Dandun Sutaryo

Potential Application of Permeable Structure

for Integrated Disaster Risk Management in Coastal Areas

Wetlands INTERNATIONAL

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By:

Dandun Sutaryo

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Coastal areas in Demak, Central Java
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Potential Application of Permeable Structure

for Integrated Disaster Risk Management in Coastal Ecosystem

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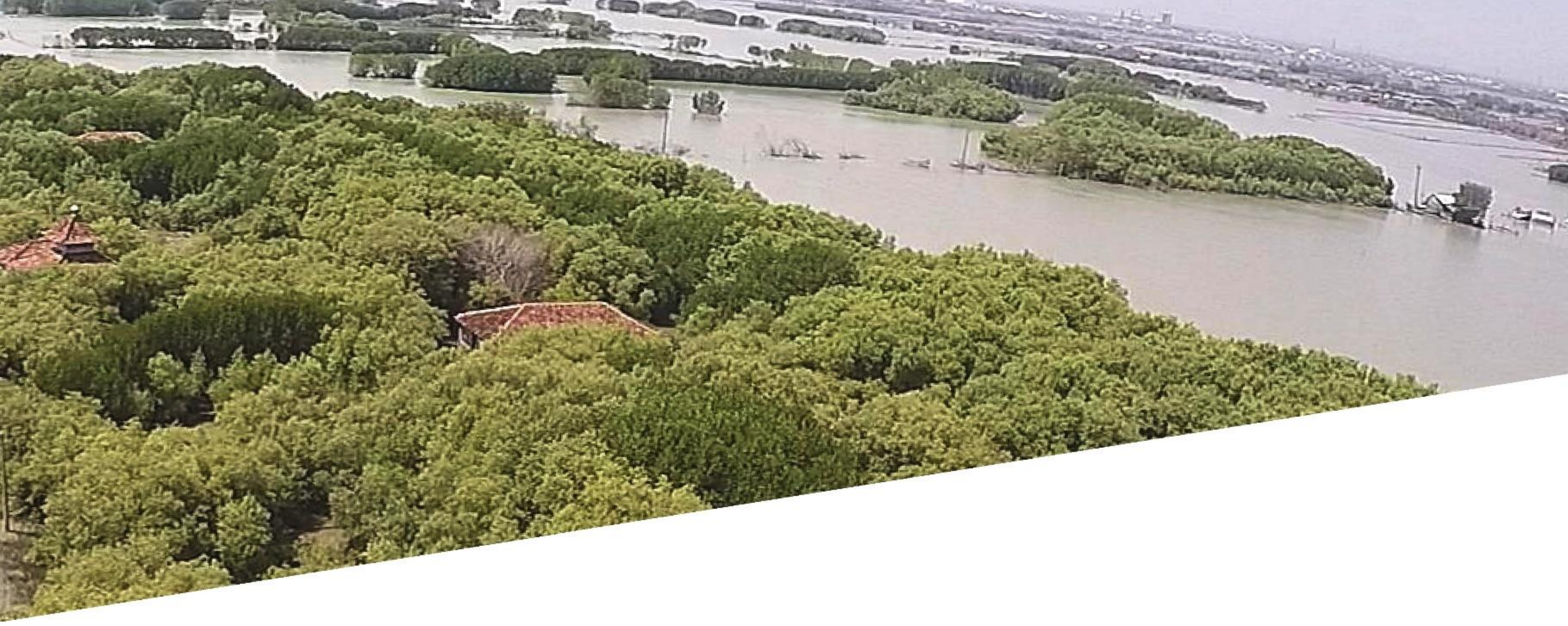

Foreword

Coastal erosion is one of the most critical problem of Indonesia . It is stated that the rate of coastal erosion is about 1.950 hectares per year,with average eroded coastline about 420 km per year (Dirjen PRL, 2017). In a few last years, the size of eroded coastal areas have been significantly increasing. In the north coast of Java for examples, the total eroded coastal areas in 10 districts/cities has reached 5.500 hectares (Damaywanti, 2013). At least 30 millions of people from 3 thousands of villages in northern part of Java have been impacted by coastal erosion and exposed to higher disasters risk.

One of the most prone areas to coastal erosion is Demak District, Central Java. In Sayung sub district, 528, 8 ha of coastal land have been inundated. In several locations, sea water have swallowed more than 3 km of land. Thousand of villagers have lost their ponds, houses and their living resources. The existing infrastructures are potentially to be sunk, and even worse, the effort of coastal ecosystem rehabilitation and restoration are impossible to be conducted since the sea water flooded the restoration areas.

Coastal erosion caused by many factors. Beside a massive mangrove ecosystem conversion, sea water level rises, development of inappropriate coastal infrastructure , and uncontrolled ground water extraction have been contributing to the increases of coastal erosion rate. Permeable structure become an alternative solution that now is being developed to answer above mentioned problems. This structure combines soft and hard structure approach , and integrates local wisdom in to the process. Aside of Wetlands International (WI), in Indonesia, this structure has been applied by several actors such as Ministry of Marine and Fisheries Affaris (MMAF) and Ecoshape consortiuom through Building with Nature (BwN) program, which WI also involved.

This book has been made through field observation in several locations of permeable structure. However, most of the case took example of permeable structure developed by Building with Nature in Demak District. The aim of this book is to give a clear ilustration for public in common on potential application of permeable structure for integrated disaster risk management practice in coastal areas, including the steps in general. Although the permeable structure still in evaluation phase, however, at least, this book may provide description of pattern and principles of permeable structure as one of alternative solution for disaster management in coastal areas. Through the permeable structure, it is expected that the disasters risk in coastal areas can be reduced and at the same time the communities resiliencies towards disasters can be increased.

"Building with Nature Indonesia" is made possible by :

Permeable structure
(Photo: Yus Rusila Noor)

Glossary

(Source : Sulaiman, Dede M., 2017. Penanggulangan Coastal erosion. Ed. 1 Cet. 1., Deepublish. Yogyakarta, xxvi + 160 hlm, ISBN 978-602-453-091-04.)

Abrasion is erosion of rock or hard materials such as wall or rock cliff, followed by the collapse of the materials .

Longshore sand drift is sediment movement along/parallel with the coastlines.

Offshore-Onshore sand drift is sediment movement towards/away perpendicular direction towards the coastlines.

Longshore current is an ocean current that moves parallel to shore.

Downdrift is a downstream areas of sediment stream path

Coastal erosion is the process of coastal lines back off from the initial state due to imbalances of sediment supply and its capacity to transport

Shore line is the line when sea water meets the land

Wave is sinusoidal water surface movement that happens periodically that generate crest and trough.

Breaking Wave is a condition when the wave is breaking which formulated by H=0,7d.

Jetty is a jut out construction towards the sea, that functioned as sediment controller on estuary / river channel

Groin is an up right construction towards the sea, functioned as erosion controller due to imbalances of longshore sand drift.

Offshore is part of the beach towards the sea that relatively has low slope, outside the breaking waves location till the edge of continental shelf.

Overtopping is process of the rise of water in the structure's surface until passed the top of the structure.

Coast is the track which becomes boundary of sea and land, toward the sea is influenced by sea physical and socioeconomic characteristics, while towards the land influenced by natural changes as well as human activities in the land.

Shore is the track when sea water and land meet. For *unconsolidated shore, in technical terms called beach*.

Back shore is part of the shore towards the land located between the edge of the shore line up to a line that already grown by shore plants or up to *cliff* or *dune*

Near shore is part of the shore between location of breaking waves and the shore berm.

Beach face is a sloppy shore under the shore berm that generally affected by the waves .

Artificial sand beach is a sand beach that developed by piling up the beach by sand materials and protect it by sea beach safety construction.

Sand nourishment is an activity to form a stable beach by adding sand in to the sea.

Tidal is the sea water surface fluctuation due to periodic pulling forces of moon and sun.

Sand by passing is a process of sand transportation from *updrift to downdrift*.

Wave period (T) is the total time to form 1 of wave length.

Breakwater is a coastal safety construction positioned in certain distance and parallel with coastal lines;functioned to reduce the waves power, blocking or reducing the sand materials transported from up right and parallel to the shore and forming a waters behind the structures.

Maintenance is a regular activities needed to maintain constructions and equipments (mechanic, electric, and civil construction) in order to be in a good condition, well functioned and safe to be operated**.**

Periodic maintenance is maintenance activities that required longer time and the impact will be bigger that regular maintenance.

Regular maintenance is a more often maintenance with smaller scale, short term and should be conducted continously

Checking is inspection conducted by operational officer and maintenance, owner and manager of sea safety construction upon sea safety construction, complementary construction and equipment for checking the construction.

Handling is the effort to preserve the condition and function of the construction without any part replacement.

Periodic handling is the effort to preserve condition and function of the construction without any part replacement, this is conducted periodicaly.

Regular handling is the effort to preserve condition and function of the construction without any part replacement, this is conducted on regular basis.

Run-up is process of the rise if water on the surface of the structure / shore when the waves hit the structure/shore.

Revetmet is un massive beach construction , parallel to coastlines, protecting the beach directly behind the construction from the waves and current.

Salien is the formation behind the krib sedimentation, which not unified with parallel to coast krib

Sedimentation is the process of sediment settling.

Incoming wave angle (α) is an angle shaped by up right shore line with the incoming direction of the waves.

Waves height (H) is the vertical distance between crest and trough

Tombolo is sediment formation behind the structure parallel to coastline (natural and artificial) that unify with respective structure

Sea dike is a coastal safety structure which developed parallel with the shore line aimed to protect lowland coastal from flooded caused by tidal, waves and storm surges.

Sea wall is a coastal safety structure which developed parallel with the shore line aimed to prevent or reduce flood from behind the wall.

Updrift is the up stream part of sediment flow channels.

