Alternative Housing System & Materials Criteria For Land Subsidence Area (Case Study: Bandarharjo, Semarang)

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Abstract. The critical land subsidence at rate 10cm per year happening in Bandarharjo district of Semarang is a big concern for the local community. With the increasing number of population, the building load increases as well thus could be one of the factors that hasten the land subsidence process. This phenomena causes the locals to spend a lot on house renovation and repairment. To keep up with the road level increased by the government, they had to increase their house floor level. Some demolished and rebuilt their houses. This paper seek to study the ideal criteria of alternative housing systems and materials that is adaptable for land subsidence and flood situation in Semarang by reference research methodology which various papers and guidelines of construction system based on the context of Bandarharjo. The existing housing material and system needs to be strategised for more affordable and adaptable housing system. Although there are already adaptation responses towards these natural disasters by the local communities but the responses are without the awareness about the ideal house system and materials that that helps them to adapt and live with natural disaster in a sustainable and more durable system.

1. Land subsidence and Flash Flood in Semarang

Semarang, located in the central of Java Island of Indonesia, with the second highest density of population is one of the participating cities that joined the 100 resilient cities network that works together in tackling tangible and intangible issues of land subsidence and the flood that results to damages to houses, infrastructures and also economic loss.

In the 6th century, the coastline of Semarang was still at the boundary of Bergota area, which was not too far from Simpang Lima area which is now is the current city center. However, the sedimentation that coming from upper Semarang to the coastal area, is shifting the coastline further to the Java Sea. Until 2007 the coastline has extended as far as ±6.5km [1].

Two main factors that influences the occurance of land subsidence and tidal flood which is also known as ‘rob’ in Indonesian language are; through excessive ground water extraction and load of building and infrastructure [2]. According to “In Monitoring Land Subsidence in Semarang, Indonesia” [3] the causes of land subsidence is categorised as naturally occurred and man-made voids which relates to the massive withdrawal of groundwater in Semarang but this paper will focus more on the load of building infrastructure that causes the land subsidence.
Figure 1. Semarang coastal line shift of 6.5km [1].

Another factor of the land subsidence in Semarang is the soil of Northern part of Semarang that is composed by very young alluvium with high compressibility [4] and currently the topography level of Semarang is at the elevation of 0-3. from sea level. Although this area is prone to flooding and land subsidence issues, this area has become a strategic area for settlements for its economic value of port, industrial and commercial area.

Due to the increasing population and urban development in Semarang area, excessive ground water has been extracted for industry and domestic use and load of development also causes increase in building and infrastructure load. This has led to serious land subsidence and tidal flood.

2. Bandarharjo District, Semarang

Figure 2. Bandarharjo. District, Semarang

Bandarharjo district which is located in the upper North of Semarang, neighbouring with the Tanjung Mas Semarang Port area is comprised of housing settlements and also industrial area. The main environmental issues that is being faced by Bandarharjo is the land subsidence which is at the rate of 7-8cm subsidence per year based on PS InSAR simulation or 6-7 cm subsidence per year based on GPS simulation calculation [4]. At this rate, a single storey house could be completely sunken in 30 years. In response, the government raised of road levels by 50cm every 5 years to catch up with the original elevation of the land. This does not only affect the infrastructure and houses but also causes economic loss to the local community which majority are in the category of low income community.
The land subsidence also gives negative impacts to the two types of floods that happens in Bandarharjo which is the tidal flood and the flash flood. However, the recent installation of flood control pumps at few points in site had stopped the flooding for two years.

![Sunken houses in Kampung Kalibaru, Bandarharjo.](image)

Figure 3. Sunken houses in Kampung Kalibaru, Bandarharjo.

Although the flood has been stopped, land subsidence is a continuous process and will grow worse if the groundwater extraction of the whole Semarang is not stopped and also urban development that increases the building loads which eventually will causes the tidal flood again in the future. Therefore, criteria of house system and materials that is suitable for this condition should be studied to prepare the local community towards awareness about these natural disasters and the strategies for them to adapt and be resilient.

3. Methodology

In order to develop more understanding about the material and construction system that suits best in adapting land subsidence and flood in the context of Bandarharjo, data and information were gathered and studied through literature studies and focusing on the literatures based on housing system and materials in respond to land subsidence and tidal flood in the context of Semarang or other regions with similar context. Besides that, to develop deeper understanding about the issues of housing that affected by the land subsidence and flood, the site visit was carried out. The purpose of the site observation is also to study the local communities respond towards the natural disaster issues, and to collect information and documentation about house construction system, material, condition and damages of selected houses. Moreover, a deep interview with locals who has lived more than 30 years in the area is carried out to further investigate the condition of the land subsidence and flood and also their responds towards the natural disaster. Last, an interview with an oceanography researcher was also carried out to develop more understanding about flood and land subsidence scientifically that is happening right now and the possibilities in the future.

