input curves with slider controlled of component sizes, which represent shelter layout. Further, columns were used as trimming objects for walls and the beams, thus, it represented a real model of a built shelter. Meanwhile, the opening holes were limited to four holes for windows and holes for ventilation. If necessary, these windows and ventilation's holes could be easily added by plug in a new Grasshopper slider parameter into the corresponding components. In this way, flexibility aspect for adding and reducing openings was easily maintained. At this stage, with one curve parameter input, the automation rules based on reinforced concrete construction method was easily modeled to further used for estimation data.

Furthermore, the material calculation took the reference from the 3D model of the shelter generated through algorithms. Every shelter's component was calculated its volume and pass it through calculation components within algorithms. For example, to obtain some steel for beams, the volume data of the beams were pass through customized steel bars estimation component. However, for wall component, it needed to convert the volume into square meter since the calculation of wall based on an area of a wall surface. All of the data was automatically updated even as design changed in the number of time. Once the centerline passed through the algorithms everything become simultaneous; the modeling, visualization, and estimation.



KOMPONEN	BESI UTAMA (Batang)	BESI BEGEL (Batang)	SEMEN (Zak)	PASIR BETON (m3)	KERIKIL (m3)	AIR (Liter)	PASIR PASANG (m3)	BATA (Buah)
KOLOM	16.25	27.083333	18.08625	0.972214	1.512333	419.25	0	0
SLOOF	11.666667	19.444444	12.173437	0.654375	1.017917	282.1875	0	0
BALOK	11.666667	17.013889	9.73875	0.5235	0.814333	225.75	0	0
DINDING	0	0	31.71459	0	0	0	3.5312	6179.6



KOMPONEN	BESI UTAMA (Batang)	BESI BEGEL (Batang)	SEMEN (Zak)	PASIR BETON (m3)	KERIKIL (m3)	AIR (Liter)	PASIR PASANG (m3)	BATA (Buah)
KOLOM	21.66667	36.11111	24.115	1.296286	2.016444	559	0	0
SLOOF	13.53333	22.55556	14.12119	0.759075	1.180783	327.3375	0	0
BALOK	13.53333	19.73611	11.29695	0.60726	0.944627	261.87	0	0
DINDING	0	0	37.34763	0	0	0	4.1584	7277.2

Figure 3. Estimation of action

The design alterations did not compromise time needed for shelter material estimation. This had improved time efficiency, which in turn, it enhanced rapidity criterion as require in post-disaster cases. As shown in figure 3, each shelter’s components were visually color coded for easy validation of component being calculated. This important in two folds, firstly, it helped authors organizing algorithms for proper calculation components. Secondly, it helped clients or users identifying components calculated for them and gave an overall overview of shelter design in 3D view. In this way, once users or beneficiaries objected to the design it could be altered in a real-time.

Also, the conversion of units as shown in figure 3 demonstrated of material information had extended the understandable of calculated information for people with non-technical backgrounds. This was important to assure precise information received by clients, which in post-disaster cases usually involved a wide range of people from different backgrounds. This had potential to enhance communication among people involved in a relief shelter. Based on the current result, this study had proved one potential of parametric technology for low-tech or area susceptible to a disaster such as Aceh. Within this method, it allowed architecture to explore for a more robust output of design dynamically to suit clients' needs, particularly in a post-disaster environment. Furthermore, it showed that parametric approach had demonstrated that design alteration did not escalate time for modeling, visualizing and calculating of preferred shelter design. This meant an improvement of rapidity criterion for shelter relieves.

Furthermore, some of the rapid estimation WIP customized GHPython components were a wall, beams, columns, all estimation components, and data organizer components. As explained earlier, the idea behind these customized components was for efficiency and optimization of algorithms. Thus, it reduced human error when constructing algorithms.