Coastal area is : 1) An interacted ares between sea and land, towards the sea affectted by physical, socio economic characteristic of the sea, while towards the land are affected by natural process and human activities in land ecosystem; 2) The area when land and ocean meets, towards the land including dry and flooded land that still affected by ocean characteristics such as tidal and sea water intrusion, while towards the sea still influenced by both natural process such as sedimentation and fresh water channelling OR human driven process such as deforestation and pollution .

A woman is making fish gear
(Photo: Yus Rusila Noor)

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Coastal biodiversity
(Photo: Apri Susanto Astra)

1. Coastal Ecosystem and Disaster Risk

1.1. Definition and Type of Beach

According to law No. 27/2007, coastal areas is a transition zones between land and sea which influenced by the changes of both ecosystems. In Indonesia, the term of coastal and beach sometime interchangeably, however, there is difference between them. In Indonesian term, beach is defined as part of land that has the closest boundary of the ocean, it is formed a lines called coastline. A beach which has different type of tophography can have the same length of coastline but will have different size of coastal areas. A slopping beach may have larger coastal areas compared to steeper ones.

Based on its composing substrate, beach can be categorised as rocky, sandy and muddy beach. From those characteristic, only the muddy beach appropriates for permeable structure application. The muddy beach composed by microscopic particles come from silt which transported by river. Another caharacteristic is a very low slope with height difference about 1 meter for horizontal distance between 500 - 2.000 meters. The muddy beach has brown and muddy colors, with no big wave since the wave already absorbed by the mud. The mud it self also functioned as wave energy reducer.

1.2. Disaster Risk in Coastal Ecosystem

A. Hazard in Coastal Ecosystem

Coastal areas is a dynamic ecosystem which has rich and interrelate biodiversity. As the transition area, coastal become disaster prone areas and vulnerable to any human activities impact.

According to law No. 27/2007 , coastal disaster is a phenomenon that happens due to natural and human activities factors that creates physical and/or biological changes of coastal areas and generate loss of lifes and/or properties and create damages in coastal areas and small islands.

Setyawan (2007) explained that at least 7 hazards coastal areas in Indonesia have been identified including Tsunami, storm surges, flood, intertidal flood, coastal erosion, sedimentation and land subsidence. All of the hazard may caused by geological or/and climate and hidrometeorlogical process. Except for tsunami, other hazards can be predicted.

Coastal erosion

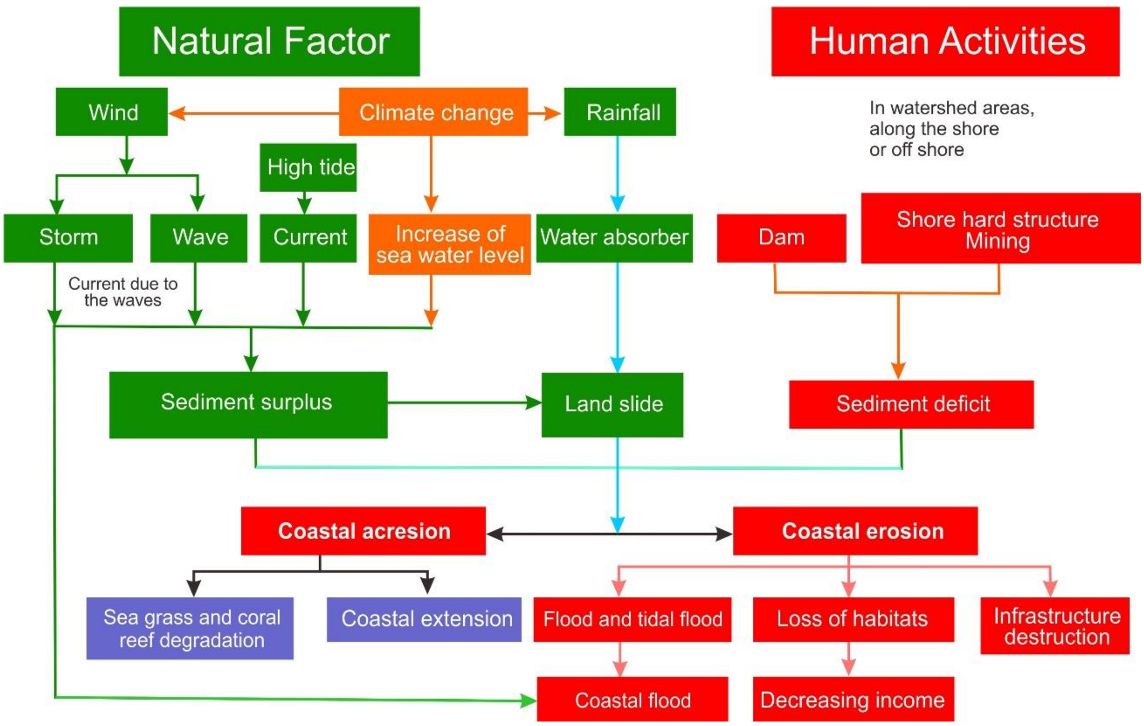
Coastal erosion is the hazard that can be overcome by permeable structure. In Indonesia, coastal erosion is a prolonged problem, in the nort coast of Java, the problem has been started since 1970 when mangrove ecosystem converted in to shripm/fish pond and other aquaculture activities. The eroded coastal also being impacted by unsustainable coastal development, and changes in fresh water supply due to changes in river path or blocking (Prasetya, 2007).

According to Ministry of Marine and Fisheries Affair, coastal erosion has been occurred in almost all of coastal areas in northern coast of Java, start from Banten, DKI Jakarta, West –Central and East Java, which most of the erosion has severely happened in northern part of Central Java and some part in northern coast of East Java province (**Picture 1**).

Generally,there are two factors caused the changes in coastline : natural and human driven factors. The natural process is due to the waves, tidal and current (long shore and off shore current), meanwhile for human driven, there are all human activities along the river channels and shorelines. The interaction of coastal lines influencing process, can be seen in **Picture 2**.

Naturally, the shore has its own natural coastal defence upon the waves. Sediment accumulation in the shore can absorb and divert energy come from the waves . If all the waves energy being absorbed, then the shore is in a balance state. In opposite way, the shore is imbalances state if erosion and accretion process occurred. This will lead to the coastal line degradation (Hidayat, 2006).

Picture 1. Map of Erosion/Acrretion of Coastline in Java Island



***Picture 2. Interaction of Natural and HumanDriven Factors that Influenced the Coastal Areas** (Goncalves and Mohan, 2011)*

B. Disaster Risk Reduction

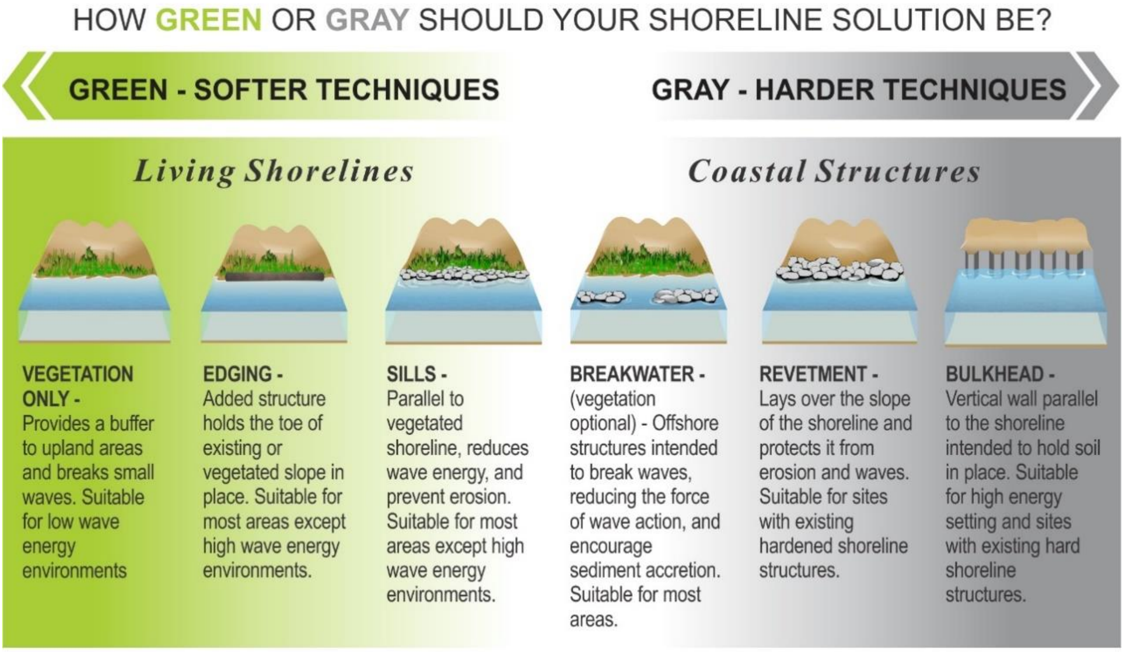
In General, the nature has provided an effective coastal protection mechanism. In a muddy beach, the mud has ability to reduce the wave. The mangrove vegetations will also break the waves energy and its root will also reduce the speed of water, so that generates the process of sedimentation in the shore base.

However, it the natural protection does not exist, then the shore protection can be implemented artificially, both by developing hard and soft coastal safety structure.

According to Faza and Kurniadi (2016), based on its function, the coastal safety construction can be categorised as follow:

- Construction that developed attached to the beach and parallel with coast line. Example: revetment and *sea wall*. Both examples are functioned to directly protect the beach behind the structures from the waves.
- Construction that developed up right and connected to the sea. Example: Groin dan jetty. Groin functioned as construction to trap the *longshore drift and changes the currents pattern*. Jetty as construction in estuary up towards the beach, functioned as current directors to normalize the estuary.
- Construction that developed not attached to the beach, but parallel with coastlines. Example: O*ffshore breakwaters*, functioned as waves energy reducer.