4. Construction system and material criteria for land subsidence and tidal flood area

Damaged caused by the land subsidence and flood disasters had come to studies of ideal types of house construction and materials which is more adaptable and flexible in adapting these issues. Ideally, the type of house construction system is a design system whereby the building could be lifted by phases [5], which the ground is left as is and the construction is built in suiting the present condition of the ground which means no road or ground level rise. As for building load factor, lightweight building materials are to be considered for a house system in context of unstable land which is prone to land subsidence and flood [5].

4.1. House construction system
There are three potential house construction systems for areas that experience both land subsidence and tidal flood; stilt house system, floating house system, and raising house level system, and these three potential systems are evaluated and analyzed based on 5 criteria as shown in the table below [6], which was then further evaluated to get the house type which best fit for the condition of land subsidence and flood in Bandarharjo.

| Table 1. Criteria score [6] |
|-----------------------------|
| Aspect                      | Value (%) |
| Ability in adapting tidal flood | 40        |
| Feasibility of construction process | 20        |
| Material availability       | 15        |
| Financial                   | 10        |
| Community preference        | 15        |
| Total                       | 100       |

4.1.1. *Stilt House System (Rumah Panggung)*
Floor is elevated from the ground surface. It is already common in the Indonesian traditional architecture which was meant to protect the inhabitants from danger; nature and wild animals. The space underneath can be utilised as a communal area for the family. Since wood is widely available and easy to assemble and disassemble, it is common to be used as the material for this kind of construction system.

The advantages of stilt house system are its flexibility of knock-down for adjustment and repairmen, extra space underneath that can be utilised as a multiuse space, and protects its inhabitants from danger of flood and so on [6]. The space underneath the stilt house can reduce the humidity from the ground to the floor and also the increment of house level can be done by phases according to the user’s financial ability.

4.1.2. *Floating House (Rumah Apung)*
Focusing on not to touch the ground, the whole structure is to be floating which usually on site with water. There are variety of floating system that can be used such as drum, kayau or bamboo. The advantage of this system is the flexibility in adapting to the water level. However, the technical aspect of this system is very complicated.

4.1.3. *Raised Floor House (Rumah Urug)*
This house construction type is whereby the level of house floor is being raised in response to the land subsidence by filling more soil to the ground. This is the most popular construction system chose by the locals. The advantage of this system is that it is easy and feasible for the locals but on the other hand, it comes with high cost and also the need of retaining wall construction.
Table 2. House system evaluation based on criteria score system [6].

|                          | RP  | RA  | RU  | RP  | RA  | RU  |
|--------------------------|-----|-----|-----|-----|-----|-----|
| Flood Adaptability      | 40  | 50  | 20  | 30  | 20  | 8   |
| Construction Feasibility | 20  | 30  | 20  | 50  | 6   | 4   |
| Local Community Preference | 15 | 50  | 20  | 30  | 7.5 | 3   |
| Financial                | 15  | 35  | 25  | 40  | 5.25| 4   |
| Material Availability    | 10  | 40  | 20  | 40  | 4   | 6   |
| Total                    | 42.75 | 20.75 | 36.5 |

RP: Rumah Panggung (Stilted House)
RA: Rumah Apung (Floating House)
RU: Rumah Urug (Raising of floor level)

Thi from the matrix of house construction type evaluation criteria and score values in Table 2 by [6] in the paper Sistem Konstruksi Sederhana Pada Perbaikan Rumah Warga di Kalurahan Kemijen, it is found that stilted houses has the highest score for its adaptability towards flood, construction feasibility, local community preferences, financial capability and also material availability.

In conclusion, every each of house types has its advantages and disadvantages for the condition of land subsidence and flood in Bandarharjo. The types as housing system and construction responds from the locals are to be further studied in chapter 3.3.

4.2. House construction system

According to Muhammad Ali, decision making of building construction material in flooding are, the aspects of durability in terms of waterproof and also corrosion are needed to be considered especially for the structural members that has direct contact with ground or the ones that are exposed to flood [7]. The alternative material should be adaptable and suitable with the condition of the existing house type and also the condition of the land subsidence and flood disaster [5].

In choosing the ideal material for houses in land subsidence and flood prone area, the materials chosen should be considered with its functionality which functions as different components of structure of the house construction which are the foundation, column, floor beam, floor panels, perimeter beam, roof structure members, roof covering, and wall panels and finishes [6]. On the other hand, in respond to unstable land that has land subsidence issues lightweight material should be considered [5].

