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Amphibious House, a Novel Practice as a Flood Mitigation Strategy in South-East Asia

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Abstract

The vulnerability of flooding in terms of exposing population and assets is increased dramatically over these decades. There are different strategies to prevent or mitigate the flood destructions in urban areas. Floating urbanization is a novel story which motivates people to face with flood rather than fighting with nature. This study proposed the new concept of the amphibious house in lowland area as a flood mitigation strategy. It evaluates the awareness and acceptance level of floodplain settlers to consider amphibious house as a safe shelter for dwelling in lowland area. The VBA programming has been used to develop a designing system for different type of amphibious house. The questionnaire survey was conducted between 6 lowland regions in Malaysia. The level of acceptance and suitability perceptions of the amphibious house were 3.08 and 3.33, which were in moderate level. There was significant higher interest for dwellers who know about floating houses on applying amphibious house.

Keywords: Amphibious house, floating urbanization, flood protection, questionnaire survey.

1. Introduction

1.1 Flood vulnerability and flood mitigation strategies

Fighting and protection against flood vulnerability is one of the most important afford of human species. The destructive impact of flood as a natural disaster is jumped to an alarming rate. The term of the natural disaster is defined regarding to the human impact. Flood vulnerability triggers economical, environmental, and social effect in floodplain area (Gad-el-Hak, 2008). This means that, people, property, society, and the environment is suffering more and more from flood danger (Dang, Babel, & Luong, 2011). Climate changes and global warming escalate flood risk and rising of the level of the sea in South-East Asia. Increasing the risk of flash-flood generates different approaches and strategies to mitigate vulnerability of this natural disaster (De Boo, 2005; E. Pasche, et al., 2008; Fit, 2006; GRAAF, FREMOUW, BUEREN, CZAPIEWSKA, & KUIJPER, 2006; Holdsworth, 2007a, 2007b, 2007c; Kuijper, 2006; Nieuwenhuizen, 2006; Rijcken, 2006; Schuwer, 2007; VREUGDENHIL, MEIJER, HARTNACK, & RIJCKEN, 2006; Warner, 1995; YANG, 2007; Zevenbergen, Snel, Eversdijk, & J.W.Roël, 2005). Climate change, land subsidence, and need of space for water are the main reasons resolute the need of smart and sustainable water management policy in South-East Asia (Fit, 2006; Holdsworth, 2007c, 2008; Kuijper, 2006).

1.2 .Floating urbanization novel and smart solution

Need for expansion of urban development and concerning about land value is one the reason for living afloat (De Boo, 2005; E. Pasche, et al., 2008; E. Watanabe, C.M. Wang, T. UTSUNOMIYA, & MOAN, 2004; Fit, 2006; GRAAF, et al., 2006; Holdsworth, 2007a; Kuijper, 2006; Nieuwenhuizen, 2006; Rijcken, 2006; Schuwer, 2007; VREUGDENHIL, et al., 2006; Warner, 1995; YANG, 2007; Zevenbergen, et al., 2005). Floating urbanization could be applied for recreational reason or to allow rivers to find their own space and even regarding to economical issues (Holdsworth, 2007c; Rijcken, 2006). The earliest houseboats in Seattle were recorded in 1905, and peaked with over 2000 houseboats in the 1930s in United States. Prefabricated boat houses or other types of floating shelters such as amphibious trailer or floating houses could be found in predecessor literatures (Carlisle V. Watson, Auburn, & Maine, 1947; Smith & Spartanburg, 1959; White, 1955). Floating houses considered as an approach with the advantage of flexibility in both vertical direction (moving with a fluctuating water level) and horizontal direction to float the buildings whereas, amphibious house limited for horizontal movement (Rijcken, 2006). However, both of the approaches have been used in water side locations previously. On the other hand, the first and novel type of amphibious houses might be happen in Malay Peninsula in Malaysia. The wooden houses are built on stilts which rest on, but without being fixed to the ground underneath the house are stacked horizontally, hundreds of bamboos. In addition, each house has four or more wooden poles and ropes are latched onto these poles. During flash flood, the entire community, with its houses, shops, a public pavilion and dog kennels, is automatically afloat (Jumsai, 1983). Thus, the integrated and new design of amphibious house which used concrete pontoons and pit system should be developed and applied as a flood mitigation strategy in South-East Asia. The benefits of amphibious urbanization are similar to floating urbanization and could be stated as:

- Cost efficiency (A.Ali, 2005; Andrianov, 2005a; E. Watanabe, et al., 2004; T. U. E. Watanabe, C.M. Wangb, 2003; Fit, 2006; GRAAF, 2009; Gunnar Rognaas, 2001; Holdsworth, 2007a; Nieuwenhuizen, 2006; Schoute, 2007; Schuwer, 2007; Suzuki, 2005; Zevenbergen, et al., 2005)
- Environmental friendly (Andrianov, 2005b; E. Watanabe, et al., 2004; T. U. E. Watanabe, C.M. Wangb, 2003; Suzuki, 2005)
- Easy to construct (A.Ali, 2005; Andrianov, 2005b; De Boo, 2005; E. Watanabe, et al., 2004; T. U. E. Watanabe, C.M. Wangb, 2003; Gunnar Rognaas, 2001; Nieuwenhuizen, 2006; Schuwer, 2007; Suzuki, 2005)
- Durability (A.Ali, 2005; Alarcon, 1997; Andrianov, 2005b; De Boo, 2005; E. Watanabe, et al., 2004; Fit, 2006; Fujikubo, 2005; GRAAF, et al., 2006; Gunnar Rognaas, 2001; Holdsworth, 2007a; Schuwer, 2007; VREUGDENHIL, et al., 2006)
- Suitable mooring and movement system (A.Ali, 2005; De Boo, 2005; H. S. Koh, 2008; Kuijper, 2006; Rijcken, 2006).

The preference of flood mitigation for each area in floodplain could be investigated under the criteria due to evaluate performance for prevention and vulnerability mitigation such as cost, land use, water quality, availability and easy to construct, Socio-factors. The objective of this study is to propose the new concept of the amphibious house by using the pit system in lowland area as a smart and sustainable flood mitigation strategy. Moreover, this study tries to evaluate the awareness and acceptance level of floodplain settlers to consider amphibious house as a safe shelter for dwelling in lowland area.

2. Methodology

The concept of the new design for amphibious house was developed including the slab (mounting platform), concrete pontoons, and pit system. The slab was designed based on normal loading by dry season and contrast of water loading and weights during floating time in wet season. The detailed design is not considered in this paper. The number and pattern for positioning of the concrete pontoons were established based on the weight of the system, type of the concrete and buoyancy forces. The point load tests were devoted for tilting clarification. The horizontal load was defined based on drag forces and FEMA standard (FEMA, 2000).

Questionnaire survey was done among 86 respondents from different lowland regions in Malaysia. All regions were selected from hazard zones regarding to the flood influence. Figure 1 shows the geographical distribution of questionnaire among Malaysia.

The frequency analysis and mean score were used to define the level of social acceptance and perception on floating urbanization and implementing amphibious house. The Mean Score (MS) for each factor was computed by the following formula:

$$MS = \sum {(f \times s)}/{N_f} \quad (1 \le MS \le 5) \tag{1}$$

Where

f: frequency of responses to each score for each factor

s : score given to each factor as ranked by the respondents

Nf : total number of responses concerning that factor

The Mean Scores can be split into discrete categories as follow:

(1) Least	1.0 ≤ MSor WA <1.5
(2) Less	1.5 ≤ MS or WA <2.5
(3) Average	2.5 ≤ MS or WA <3.5
(4) High	3.5 ≤ MS or WA <4.5
(5) Highest	4.5 ≤ MS or WA ≤ 5.0

Non-parametric method was employed for defining significant differences between the opinions of respondent in each question. The Mann-Whitney U (Wilcoxon-Mann-Whitney) as a non-parametric test was used since, the data set, including the dependent variable, were measured on a nominal or ordinal scale. This test was used to investigate the relationship between two variables with pair grouping structure.

