THE INTEGRATION OF CLIMATE CHANGES ADAPTATION AND MITIGATION IN SUSTAINABILITY CONCEPT

S.P.R. Wardani [1),2)], Bagus Hario Setiadji [1),2)],, Harsono Wuryanto [1)]
Muhammad Zaki [2)]

Abstract

Climate change is definite and it is difficult to be avoid, however, its impacts can be reduced with proper mitigation and adaptation. At this moment in Indonesia, there are many inverse impacts as a result of climate change, unfortunately, only less attention was received to mitigate the amount of GHGs and to develop adaptation activities to reduce the impact of climate change. The adaptation performed so far usually only to address the hazards occurred, with the goals to minimize losses as well as victims that may arise. In this paper, the existing condition as a result of the impact of climate change is presented and some adaptation activities to reduce the impact are proposed. It is expected that the implementation of adaptation activities proposed together with the implementation of better mitigation can create efforts to sustainably address climate change.

Keywords: climate change, mitigation, adaptation

INTRODUCTION

Asia occupies a wide area on the globe with different geological, geographical and climate conditions, which highly affect geo-disasters that have occurred and will potentially occur in the future. Moreover, global warming, that is mostly contributed by certain human activities (National Research Council, 2010), is currently happening and together with other factors, such as biotic processes, variations in solar radiation received by earth, plate tectonics, and volcanic eruptions, could be the main causes of extreme weather and climate change, although the latter needs to be observed for a long period and extreme weather is a rare occurrence that cannot be used as evidence of the impact of climate change (Latif and Wiegandt, 2007).

Global warming and climate change make sea level rises, and have engendered rising water level in coastal regions. The increasing frequency of strong typhoons, heavy rainfall, and floods hazards are effected by climate change. These heavy rainfall, high river flow velocity, and wind-driven waves as well as strong water current are the main causes of disasters, such as coastal and riverbank erosions, landslides, and liquefaction and all of them lead to huge losses of human lives and property, besides the destruction of roads, bridges and other infrastructure (Kokusho, 2005).

Indonesia has more than 245 million people located in the World's largest archipelago on the "Ring of Fire" that is at risk from earthquakes, tsunamis, volcanoes, and landslides. Most islands in Indonesia forms part of an active volcanic mountain chain. The geotectonic activities in terrain consisted of extremely complex morphostructural units within an uplifted sedimentary and frequently active volcanic mountain system. Weathered soils are commonly found in Indonesia as a result of the volcano activities. The soils predominantly consisted of clayey and sandy mixtures

[1)] Indonesian Road Development Association of Central Java Province
[2)] Faculty of Engineering Diponegoro University, Indonesia

(S.P.R. Wardani and A.S. Muntohar, 2013). Lately, tsunami, earthquakes, floods, landslides, volcano eruptions, and other disasters have occurred in many countries, including Indonesia. After the Aceh tsunami tragedy in 2004; earthquake in Yogyakarta and Padang (West Sumatera) in 2006 and 2009, respectively; flooding in Wasior (West Papua), tsunami at Mentawai Island (West Sumatera Province) and Mount Merapi (Yogyakarta) eruption in 2010, Indonesia is now faced with floods in almost all regions of the Republic of Indonesia, from Jakarta, West Java, Central Java, East Java, Kalimantan, Manado, Makassar, and volcano eruption at Mount Sinabung (North Sumatera and Mount Kelud (East Java) in 2014.

To respond climate change, two kinds of activities are usually considered (Secretary of State of Environment, Food and Rural Affairs, 2011), i.e. mitigation and adaption. In this case, mitigation is actions to limit the magnitude climate change by reducing the possibility causes, while adaption means to anticipate the adverse effects of climate change and to take appropriate action to minimize the damage occurred. Mitigation and adaptation can be executed independently, but the results obtained are not optimal. In order to obtain the optimal results, both activities must go hand in hand to create sustainability concept. Adaptation activities can be first applied to address the impact occurred as a result of the current climate change, and then followed by mitigation activities that can be proposed for future planning in order to minimize the impact of climate change on road infrastructure, those activities, however, can be applied in the same time.