Of these studies about ideal house construction material criteria’s, it can be concluded that materials for houses in land subsidence and flood prone area should consider the following criteria [6];
1) Durable
2) Waterproof
3) Corrosion proof
4) Lightweight

However, in the context of Bandarharjo which involves the local community, material choice decision should also consider the following criteria [6];
1) Structural strength
2) Economic capacity
3) Material availability
4) Construction feasibility and skill availability
5) Sea water durability
Considering the ideal material criteria, there are variety of materials than can be considered in both bio based and non-bio based materials such as wood, bamboo, lightweight steel and lightweight concrete respectively.

5. Bandarhajo Houses condition

5.1. Existing Houses System

In 2010, there are 1614 units of permanent concrete houses at 40.97% (refer figure 4), 1018 units of semi-permanent at 25.65% and 1311 units of non-permanent or wooden houses 33.66% (refer Figure 5) in Bandarharjo district which is prone to land subsidence and flood [7].

Most of the existing houses in Bandarharjo are landed house with direct contact to the ground which uses concrete as main structural material. From site visits, no stilt house type was found except for few blocks of 5 storey apartments which are lifted up and ground floor serves as open public area for community activities and also community market. The type of foundation system commonly used by the existing houses is the strip foundation, buried underground.

In responding to the flood condition, this landed house system is not a suitable house system for its direct contact towards the ground that could allow flooding in both short-term and long-term condition of land subsidence in Bandarharjo district. Majority of the houses are lower than the road level whereby this condition could lead to more serious flood damages due to the ground level differences that allows more water to flood the house compared to a house which its ground floor is the same or higher than the road level.

5.2. Existing Houses Material

The condition of land subsidence and flood could be worsened with the big number of houses in Bandarharjo district that uses brick and concrete as the main structure which increases the construction load towards the ground.

Although wood and bamboo are used as non-structural material which are mainly as roof structure or secondary structural member, such as column for porches and smaller structural members for roof, there are still room for the local lightweight material to be further developed and innovate to attract the local community to use it as the main structure in reference of a small number of good quality existing old wooden house in the area.

Today there are variety of choices for lightweight and durable materials for houses in land subsidence and flood prone area. However, it is also important to consider the other aspects of
decision making in relation to Bandarharjo context involving the 5 criteria mentioned in chapter 3.2 [6]; structural strength, economic capacity, material availability, construction feasibility and skill availability and also sea water durability.

5.3. Adaptation to Flood and Land Subsidence

Living in an area with the extreme condition of flood that happens almost every day and land subsidence at the rate of about 10cm per year had given no other opportunity for the local community of Bandarharjo other than adapting to the condition by renovating their houses.

| Reason                  | %  |
|-------------------------|----|
| Moving to other area    | 9  |
| Increasing House Level  | 74 |
| Do nothing              | 13 |
| Others                  | 4  |
| Total                   | 100|

Table 3. Local community Wants in Rob Area [7]

According to a survey of what the local community wants in respond to land subsidence and rob, 74% of the community wanted to raise up their ground floor level and 9% of the community chose to move to another area [7]. The house system adaptation behaviour of the local community of Bandarharjo district is influenced by both internal and external factors as follows [8]:

a. Internal Factor:

Internal factors that influence the adaptation behaviour in housing adjustment in respond to extreme condition in Bandarharjo district are education background, knowledge and experience for the community to adapt, economic capacity in affording house adjustment, community network and also land and house ownership status.

b. External factor

External factor that influences the adaptation behavior in housing adjustment in adapting the land subsidence and flood condition in Bandarharjo are environmental condition, infrastructure network system that plays important role in flood management such as drainage system and also other infrastructure and facilities of the area.

5.3.1. Current Adaptation System. House adjustment raising the floor level or renovation towards elevated house type are usually done according to economic capacity of the home owners. Based on the House Adjustment in Flood Area Guideline Theory [8], there are four types of adaptation system introduced which are:

Type A : Raising up house structure
Type B : Raising up ground floor level
Type C : Waterproof fence construction
Type D : Using waterproof material
In relation to the guideline, referring to a thesis titled “Housing Building Loss Cause by Rob and Direction of Management Policy” by Muhammad Ali, 74% of the community in Bandarharjo district which is facing land subsidence and flood disaster choose to adapt the condition by raising their house’s ground floor level by adding concrete layer. This system of adaptation is chosen for its construction feasibility and also material availability.

This method of raising up the ground floor level by adding concrete layer is not the best solution in responding to rob and also land subsidence. The addition another layer of concrete onto the existing floor results to accumulation of volume of concrete that results to accumulation of building load towards the unstable ground. This will hasten the sinking process of the house into the ground yet the road level is raised up to 50cm every five years by the government.

