Combining Embankments and Infiltration Ponds for Flood Prevention in Indonesia

[1] Audrianne Gunawan [2] Kaylee Fayola Husni [3] Jaslene Orianna Yang [4] Josias Nathaniel Limit [5] Jonathan
[1] SMA Bina Bangsa Semarang [2,3] SMA Bina Bangsa PIK [4] SMA Penabur Jakarta [5] SMA Kanisius Kolase

Abstract

As climate change, global warming, and trash build up increase, Indonesia has experienced more floods. Our study focuses on flood prevention in rivers through water absorbing embankments. This design makes use of permeable water absorbing paving blocks applying the process of osmosis, adhesion, and cohesion. With the help of the impervious zone and grout curtain, the embankment can effectively regulate water flow to the infiltration pond through PVC pipes. The PVC pipes are located in the drainage zone where they are built into the paving block to act as a suction in an air-tight space which forces water to flow into the pipes. The infiltration pond will then allow the water to be filtered using materials such as sand, palm fibers, and river stones. The clean filtered water is then stored in wells that can be used by the citizens. The embankment also has accurate pipe positions, measurements, and support such as a brick wall which ensures the stability of the system. By utilizing this design, it not only blocks water flow, but also absorbs water and regulates it to a filtration system resulting in clean usable groundwater. Hence promoting water recycling, environmental sustainability, and financial long-term benefits. Not only does it possess great benefits, this design is also simple and cost effective as it uses compacted earth materials.

Keyword: *Water Management, Water Recycling, Overflow Precautions, Filtration*

INTRODUCTION

Indonesia is one of the countries prone to disasters due to its diverse and dynamic nature. During the period 2000 to 2011, of the many disasters nationally, 77 percent of the disasters that occurred were hydrometeorological disasters, namely floods, tornadoes, landslides. In the past two years alone, there have been many floods that have occurred in Indonesia. Floods that occur are not only floods at a small level, but floods with a very large level, resulting in a very large impact as well. Flooding in Indonesia has been happening for a long time, but sadly the area and frequency of flooding has increased with greater losses in the last period of time [1].

Floods have occurred in almost all areas in Indonesia. In the western part, floods occurred in the Demak area, Central Java. The flash floods that hit Karanganyar and Gajah sub-districts in Demak Regency have lasted for almost a week, displacing 21,000 residents. This figure is recorded as one of the disasters with the highest number of evacuees in early 2024. Dozens of houses in Karangwangi Village, Cianjur, West Java were also submerged in one-meter-high floods as the Cibodas River overflowed due to heavy rains on Thursday. BPBD Cianjur has sent officers and volunteers to help evacuate residents. More than 50 houses were submerged, mostly on the banks of the river [2].

Eastern Indonesia also experienced flooding due to heavy rain that caused the Kendo River to overflow in Bima City, West Nusa Tenggara. 248 houses were flooded and one hectare of agricultural land was inundated. Flooding also hit Jambi City due to the overflowing of the Batanghari River which resulted in thousands of houses in Legok Village, Danau Sipin Subdistrict, being flooded. A total of 1,178 housing units and 1,258 families with 4,453 people were reportedly affected by the flood. Although the flooding only lasted a few hours, the waterlogged roads caused traffic congestion. Residents' anxiety can also be seen from the houses that are still flooded. The flooding was caused by high rainfall intensity in early 2024, which caused the Batanghari River to overflow. The road to Danau Sipin village was also submerged in water with a height of 40-50 cm, disrupting the daily activities of residents [3].

Floods can be caused by many factors. Firstly, climate change and global warming. Over the past few years, our Earth has experienced climate change and global warming and this affects our sea levels as well as rain water precipitations. Sea level rise is primarily caused by two factors, the melting of ice sheets and glaciers; and the expansion of sea water [4]. The melting of ice adds water to the ocean, while the expansion of sea water causes it to take up more space in the ocean basin [5]. This is all due to global warming which causes the Earth's temperature to increase. On the other hand, climate change affects the intensity and frequency of precipitation. Due to global warming, the oceans temperature increases causing more water to evaporate into the air. As the moisture in the air builds up, it causes the air to move and build up to a storm system causing extreme precipitation (heavier rain falls) [6].

The second factor is deforestation. Forests are important as they have a high level of evapotranspiration, which is when water is transferred from land to the atmosphere by evaporation from soil and transpiration from plants, that returns excess water to the atmosphere [7]. Moreover, forests allow more water to be absorbed into the ground through plant roots, rather than running off to rivers. Lastly, the presence of trees leads to lower soil erosion levels as there are more roots to support the ground. Hence less soil fills up the rivers that could make them shallower and easier to overflow [8].

