Bio-Retaining wall as an adaptive design of constructed riverbank into sustainable urban riparian landscape management

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Abstract: Indonesia has been struggling in managing erosion and existed adjacent settlement in urban riparian landscape. Retaining wall construction has been done to handle the problems. It has protected the riverbank, but has not considered the ecological issues. Moreover, some of the existing retaining wall in Indonesian urban riparian has been built without any standard and proper management by the community who lives surrounding it, include in Ciliwung Riparian along Bogor City. The retaining wall may potentially risk and clearly not have any environmental benefit. This research was conducted to discover the design of retaining wall that has more adaptive to environment and household grey water biofiltering, called as Bio-Retaining Wall. The case study was carried out in Ciliwung Riparian along Bogor City. Research data such as Retaining Wall Information Collection and Assessment System (WICAS) and design processes by adaptive model approach were combined as the methods for generating design in this research. The assessment result showed that most of retaining walls in the riparian were in risky condition of erosion, landslide, and poor household drainage. Bio-Retaining Wall is designed as adaptive retaining wall by having particular components for wastewater separation, water filtration, and plant cultivation. Despite the fact that Bio-Retaining Wall need further development, it may have prospect for the future of constructed riverbank into more sustainable by considering ecological aspect.

Keywords: Bio-Retaining Wall, Ciliwung Riparian, biofiltering, grey water, Bogor City

1. Introduction

Riparian are a narrow green area right adjacent to the water bodies. It has unique plant communities with soil and topography formed from the availability and dynamics of river water. Riparian landscapes are preferred to natural areas (forest vegetation, grasses, etc.), but many urban riparianlandscapehas changed for settlement use.

Based on the Ministerial Regulation of PUPR No.28 / PRT / M / 2015, river banks are "the space between the banks of the river basin and the inner embankment legs located on the left and / or right of

the river bank". The boundary of the riverbank is the virtual line on the left and right of the riverbed which is defined as a river protection boundary."

Riverbanks in urban areas, such as Ciliwung River in Bogor City, are not only affected the quality of river water, but also affected by the community's behavior on their environment. Improving the quality of riparian and riverbed landscapes can support scale-change changes [1]. In addition, the riverbank facilitates lateral and vertical connectivity along the river. People in developing countries make the river as a place to do various activities such as fishing, washing clothes, supplying raw water, recreation, or farming. The riverside farm provides local crop production for the surrounding settlements. Such riparian and river utilization activities are very useful and serve to maintain and improve its quality [2].
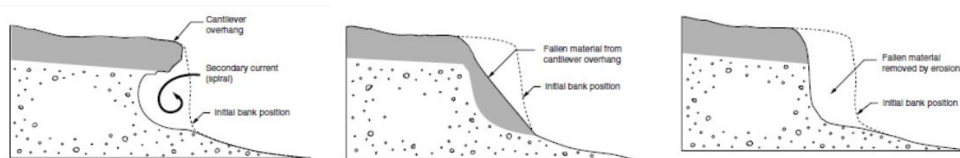

Figure 1. Riverbank destruction process [3]