Associated with mitigation of disaster, it is extremely important for predicting extreme events in natural disasters at the future, even though it not so easy to predict them. However, by knowing and understanding the typical of extreme events from past experience before, it will be more helpful in the preparation and predicting impending disaster for minimizing the risks that might occur.

In this paper, the existing condition of road infrastructures that is damage due to extreme weather and its corresponding impact was presented. To support this facts, a trend of extreme weather that occurred within 10 years ago along with the problems that then arise on the road infrastructure due to the weather were also provided. And at the end, several mitigation and adaptation that have been already applied or will be proposed were stated. To provide a better understanding, infrastructures in several sites in Central Java Province, Indonesia, used as case studies.

EXISTING CONDITION

Global warming, the cause of extreme weather makes the air temperature and rainfall increasing and it impacts on civil engineering infrastructure, including the road infrastructure. Water is one of main factors that contribute in the damage of road infrastructure. In theory, the road surface constructed with appropriate planning and implementation, as well as material that meets the requirements should be water-resistant. The water or rain drops that fall on the surface of the road should not penetrate the surface of the road and will immediately be discharged into the side ditch/drainage channel. This happens because the road surface is generally made with a certain transverse slope (or super-elevation), which is normal slope 2% on the straight path and a higher slope of 2% on the curve. This concept has to be fulfilled, otherwise, water can slowly penetrate into the pores of the asphalt mixture, and the pore water pressure could damage the adhesion bond between asphalt and aggregate or the cohesion bond of asphalt materials.

At this moment, the aforementioned drainage concept in pavement system cannot work well since the drainage system is not possible to accommodate the high rainfall, so that flood was occurred. This has gone on for years, especially years with high average rainfall and number of rainy days. Figure 1 shows the trends of average rainfall and rainy days in Central Java Province in last 10 years.

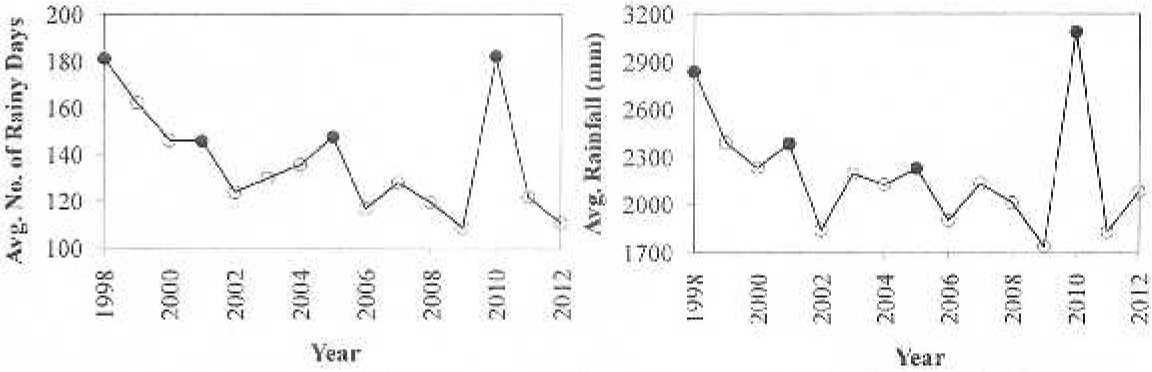

Figure 1. Trends of Average Rainfall and Number of Rainy Days in Central Java Province in Last 10 Years (BPS, 2000; 2005; 2008; 2013)

It appears that there is a pattern of high average rainfall every five years in Figure 1. This finding also was supported by the number of rainy days that showed above average occurred once in every five years, despite the fact that extreme rainfall was not always directly proportional to high number of rainy days. Around the year 1998 and 2010, when the rainfall was prohibitive, some places in Indonesia experienced significant flooding. Similar disaster occurred again in Indonesia in early 2014, especially in Manado (North Sulawesi) and Northern part of Java Island. Some major roads were flooded, so it inhibits the transport activities, as seen in Figure 2. After the flood receded, the damage was very severe as seen in Figure 3 (Bina Marga Jateng, 2014).

