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The Application of Building Systems in Coastal Settlements

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ABSTRACT

Many coastal settlements in humid tropical developing countries (DCs) face the burdens of risks due to their location as well as due to a rather low quality of housing that does not meet the sustainability requirements. The main aim of the paper is to investigate and identify building systems requirements that applied internationally for the determination and adaptation of the performance of low cost housing in urban coastal tropical settlements (UCTS) towards improved sustainability. For this purpose a literature study and preliminary observation was carried out whereby the existing building systems were applied. The paper's relevance is to know the present building systems that used in the location, the standard and requirement that used internationally and the gap. The derived methodology and research tools are to be applied in a survey amongst low cost housing projects in urban tropical coastal settlements at Java, Indonesia. Once the performance of existing technologies as well as the features of the context in which they are applied is known, it will be possible to adapt or develop technologies that better respond to the contextual requirements. By means of applying the developed methodology and research tools in the survey also their usefulness will be validated for the purpose of increasing the insight and understanding of the sustainability and lifespan performance of building systems, particularly of those building systems that can be applied in low cost housing in UCTS in DCs.

Key words: building systems, urban coastal tropical settlements, sustainability

1. INTRODUCTION

The rapid growth of cities, especially in developing countries (DCs), leads to social problems as well as to serious burdens for human health and the environment (UNHABITAT 2003). Indonesia is a country with more than 17.500 islands. The 81.000 km coastal line in the country makes that more than 25 % of the people in Indonesia live in a settlement along the coast. (Dahuri, R, et al; 2001) The housing conditions in these settlements are more than often improper for habitation. Infrastructure, services and physical facilities are still limited; clean water is difficult to get and sanitation is improper. The population here has a relatively low income level (Dahuri 2001). Besides, the coastal areas have a physical problem related to the corrosive land and air conditions. (ADB 2003)

Currently there is an increasing pressure in many regions in the world to provide a sustainable environment for present and future generations. It involves the simultaneous pursuit of social equity, environmental quality and economic prosperity (people, planet and profit) (UN 2005). Together with solving the housing problem for the urban low income households in a sustainable lifespan based manner, sustainability has become one of the most urgent imperatives in many tropical DCs. This counts particularly for coastal settlements that have to face natural hazardous impacts. (UNHABITAT 2003). To reduce and avoid sustainability problems, it is necessary to have more insight and understanding of the sustainability of building systems in different societies and locations in coastal areas. Given the particular context of coastal tropical urban settlements of low income households in DCs, important aspects that need to be investigated are safety of the building systems, inclusion of services (water and sanitation) and user requirements for the housing units in the short term and lifespan perspective.

This paper is a part of PhD study. The final aim of the PhD study is to adapt, apply and validate a methodology for the determination and adaptation of the Sustainability and Lifespan Performance of Building Systems applicable to Low Cost Housing in UCTS.

In the following our examination of some sustainable building systems will be discussed. Building Systems that will be discussed in this paper are: utilities system, constructions and material type of the housing. This exercise had the objective to gain insight in various approaches that might be appropriate to be applied in tropical coastal urban settlements in a developing country (such as Indonesia).

2. Local context of UCTS in DCs

The environmental context of housing and building construction in UCTS is characterized by phenomena in the geo-physical environment, such as earth surface features, climate and natural hazards (tidal flooding, salt water intrusion), air, water, soil and vegetation.

Various studies have been carried out on coastal settlements lately focused at the impact of flooding and salt water intrusion. As commonly faced by the coastal areas near the sea, there is a relatively high potential for flooding / tidal flooding (floods that happened by uprising sea water fluctuation) and sea water intrusion due to a high intensity of ground water exploitation in densely populated areas. This declines the ground surface water rapidly. Even, in some other coastal areas it can cause land subsidence and sea water intrusion to the far-reaching land.

(Kusumaatmadja, S. 1994). This decline in ground water surface could result in other disasters such as corrosion of the built environment and buildings construction (Zainuddin, 2004).