3. Results and Discussion

3.1 Design of amphibious house

Regarding to the area of the house, the dead loads and live loads of the house calculated. 2.5 KN/m2 for dead load and 1.5 KN/m2 for live load have been considered. Figure 2 shows the first step in VBA-Excel Program, which is developed for this system. In this example, the area of the house considered as 90 m2. The slab also designed based on BS standard and the results, for instance, have been illustrated in Figure 2.

Pre-cast and interlocked concrete pontoons have been used to provide buoyancy for the whole system. The dimension and design of concrete pontoons was carried out based on Archimedes's principal and free board considerations. With the maximum load, the free board of floating house shouldn't be less than 20 cm. all pontoons are pre-cast and fabricated on site which contains steel bars. The buoyant part is filled by EPS blocks and attached and casted in-situ with slab concrete. The final attaching system illustrated in figure 3.

Figure 4 illustrate the design of pontoon, estimation of number of required pontoon, feasibility control, and pattern of pontoon positioning for aforementioned example.

The pit area provided underneath of the house which helps the stability during floating by decreasing turbulence under the house during the flood. It helps decrease interaction of pontoons' surface with water flow during the flood. Moreover, it provides area for cleaning and maintenance after each flooding. The pit system provides a place for pavement, connection of the lateral system to pavement and space for main columns, which should carry the system during normal time and dry season. The pit height is equal to pontoons height in addition to 1.5 meter service height area. Figure 5 illustrates the concept of pit area during construction. On the other hand the mooring system is provided by roller fenders, which give the vertical movement ability to the system around lateral support columns.

Tilting and rotations control were considered in this study. Thus point load effect was determined for each dimension. Any rotation more than 5 degrees was considered as a failure then, the system redesigned with extra pontoon to decrease the rotation with different point loads. Figure 6 and 7 illustrates the point load analysis and relation between the number of pontoon, different width of the slab with 12 KN point load on the corner and rotation degrees.

3.2 Perception and acceptance level from lowland dwellers

The results of the questionnaire survey showed that 100 percent of respondents aware of flood damages and near 99 percent of them completely aware of flood danger. Moreover, more than 78 percent of them experienced flood previously. The mean scores achieved from respondents according to the level of danger and level of vulnerability (damages) of the flood, defined the importance of

protection and flood mitigation strategies in Malaysia. Table 1 shows the mean scores achieved for different questions. Based on the results, the level of danger is 4.27 and the level of damages is 4.20 which are both in high rate according to aforementioned discrete categories.

On the other hand, 62.7 percent of respondent revealed the lack of enough flood mitigation around their area while the importance of applying any flood protection strategy achieved high rate regarding to its' mean score. While the lowland dwellers were asked about their reaction during flood, the acceptance of new strategy which has ability of facing with flood was highlighted in their responses. Figure 8 illustrate the frequency of their answers.

Since, amphibious house could be applied on low population areas and gives the opportunity of individual safety; it could be useful for small rural areas or semi-urban areas. Even though, just 40 percent of respondents were familiar with floating urbanization, the usefulness of applying floating house in their side of view achieved moderate level (table 1). The result shows that, the level of acceptance and suitability of the amphibious house are 3.08 and 3.33 which are in moderate level.

However, based on the results achieved from Mann-Whitney U (Wilcoxon-Mann-Whitney) as a non-parametric test, there is a significant difference between the level of acceptance and suitability perception of the respondents who had familiarity with floating and amphibious house rather than others. Table 2 illustrates the results and shows the α is less than 0.05 for level of acceptance and suitability perception. Based on the ranks achieved from this test, people who know about floating houses are more interested on applying amphibious house and have got higher level of acceptance rather than other people. Moreover, the suitability perception of applying amphibious house achieved a significantly higher score with people who aware of floating houses rather than others.

However, the mean score regarding to the extra cost of this system shows that people are so sensitive about economic consideration. Although, the people with familiarity to the floating system have higher payment admission, the expecting level of cost is in low category. This issue should be covered by governmental founding, which is normally spent for flood mitigation strategy in developing countries.

4. Conclusion

Floating urbanization is a high-potential strategy for flood vulnerability mitigation. There were different types of mooring and floating system, which could be applied for floating urbanization. By concluding from all, amphibious house with concrete pontoon is the most appropriate and applicable choice in Malaysia. Lateral forces during flood rush are transferred by roller fenders and absorbed by lateral columns. The mounting system designed for normal house loading, and point load analysis have been conducted for it.