Figure 2. Flooded Road along Kudus - Semarang Arterial Road (Bina Marga Jateng, 2014)

Figure 3. Damaged Roads after Flood (Bina Marga Jateng, 2014)

Figure 3 shows that the major damage after flooding on the road is the presence of potholes or road surface stripping. The potholes occurred generally begins in the form of small ones or cracks. The occurrence of potholes in the road surface due to the loss of aggregate during flooding, or transported at the time of the vehicle wheels running through.

Through the cracks on the road surface, the water will infiltrate pavement structure, and slowly diminish the adherence between asphalt and aggregate. If water is found under surface layer, it could weaken the carrying capacity of the foundation layer and leading to other distresses such as depression, rutting, and so forth.

Another hazard that may occur in the presence of high rainfall is the landslide. It is often occur especially at mountainous terrain and marginally unstable slope with the absence of slope stabilization efforts, such as providing horizontal drain, structural wells, piles or reinforced ground, and so on. Landslide is very highly hazardous, especially if there is road infrastructure over the terrain as it inflicts many casualties and potential economic loss due to traffic disturbances. Figure 4 depicts the landslides at several sites in Central Java Province (Bina Marga Jateng, 2014).

Figure 4. Landslides at Several Sites in Central Java Province (Bina Marga Jateng, 2014)

Aside from water, the air temperature can also affect the pavement structure. The impact of temperature changes on the road was on the quality of road materials, especially asphalt which is inherently temperature-dependent. The temperature increase in the air and pavement surface causes the asphalt material to be easily softened, so its stiffness could be decreased. High temperature changes can also affect concrete pavement, where it can cause warping phenomena or excessive expansion and will damage the joint or destroy the slab. This in turn will impact on the performance of asphalt mixture in the weight-bearing. Figure 5 shows the trend of average air temperature in Central Java Province in last 10 years (BPS, 2000; 2005; 2008; 2013).

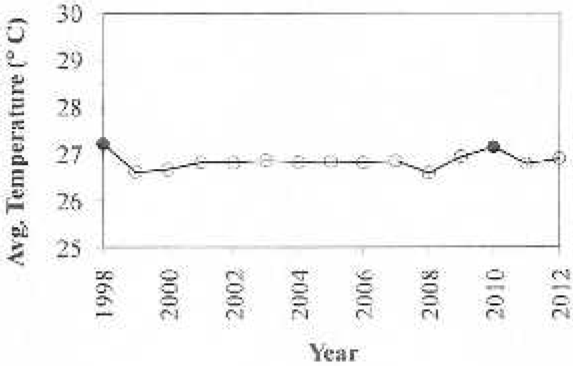

Figure 5. Trend of Average Air Temperature in Central Java Province in Last 10 Years
(BPS, 2000; 2005; 2008; 2013)

As shown in Figure 5, there is only less than 1° C difference in average air temperature in the last 10 years in Central Java Province. It needs more observation more than 10 years to provide evidence that there is temperature rise in Central Java Province. It could be observed from the figure that higher relative temperatures occurred in 1998 and 2010, where flood occurred in several cities in Indonesia in those years. This may be analyzed that the high number of rainy days in both years indicates the length of the heat trapped in between the earth's surface and clouds, thus causing an increase in heat in the air. Based on statistical data of year 1998 - 2012, when viewed spatially, more pronounced temperature changes actually more visible in cities having large population, because in these cities there are high concentrations of human activities in producing green-house gases (GHG), which is one of the major contributors to global warming.