Hard structure application is a rapid effort for mitigating coastal erosion. From time matters, this is the most effective solution, however, it is costly and to some extent, option like sea wall is not an effective solution for rural areas. Even for the long term effect, if it is not appropriately designed, the hard structure might worsen the coastal erosion (coastalcare.org). The process of coastal erosion deterioration can be seen in below illustration. For communities, this artificial structures do not provide any vital economic, social and environmental services.



Picture 3. ***Scematic** Pictureof coastlines stabilisation techniques (https://coast.noaa.gov/data/digitalcoast/pdf/living-shoreline.pdf)*

Aside from hard structure development, another option for coastal protection can be implemented through development of soft structure. One of the example is to do mangrove ecosystem restoration or rehabilitation. Compared to hard structure, this approach has a long term benefit by providing economic, social and environmental service to the communities . However, soft structures requires a longer time to achieve the goals. The short term failures often happens due to lacking knowledge on mangrove rehabilitation process. For example, in Aceh coastal rehabilitation programme, the survival rate of planted mangrove was only 40% - 60% (Wibisono and Suryadiputra, 2006).

Setyawan (2010) found that in the north coast of Java, mangrove rehabilitation process took place in eroded coastal areas. This shows that the mangrove rehabilitation process were conducted to address coastal erosion and to restore the shore ecosystem degradation caused by erosion. However, the fact shows after the planting process, mangrove could not be able to grow. This situation occurred in almost all locations of rehabilitation , and indicate that all the rehabilitation process need to consider to increase the survival rate of mangrove by providing favourable habitats for mangrove to grow.

Table 1. Condition of Mangrove Rehabilitation in Northern Coast of West Java (Setyawan, 2010).

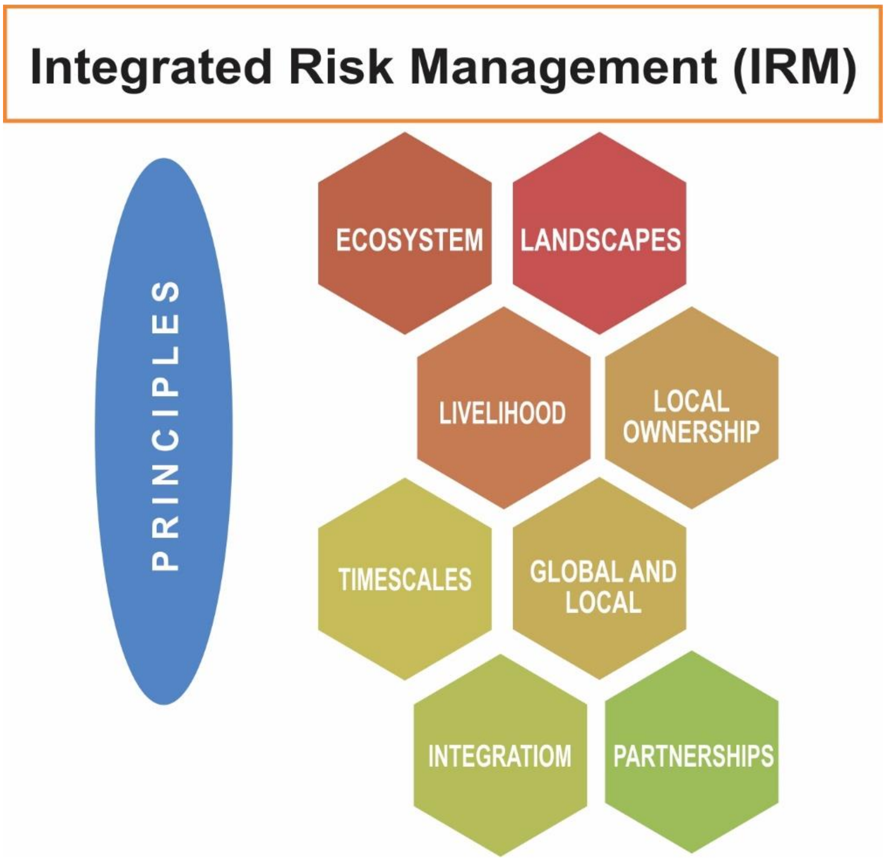
Location	Characteristic of the shore	Location	Mangrove Condition
Lontar, Serang	Low slope shore, erosion in the front area ,dominated by compacted silt	On the silt plate	Failed (dead)
Krangkeng , Indramayu	Low slop shore, dominated by temporary mud sedimentation	On the temporary mud sedimentation	Degraded
Tanjung puran , Indramayu	Low slope shore, erosion in the front area ,dominated by rock and sand	On the sandy pile behind the beach wall	Failed
Pegagan, Indramayu	Low slope shore, erosion in the front area ,dominated by compacted silt, temporary sand sedimentation	On sand sedimentation / berm	failed
Muara, Indramayu	High slope and hilly shore, erosion in the front area ,dominated by compacted silt, rice field on the back	On rice field area	Degraded
Mundu, Cirebon	Sandi and low slope shore	On sand sedimentation / berm	Failed
Kramat, Tegal	Low sandy slope, erosion in the front area ,dominated by compacted silt, Aquaculture ponds on the back	On sand sedimentation / berm	degraded
Maribaya, Tegal	Low sandy slope, erosion in the front area ,dominated by compacted silt , stable	In the excavation pond behind the shore	degraded

C. *Integrated Risk Management*

Integrated Risk Management (IRM) is a systematic approach to mitigate disaster by utilizing all the opportunities that potentially reducing the risk of disaster. The opportunity can be the ability to adapt, anticipate and reduce disaster risk and increasing the capacity to recover. The integrated risk management incorporate disaster risk reduction, climate change adaptation, ecosystem restoration and sustainable management as one approach. It works in geophysical, hydrological, meteorological and climatological disasters through the application of landscape approach.

IRM is promoting the *nature base solution* and consider the local community livelihood within the ecosystem. In general, the IRM has the following criteria:

- Focus on pre disaster assessment by analysing risk based on climate prediction and considering all type of hazard, estimating the risk in short, medium and long term
- Highlighting and considering the role of ecosystem as natural buffers in mitigating disaster
- Bridging the global solution and the local experience
- Applicating the landscape approach, highlighting the transboundary functions of ecosystem
- Addressing the cause of problem, increasing capacity and resource and improving local livelihood
- Applicating the multidisciplinary approach, participatory process and supporting for multistakeholder partnership.



Picture 4. *The principles of Integrated Risk Management (IRM)*

Sediment formed by permeable strutcre
(Photo: Apri Susanto Astra)

2. Basic Concept and Application of Permeable structure

2.1 Basic Concept

In a balance state, the land in a muddy beach generally has a convex shape. However, the changes in sediment transporting pattern and waves intensity due to land conversion or infrastructure development, may influence the balance state. In a most cases, those two human activities may create imbalances between sediment supply and erosion process, as the result, the coastline will move backward followed by mangrove ecosystem degradation. The degradation and loss of mangrove ecosystem will further reduce sedimentation process, at the end, the muddy beach turns from a convex to concave shape (Winterwerp, 2013).

The changes in muddy beaches profile from convex to concave shape become the factor of the failure on mangrove rehabilitation. The profile changes will alter the depth period of water pool. The natural mangrove regeneration will not happens and the planting effort will be failed as the mangrove crashed by the waves and uprooted. Therefore, the coastlines restoration need to be conducted to enable the natural mangrove regeneration as well as securing mangrove survival rate after planting process (Winterwerp, 2013).

The waves and currents are two components that influence the sediment transport. Both of them can alter the coastlines and its structures through erosion and sedimentation (Arnott, 2010). Erosion occurred when there is sediment transport from the eroded spot to other location. To stop the process, the balances of sediment should be brought back through sedimentation process. This situation might be take place through the application of permeable structure. The structure aim to create a low energy zones that will ensure the sediment trapped in the location.

Permeable structure is a permeable dam. It has certain materials that allows water to pass but trap the transported sediment and/or mud. The permeable materials are piled up and supported by the poles and beam so that form like a dam. The filling materials can be tree branches, grass or other materials that has the ability to catch and trap the sediment. Permeable structure will absorb and will not divert the waves, and enable the sedimentation process.

Picture 5. *Permeable structure in Bedono Village, Sub district of Sayung, ditrict of Demak. In the inner side, it shows the shrinking breakwaters.*

Permeable structure is developed for a temporary period of time. It is act as the mangrove root function in reducing the waves energy and trapping the sediment. Event it is designed for a temporary time, however, it should be able to last for a certain time until the sediment in a stable condition and allow the mangrove to grow naturally.

Permeable structure is not developed for blocking the waves, but to naturally increase the sediment catchment. Therefore, the filling materials acts as permeable layers that allows the tide currents to pass om but trap the sediment.

The aim of permeable construction in a landscape scale is to reduce erosion and bring back the ‘loss’ land by restoring the sediment balances trough sedimentation. This activities will increase the opportunity to increase the survival rate of mangrove life in order to mitigate further erosion and provide more environmental services to the communities.

To support the rehabilitation process , after permeable structure developed and sedimentation took place, the hydrological improvement in coastal area is advised. It can be done through river naturalisation or dams removal to ensure the supply of enough fresh water and providing an appropriate tidal conditions for mangroves (Sensu Lewis, 2005).

For the most cases, the mangrove planting process is not necessary as long the seed sources are exist near to the structures especially for certain species that has a wide spreads propagules like *Sonneratia* and *Avicennia*. Mangrove will grow naturally if they are in a conducive habitat. Mangrove planting might be needed if there is no seed sources surrounding the areas.

2.2. Development of Permeable structure

A. Feasibility Study

This process is one step ahead from the preparation phase of permeable structure development. It is a comprehensive assessment towards feasibility of permeable structure development in certain location. This step become the determining process of development planning.

The scope of assessment might be wider from the designated areas of structures development. In the construction process, the location selection means the spot where the structure will be developed. However, in feasibility assessment process, the location selection can be defined as village or wider administrative areas selection. According to the principles of landscape approach in IRM , the ecological assessment should be conducted in a landscape scale.