Pre-cast concrete pontoons, which are filled by expanded polystyrene blocks (EPS) are one of the approaches towards economic and time saving strategy. These pontoons provide buoyancy for the whole system. The number of pontoons, and pattern of positioning calculated. Tilting of the system is considered for less than 5 degrees and the free board of floating house was considered 20 cm.

Based on the questionnaire survey the acceptance and suitability perception of lowland settlers is in a moderate level, and it triggers to be high while their perception of floating house was increased. On the other hand, this method helps to boost the land value and give buffer time for any evacuation, if it is necessary. Thus, by more attempt on promoting amphibious system and making the show rooms the acceptance level would be increased. Based on the results following strategies should be applied to implement amphibious house in South-East Asia.

- Promoting R&D and training Centre;
- Subsidizing from government for low population and rural area;
- Promoting the exhibitions and showrooms for different approaches;

- Promoting these houses for recreational reasons in lakes and retention ponds;
- Collaboration with international markets, use their experience in European countries and develop branding for special components.

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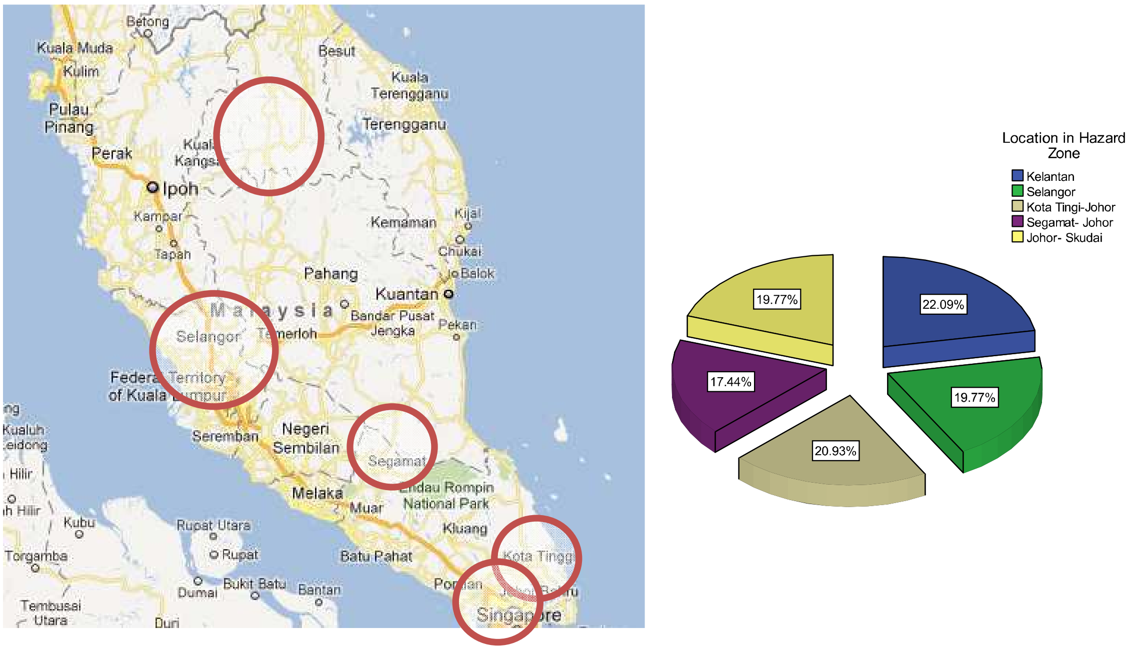

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Figure 1 Geographical distribution of respondents among Malaysia in questionnaire survey