CAUSES OF DAMAGED ROAD INFRASTRUCTURE

Changes in the nature of weather, such as temperature and rainfall, was more or less contributed by human behavior, resulting in global warming caused by green-house gases (GHG). Global warming is likely to have an impact on the increase in rainfall (Latif and Wiegandt, 2007). The water content in the air is dependent upon the temperature and the temperature regulates how much water can evaporate. The water is released when it rains and back to the ground. The higher the temperature, the more water evaporates and the greater the potential for heavy rain

However, associated with the flood, at this time there has been a long debate about what exactly is the cause of flooding. Whatever it is, flooding may not occur because only one factor. The first cause of flooding is the excessive development, such as felling trees, city expansion and changes in the landscape. This will reduce and eliminate water buffer zone. This has been lasted for years and its consequences have been realized by many parties, but no or little effort to evaluate and make improvements.

The second one is the case that the drainage system is not sufficient. Road drainage systems that exist today are generally designed with simply following the applicable general rules and there is no attempt to evaluate the adequacy of drainage system installed against the existing and future rainfall. The availability of road drainage system (transverse slope, side ditch, catch drain, culverts) is often considered as accessories of a highway system. However, the provision of drainage systems is sometimes sub-standard, such as roads without transverse slope, wrong cross slope direction, no culverts, presence of grass on road shoulder and so on) so that when the rainy season arrives, the road drainage system that should serves to protect the roads becomes unable to work properly. In addition, the habits of the people throw the trash anywhere which in turn, it can eventually clog the channel reduce the capacity of the drainage system in the drain water.

Another cause is the high rainfall. When the rains fall for a long period, the water causes the soil becomes saturated and cannot longer absorb water. In the meantime, if there is not any buffer zone, the water will flow toward channels and river and make them to overflow quickly. Indeed, some flooding roads are located on the basin, for instance Kudus and Pati and their surroundings, so that the region has always been flooded. However, it still needs to be addressed so that the flood events could be minimized. On the other hand, land subsidence at some locations, especially locations with dense human activity in Northern part of Java Island. and in conjunction with an increase in sea level making the effort to tackle flooding cannot be optimal.

MITIGATION AND ADAPTATION

Climate change mitigation generally is performed by reducing in emissions of greenhouse gases (GHGs) and all activities which generate GHGs. Global Environment Facility (GEF) (2013) stated that climate change mitigation has six objectives as follows:

1. Promote the demonstration, deployment, and transfer of innovative low-carbon technologies.
2. Promote market transformation for energy efficiency in industry and the building sector.
3. Promote investment in renewable energy technologies.
4. Promote energy efficient, low-carbon transport and urban systems.
5. Promote conservation enhancement of carbon stocks through sustainable management of land use, land-use change, and forestry.
6. Support enabling activities and capacity building.

All of the objectives above are proposed by GEF to assist developing countries in transition to move towards a low carbon development path. The government is responsible for ensuring that all the objectives can be fulfilled.

The Directorate General of Highways has also set up the policy of prioritizing the preservation of national road so that it remains functional, improving and developing roads at border areas and remote islands, as well as prioritizing activities related to global climate change, that is in line with the National Action Plan for adaptation to climate change mitigation (Djoko Murjanto, 2011). In the same time, a resilient infrastructure has to be realized to make sure that it can minimize the impact occurred as a result of climate change. Secretary of State of Environment, Food and Rural Affairs (2011) conveyed that new infrastructure can be climate resilient by ensuring that an asset is located, designed, built and operated with the current and future climate in mind, while existing infrastructure can be climate resilient by ensuring that maintenance regimes incorporate resilience to the impacts of climate change over an asset's lifetime.

To achieve this, possible adaptation measures include:

1. Ensuring infrastructure is resilient to potential increases in extreme weather events such as storms, floods and heatwaves as well as extreme cold weather.
2. Ensuring investment decisions take account of changing patterns of consumer demand as a result of climate change.
3. Building in flexibility so infrastructure assets can be modified in the future without incurring excessive cost.
4. Ensuring that infrastructure organisations and professionals have the right skills and capacity to implement adaptation measures.

Technically, some adaptation has been made to address the impact caused by climate change (flood and so on), and some others still discourses. There is an adaptation that needs an immediate action, such as repair damaged road (see Figure 6; Bina Marga Jateng, 2014), although the results often do not last for a long time. This process does not make the infrastructure resilient since it is performed without any adequate technical plan and it is for short-term solution only.