The assessment will recommend several locations that need the application of permeable structure. The assessment is not necessary end up with positive conclusion, since there is opportunity that certain place are not appropriate with the application of the structures. As a participatory and collaborative process, feasibility study should also cover certain points as follow:

- Development of program approach.
- Stakeholder identification.
- Networking.
- Local manager and facilitator selection, including the development of the program.

B. Preparation and Construction Planning

<u>Socialisation</u>

Ideally the permeable structure project development should be a multistakeholder process that planned and developed in addressing the common problem. Socialisation should be conducted to all local stakeholders. The understanding of permeable structure concept should be highlighted to be understood and accepted by the stakeholders. The project implementor should also led the participatory process ensuring the local thoughts and idea are compiled and considered.

Tenurial aspect and management planning

In several cases, coastal erosion has reached the community owned land/ asset. In other cases, the ownership of local community have shifted to external parties. If this happens, the agreement between project implementor and the land owner should be made. The agreement can be facilitated by village authority or higher authority level.

The problem of land ownership is not necessarily to be overcome with land clearing. The main agreement should highlights the owner guarantee to support project implementation, including the point for not conducting any activities that may hampers the project achievement.

From the policy perspectives, On May 1996, The ministry of Agraria/ Head of National land agency has released letter No. 410-1293 which explains the problems of channel bar, land obtained through reclamation and the lost land due to disaster. Two important points related to development of permeable structure are:

- The naturally lost land due to coastal erosion, earthquake or *land slide*. This land declared as lost land and the ownership right also automatically abolished. The owner have no rights to ask for compensation to anyone and have no right to sue if there is reclamation or drainage in the future.
- Reclamation land acknowledged as the state owned land which the arrangements managed by Agrarian Minister/head of national land agency. The party that conducted reclamation are given the priority to submit land right application upon the "new" land.

The future management planning of the project should be cleared, both on individual or public owned lands. The main point of management is not repetition of the failure in the past. If the coastal erosion occurred due to mangrove ecosystem conversion for aquaculture for example, then will the future management repeat the same thing?. If it kept as aquaculture land for example, will the aquaculture management use the same patter as the past?. In addition, the decision making will be much easier when the land values is low, but if the project is successfully conducted, coastal erosion can be mitigated and the land are stabilized, will the owner think the same?

Based on those consideration and considering the sustainable issue, the land ownership of the land obtained from permeable structure should be on government /local government's hand and managed as coastal green belt areas.

Support

The permeable structure initiatives can be raised from the community, however, the support from local authority also needed. The support can be in different shape such as technical, administrative and policy support in permeable structure integration in to local development planning.

Does Permeable structure Development Requires Environmental Impact (AMDAL) Assessment/Environmental Monitoring and Management Effort (UKL/UPL)?

Ministry of Public Works Regulation No. 10/PRT/M/2008,stated that for development of coastal safety structure and estuary improvement need **the Environmental Monitoring and Management Effort (UKL/UPL)** , for the construction parallel to the sea (revetment*, seawall, and breakwaters*) more than 1 km or a perpendicular construction i(groin) 10 m - < 500 m.

Timeline

The construction process will be influenced by climate , tide and other environmental factors. Therefore it should be conducted during the low intensity of the wind. The exact time can follow the seasonal calendar being used by local community.

If the date already settled, do the counting down for materials preparation. Even the type of materials are easy to be obtained, the large quantity should be also anticipated. Please provide enough time for materials transportation, if it is supplied from other areas, please provide the drop and collection point.

Location Survey

Survey is conducted to assess the information on tidal patterns, the depth of mud materials, source of sediment, hydrological information, currents and the state of mangrove ecosystem.

The first thing should be checked is the height of tidal pattern in the location. To collect the data, we need a measuring poles and vertical board to show the height of water. The next step is to collect the information of conditions and the depth of muddy substrate. The upper part of the mud is more fluid and have less capacity to hold the load, while in lower part, the mud substrate is quite solid and able to support the construction part of the structures. If the depth of fluid (soft mud) and solid mud (stiff clay) already obtained, the tidal patterns can be easily measured, therefore the minimum height of structure's poles can be determined. Please ensure all the measurement refer to the same measuring pole/board.

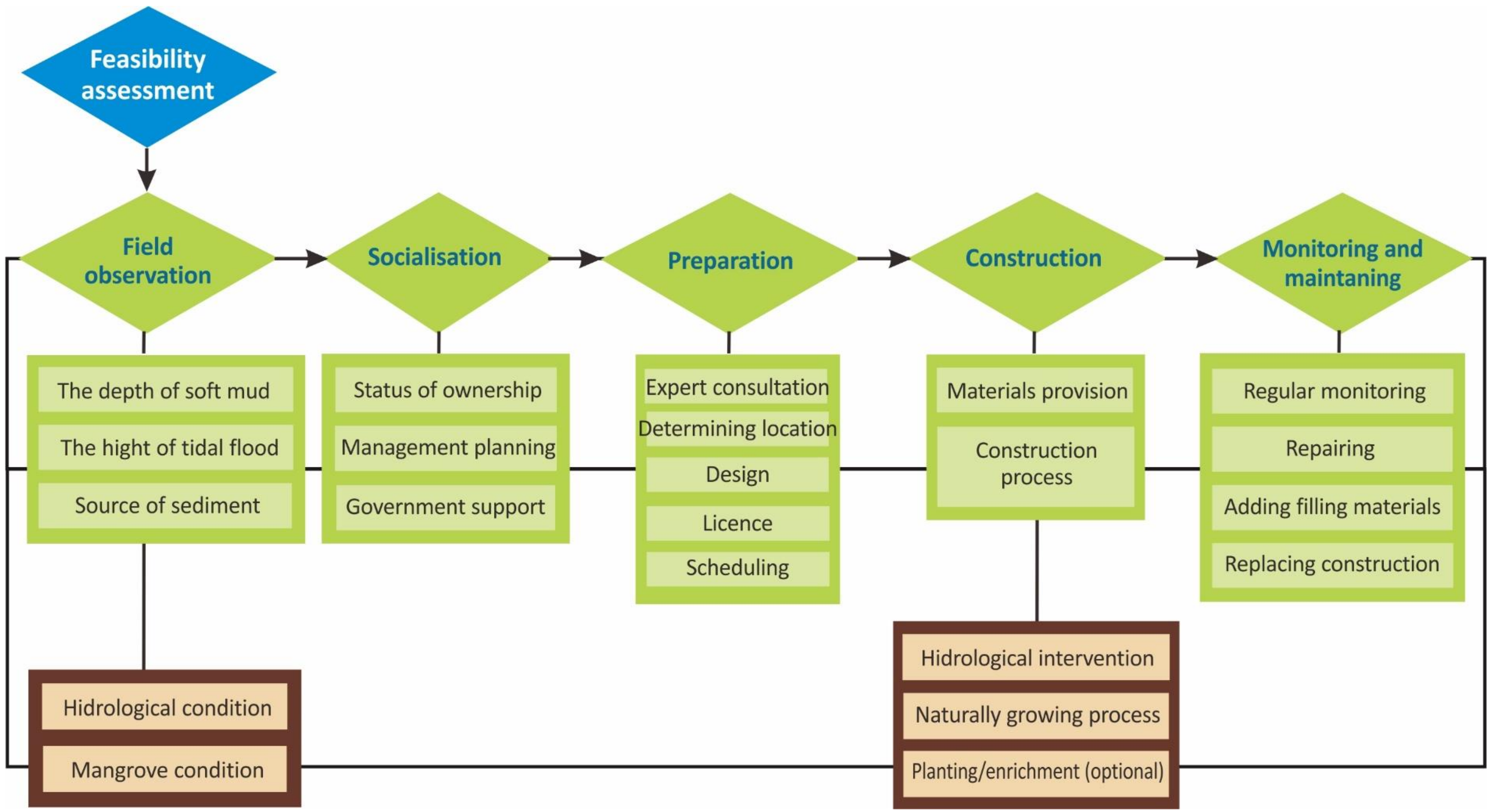
Another information should be compiled during the survey is the history of biophysical information in the location, including hydrological information and the mangrove ecosystem condition. The information can be collected not only from secondary data but also can be obtained from the local communities. The hydrological improvement might be needed to support and naturally mangrove's seed distribution. In addition, mangrove planting might be optional, if the mangrove ecosystem is severely degraded and natural growing of mangrove is challenging to be conducted, then the mangrove planting might be needed.

Avicennia sp

Sonneratia sp

Picture 6. *Mangrove seed examples that can widely distributed through water flow*

Following diagram shows all the step of permeable structure development. The arrow lines show the step of the works, the boxes explained the each activities. The diagram summarised 3 aspects of development : need assessment, permeable structure physical construction/development and mangrove ecology.



Picture 7. Permeable structure development diagaram

C. Permeable structure construction/development

c.1. Component and Materials Selection

The main component of permeable structure are including poles and beams, filling materials and supporting materials.

1. Poles and Beams

Poles is the frame of permeable structure which plugged in to the solid mud layer under the water. Recommended diameter for the poles is 15 cm, or at least 12 cm for both end points. The bigger poles do not necessarily the stronger ones. The bigger poles, will give consequences of more costly and more difficult to be plugged in.

The poles should be tied up to both horizontal and longitudinal beam. Horizontal beam tied up the face to face poles , while the longitudinal beam tied up the side by side poles. If needed, the poles can be strengthened by diagonal support. (see the design pictures).

There are several option for the poles materials with weakness and strong points, the options are as follows:

- Bamboo. The materials is quite firm, solid and costless. The best option is Betung Bamboo *(Dendrocalamus asper*) since it has quite large and thick diameter. Another option is Ori or Duri Bamboo (*Bambusa blumeana).* The size is less than Betung Bamboo, but has medium thickness has short segment that makes it has firm shapes like Betung. Bamboo ater (*Gigantochloa atter*) or bamboo tali *(Gigantochola apus)* are not recommended due to is small diameters.