However, the smaller spaces in the riverside make it difficult to develop the river as a riverfront. In addition, urban riverbank tend to be constructed with rigid and high retaining walls that prevent people from interacting with water. In fact, based on history, access to the river is so easy that it used to be a busy human activity center for washing, fishing and transportation because of the relatively better water quality. However, at the end of the 20th century, the riverbank has undergone many changes from publicly accessible open green spaces to private property, restaurants, police stations, including highways that disrupt the environmental quality and comfort for all residents [2]. Whereas the vegetated riverbankhas ecosystem functions as climate amelioration regulator, erosion control and flood wave [4].
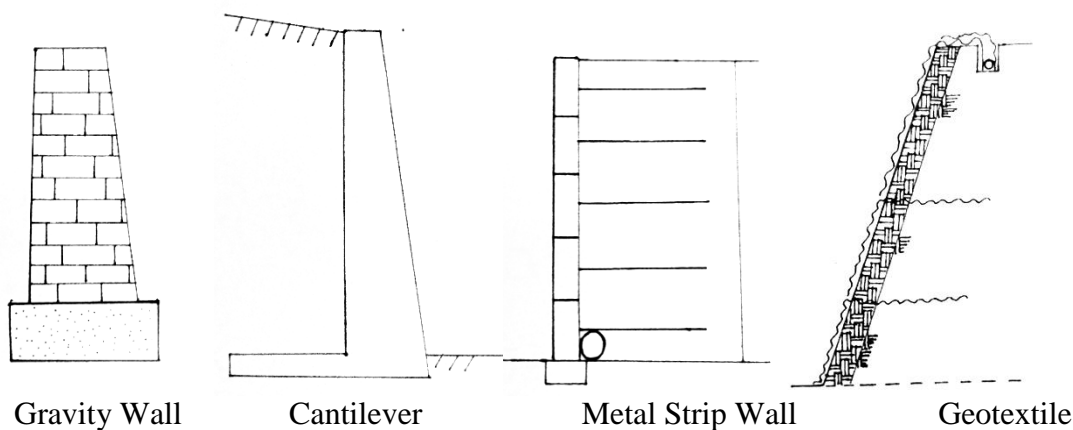

Gravity Wall   Cantilever   Metal Strip Wall   Geotextile

Figure 2. The types of retaining wall [5]

Retaining walls with rigid structures were used if the slope of the ground is above 60% because the more natural retaining wall of the slope is not able to withstand the soil mass and may cause erosion. If conventional structures can be stronger in protecting soil and water, additional environmental considerations should be made more ecologically by the ecological engineering approach [6]. The use of ecological engineering can be done with the use of vegetation and materials that can support the quality of the environment in the river (e.g. riparian tree planting, geotextile use, etc.). Thus, adaptation and modification are required to produce adaptable, high-quality ecological engineering design

model.This research was conducted to discover the design of retaining wall that has more adaptive to environment and could potentially support household grey water bio-filteredto the river, called as Bio-Retaining Wall.

2. Materials and Methods

2.1. StudySite

The research was conducted in December 2016 until August 2017. The location of this research is in riparian landscape of Ciliwung River in Bogor City. In this research, Ciliwung Riparian studied were divided into two segments: North Segment (NS) and South Segment (SS) based on Bogor Botanical Gardens (KRB) as the center of Bogor City. Each segment has two research locations. The four locations are location 1 and location 2 were in NS, location 3 and location 4 were in SS. A retaining wall was selected on two side of each sample location, east side and west side. The retaining wall samples were measured for visual assessment and further observation.
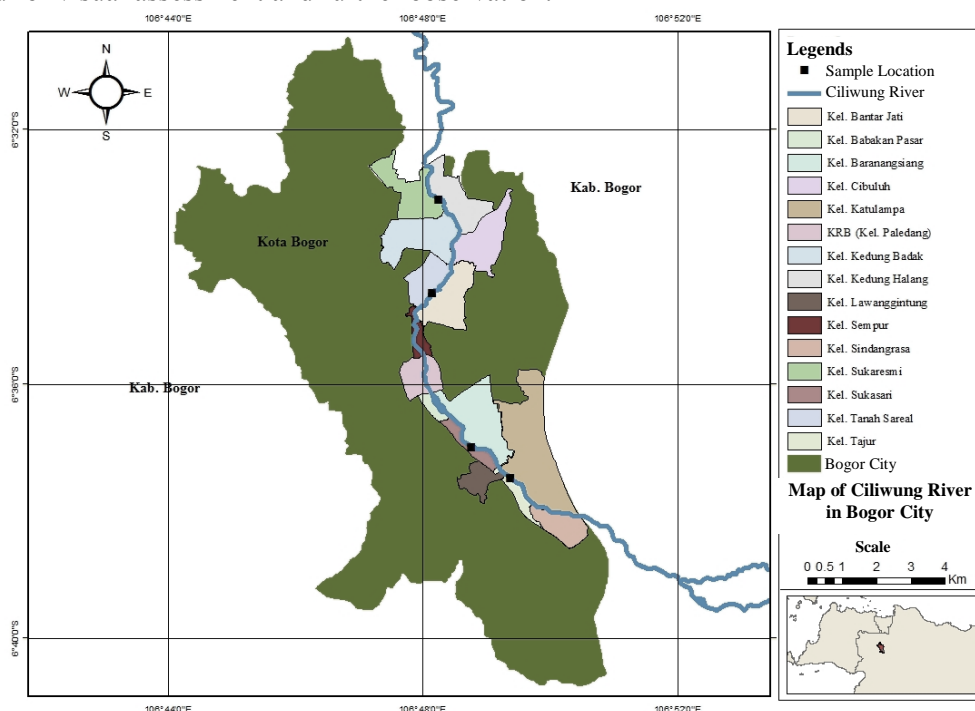