Figure 2 Preliminary steps to define loads and slab details

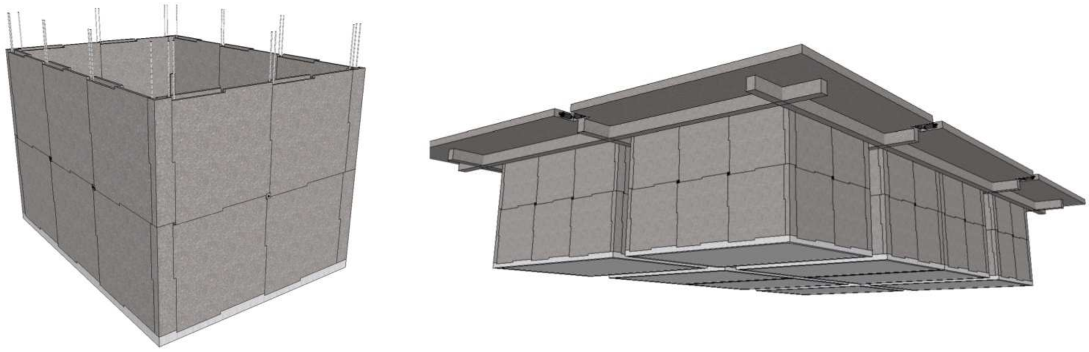

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Figure 3 Pre-cast concrete pontoons a) Fabricated pontoon b) The whole floating system

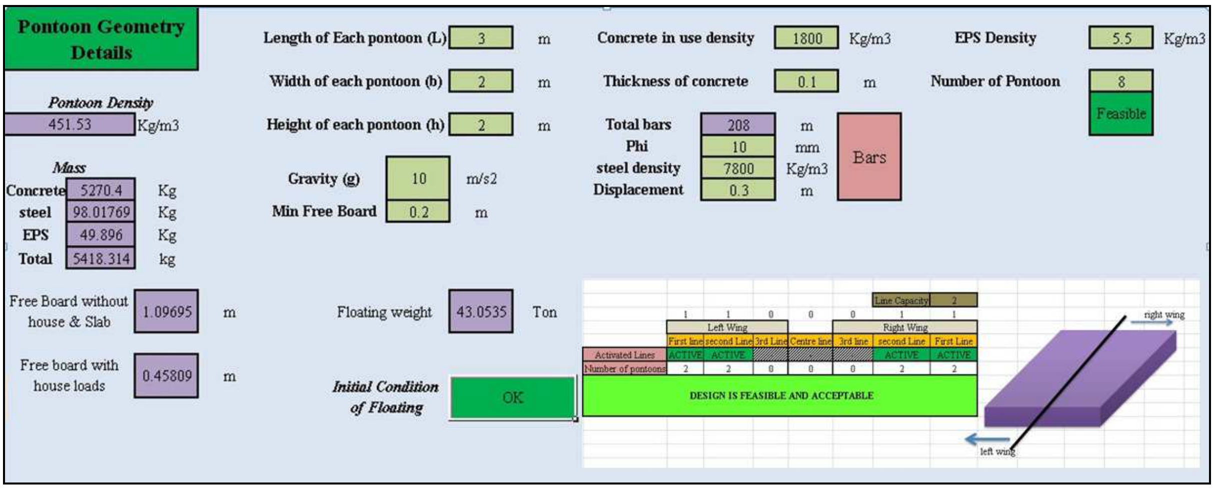
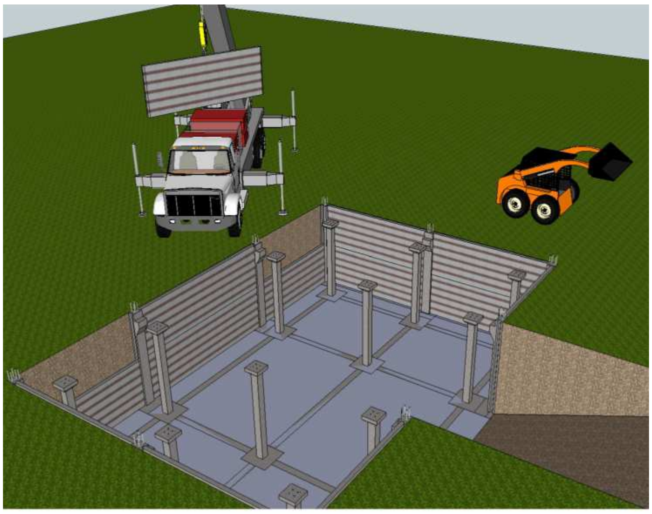