Picture 8. *Bambos fo permeable structurein Demak (Foto: Eko Budi Priyanto)*

- Wood. The best option is to use kayu gelam *(Melaleuca Leucadendra).* This type of wood has a straight shape that can make the construction process easier. However, to get the large diameter and appropriate length is quite challenging. The wood that being used for Permeable structure should follow the criteria of appropriate diameters. Please keep the tree bark to protect the wood under flooded conditions (same analogy with the use of the wood for the dykes).
- PVC pipe filled by concrete. This option is costly and time consuming but has longest durability compared to bamboo and wood, especially to face the barnacles problem.

2. Filling Materials

Filing materials is the part that has role as sediment trapper. The filling materials should have permeable to water but able to trap the sediment. It is better to have a “not easy to decay” materials. For Demak case, the filling materials used is tree branches. No Specific recommendation for the type of filling materials but it is recommended to use the firm, hard and medium to small tree branches (has 3- 7 cm diameter). The bigger size of tree branches will left so many empty room and make the trapping process less effective.

Picture 9. *Tree branches for permeable structures in Demak (Foto: Eko Budi Priyanto)*

3. Supporting Materials

The supporting materials role is to ensure the filling materials are kept in the place, and revert to be drifted. They are including Nylon web, Nylon wires and sand bag.

Nylon web covers the filling material and prevent them to be drifted especially when the materials start to decay . It wraps the filling materials from front, up and back and lower side.

Nylon wires selected due to is durability. It is being used to tied up the poles to the beams, tied up the net to longitudinal beams and tide up the net in uppers side. It is also being use to tide up the bundles of smalls filling materials.

Nylon web and wires selected since it is costless and easy to use. Nylon net and wire that can be last for 2-3 year is sufficient for permeable structures. The coated steel wire is not recommended due to its costly prices and difficulties to be detached. The net and wire from polyethylene and natural fibre are not recommended due to nondurability issue.

Sand bags roles are to retain the nylon web in the upper side. It is easy to be implemented and the construction is sufficiently stable.

c.2. Location and Macro Design

Each locations has different physical conditions (i.e. climate, geology and hydrology. Therefore the macro design could not a “copy-paste” process. The location should be pre accessed and it is advised for the project implementor to communicate/consult with professional expert/scientist for the planning process.

The permeable structure location should consider river channel that potentially transporting sediment and mangrove seed. Permeable structure could not block the river and should be placed near enough with the current coastlines, therefore:

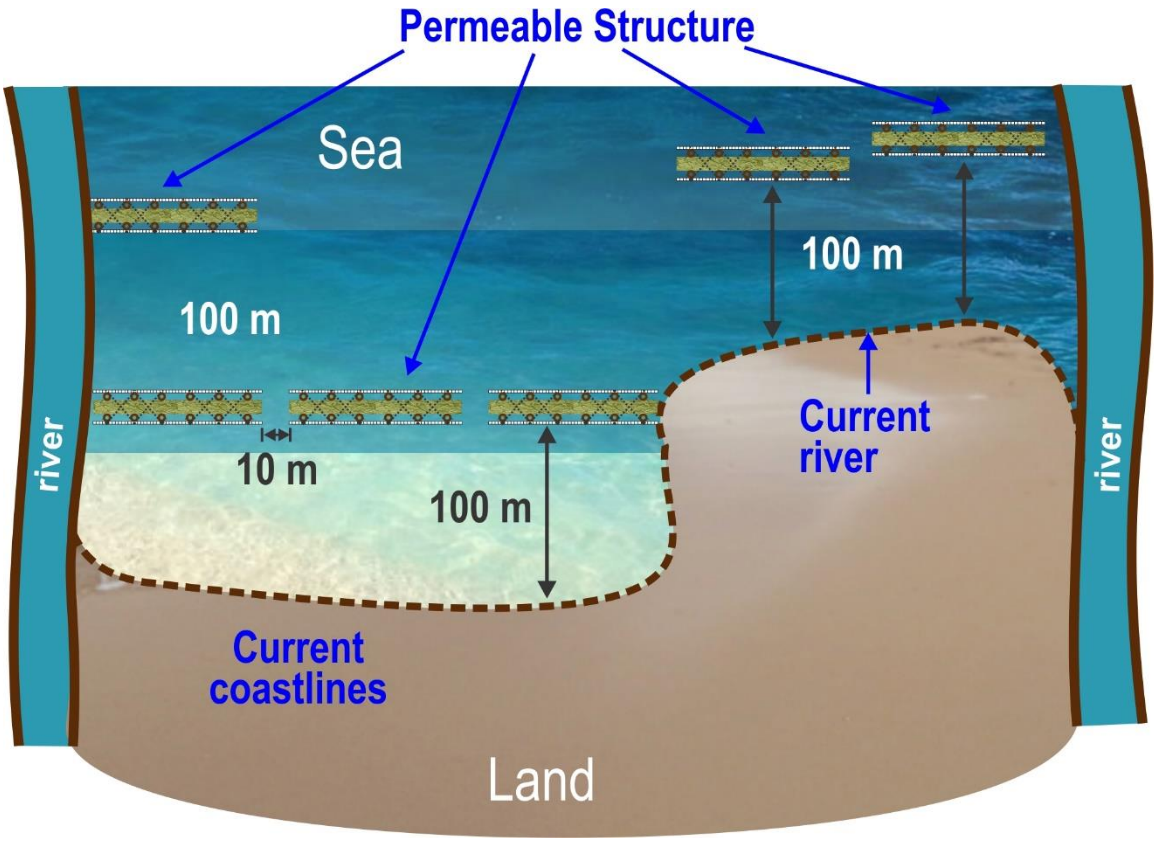
- The areas behind the structures is small enough to prevent the drifting off/erosion of sedimented areas. If the areas behind the structures is too wide, the currents will be stronger and potentially bring back the sediment to the sea.
- The sedimentation process still occurred to fill in the sedimentation areas behind the structures. It is an obligatory process to pre check that at least the sedimentation process still take place in the locations. If there’s no sedimentation process already, the project implementor should calculate the sediment supply in the area.
- Mangrove seed should be able to migrate to the new sedimentation areas formed by permeable structure.
- The current that passed on the structures has to be able to bring sedimentation suspension to the back part of permeable structures.

Regarding the optimal distance of permeable structures with coastlines, there are several factors should be considered, including the volume of sediment materials, the currents power, the direction of the currents, and other oceanography factors. In Demak, the distance of structures and coastline is 100 meters. The distance might vary from one area to others depend on several above mentioned factors. In the application, the structures location can be started from the closest distance first, if it possible, the structures should be linked *revetment or to remained mangrove ecosystem* to ensure the end of the structures are firmly constructed

Permeable structure should perpendicularly direction with the main waves in order to maximize the sediment trapping process. The length of the structures may vary based on local condition and other factor such as suspended size and volume of sedimentation, tidal periods and frequencies, as well as the wave dimension. The distance between side by side structures depend on the tidal prism area, or area where the water volume from the sea enters or out to the river channel through the mouth of the channel. For Demak case, the distance between structures is 10 meters.

The new structure can be developed to the sea direction after the previous structure has been filled with enough sedimentation until the level that enable mangrove to grow. The logic is that the area where structures developed was inundated areas that hampering mangroves to grow, if the sedimentation is successful then the land surface will rise, the flood is reduced and mangrove has the potency to grow. The new structure can be constructed after the height of sedimentation above the highest tide level or when the mangrove has grown naturally. Developing the structures in several layer at the same tie is not recommended because it will block the sedimentation process in the back areas.

In ex pond areas, the structure should be developed in the dykes, since it is the solid soil that can become the strong foundation for structures. Therefore, the spatial planning should consider the previous aquaculture community groups. The exact position of permeable structure should be discussed with local community and based on actual field survey .



Picture 10. Permeable structure positioning

The macro design development needs modelling, however the distance shown in the picture 10 is approaching the real calculation. The simple logic is the more the distance, the longer the sedimentation process , if it too close , the sediment areas will not effectively formed. Regarding tidal prism principle, the higher the prism, the water volume that passed the distance between two structures are also bigger. This situation will influence the transported sediment that will fill the areas behind the structures.

c3. Dimension and Construction Design Unit

1. Poles

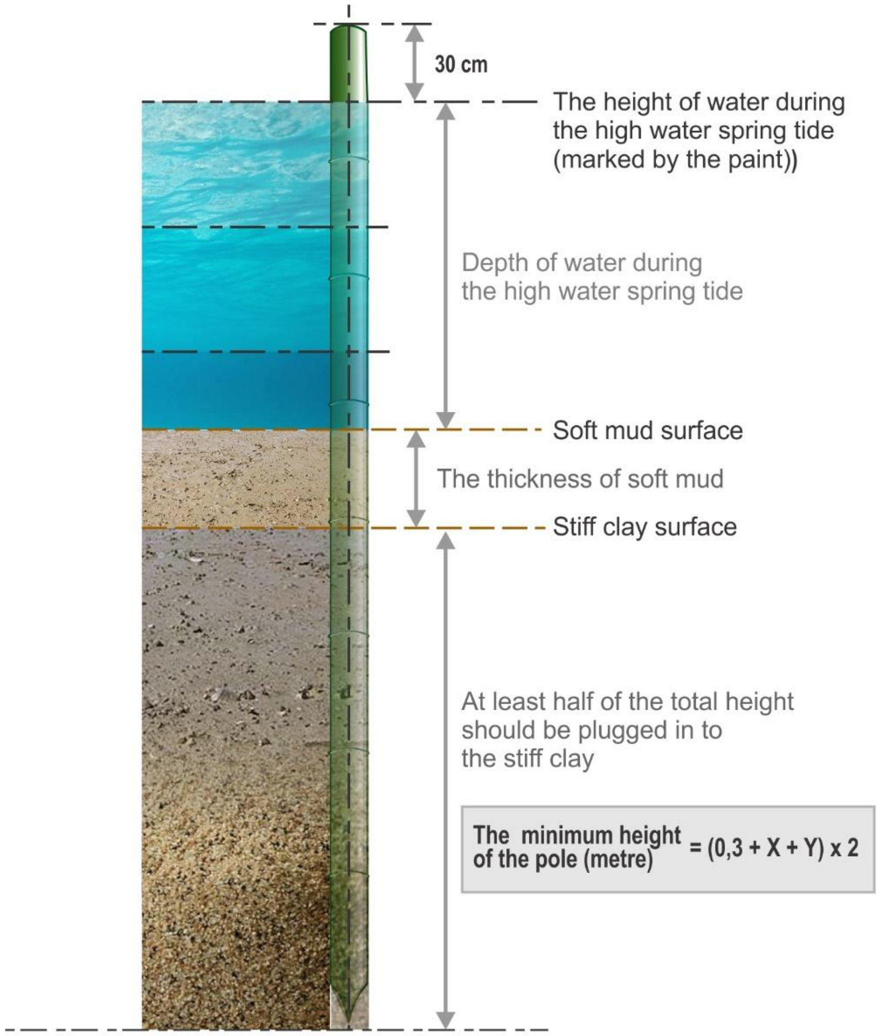
In permeable structure development there are several factors need to considered :