Figure 3. Site location

2.2. Retaining Wall Assessment Method

The strength of the constructed riverbank on two sides of each location was tested in the field using the Retaining Wall Information Collection and Assessment System (WICAS) method. WICAS is an important approach to prioritize management and improve the function of riparian edges. Retaining walls on the river banks are the focus of this visual analysis. The fault can be detected early. The assessment was started by evaluating each character from the criteria through a value of 1-4 by identifying a sample. Then all the information was written into a form that was developed by Butler [7]. The criteria identified included six sections, namely: 1. General wall data; 2. Assessment of wall elements; 3. Assessment of backfill elements; 4. Assessment of drainage element; 5. Assessment of other observations (optional); 6. The rating process by synthesizing those elements.

After all criteria of each parts (include: wall, backfill and drainage elements) were rated with scale of 1 that shows a "good" value to a value of 4 indicating a "bad" value, then all values are calculated and averaged. Accordingly, walls with composite values of less than 1.5 are considered as a good condition, walls with composite scores of 1.5 to 2.4 are considered as moderate / moderate conditions, walls with composite scores of 2.5 to 3.4 are considered as bad shape, and walls with composite scores of 3.5-4.0 are considered as having severe state conditions. The overall assessment method that is done is to consider the average and the worst value. Therefore, if any element value received a rating of 3 or 4 which are "bad", then the overall rating of the wall is 3 or 4 or worse. This decision based on the predetermined criterion which is a safety standard on a retaining wall [7].

2.3. Design Analysis

The next part of this research is design analysis. This study was conducted on the riparian of the Ciliwung River, especially on riverbank. The study in design analysis was using integration method approach between design and research, which is integrating adaptive design model with design model [8].

According to Milburn and Brown [8], the adaptive model is very responsive to the site or research location. Therefore, the design as a landscape product was based on research results that were implemented as general concept in the design. Therefore, the resulting design was inspired by research conducted in the field so that the concept was adapted to be a design.

In this case, research was carried out as an element that was absorbed as a concept in design. Subsequently, the concept containing the information was processed and inspired to be adapted to site design in response to the target site[8].

Both sections are carried out as an integral part in the preparation of ecological engineering design recommendations on the banks of the Ciliwung River. The integration of research in design can lead to an objective process while still considering creativity. This is a challenge and complexity for research in the field of landscape architecture to be able to offer solutions to complex problems based on research done [8].

Field observations and expert or stakeholder engagements are essential for learning in designing a future product design or landscape concept. Experiments conducted in landscape approaches tolerate uncertainty, acknowledging alternatives for conceptualizing and generating innovations. [9,10]

3. Result and Discussion

3.1. Retaining Wall Assessment Analysis

The Changes of land cover and land use along the watershed, including the riparian, affected the hydrological conditions of watershed. All matters relating to rivers and streams are interconnected so that instability of landscape caused morphological conditions and river functions unstable. The river and its riparian are need to be improved physically, rehabilitated and even restored. If it has be done, the landscape services will automatically greatly benefit humans and the environment [11].

In this study, physical condition of the constructed riverbanks of Ciliwung River was possibly assessed by visual assessment [7] of sample locations. It is important to do assessment because the constructed riverbank influenced by intensive human activity, it holds as a settlement barrier, the road or flood retaining structures. After all the sample locations were assessed, the result can be seen that only one structure of a retaining wall on the riverbank has 'good' criteria, i.e. in the 4th location of the West side (L4 West) with "*bronjong*"or gabion structures. In addition, five structures of 'fair' retaining wall were in the 1st East side location (L1 East), 2nd East side (L2 East), 3rd West side location (L3 West), 3rd East side location (L3 East) and 4th West side location (L4 West). While the retaining wall on the location of the West side and the location 2(L2 West) were 'poor'.

