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Post-Construction Problems of Embung in Lombok Island and the Operation and Maintenance Works

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Abstract

Embung or small-scale reservoir has been pivotal in the history and development of agriculture, most notably in the southern part of Lombok Island where the so-called critical area exists. Embung's main purpose is to secure harvest in the first cropping season when the rainfall is insufficient. Otherwise rainfall and surface runoff are stored and will be used for the second cropping season, as well as for the cattle and domestic needs. More than 2000 embungs of simple structures and modern types have been built and subsequently followed by an increased in the operation and maintenance cost. In order to preserve the function of embung, post-construction problems have been identified to allow an adequate and proper maintenance works to be carried out. However such works have been partly hindered by the limitation of government's budget. This underlines the important of routine inspection to identify an early state of damage so that further damages and expensive maintenance cost are avoidable.

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Keywords: embung; critical area; agriculture; maintenance works.

1. Introduction

Embung, which means a small rain harvesting reservoir has widely been known in Lombok Island and has been used since approximately 700 years ago (Marsudi et al, 2005). The word embung was derived from its original word *mbung* which in native language means a place to store water. Today the term embung has been adopted in

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official language of Bahasa Indonesia and already used in many schemes of water resources projects outside Lombok Island.

The main purpose of embung is to secure harvest in the first cropping season when the rainfall is insufficient. If the rainfall is sufficient to support the first cropping season, rainfall and surface runoff from the catchment is stored in embung and will be used for the second cropping season. The stored water is also allocated for the cattle, inland fisheries, and for other household or domestic needs.

The existence of embung is very important in the history and development of agriculture in Lombok, most notably in the southern part of the island. In this area the ratio of demand and water availability is in a deficit state (Saadi 2010). It has a semi-dry climate with the mean annual rainfall ranging from less than 1000 mm in the coastal region to as much as 2000 mm in the upland. Part of the region is described as critical area, which has been defined by Crippen International Limited as a relatively densely populated area in which the physiography and climate combine with particularly unreliable or non-existent supplies of irrigation water to produce failure of the rice crop to the extent that famine conditions can occur (Crippen International Ltd, 1975). According to Sir Mott Macdonald & Partners Asia and Associates famines were reported to have occurred in 1946, 1953, 1957, 1966, 1969 and 1972 (Sir Mott Macdonald & Partners Asia and Associates, 1986).

In Lombok Island, there are currently more than 2000 embungs of small size to large size with storage volume ranging from several thousand cubic metres to more than one million cubic metres. The informal leaders such as religious leaders have played very important role in the existence of those embungs. There are many religious leaders who are not only concentrated on the teaching of religion but also concerned in the welfare of the community. They are believe that relieving poverty can be done through the establishment of infrastructure such as embung as most people in Lombok are rely upon the agriculture sector. There was one charismatic religious leader who is highly regarded as a pioneer in the establishment of around 30 embungs with and without government's assistance (Marsudi et al, 2005).

2. Development of Embung

Originally embung was built and own by individual to store water mainly for paddy field and drinking water for cattle of one or more than one households. This type of embung called people's embung or *embung rakyat* and very often the owners name is attached to the word embung as a symbol of ownership. The embankment of this embung could reach as high as 3 m with the storage capacity between 2500-5000 m^3 and the irrigation area up to 5 hectares.

The construction of *embung rakyat* is fairly simple in the form of a small pond surrounded by hand compacted soils as its embankment with rectangular shape (see Figure 1). On top of the embankment, the owner plant trees and bamboos to prevent landslide or erosion caused by human or cattle. *Embung rakyat* is equipped with a simple intake using a perforated palm tree as a replacement of pipe (Marsudi et al,

2005). When *embung rakyat* is not in operation or during the period of storage filling, the hole of intake is blocked using a cut of banana tree or small size of sand bag.

Figure 1. A typical *embung rakyat* (Saadi et al, 2010)

The larger type of embung is called the village's embung or *embung desa* as it is built by a group of people in a village and own by the village. Site selection of *embung desa* is conducted and agreed by villagers and village official at nearby river or valley owned by village. In comparison to *embung rakyat, embung desa* has a stronger structure (see Figure 2). The embankment is generally between 4-8 m high and the irrigation area is up to 8 hectares. The structure of embankment made by a pile of compacted soil or masonry equipped with intake and spillway. The operation of intake is more sophisticated than that of *embung rakyat* in the way that a lifting gate or turning valve is adopted.