8. Future Development

All components that were produced within this study was made open source in its final release. In the future, the framework offered within this study was developed to model and calculate a complete construction of shelter including substructure, interior, opening, and roof. It was our vision to develop this parametric framework to perform complete bill of quantity (BoQ) for reinforced concrete construction. Also, authors envisioned altering this framework for a more complex building system, such as multi-story construction. Furthermore, we envisioned integrating optimization tool using Galapagos within our framework. The optimization benefited in two folds; firstly, it provided design alternative automatically with budget constraint. Secondly, authors integrated environmental analysis tool such as Ladybug and Honeybee for shelter generation and used Galapagos for optimization. Therefore, shelter design left a minimal negative environmental footprint.

9. Conclusion

The current state of the parametric framework within this study was still underway for its perfection. There was a partial part of construction estimated in the current state. However, a significant potential had been revealed from this study for performing rapid estimation of relief shelters. Firstly, the framework was able to shortcut modeling by limiting one input of curves parameter, to collect centerlines, to perform 3D visual of shelter designs while simultaneously calculating and writing data into a spreadsheet. Secondly, the framework provided the benefit of design alteration with no time extension for modeling, visualizing and estimating of construction materials. Thirdly, calculated data provided was understandable by a wide range of people. Lastly, color-coded visualization offered a better understanding of a design to a client and helped validation of the calculated component easier. Consequently, all of these contributed to a better and faster system of calculating culture of shelter materials. Potentials available within the framework of this study, also, it possibly is implemented on every reinforced concrete construction, of course, with the perfection of the framework. For example, integrated this framework into government procurement system of reinforced concrete building projects. For another type of construction, there were lessons learned as shown earlier in this study or conducted further research implementing parametric framework into current or future procurement system of government projects.

References

[1] Yeung W K and Harkins J 2010 Digital architecture for humanitarian design in post-disaster reconstruction *International Journal of Architectural Computing* **9** 17-31
[2] Benros D, Granadeiro V, Duarte J P, and Knight T 2011 Automated design and delivery of relief housing: the case of post-earthquake Haiti *Proceeding of the 14th International Conference on Computer Aided Architectural Design, Liege* 247-264
[3] Schodek D L 1995 *Struktur* (Bandung: PT Eresco) (in Indonesian)

[4] Ching F D and Adams C 2008 *Ilustrasi Konstruksi Bangunan, 3rd ed* (Jakarta: Erlangga) (in Indonesian)
[5] Zhou Y, Briceno S, Asplund B and Mangkusubroto K *2007 Handbook on Good Building Design and Construction Aceh and Nias Islands* (UNDP Regional Centre, Bangkok)
[6] Kertopati P I, Larsen O and Tedjo S 2007 P*edoman Membangun Rumah Sederhana Tahan Gempa* (Palang Merah Indonesia & International Federation of Red Cross and Red Crescent Societies Yogya-Jateng Earthquake Response, Yogyakarta) (in Indonesian)
[7] Atthaillah 2014 Arsitektur parametrik dengan Rhinoceros dan Grasshopper: Kajian workflow dari desain, fabrikasi hingga hitungan kebutuhan material *Arsitekno* **3** 10-23 (in Indonesian)
[8] Khabazi Z 2012 Generative Algorithm using Grasshopper Morphogenesism http://www.grasshopper3d.com/page/tutorials-1
[9] Akos G and Parsons R 2014 The Grasshopper Primer Third Edition http://modelab.is/grasshopper-primer/ (Accessed 2 April 2015)
[10] Sener S M and Torus B 2009 Container Post Disaster Shelter-CPoDS *Proceedings of eCAADe 27* 599-604
[11] Daher E, Kubicki S and Halin G 2015 A parametric process for shelters and refugees' camps design *Proceedings of the 33rd International eCAADe, Vienna* 541-548
[12] Goncalves A M d C F A 2014 A Grammar for Shelter: An exploration of ruled based designs n prefabricated and modular shelters *Proceeding of the 32nd International eCAADe, Newcastle* 327-336
[13] Anonymous SNI 6897:2008 Tata cara perhitungan harga satuan pekerjaan dinding (Badan Standardisasi Nasional, Jakarta) (in Indonesian)
[14] Anonymous SNI 7394:2008 Tata cara perhitungan harga satuan pekerjaan beton (Badan Standardisasi Nasional, Jakarta) (in Indonesian)