The third factor is waste blockage. The presence of waste in rivers blocks its flow causing the water to overflow, especially plastic waste. Plastic waste contains less voids hence causing higher blockage density. Plastic waste also leads to a faster and denser blockage when rain occurs, which results in more sudden backwater increase. Hence, the water level increases. Additionally, when waste is deposited into the river's sediments it makes the river more shallow. To illustrate this, according to locals in Bandung Regency, the Citarum River's sediment contains more plastic than before. This was discovered as locals started mining the river's sediment for soil, instead of soil, they found [9].

Embankments are one of the things that hold back water to prevent flooding. Current embankment designs only aim to hold back water discharge when the water rises, but not reduce the water level. As a result, when rainfall is high and the water level rises, the embankment is often unable to withstand the high water discharge and eventually causes water to overflow onto the land. As happened in Demak, Central Java, the embankment separating the Wulan River broke and caused severe flooding [10].

Levee failures in Indonesia are due to the fact that levees in Indonesia are often made of concrete, making them look like concrete walls. As such, this makes the levees look unattractive and also incurs high construction costs. Natural levees, on the other hand, are made of earth and are therefore prone to collapse[11].

Paving block is one of the choices of concrete replacement material for embankment construction. Along with the development of technology, paving block designs are also increasingly diverse. One of the paving block designs created to overcome environmental problems is water-absorbent paving blocks [12]. Water-absorbing paving blocks, also known as permeable paving blocks, are designed to control the release of surface water to the natural environment. They achieve this through a technique called attenuation, which involves using a specially adapted sub-base with a high proportion of void spaces to store collected water. This sub-base material is made of a hard, angular primary or secondary aggregate, and it acts as a sponge, soaking up and storing incoming surface water [13].

The strength of these blocks in absorbing and retaining water lies in their unique design and materials. The sub-base material contains almost no fines, which results in a high proportion of void spaces, allowing it to store large amounts of water. The blocks themselves are also designed to allow water to pass between them and into the sub-base, where it can be stored and gradually released to the environment at a controlled rate.Some of the key differences between water-absorbing paving blocks and ordinary paving blocks include: Attenuation, sub-base and the materials required to make the blocks [14].

For Attenuation, water-absorbing paving blocks are designed to control the release of surface water to the natural environment, while ordinary paving blocks do not have this feature Their sub-bases differ as the sub-base material used in water-absorbing paving blocks is specifically designed to store water, with a high proportion of void spaces, while the sub-base for ordinary paving blocks is not optimized for water storage As for the materials, the blocks and sub-base materials used in water-absorbing paving blocks are different from those used in ordinary paving blocks, as they are designed to allow water to pass through and be stored. The strength of water-absorbing paving blocks in absorbing and retaining water is significant, as they can store large amounts of water and release it at a controlled rate, helping to reduce the risk of flooding and inundation [14].

In addition to embankments, infiltration ponds are also one of the technologies designed to overcome flooding problems in several big cities. Infiltration ponds the house is not channeled into the gutter or yard, but is channeled using pipes or drains or drainage into the infiltration well so as to reduce the amount of rainwater runoff that occurs [15].are a means to collect rainwater and infiltrate it into the ground. Rainwater that falls on the roof of

As rain reaches the earth's surface, a small amount of water from the rain is absorbed into the ground, while the remaining water reaches an infiltration well, referred to as runoff water. infiltration well, this runoff water flows into the infiltration well and then seeps into the ground, aided by filtration through rocks to slow down its speed. The benefits of using an infiltration well includes its ability to retain and reduce the volume of run-off water, and absorb surface water (run-off) into the ground. It can also increase the surface/volume of groundwater quickly, all while protecting the quality of earth's soil. Finally, it can also maintain the balance of groundwater reserves [16].

Our ultimate goal is to build an embankment embankment design using water-absorbing paving blocks that apply the process of osmosis, adhesion and cohesion for water movement so that rising river water can be absorbed and stored in wells. This is so that it can be used for human needs such as irrigation and washing, especially during the dry sea.