Table 1. The assessment rating of the constructed riverbank of Ciliwung riparian in Bogor City
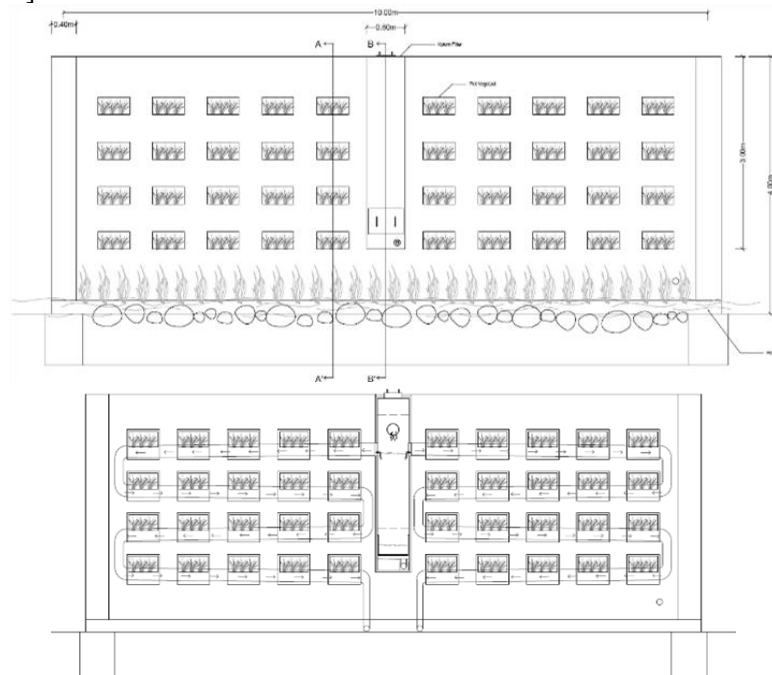
Location	Type of retaining wall	Element Assessment			Rating	Status
		Wall	Backfill	Drainage		
L1 West	*Bronjong*(Gabion)	2.8	3	2	3	Poor
L1 East	Riprap stone, Masonry	1.7	1.5	NA	1.6	Fair
L2 West	Riprap stone	2.63	2.67	2.5	2.6	Poor
L2 East	Riprap stone	2	1.6	2.5	2.03	Fair
L3 West	Riprap stone	2.5	2.1	2.5	2.38	Fair
L3 East	Riprap stone, Masonry	2.2	2.25	2	2.15	Fair
L4 West	*Bronjong*(Gabion)	1.3	1	1	1.1	Good
L4 East	Riprap stone, Dry Laid stone	1.9	1	2	1.63	Fair

Note: L(number) East/Westmeanslocation in the riverbank, west or east side

The riparian condition of the sample locations represented the overall condition of the Ciliwung Riverbank. Based on the observation along the riverbanks of the Ciliwung River, the researchers focused at the condition of the retaining wall structures as the result of structural condition analysis (Table 1).In fact, the Ciliwung River riparian region was the territory of the Ciliwung Cisadane River Basin Authority (BBWS Cilicis). However, based on BBWS Cilicis planning staff, there was no environmental planning for the construction of the Ciliwung River bank structures in Bogor City. The construction of the Ciliwung Riverbank structures should be used by the government in issuing regulations to make riparian landscape conserved from developments such as settlements and buildings that caused destruction to river.

3.2. Bio-retaining Wall Model Design Analysis

From field observations and previously collected data, we found that riparian conditions with different characteristics needed different approaches in ecological engineering design and management. The watershed conditions which are discussed in this analysis of ecological engineering designs construct the riverbank [12,13].

A. Front view   B. Cross-section view

Figure 4. Illustration of Bio-Retaining Wall design on the constructed riverbank of Ciliwung Riparian in Bogor City (not scaled).