The impact of tidal flooding on the coastal community and identified the community's and local government's response to tidal flooding along the coast of Semarang, Indonesia has been assessed by Marfa'i et. al (2007). The focus in this research was on tidal floods related to the socio-economic features of the coastal communities; on the impact of the tidal inundation on local communities; and on the community and government's response to tidal flood hazards. Kobayashi (2003) used technical standards for the investigation of river economies related to the economic effects of river management and applied this methodological approach to evaluate its applicability for the management of Asia-Pacific coastal settlements regarding the uprising of sea level. Marwasta, D et.al (2005) used a comparative morphological and behavioral approach to investigate coastal settlements. This research revealed the pattern and socio-economic conditions of the settlements in rural coastal areas.

Next to the hazardous situation in UCTS that may occur due to flooding or tsunamis also other natural hazards may take place, such as earthquakes and hurricanes. Much literature has been published on earthquake and hurricane resistant building construction, which is applicable to residential building for sub tropics, but donot mention requirements for settlements for low income households in coastal tropical as well. The literature shows the requirements and building codes for residence in subtropical coastal (FEMA, 2005), (FORCE 10, 2003), (APA, 2003).

The social context of the low income coastal settlements – alike many other low income settlements in tropical DCs- is characterized by most deplorable living conditions within the city with inadequate water supply, squalid conditions of sanitation, overcrowded and dilapidated habitation on hazardous locations, insecure tenure and vulnerability to serious health risks. (UNHABITAT 2003) This has all to do with the socio-economic situation in DCs which is characterized by a relatively low GDP/cap, a limited level of technological capabilities and a dualistic technology system

at macro level. The latter means the existence of (1) at one hand a modern sector linked to the international market, employing imported technologies and requiring specific production technologies which are in principle alien to the local environment (skills, use of materials, organization styles) and (2) at the other a traditional sector, usually in a rural setting and in poorer communities living in big cities on the fringe of society. (Egmond, 2000)

3. THE PRINCIPLE OF SUSTAINABLE CONSTRUCTION

The Conseil International du Batiment (CIB) 1994, in Kibert 2005 defined the goal of sustainable construction as "...*creating and operating a healthy built environment based on resource efficiency and ecological design*".

According to CIB, sustainable construction articulated seven principles which would ideally inform decision making during each phase of the design and construction process. These factors will use to apply when evaluating the component and other resources needed for construction. The seven principles are : reduce resource components (reduce), reuse resources (reuse), use recyclable resources (recycle), protect nature (nature), eliminate toxics (toxics), apply life cycle costing (economic), focus on quality (quality).

The term of sustainable construction most comprehensively address the ecological, social, and economic issues of a building in the context of its community.

Many advantages shown by the building which were constructed according to the criteria of sustainability compare to the conventional building in some developed countries. The most important are : higher value of real estate and higher productivity, enhance image, lower risks, better influence of the health and residence and users, reduce effect of infrastructure, environmental, local economic structure (Braune, et.al (2007).

Green building is a process of integrated design that incorporates architecture/ design to minimize a building's impact on the natural and human environment (Southern California Association on Non Profit Housing, (2005).

4. THE APPLICATION OF PRESENT BUILDING SYSTEMS AT UCTS IN DTS

4.1. The geographical condition at coastal area in northern part of Java

Coastal area” the concept of coastal area is the interface between ocean and land, extending seawards to about the middle of the continental shelf and inland to include all areas strongly influenced by the proximity to the ocean. *Boundary Limits for Mapping: area between 50 m below mean sea level and 50 m above the high tide level or extending landwards? to a distance 100 km from the shore, including coral reefs, inter tidal zones, estuaries, coastal aquaculture and sea grass communities*” (UN-Nature Resources Management and Environmental Departement, 2003, chapter 2).