Figure 4 Design stage for buoyant part



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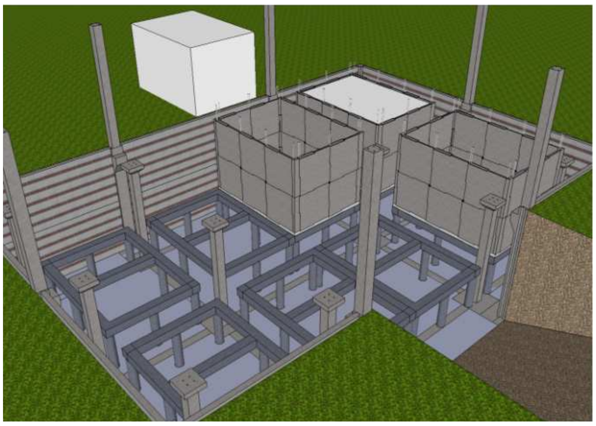

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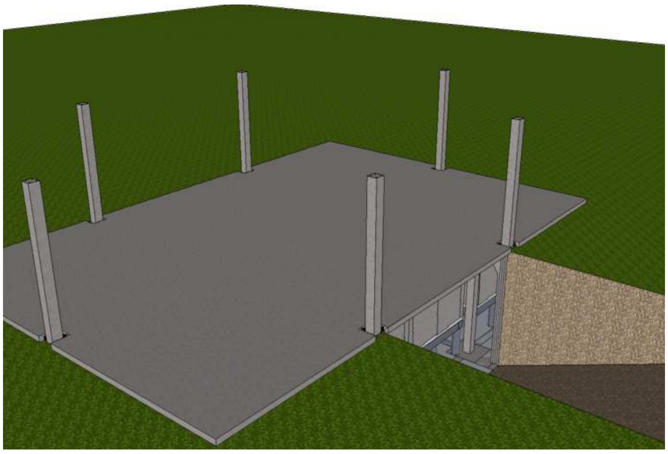

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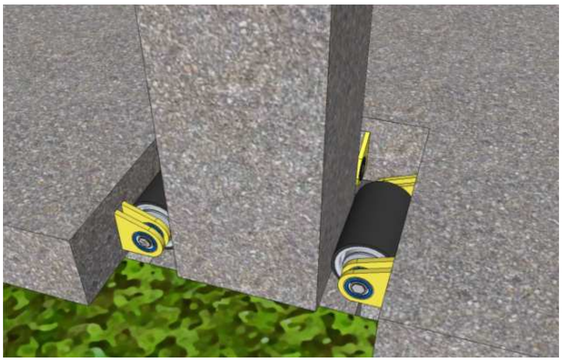

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Figure 5 Design and construction stages for pit system mounting system a) Pit and pavement b) Pontoons and lateral support c) Slab and mounting system d) roller fenders