Figure 2. An *embung desa* with masonry structure as its embankment
(Courtesy of BISDA NTB)

Based on the benefit of the existence of *embung rakyat* and *embung desa* in overcoming water shortages in Lombok, government through Directorate General of Water Resources Development Ministry of Public Works established a programme to upgrade the existing *embung desa* to a larger scale and also to build new larger embung based on the SIDLACOM (Survey, Investigation, Design, Land Acquistion,

Construction, Operation and Maintenance) approach. Embung of this type is called government's embung or *embung pemerintah*. The SIDLACOM approach is applied since the structure of *embung pemerintah* is more complex involving many considerations in the process. The embankment height can reach more than 10 m and the storage volume is more than 1000000 m^3. Two examples of large embung are Batu Bokah Embung in Kateng Village of Central Lombok District with an embankment of 21.20 m high and storage volume of 1560000 m^3 whilst Pare Embung in Semoyang Village of the same district has 11.55 m high with the storage volume of 767500 m^3.

The construction of *embung pemerintah* can be of many types, depending upon how the available materials are utilized. It could be in the form of masonry or concrete dam (see Figure 3) or in the form of earthfill or rockfill dam. *Embung pemerintah* requires ancillary structures to enable it to operate safely and effectively. Spillway is important for the safe passage of flood whilst outlet work or intake is intended to fulfil the irrigation purpose. Other ancillary facilities are incorporated as necessary. In an *embung pemerintah* it is expected to see Open Standpipe Piezometers to measure the pore pressure, Seepage Chamber to measure seepage and Crest Settlement Points for measuring surface movement of embankment both in horisontal and vertical direction.

3. Embung Post-Construction

3.1. Visual Inspection

Apart from the instrument such those mentioned earlier in *embung pemerintah*, there is no other extensive modern instrumentation equipped to the structure. In this case visual inspections on regular basis are very important to ensure the structures are in a good state as expected.

Visual inspections of embung are commonly applied in the following areas:
1. Embankment (crest, upstream and downstream slope),
2. Ancillary structures such as intake and spillway,
3. Foundation and the surrounding areas.

Figure 3. An *embung pemerintah* equipped with adequate intake and spillway (Courtesy of BWS NT I)

3.2. Common Problems Encountered

Visual inspections indicate that common problems found in the embankment of embung include uneven surface caused by lack of maintenance, differential settlement and poor quality of compaction. In many cases, this leads to the existence of crack along the embankment's crest (see Figure 4).

Figure 4. Cracks on top of the embankment (Courtesy of BWS NT I)

Typical operating condition of embung is marked by a high variability in water level between wet and dry season. This condition may not directly affect the concrete or masonry structure although to some extent a considerable fluctuation is not an ideal situation and should be avoided. However, in an embung such those with earth fill type of embankment, it should have an upstream zone with permeability sufficient to dissipate pore water pressures exerted outwardly in the upstream part of the dam (USBR, 1987).

The spread of bushes and other undesirable vegetation on top of the embankment are often ignored by the Operation and Maintenance (O&M) personnel. Figure 5 shows an example of bad maintenance where the unwanted vegetations cover the crest and downstream slope of the embung. Many think that vegetative cover on the downstream slope of embankment can afford sufficient protection from the erosion caused by wind and rainfall runoff. Although there is a good example of using native grasses that have protected the downstream slope of a dam for decades, careful consideration must be taken into account when applying vegetative cover (USBR, 1987). The growth level of grass should be maintained, where fertilizer and uniform sprinkling of the seeded areas are regularly necessary. Most embung cannot provide sufficient water along the year so that in one way or another, this activity is not very simple to carry out and probably costly.

Figure 5. Undesirable vegetations cover the top and downstream slope of embung
(Courtesy of BWS NT I)

The existence of unwanted vegetation such as trees can displace the rock cover or riprap, forming a gap in between and the rock become more expose and less easier to move downward. Where the cost is not prohibitive, in arid regions such as in the southern part of Lombok protection by cobbles or rock is preferred than vegetative cover and should be used to provide sufficient protection.

In many cases, illegal activities such as the collection of timber from nearby forest involving frequent movement of heavy vehicles and a large group of cattle, e.g buffalo, along the embung crest also contribute to the deformation and consolidation of the embankment. The existence of deformation and internal cracking leads to the settlement of embankment (see Figure 6). Settlement means loss of freeboard and the possibility of overtopping increases. Overtopping mechanism is of particular concern as this mechanism couple with internal erosion, being responsible for 60-70 % of serious incidents and failures of the embankment (Novak et al, 1996).