Sunken house in catching up the raised road level had raised the urgency to keep raising up the floor level therefore the head clearance between floor to ceiling will be reduced. In 20 to 30 years period, the ground floor space will be no longer functional as a living space. Thus, the house needs to be renovated or even demolished to be functional again as a living space creating an unsustainable cycle of house adjustment which not only cost more money but also not environmental sustainable in terms of material usage.

This indicates that the local community is not aware or does not prefer the ideal housing system suggested by some studies which the building could be lifted by phases, according to the condition and also affordability of the house owner [5]. The ideal house construction system is further described as elevated stilt house system that uses lightweight material in reducing load towards unstable ground [5].

In addition to the load reduction, this house construction system has more flexibility for adjustment and also repairmen. The elevated ground floor provides protection for the house residents from flood danger in compared to a landed house system which is more prone to flood. Besides that, space underneath the elevated floor could be serve as a multifunctional space, providing additional living space and also space for storage or as small barn for living stock.

6. Conclusion
Based on recommendations and suggestions from various references, in can be concluded that stilt house construction system fulfills most of criteria suggested specifically in the context of Bandarharjo district which has the feature of adaptability and flexibility that enables the house to be lifted by phases according to the flood condition. This will provide protection for both residents and their properties from flood. The flexibility also considers the economic capacity of the Bandarharjo residents which mostly are under the low-income category.

Lightweight material either bio based or non-bio based, agreed as the ideal material in most references for its capability of reducing building load but in context of Bandarharjo, it should be durable, waterproof, corrosion proof, affordable and widely available for construction. However, it is
also important to consider the local community preferences which usually determined by their knowledge and familiarity.

The introduction of lightweight elevated house on stilts may not be the silver bullet for this land subsidence and flood issue for its drastic requirement of demolishing the current permanent concrete house for a new one which is totally different than the common house type in Bandarharjo district but it can be slowly implemented and further developed with the available small construction industries in the area.

The possibilities of house construction system and materials could be anything as long as it fulfills the concluded criteria that specifically refers to the context of Bandarharjo.

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References

[1] Semarang City Government. (2016). Resilient Semarang Strategy Book. Semarang: Semarang City Government. [Online]. Available: http://www.100resilientcities.org/wp-content/uploads/2016/05/Semarang20Resilience20Strategy20-202016.pdf [Accessed: 05-July-2017].

[2] Radjawane, I. M. (2017). Memahami Banjir, Kekeringan dan Penurunan Muka Tanah Studi Kasus: Kota Semarang. Bandung.

[3] Muh , A., & Lorenz, K. (2007). Monitoring Land Subsidence in Semarang, Indonesia. [Online]. Available: https://link.springer.com/article/10.1007/s00254-007-0680-3 [Accessed: 05-July-2017].

[4] Abidin, H. Z., Gumilar, I., Sidiq, T. P., Andreas, H., Maiyudi, R., Gamal, M., & Fukuda, Y. (2013). Mapping And Evaluating The Impact Of Land Subsidence In Semarang (Indonesia). Geospatial Vol. 2, 26-40. [Online]. Available: http://journals.itb.ac.id/index.php/iog/article/view/2185/1120 [Accessed: 05-July-2017].

[5] Krisprantono, & Ch, K. (2012). Pemecahan Masalah Rumah Ambles Di Semarang Utara. VitaspHERE, 45-48, [Online]. Available: http://journal.unika.ac.id/index.php/vit/article/view/366/323 [Accessed: 05-July-2017].

[6] Pribadi, S. B., Indriastjario, Wulandri, A. R., Wibowo, Y. T., Janatin, B., & Muzammil, M. (2011). Sistem Konstruksi Bangunan Sederhana Pada Perbaikan Rumah Warga di Daerah Rob (Studi Kasus: Kelurahan Kemijen, Semarang Timur). [Online]. Available: https://ejournal.undip.ac.id/index.php/modul/article/view/1461/1226 [Accessed: 05-July-2017].

[7] Ali, M. (2010). Kerugian Bangunan Perumahan Akibat Rob dan Arah Kebijakan Penangannya di Kelurahan Bandarharjo Kota Semarang. [Online]. Available: http://eprints.undip.ac.id/23702/1/MUHAMMAD_ALI.pdf [Accessed: 05-July-2017].

[8] Ariandini, D., Utami, S., & Yatnawijaya, B. (2016). Adaptasi Fisik Bangunan Rumah Tinggal di Permukiman Rawan Banjir (Studi Kasus: Kelurahan Bandarharjo, Semarang Utara). Vol 4, No 2. [Online]. Available: http://arsitektur.studentjournal.ub.ac.id/index.php/jma/article/view/263/255 [Accessed: 05-July-2017].