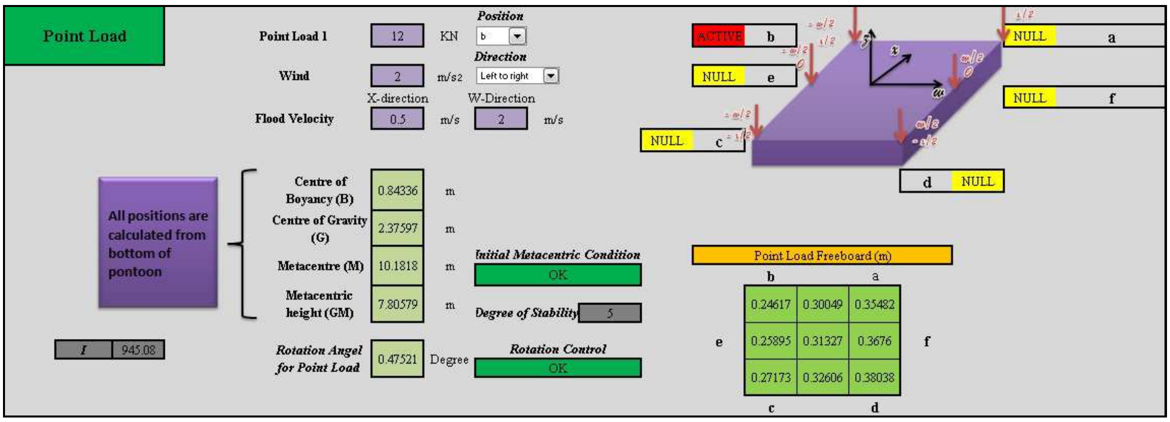

Figure 6 Point load analysis

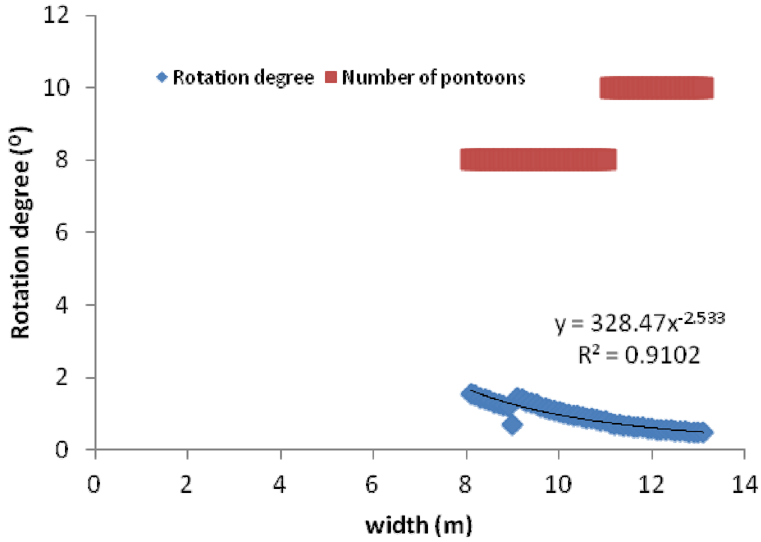

Figure 7 Rotation control for different slab width with fixed length and calculated pontoons

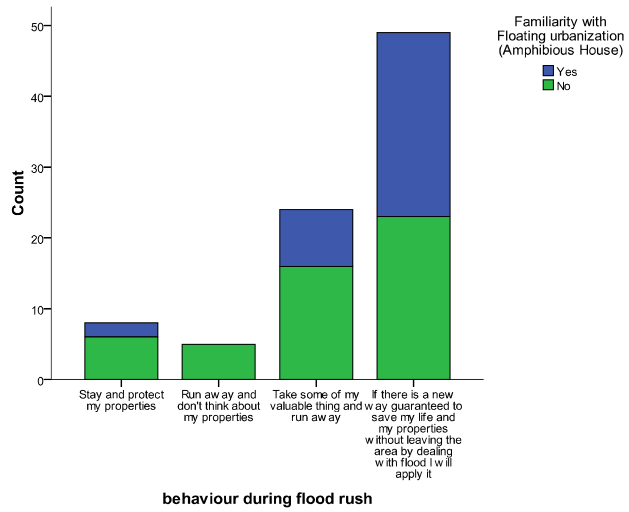

Figure 8 Lowland dwellers' reaction during flood rush

Table 1 Mean scores results for acceptance and awareness

Question	Mean Score	Std. Deviation	Category
Level of flood danger	4.27	0.758	High
Level of flood vulnerability	4.20	0.823	High
Importance of applying flood protection strategy	4.36	0.810	High
Usefulness of Floating house	3.17	1.218	Moderate
Level of acceptance to apply floating capability on ordinary houses	3.08	1.054	Moderate
Level of suitability to apply floating capability rather than evacuation	3.33	1.089	Moderate
Extra payment for floating system	1.72	0.849	Low

Table 2 Non-parametric test analysis

	behaviour during flood rush	Level of acceptance to apply floating capability on ordinary houses	Level of suitability to apply floating capability rather than evacuation	payment
Mann-Whitney U	641.000	635.500	638.000	516.500
Wilcoxon W	1916.000	1910.500	1913.000	1791.500
Z	-2.547	-2.452	-2.402	-3.661
Asymp. Sig. (2-tailed)	.011	.014	.016	.000

Grouping Variable: Familiarity with Floating urbanization (Amphibious House)