Figure 6. A noticeable settlement of embankment exists around the intake gate
(Courtesy of BWS NT I)

Except during wet season, embung experiences low water level most of the time. This means the O&M personnel have the opportunity to carefully inspect the upstream side for irregularities such as blockage of the intake, cracking in the upstream area, seepage holes, disintegrated embankment or eroded materials, and sedimentation etc.

Figure 7. Seepage with mud flow accelerates mass failure (Courtesy of BWS NT I)

Seepage and leakage are also the common problem found in embung construction. Seepage occurs in an embankment (see Figure 7) whereas leakage occurs in masonry structure such as spillway (Figure 8). Seepage within embankment is particularly important to observe. Brown colour indicates that flow contain mud or embankment material. Continuous occurrence will result in mass failure.

Figure 8. Leakage underneath spillway crest (Courtesy of BWS NT I)

There are conditions where seepages and leakages take place at joint such those along the conduit and other types of outlet works (Figure 9) and between embankment and the wing wall of spillway (Figures 10 and 11). Continuous section of conduit is

prone to cracking although the longitudinal reinforcement continuous through the conduit is already applied.

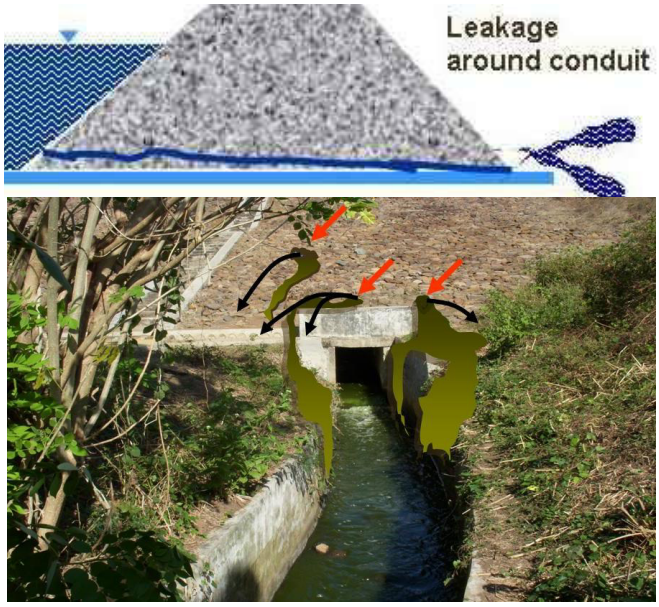

Figure 9. Seepage and leakage around the outlet structure (Courtesy of BWS NT I)

In embung case, leakage between embankment and masonry or concrete structure is normally occurs as a result of different settlement and the existence of other factor such as earthquake. Therefore, sufficient flexibility should be considered to tolerate small settlement as well as the amount of steel reinforcing which should meet the generally accepted requirement.

Figure 10. Leakage between embankment and spillway (Courtesy of BWS NT I)

Figure 11. Leakage at the vertical wing wall of stilling basin (Courtesy of BWS NT I)

Other problem face by embung is the decrease in the level of service such as damages to the spillway crest (Figure 12), malfunction of outlet work due to improper installation of valve (Figure 13) and disintegration of concrete (Figure 14).

Figure 12. Damages to the spillway crest (Courtesy of BWS NT I)

Figure 13. Improper installation of outlet valve (Courtesy of BWS NT I)

Figure 14. Disintegration of concrete at stilling basin (Courtesy of BWS NT I)

The construction of embung often found to be different than the original design. This inconsistency caused by the temptation to increase the capacity and the level of service. The easiest way is to raise the embankment without due consideration such as the relation of the resulting increased pressures to the limitations of the initial design. In the case of *embung rakyat*, such action may not have dangerous consequences but for a bigger construction of *embung desa* and *embung pemerintah*, structural modification should be made with approval of a qualified engineer, preferably the designer (USBR, 1987). Figure 15 shows an attempt to raise the height of embankment that leads to the failure of embung.

Figure 15.Additional height with different materials (Courtesy of BWS NT I)

Like any other reservoir, sedimentation is also threatening most embungs in Lombok Island. Rapid changes in land use within the catchment area and deforestation increase the soil loss and contribute to the high sediment transport rate into the ponding area. However, the nature of embung with low water level or empty condition for quite long period allow individual and O&M personnel to carry out sediment dredging works and relocate them to the outside part of embung.