Methods

Planning

1. Research about the environment
2. Research about the embankments
3. Research about the Infiltration
4. Research about the materials used

Conceptual Design

1. Think about what processes need to be done
2. Think about the flow of the process
3. Sketch the design of the embankment

Evaluation of the design

1. Think about the care of the tools and materials used
2. Provide an overview of the advantages of the design compared to other designs

Result dan Discussion

A. Overall Design of TASURA

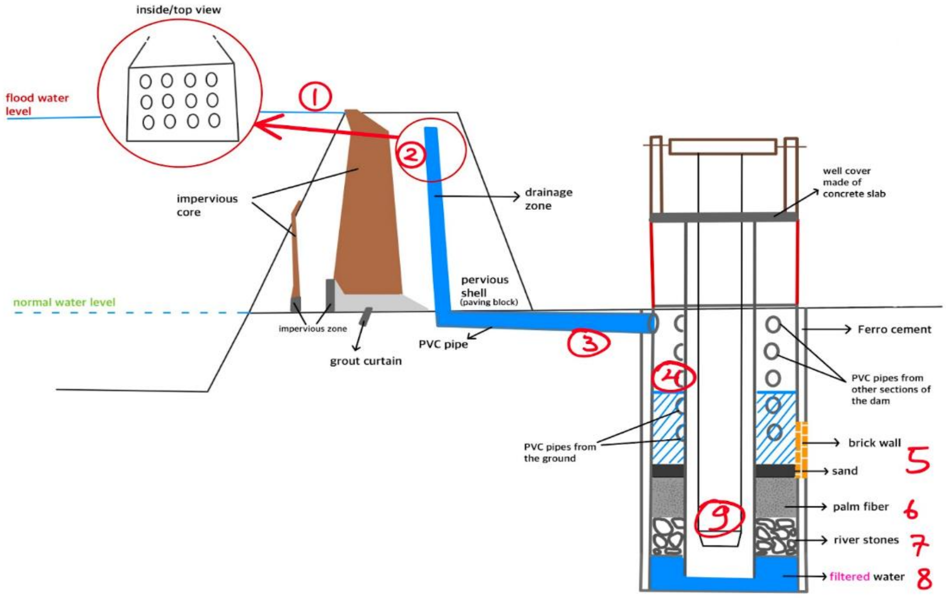

Figure 1. Overall Design Of TASURA

TASURA (Infiltration Well Embankment) is an embankment design that we combine with infiltration wells as one of the preventive efforts to prevent flooding.

When there is heavy rain, the water level rises above the ground level. In this case, a dam acts as a barrier to protect homes from risks of flooding. This dam is made of paving blocks, which then can gradually absorb the floodwater. It acts as a pervious shell, which allows the rain to permeate into the ground. However, too much of the rain should not seep into the ground as it would be lost or cause soil erosion. Hence, the usage of impervious zones assist in the control of water flow, directing the water absorbed into the paving block to be allocated to an area of pipes called the drainage zone. The impervious zones are made of concrete due to its poor absorption qualities. About 10.000m^2 of concrete is used per 50.000m^2 of paving block to ensure that an efficient ratio(1:5) of the dam is used for these zones. Additionally, the grout curtain is used to prevent the water from seeping into the rock mass of the dam. It does this by reducing the hydraulic conductivity of the rock mass and pore pressure.

In the drainage zone, PVC pipes are built into the paving block to act as a suction in an air-tight space and force water to flow into the pipes. The pipes are aligned in a zigzag manner and are spaced 1m from each other to allow variation of gradients, which keeps the water flowing at a more stable pressure. This is to prevent cracks forming in the paving block while still ensuring a consistent water flow. The drainage zone is basically just a collection of pipes, acting as inlets of water, of assorted heights so that it maximizes the amount of water collected from the dam.

After the drainage zone, a 100m long PVC pipe is dug underground.It connects the dam to the well, which will be the water storage. In order for the water to flow, it must go down a certain gradient; in this case, it is the pressure gradient, where, at the start(joint connection of drainage zone to pipe), a higher hydrostatic pressure is exerted due to the lower pipe volume forces the water to a lower hydrostatic pressure caused by a higher pipe volume. The PVC pipe's diameter will increase gradually from 10 at the start to 50 at the end; the purpose of these measurements is to minimize the space taken up by the ground while also ensuring a stable water pressure, preventing the pipes from bursting.