“The most common definition driving a determination of coastal areas is based on geography. Here the definition can be as simple as 100 kilometres from the beach to more refined approaches focused on coastal watersheds” (UN-Nature Resources Management and Environmental Departement, 2003, chapter 2).

Coastal zones, by Supriharyono 2005 are *the interface between ocean and land*. Towards the coastal areas include parts of the mainland, either dry or under water, which is still influenced by the sea, such as tide, ocean wind, and salt water intrusion. While toward sea direction, coastal areas include parts of the sea which is still influenced by the natural processes that occur on land, such as sedimentation and fresh water flow, or due to human activities on land, such as forests denudation and pollution. The definition shows that there are not real boundary coastal areas. The boundary of coastal areas is an imaginary line which is determined by the local condition and situations.

Thus in this paper, the coastal area (coastal settlements) mean that the settlement geographically located closed to the coastal area and the residents still influenced by the coastal area and its physical conditions. The coastal areas have a physical problem related to the corrosive land and air conditions. Not all design and building technologies applied to build housing units respond properly to this. Diverse sustainable housing strategies, design concepts and building technologies have been developed all over the world, not all of them have shown to be adequate or widely accepted for implementation in tropical developing countries alike in the situation of the coastal areas of Java in Indonesia (ADB 2003). This paper will find the characteristics of existing building systems that used in case study area comparing with the requirements of sustainability lifespan housing in coastal area.

4.2. Building Systems Application : the existing condition and its problems in UCTS

The building systems that is meant in this paper are the integrated building technology supported the building construction itself. Building system featured for low cost housing: utilities system, constructions and material type of the housing.

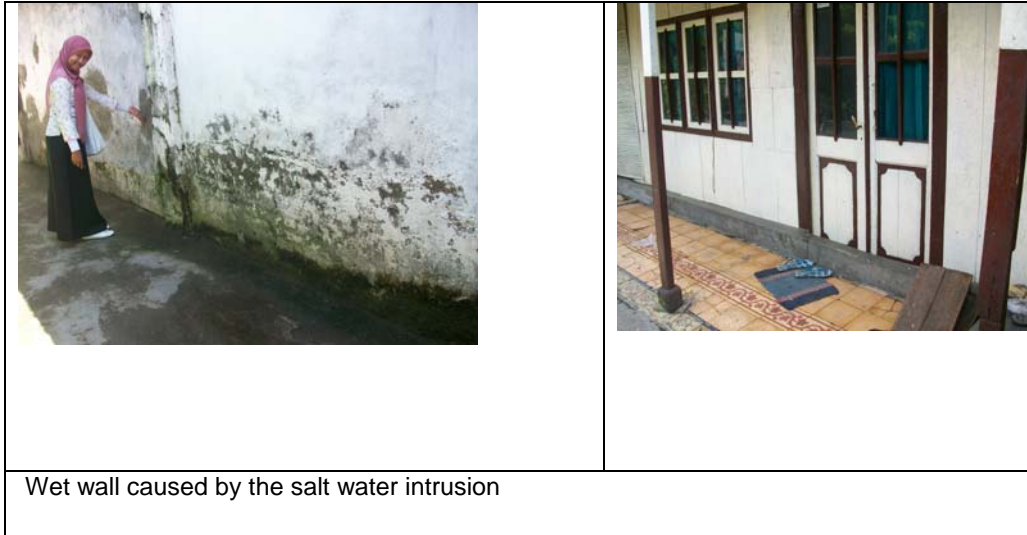
From the preliminary observation result obtained from several residence in coastal area, general major problems of coastal area are found, which are:

- Building systems do not comply with local geo-physical conditions. (ABB 2003, Zainuddin 2004). From the field observation conducted, it is found that the buildings in zone A and Z do not apply the standard for coastal building, therefore many buildings are in bad conditions, which are: wall corrosion caused by salt water intrusion, cracks, floor surface decline.
- Impact to the environment : Many development of settlements does not comply environmental sustainability. Site opening by doing reclamation, utilization of unsustainable building materials, building process that does not pay attention to the environment, etc.
- Provided houses do not meet user needs and demands (Tipple 2002, UNHABITAT 2003, Silas 2003, Septanti 2004); field observation result shows that low income housing are changed or renovated by the occupants when their economical situation improves and when there are additional needs of the family. This implies that the house should be *adaptable and flexible* to respond to the present and future social needs and demands of the households.
- Un-safe living environment in coastal areas Kobayashi (2003) Marwasta, D et.al (2005) , FEMA 2005; Marfa'i et. al (2007) : un standard building systems that used by people due community live in unsafe situation. Houses built too closed with sea with unsafe building structure, lack sanitation and water.
- In-sufficient services: water , sanitation (UNHABITAT 2003, ADB 2003).
- Variable service life of materials and components of the building systems and resulting deterioration and waste generation (Crowther 2001, Post 2002, Duffy 2003). Following by data from Septanti (2007) shows that community inclined (user satisfaction) is more convenient with permanent building material without consideration with geographical situation.

- In-flexibility/ in-adaptability of building systems and floor plans not responding to user requirement changes in the course of time : many settlements have been changed / renovated by the users according to their needs.

Building systems used in this area of study does not pay attention to the standard that has been applied internationally for the coastal settlements. This is caused by the limited building codes that regulate settlement buildings in the Indonesian coastal area. This is related to the application of building systems that does not complying the standard on the coastal settlements.

Several pictures below shows the condition of housing in coastal settlements :







Cracks on the wall influenced by the unstable land condition that caused foundation movement.



Door and window frame changes caused by the movements of land and building foundation.



Cracked floor caused by unstable building structure.

	
<p>Building that is located in the edge of the beach, but does not pay attention to the sea water tides (photo source : Khadiyanto, P, 2009).</p>	<p>Beach reclamation that is conducted by the people, this activity will disturb beach ecosystem and environmental sustainability.</p>

4.3. Geographical Responsive for Design and Architecture in Worldwide

The Building Systems Requirement for UCS in worldwide has been used in developed country since several decades. It even has been established as a standard that must be applied to the buildings in the coastal area. However, the standard cannot be applied completely in the developing countries. Therefore, many building was built without fulfilling the requirements.

Many building systems requirements that is internationally used can be followed on the table below:

Table 1. Summary of Building system's requirements approaches for UCTS geographical condition

General Requirements	V ZONE	COASTAL A ZONE	A ZONE
Design	Requirement: Building and its foundation must	Requirement: Building must be designed,	Requirement: Building must be designed,

General Requirements	V ZONE	COASTAL A ZONE	A ZONE
	<p>be designed, constructed, and anchored to prevent flotation, collapse, and lateral movement from simultaneous wind and water loads.</p>	<p>constructed, and anchored to prevent flotation, collapse, and lateral movement resulting from hydrodynamic and hydrostatic loads, including the effects of buoyancy. Recommendation: Same as a V zone.</p>	<p>constructed, and anchored to prevent flotation, collapse, and lateral movement resulting from hydrodynamic and hydrostatic loads, including the effects of buoyancy.</p>
	<p>Requirement: Building and its foundation must be designed, constructed, and anchored to prevent flotation, collapse, and lateral movement from simultaneous wind and water loads.</p>	<p>Requirement: Building must be designed, constructed, and anchored to prevent flotation, collapse, and lateral movement resulting from hydrodynamic and hydrostatic loads, including the effects of buoyancy. Recommendation: Same as a V zone.</p>	<p>Requirement: Building must be designed, constructed, and anchored to prevent flotation, collapse, and lateral movement resulting from hydrodynamic and hydrostatic loads, including the effects of buoyancy.</p>
Materials	<p>Requirement: Structural and nonstructural building materials at or below the BFE must be flood-resistant.</p>	<p>Requirement: Structural and nonstructural building materials at or below the BFE must be flood-resistant.</p>	<p>Requirement: Structural and nonstructural building materials at or below the BFE must be flood-resistant.</p>
Construction	<p>Requirement: Building must be constructed with methods and practices that</p>	<p>Requirement: Building must be constructed with methods and practices that</p>	<p>Requirement: Building must be constructed with methods and practices</p>