3.3. Operation and Maintenance Works of Embung

There is no specific guidance or written instruction in the operation and maintenance of *embung rakyat*. The system is based on the daily habit inherited from older generation. In dealing with overflow, for instance, the owner dives into the water to open the intake by pulling a cut of banana tree from perforated palm tree to decrease the level of water. In the case that the inflow intensified and rapid filling are expected, intake opening may insufficient to reduce the water level. In such circumstances the owner cuts and digs the embankment at one side to certain level until it is safe from overtopping (Marsudi et al, 2005). The owner also has a task in dealing with cattle passing through the embankment as the structure is relatively weak to carry such heavy load. This type of maintenance prevents the embankment from sliding and further erosion.

The maintenance works of *embung desa* is relatively similar to those of *embung rakyat*. However, routine inspection to the potential blockage of intake by garbage from the surrounding area should be carried out. The operation of intake is easier by lifting the gate or turning the valve to the intended level. An individual or a team appointed by villagers or Head of the village is responsible for daily operation of *embung desa*. Person in charge may keep a logbook containing information, such as releases and all significant action related to the operation and maintenance of embung.

Regular inspection is particularly important in the operation and maintenance of *embung pemerintah* both masonry or concrete and embankment type. This should be performed in accordance with specific written instructions and procedures referred to as Standard Operating Procedures (SOP) which have been prepared for that particular embung. The personnel responsible for the operation and maintenance of *embung pemerintah* should be trained to adequate level before carry out an independent operation of an embung. Routine maintenance and inspection of an *embung pemerintah* and its ancillary structures should be an ongoing process where all unusual conditions that may adversely affect the operation, maintenance or safety of the embung should be reported promptly using predetermined written procedures.

The effectiveness of O&M works very much depends on many factors such as the quality of existing structure, the ability and skills of the embung operator, the sense of belonging and responsibility of community in the surrounding area, etc. Although there are Standard Operating Procedures (SOP) available for daily operation and maintenance of *embung pemerintah* in particular, non-technical aspect is always an important issue. In Lombok case, the number of embung is highly considerable and therefore need a huge sum of money to guarantee an adequate operation and maintenance cost. Government may not responsible for the operation and maintenance of *embung rakyat* as it is self-operated and self-maintained by the owner. Partly funded situation may be applied to the operation and maintenance of *embung desa* but government should encourage local community in the village to carry those activities by themselves without government's support. Most of the available budget should therefore be allocated to the operation and maintenance of *embung pemerintah*. In practise, there is a limit to what government can do and prioritise should be arranged. Depending on the budget,

operation and maintenance works for *embung pemerintah* may have to be split into stages in the form of very urgent, urgent and less urgent activities. The routine inspections of embung are particularly important to allow the finding of early state of damages so that further and costly damages are avoidable.

In the operation and maintenance of embung the O & M personnel also equipped with the knowledge on the so called 3-pillar of safety to ensure the ability of embung to store water safely. The 3-pillar of safety includes the following three aspects:

1. Embung should be in a safe condition both structurally and operationally
2. Embung should be monitored, maintain and operate in the right manner
3. Embung should have Emergency Preparedness Plan (EPP)

The first and the second pillars include rehabilitation works if necessary. The EPP should be developed to avoid the failure of embung which endanger human life and cause substantial damage to the property. Upon completion, EPP should be discussed with all related parties including embung operator, leader or representative of local community and other government institution dealing with disaster handling management. The EPP should include warning systems or procedures to increase the awareness of local official and community of the hazard potential in their area.

4. Conclusion

The long period of existence of embung in Lombok Island has been very pivotal in the improvement of the community's welfare as the agriculture is the prime sector where Lombok people are rely upon. The spread of *embung rakyat* and *embung desa* is also a reflection of spirit of those who particularly live in the critical area to improve the quality of their life.

Government involvement through rehabilitation and structure upgrading programme of *embung desa* and the establishment of new modern and bigger structure of *embung pemerintah* increase both the benefit of embung and the dependency of people to it.

Particular attention must be addressed to the post-construction problems as the budget for operation and maintenance of the structure is limited. Routine inspection should be carried out to allow damages and improper use of the structure to be spotted as early as possible before further and costly damages take place.

The personnel responsible for operation and maintenance of embung should have knowledge on the 3-pillar of safety. Emergency Preparedness Plan (EPP) should also be discussed and disseminated to all related parties to increase the awareness of hazard potential in the case of embung's failure.

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