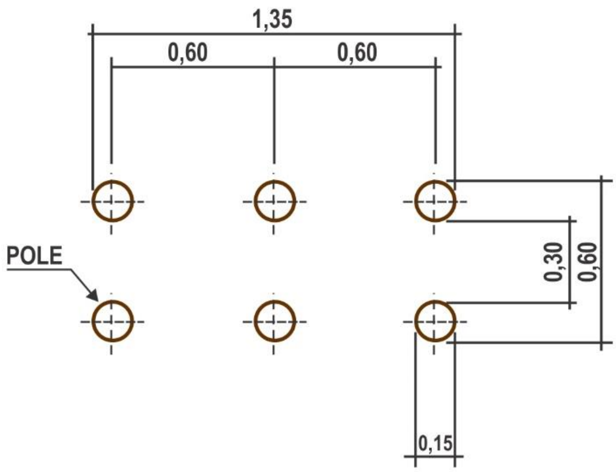
- The broken or failed poles means failed permeable structure. Please ensure the diameter of the poles is approaching 12-15 cm.
- The height of the poles should base on actual mud measurement during survey. Picture 11 shows that the length / height of the poles should at least 0.3 m above the highest tide point. This position enable for more filling materials to be put exceeding the highest tidal point to anticipate the compaction due to decaying process. Please ensure that the height of filling materials exceeding the heights of the average tide points.

  Half (1/2) of the total height should be plugged in to the stiff clay

  For the water depth during the full moon, if the soft mud (0.3+X+Y) exceed 2 meters, the total minimum length to be plugged in2 meters.

- The space between side by side pole measured from the centre of the pole is 0.6 m and distance between head to head pole measured from the inner edge of the pole is 0.3 m (if the diameter is 15 cm, the total space measured from the outer edge of the pole is 60 cm). The space should be maintained even there will be difficulties during assembly. The attachment of the pole will be easier if the space wider, however, it will require more filing and tightens materials. Please consider the condition and all information related to the mud obtained from the survey. To anticipate the current during the storm , please ensure the pole are plugged in deeply.





CONFIGURATION OF THE POLES
SKALA 1: 20

Picture 11. Minimum pole height *(side view) and permeable structure pole's configuration (top view).*

2. **Horizontal and longitudinal beams and supporting structure**

The horizontal and longitudinal beams are used to gather the poles. Bamboo is the best materials because it is cheap and durable . The beams can be repaired twice a year together with the filling materials addition.

The diagonal supporting structure in the back (see picture) can strengthen the whole structures, however it is conditionally and may not necessary to be added.

c.4. Structure installation

The structure installation should refer to the water height during the highest tide/ High Water Spring Tide (see Picture 11). Picture 13 explains how to install the poles and illustration on the poles height measurement. Several information related to the height of the poles are as follow:

- The pole should be plugged in to the stiff clay for (0.3+x+y) meter (see Picture 11) or at least 2 meter from the stiff clay if the height of (0.3+x+y) more than 2 meters.
- The filling materials should be higher than the water surface during the Highest Tide
- The lower part of filling materials are partly buried bellow the soft mud.
- The ballast materials (sand bags) that functioned to hold the net, are located above the stiff clay and buried by the soft mud.

The step are elaborated in the following diagram.

Poles Instalation

- Sharpens the lower parts;
- Mark the highest tide point as the position to tie up the longitudinal beam, put mark as well to the point indicated the depth of the poles parts that should be buried under the soft mud zero point
- Tie up the nylon wires in the marking points, and attach the lever in to the poles (see pic 16)
- Plug the poles by pressing /stepping down the upper part of the lever ;
- Wait 1-2 days to ensure the stability of the problems, the installation process can be deepened if needed

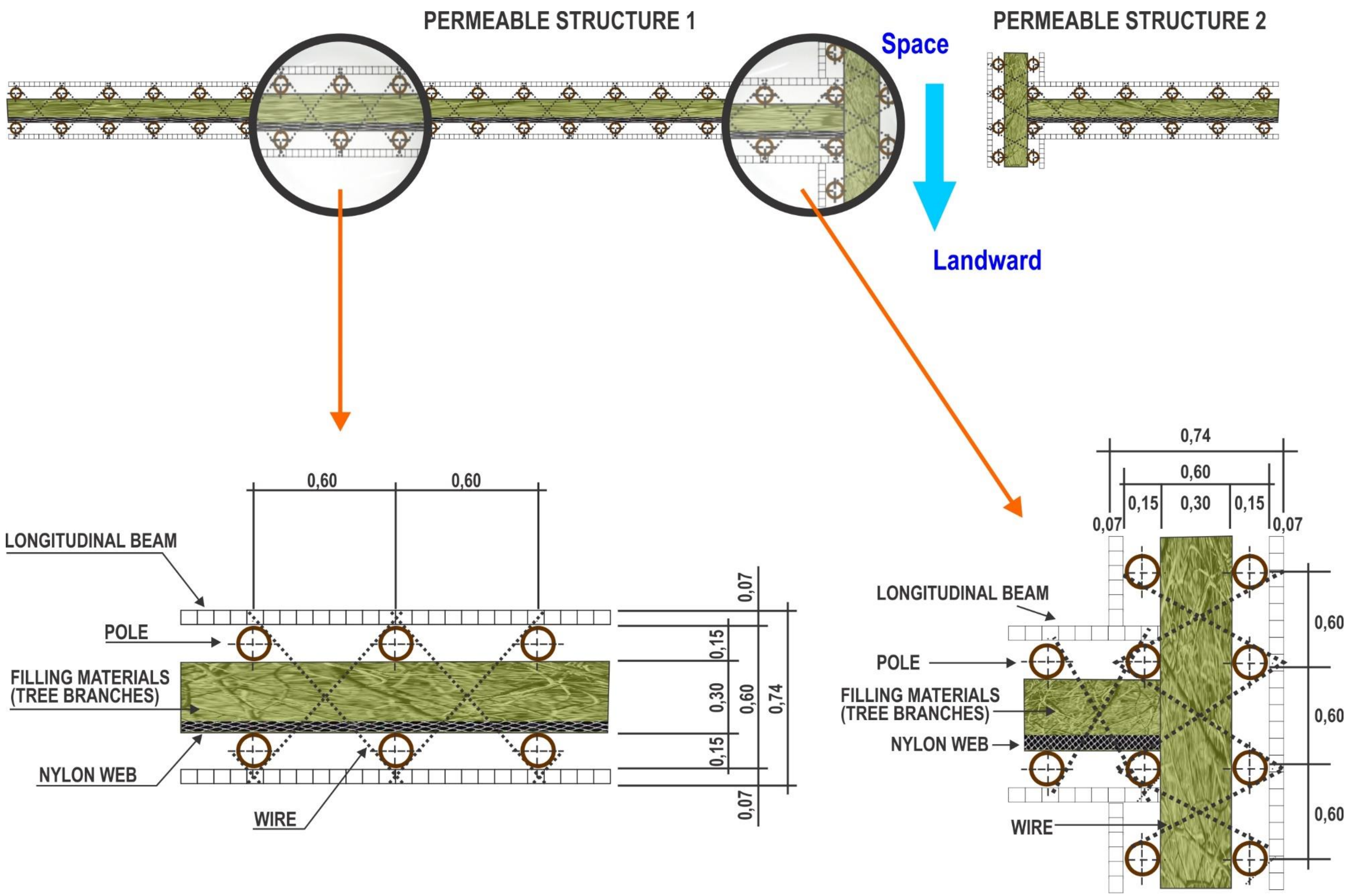
Logitudinal Beam instalation and Web

- Attach the longitudinal beam in to the marked points
- Tie up with the nylon wires
- Tie up the net in to longitudinal beam , please spare the upper part of the web to cover the filling materials
- Tie up the web in both side, inside the poles;
- Pull down the web and put the sand bag accordingly .