General Requirements	V ZONE	COASTAL A ZONE	A ZONE
	minimize flood damage.	minimize flood damage.	that minimize flood damage.
Siting	<p>Requirement: All new construction shall be landward of mean high tide; alteration of sand dunes and mangrove stands that increases potential flood damage is prohibited.</p> <p>Recommendation: Site new construction landward of the long-term erosion setback and landward of the area subject to erosion during the 100-year coastal flood event.</p>	<p>Requirement: Encroachments into the SFHA are permitted as long as they do not increase the BFE by more than 1^b foot. Encroachments into the floodway are prohibited.</p> <p>Recommendation: Same as V zone.</p>	<p>Requirement: Encroachments into the SFHA are permitted as long as they do not increase the BFE by more than 1^b foot. Encroachments into the floodway are prohibited.</p>
Utilities	<p>Requirement: Must be designed, located, and elevated to prevent flood waters from entering and accumulating in components during flooding.</p>	<p>Requirement: Must be designed, located, and elevated to prevent flood waters from entering and accumulating in components during flooding.</p>	<p>Requirement: Must be designed, located, and elevated to prevent flood waters from entering and accumulating in components during flooding.</p>
Structure	<p>Required: Registered engineer or architect must certify that the design and</p>	<p>Recommendation: Same as V zone.</p>	<p>Recommendation: Same as V zone.</p>

General Requirements	V ZONE	COASTAL A ZONE	A ZONE
	methods of construction are in accordance with accepted standards of practice for meeting the design requirements described under General Requirements.		
Openings in Below-BFE Walls (Also see Enclosures Below the BFE)	Not applicable ^j	Required: Unless number and size of openings meets regulatory requirements, registered engineer or architect must certify that openings are designed to automatically equalize hydrostatic forces on walls by allowing the automatic entry and exit of flood waters.	Required: Unless number and size of openings meets regulatory requirements, registered engineer or architect must certify that openings are designed to automatically equalize hydrostatic forces on walls by allowing the automatic entry and exit of flood waters.

BFE : 100- year wave crest elevation

Source : American Planner Association (APA), 2003

Building Elevation

Zones AE and A1–A30

All newly constructed, substantially damaged, and substantially improved buildings must be elevated on pilings, posts, piers, or columns so that the

bottom of the lowest horizontal structural member of the lowest floor (excluding the vertical foundation members) is **at or above the BFE** (100-year wave crest elevation) see Fig. 1.

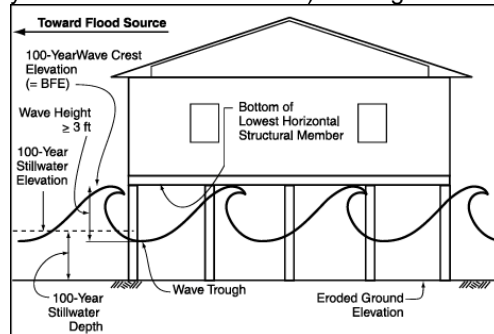


Figure 1.

Minimum V zone requirements.

Buildings must be elevated on an open foundation so that the bottom of the lowest horizontal structural member is at or above the BFE.

Building Elevation in Zones AE and A1–A30

The top of the lowest floor, including the basement floor, of all newly constructed, substantially damaged, and substantially improved buildings must be **at or above the BFE** (see Fig. 2).