In the cylindrical wall of the well, PVC pipes are poked into them. These pipes flow from various different sections of the dam, all connected to a single well. Thus, to decrease the pressure of the water collected, the well's great diameter of 100m is required, built of Ferro cement, a thin, hard, strong surface material with higher specific surface of reinforcement. It is important to use Ferro cement mostly because of its density, allowing it to be thin, but very strong, so that it does not take up too much space and is easier to build into the ground. The PVC pipes are aligned normally, 2m horizontally apart, and 5m vertically apart. The reason for its shorter horizontal distance compared to its vertical distance is because of the arrangement of the pipes in the ground, where they must be diagonally slanted downwards for gravity and its increasing diameter. It is also important to note that the pipes must be compactly arranged so more water can be stored and to efficiently maximize the wall's surface area to reduce unnecessary costs.

2. In this section, suspended matter is removed by sand filtration. Mineral sand is used in this step as it is cheap and easy to find, so the search for it does not damage the earth geothermally because of its richness. The sand filters the water by physical encapsulation, where its droplet interface bilayers absorb the aqueous droplets of water and trap them within lipid monolayers of solid substrate compartments, hence, only allowing these purified water droplets to pass through. Note that it filters off the suspended fine particles only, larger particles of higher mass may push through the sand which will be filtered off by the following filtration methods. The sand section is located next to a brick wall. This will enclose the well in a semicircle to increase rigidity. Ferro cement is a very thin material and it may waver and may not always hold off well. Hence, a brick wall is implemented to start the mold of the rigid structure of the well to the Ferro cement, which will encapsulate the rest of the cylinder. However, to maximize the function of the Ferro cement, the brick wall will only be 2m in height and take up half the circle of the well.

After the water passes through the sand, it will pass through palm fiber. Palm fiber has the ability to absorb certain pollutants and impurities from water. Adsorption occurs when molecules of contaminants cling to the surface of the fiber which helps dissolve organic compounds, and other harmful materials. Palm fiber can also be a part of biofiltration by providing a substrate to benefit microorganism to colonize. These microorganisms are not harmful to humans and they can metabolize organic matter, further improving water quality

Next, the water will pass through river stones. River stones are placed in the water filtration systems to create turbulence which increases oxygenation of the water to support aerobic microbial activity and to maintain the water quality. River stones also contain minerals that can chemically interact with certain contaminants in the water. For example, minerals like calcium and magnesium can help to neutralize water acidity.

After passing the whole water filtration system, the clean water will then be stored in the well. The well has a volume of 7700m^3. The well has a maximum capacity of 7.700.700liters of water to store clean water which has been filtered by the rocks

The filtered water can then be taken up from the well to be utilized into homes, buildings, and other facilities.

B. **Embankment Design Advantages**

In Indonesia, embankment dams come in two primary forms: those constructed from concrete, resembling walls, and those naturally formed from soil. The concrete embankments, while sturdy, are often criticized for their unattractive appearance and the high costs associated with their construction. On the other hand, natural soil embankments, while more organic in appearance, are prone to erosion and breakage, posing challenges for long-term stability and effectiveness.

Embankments made outside of Indonesia are more advanced. For example, other countries' embankment dams have spillways that release excess water. Additionally, it has drainage features and filters to prevent internal erosion. The combination of embankments and infiltration ponds can overcome all of these issues faced by Indonesian dams, while also incorporating methods from embankments outside of Indonesia.

Our embankment serves many purposes, offering solutions to water management issues. By effectively regulating water flow, the embankment can reduce the risk of flooding, by regulating water so that it does not overflow. This not only avoids damage to lives and property but also promotes economic stability by reducing the need for costly repair efforts in flood-affected areas.

Moreover, the embankment plays an imperative role in establishing a sustainable water cycle. Through management, they facilitate the production of clean water, addressing the persistent challenge of water scarcity in Indonesia. This not only ensures a reliable supply of water for various needs but also promotes environmental sustainability.

From an economic view, the adoption of this embankment is extremely advantageous. Substantial financial savings are achieved by averting floods and the damages they cause, thus saving resources that would otherwise be needed for repairs and rehabilitation. Furthermore, by eliminating the need to buy clean water, the incorporation of water recycling technologies into embankment designs results in financial benefits that lower operating costs and improve long-term profitability.

Conclusion

Flooding incidents and overflowing of rivers in Indonesia can be reduced by utilizing our embankment design. Our embankment design implements a water recycling system involving the absorption of river water and converting it into clean filtered water. Not only does it benefit the environment, but also increases the volume of clean groundwater that can be used by the citizens. Additionally, the design is simple, cost-effective, and has a strong stability. For all these reasons, this design is the optimal solution to flooding issues in Indonesia.

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combination of embankments and infiltration ponds, practical testing remains to be undertaken. We eagerly anticipate progressing to the next phase of our research

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