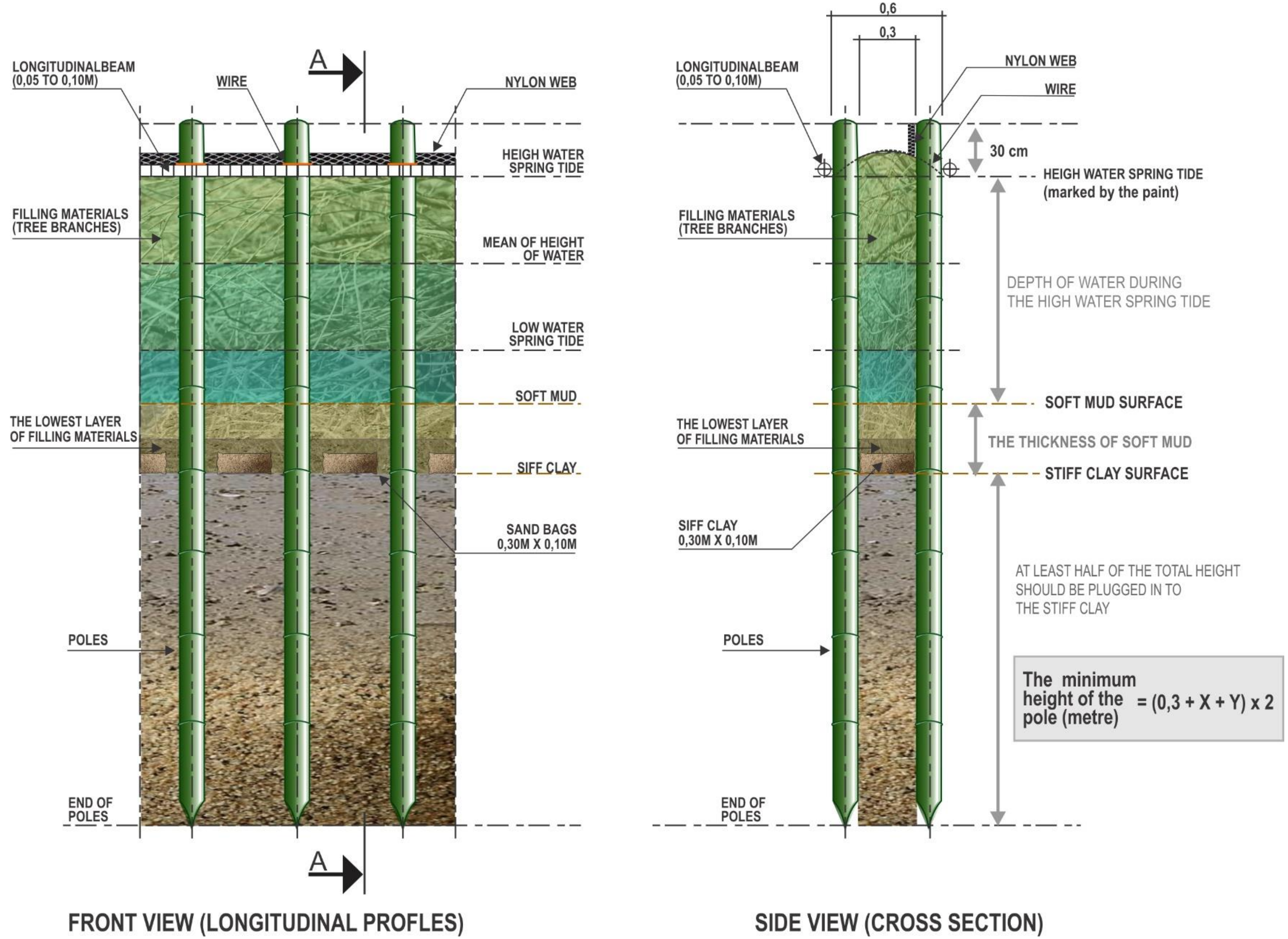
Filling materials

- Filling session can be done during the lowest tide period to ensure the filling materials can be more compact and solid,
- Put the filling materials bundles carefully, step by step by stepping down carefully ;
- Close the surface with nylon web and tie up
- The length of the wires should not be more than 10 meters to make the process of maintenance and refill easier.

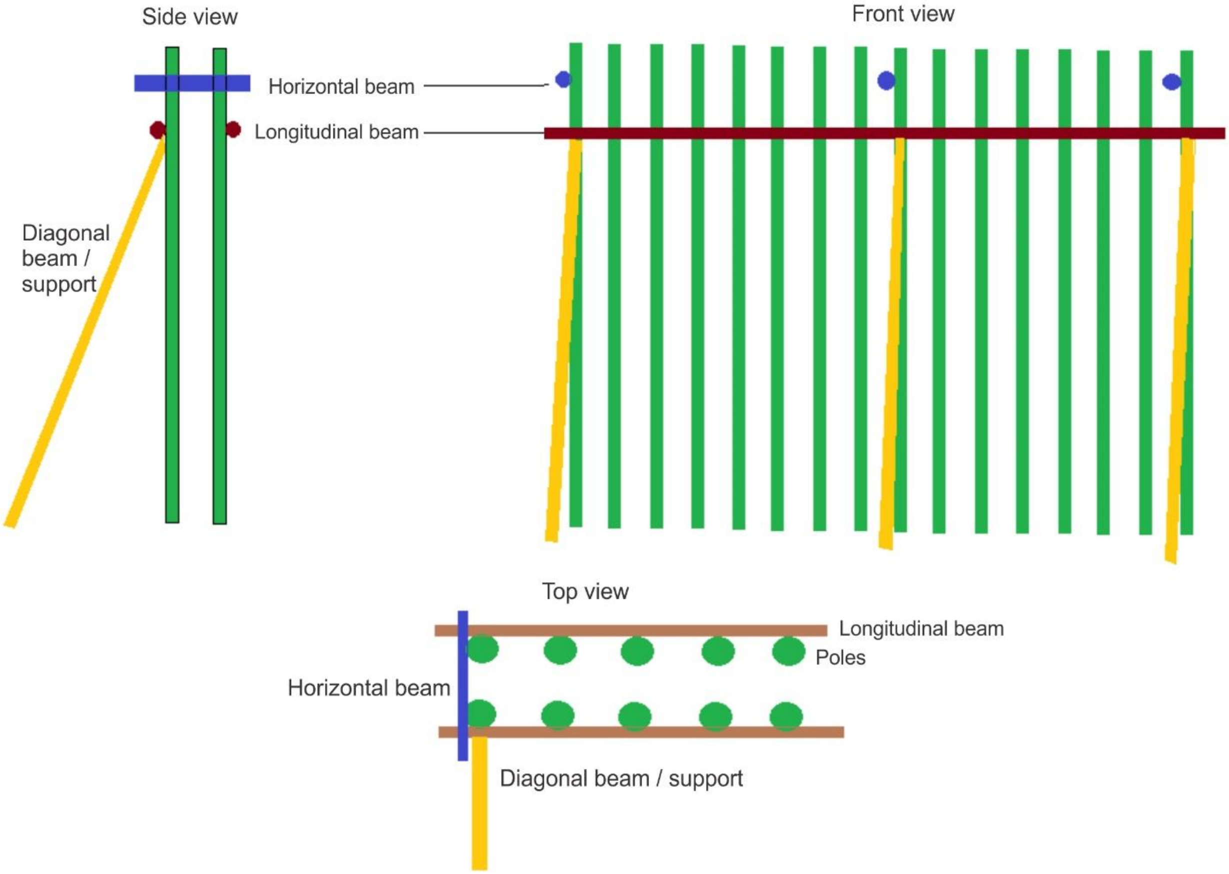
Picture 14, 15 dan 16 show the simple macro design, web and sand bag installation, as well as poles tacking



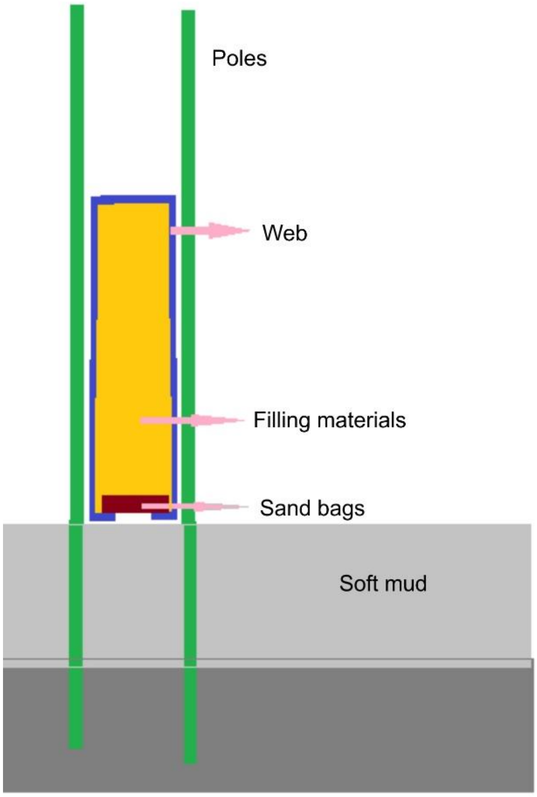
Picture 12. Top View Configuration



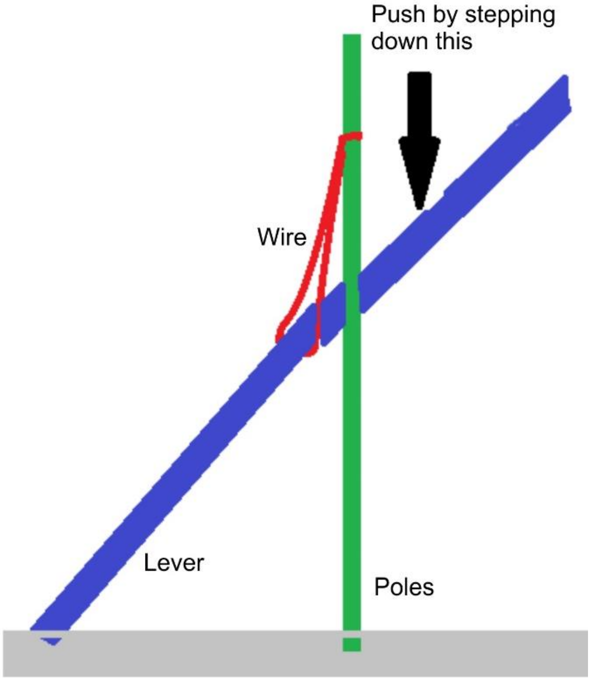
Picture 13. Step for poles plugged in and poles height measures ilustration



Picture 14. Longitudinal, horizontal beam and diagonal structure



Picture 15. Web and filling materials instalation



Picture 16. Poles tacking principles

D. Working Safety

The construction of permeable structure is conducted in an extreme environment. Please ensure that each of the team has an adequate working and safety equipment. Prepare the emergency kit and evacuation equipment in order to be ready to be used. Ensure the number of the team that has ability to do self-evacuation, and don't forget to distribute they evenly in each working groups. Do the construction process during a good weather period. The materials transportation should anticipate the tide schedule, be ensure for an adequate lighting in the night.