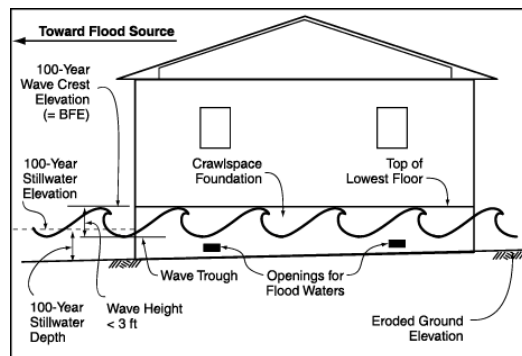


Figure 2.

Minimum A zone requirements.

The lowest floors of buildings in Zones AE, A1–A10, and A must be at or above the BFE. Foundation walls below the BFE must be equipped with openings that allow the entry of flood waters so that interior and exterior hydrostatic pressures can equalize.

Building Elevation in Zone A

The lowest floors of buildings in Zone A must be elevated to or above the BFE whenever BFE data are available from other sources. If no BFE data are available, communities must ensure that the building is constructed with methods and practices that minimize flood damage.

Building Elevation in Zone AO

Zone AO designates areas where flooding is characterized by shallow depths (averaging 1–3 feet) and/or unpredictable flow paths.

In Zone AO, the top of the lowest floor, including the basement floor, of all newly constructed, substantially damaged, and substantially improved buildings must be above the highest grade adjacent to the building by at least the depth of flooding in feet shown on the FIRM.

For example, if the flood depth is 3 feet, the top of the lowest floor must be at least 3 feet above the highest grade adjacent to the building.

If no depth is shown, the minimum required height above the highest adjacent grade is 2 feet.

Based on the preliminary observation, it is found that the foundation used for coastal buildings is still far from the standard. The foundation used does not even appropriate with zone A, coastal zone or zone V conditions. In several locations, beach reclamation, occlusion and using land type foundation, can trigger environmental instability.

Foundation Design

APA (2003), explain that the piling or column foundations for all newly constructed, substantially damaged, and substantially improved buildings, as well as the buildings attached to the foundations, must be anchored to resist flotation, collapse, and lateral movement from the effects of wind and water loads acting simultaneously on all components of the building.

A registered engineer or architect must develop or review the structural design, construction specifications, and plans for construction and must certify that the design and methods of construction to be used are in accordance with accepted standards of practice for meeting the building elevation and foundation design standards described above. Erosion control structures and other structures such as bulkheads, seawalls, and retaining walls may not be attached to the building or its foundation.

Based on the preliminary observation, it is found that the foundation used on coastal buildings is far from the standard. Material, foundation perpendicular direction to the beach and the foundation dimension and distance does not appropriate with zone A, coastal zone or zone V condition. In several area, we encounter foundations that is used for land type building is used in the coastal buildings. Therefore, unstable land

condition, high water level, sea water tides caused the foundation unable to hold the building structure. Foundation brittleness property and its quicker movement can be the main cause for the damaged building construction.

DISCUSSION

1. Building design and system should follow the standard established. From the temporary investigation, many design encountered does not appropriate with the requirements of coastal buildings. Most of the designs follow the common pattern of the public house, thus causing an inappropriate condition with the coastal people needs and also the building itself.
2. There are discrepancies between the building code used and its application on developing country. That is caused by:
 - The existing building code does not appropriate for Indonesian tropical climate. Therefore, adjusting is needed.
 - Community affordability on supplying / applying standardized building system used in the developed countries.
 - Inappropriate building technology that is applied in the coastal area is caused by the lack of human knowledge.
3. Utilization of inappropriate materials for coastal area.
4. Planning that does not consider the sea water tides caused by intrusion and main sea level rising.

IV. CONCLUSION

Inexistence of the standard (building code) that organize settlements development in coastal area could be the main reason why there are many buildings that does not meet the requirements or does not appropriate with the condition of coastal area itself.

Climate inappropriate is one of the reasons as to why the existing building code from developed country cannot be used, therefore an adjusting is needed.

Each area has its own characteristic; therefore the existing building code cannot be applied directly in several area or country. Further study is needed to determine the appropriate building code in a planning area.

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