One of the efforts to establish ecological engineering of riverbank is adding ecological function of existing construction by revitalizing the existing retaining wall. The existing retaining wall only has the function of preserving riverbank fromlandslide, but there is no additional benefit to conserve sustainability of Ciliwung River. Whereas existing retaining walls have the potential to play a significant role in improving the services of riparian landscapes.

Thus, we approached the modification of gravity wall [14] using a more ecological concept of construction. Modificationwas done by making Bio-Retaining Wall. The concept of Bio-Retaining Wall was a gravity wall modification that has a water filter column component from the road drainage and residents' wastewater channel and the media box planting component.

Bio-Retaining Wall work system was to drain wastewater and drainage to the planting medium along the Bio-Retaining Wall. The wastewater stream from the settlement is not directly discharged into the river but can be flowed first to the filtration column to be filtrated and then the resultant water from the column was flown into the planting media box connected by the pipe.

The term of Bio-Retaining Wall was not widely found in the literature. In principle, Bio-Retaining Wall was similar to the living wall [15], eco-retaining wall, green-wall [16] and other terms. It refers to the vegetated wall to improve the more ecological function (multifunction) of construction, in the context of this study is the modification of retaining wall [16]. Bio-Retaining Wall was to make water flow into the river will be cleaner. In addition, various plants can grow on retaining walls to improve landscape services in absorbing pollutants or as a provider of other organisms' habitats.
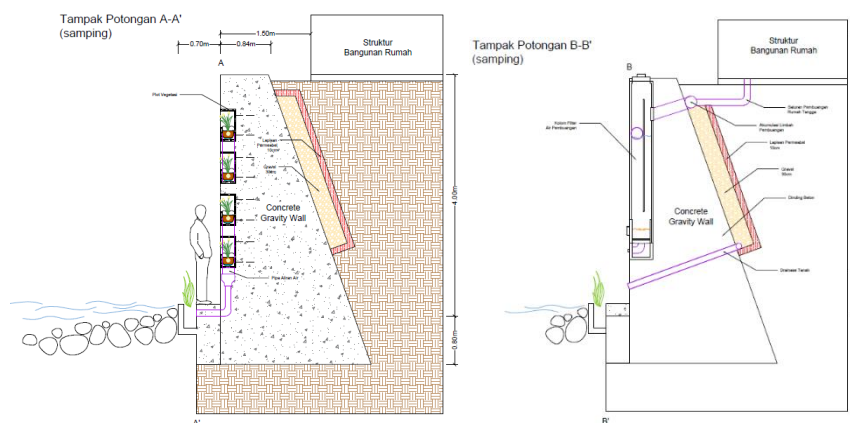

Figure 5. Bio-RetainingWall design (side pieces look) on the constructed riverbank of Ciliwung Riparian in Bogor City (not scaled).

The system was a part of an effort of ecological engineering in construction by restoring morphology and ecology. Restoration experts argue that this construction (Figure 6) can be applied to riparian that have been built by RW to be reconstructed so that Bio-Retaining Wall also plays a role in helping to improve river quality by filtering the water [13, 17, 18].

Alternative management that can be implemented was the delay/stoppage and supervision of construction of riverbank wall construction, whether done by self-help, private and local government; improving the function of existing retaining walls by reconstructing them to be multifunctional such the concept of Bio-RetainingWall. Upgrading theexisting retaining wall by revitalization using Bio-Retaining Wall design is important and this concept could be developed in the future. Many urban areas were concerned to be able to handle using Bio-retaining Wall, such as Katulampa, Tajur, Sukasari and Babakan Pasar areas.

4. Conclusion

The condition of the Ciliwung River in Bogor City was dominated by steep slope above 75°. The existence of constructed riverbank development poses a considerable threat to the ecological quality and diversity of riparian floor vegetation and has an impact on the degradation of river ecosystem. Bio-retaining wall design model is a way of improving environment of riparian. Bio-Retaining Wall becomes important alternative solution while the building removal strategy from the riparian is not yet a solution. In addition to considering its strength, ecological functions also become the main concern to support the quality of the river by this Bio-Retaining Wall.

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