Picture 17. *Construction of permeable structure by communities(left); Permeable structure (right). (Foto Eko Budi Priyanto)*

2.3. Monitoring and Maintenance

A. Monitoring

Monitoring is conducted to check the necessity for improvement, or to repair any failure. At the initial phase up to 2 months after construction, monitoring should be conducted once a week. The next monitoring should be conducted when storm season approached.

Monitoring should assess the strength of the structure and observing any disturbance towards the structures. This can be done through visual observation on all the parts of the structure (poles, beams, filling materials, wires etc) as well as through strength and durability test. The durability test for the poles can be done by hitting the poles using big axes, for wire and net durability test, it can be done by pulling out the wires. Monitoring can be also conducted by observing the natural disturbance/pest such as barnacles.

Monitoring on the permeable structure function can be conducted by placing the measuring poles behind the structures, the sedimentation progress should be observed and measured periodically . Aside of mud sedimentation, the total number of naturally growing mangrove trees should also be monitored.

B. Maintenance

All the maintenance action should be based on monitoring report. The replacement of damaged poles would be very challenging, following are the step for poles repairing/replacement:

- If there are few minor damage poles , therefore, the damage part should be strengthened by adding extra longitudinal beam.
- If 40% damaged poles are took place in one side of the structure, therefore the new poles should be installed in front of another better/good side. The filling materials should be filled between new and old poles.
- If more than 40% of damaged poles took place in both side of the structure , therefore the new structure should be constructed , 1-2 meters ahead from the old and broken structure.

Longitudinal beams maintenance conducted by replacing the broken/damaged beams with the new one. Net maintenance or fixing should be very challenging due to its position that lies between poles and filling materials. Maintenance for net can be done through addition of web node . For wire, the improvement can be done by tiding up the wire or replacing with the new one if needed

Filling materials maintenance can be conducted by adding the new filling materials if the height of filling materials already below the longitudinal beam. Filling materials should be added regularly for approximately half of their initial volume/year.

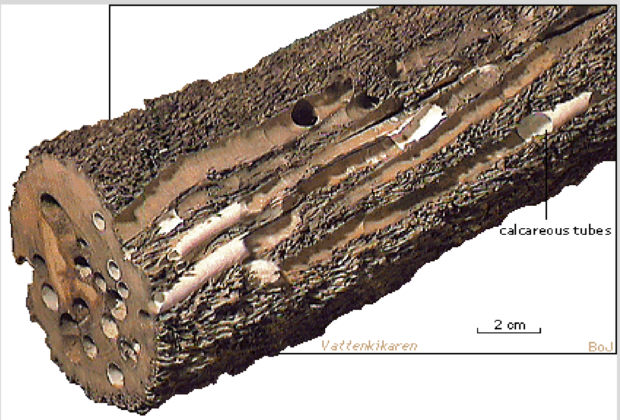
C. Current Update and Observation

From the ongoing process, the durability of bamboo poles is approximately 2-3 years. Most of the poles are broken on the water surface due to the existence of a certain type of Mollusca. The use of plastic layer on bamboo poles did not help much due to its thin layer and non-durability. At the moment, the project do the experiment to attached carpet layer in to the bamboo poles. No yet update info obtained regarding this experiment result.

The field observation also show the fast rate of filling materials subsidence, therefore, it is important to ensure the compaction of filling materials during the construction. The filling materials should be tied up and protected by the net to avoid the current drifting. The net and sand bag should be appropriately installed.

SHIPWORMS

Shipworms are marina bivalve Mollusca in the family Terediidae *(Teredinidae).* At least has 65 species from 4 genera. The shipworms often cause economic lost due to its ability to destruct the ships, port and wood made structures that installed in the ocean. The most destructor is from genus Toredo (15 species). *Toredo navalis* is one of widely distributed shipworms in the world



Another alternative for a stronger and more durable materials are including concrete pipe, nibung and coconut trees- has already discussed, but it has their own problems , i.e. expensive for Concrete – PVC poles. Nibung is limited and coconut trees is not recommended due to its role in providing cash to the communities

Assisted Mangrove Rehabilitation

According to Tonneijck *et al*. (2015) and Winterwerp *et al.* (2014), the permeable structure has been designed for a wide landscape initiatives. In the implementation, some other activities are needed, such as environmental manipulation for increasing the volume of transported sediment. It is noted the macro design of permeable structures require a complicated modelling and calculation. The question is how permeable structure can be applied in a smaller areas?

Reflecting to the failure of rehabilitation effort in eroded coastal (Setyawan, 2010) *Assisted mangrove rehabilitation concept has emerged*. In this case, permeable structure roles is to assist the rehabilitation process by providing a stable and conducive habitat for mangrove before he planting activities take place. The planting activities also become another 'assistance' activities to ensure mangrove colonisation in the area where permeable structure successfully trapped the sediment.

Since this approach applies without any sediment transportation manipulation, therefore, the concept can be only applied in low to medium eroded coastal. This can also be placed in a high sedimentation areas such as in estuaries, the area that has no direct influence by current alteration, and areas that has no land subsidence at all.

2.4. Cost

Even seems like a simple technology, permeable structures has a quite high expenses. Therefore, the initiator should do details research to ensure the most effective and efficient way of spending the money. It is suggested that the initiator should provide budget allocation for about 8-10 years to ensure 1 (one) project cycle of permeable structure accomplished.

A rough calculation in 2016,shows that the construction cost is approximately 1 million rupiah/meter. This is not including preparatory and maintenance works. For maintenance, the cost is approximately 5 hundred thousand rupiah/meter /year (2016).

If the construction development conducted by the community, here will be a chance to reduce the cost however, the cost will be still needed for community development program as the incentive for the communities to actively monitor and maintenance the construction . It is possible that the community development cost will be higher than the construction cost itself.

Following table show the rough calculation of permeable structure cost as for reference . The table content is an illustration based on WII's projects in Banten and Demak in 2015-2016. The calculation is not necessarily accurate, but representative for reference. The calculation conducted with assumption that the height of the structure is 2 meters and the length of the structure is 100 m.

Tabel 2. Cost estimation for developing Permeable Structure (100 m) in 2015 / 2016.

Need	Spesisification	Number	Unit	Price per unit (Rp)	Price for 100 m (Rp)
Poles	Babu betung diameter 12-15 cm, Length 6-7 m	450	poles	40.000	18.000.000
Nylon net	Net holes 1 inchi	450	m2	8.000	3.600.000
Filling Materials	Tree Branched	70	m3	250.000	17.500.000
Wire, horizontal beams and sandbags	*Nylon that has diameter 66 mm	1	lumpsump	1.500.000	1.500.000
	*Bamboo, horizontal beam				
Fee for local support		1	lumpsump	30.000.000	30.000.000
Materials transporting		1	lumpsump	15.000.000	15.000.000
T o t a l					**85.600.000**

The above calculation shows that the budget needed is lower than previous rough calculation. Be aware, the table has not yet included profit for the initiator and its tax policy . For the big scale please be ready to transport materials from outside the regions.

According to experience, the durability of bamboo poles is approximately 2-3 years. For maintenance cost we can calculate that along the project cycle period of the structure (8-10 years), the maintenance should be conducted and materials are replaced for approximately 3-4 times.

Mangrove as natural buffer for the coastal (Photo: Triana)

3. Closure

Permeable structure development is one effort to ovecome coastal erosion problem particularly in the muddy beaches. This concept are aplicable for low to edium erosion..

Coastal is a complex ecosystem , each location will have different characterisic. Therefore the construction of permeable structure will not be able to be conducted if only using copy and paste formula, instead, the initiator should conducted deep assessment on permeable structure and do the consultation with the competent technician .

Currently up to several years on ward the ***Building With Nature,*** as a coastal resiliency project that has construction of permeable structure as the element will be took place. The program is acollaboration works betwee ministry of marine and fisheries affair, ministry of public works and housing, and ***Ecoshape consortium***. The project is on the way of developing *helpdesk* to provide direct assistance on information sharing for interested party that want to develop permeable structure. For initiator that interested to develp permeable structure in their areas can contact the program ***Building With Nature or the consortium through following contact***i:

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Coastal Safety Manager, Building with Nature Programme
Wetlands International Indonesia

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Coastal erosion in the north coast of Java, particularly in Demak District is one of the concerning issue. The impact has been burdening the people, when the sea water flood at least 3 km landward, thousands of people lost their ponds, home and their livelihood. The coastal erosion happens due to sediment supply imbalances, the amount of sediment eroded by the waves and current are higher than transported sediment to the shore. This also being worsened by several activities such as mangrove ecosystem conversion in to ponds, housing etc.

The high rate of coastal erosion in the muddy beach caused by the decreasing areas of mangrove ecosystem, in addition the high rate of ground water extraction that led to land subsidence become another significant factor.

The book provide the information on permeable structure, as one of the effort to overcome coastal erosion in muddy beaches and to protect the coast by ensuring the successfulness of soft structure approach i.e. Mangrove ecosystem restoration/rehabilitation, at the same time reducing the disaster risks in coastal areas. This approach has long term benefit, providing economic, environment and social benefit for the community. Through the development of permeable structure, the disaster risks in coastal areas can be minimized and the coastal ecosystem can be naturally restored, which will further strengthen the community resilience in facing the disasters.

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