Some other adaptation processes could be alternatives to be implemented, such as re-design drainage system (to improve the effectiveness of surface water drainage), pavement preservation and protection on soils and unbound materials. The last two alternative adaptation actions are more to improve the resilience of pavement materials against water. The details of the adaptations are described as follows.

(a) Damaged Road (b) Repair in Progress

(c) Road after Repaired

Figure 6. Repairs on Damage Road (Bina Marga Jateng, 2013)

Re-design Drainage System

When it seems that the drainage system available is no longer able to play a role in overcoming the flooding problems, it is necessary to be considered to re-design the drainage system. One of good examples is what is planned in Semarang (Central Java Province).

Semarang has similar characteristics with those of other cities at Northern Corridor of Java Island, i.e. the soil is composed of young alluvial layers with high compressibility so that the consolidation process still on-going and it triggers land subsidence, flood, tidal inundation, and coastal abrasion and erosion. The presence of land subsidence and tidal inundation causes surface water from high rainfall is difficult to be flowed into the sea through the existing urban drainage system. The solution offered, it can be seen in Figures 7 (Ikateksi Undip, 2013) and Figure 8 (Bappeda Semarang, 2007) are to construct belt channel which functions to collect surface runoff from the upstream (zone 1) and discharged directly to the sea through the floodway, so that it will not burden the drainage system in the lower parts of the city (zone 2).

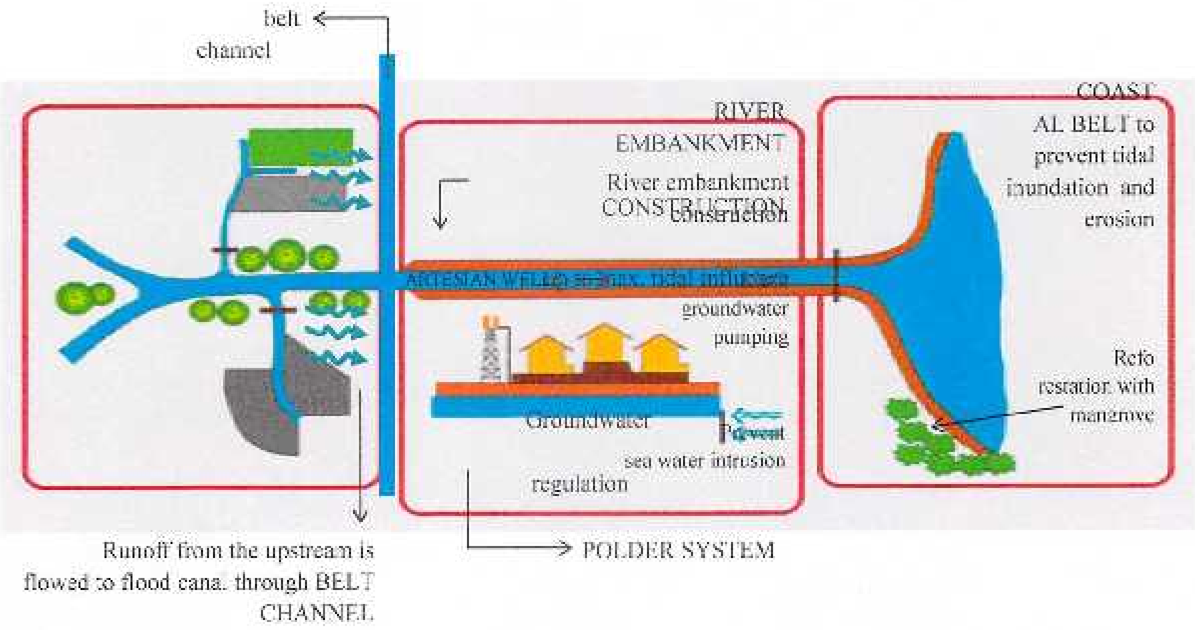

Figure 7. Concept of Coastal Belt and Belt Channel (Ikateksi Undip, 2013)

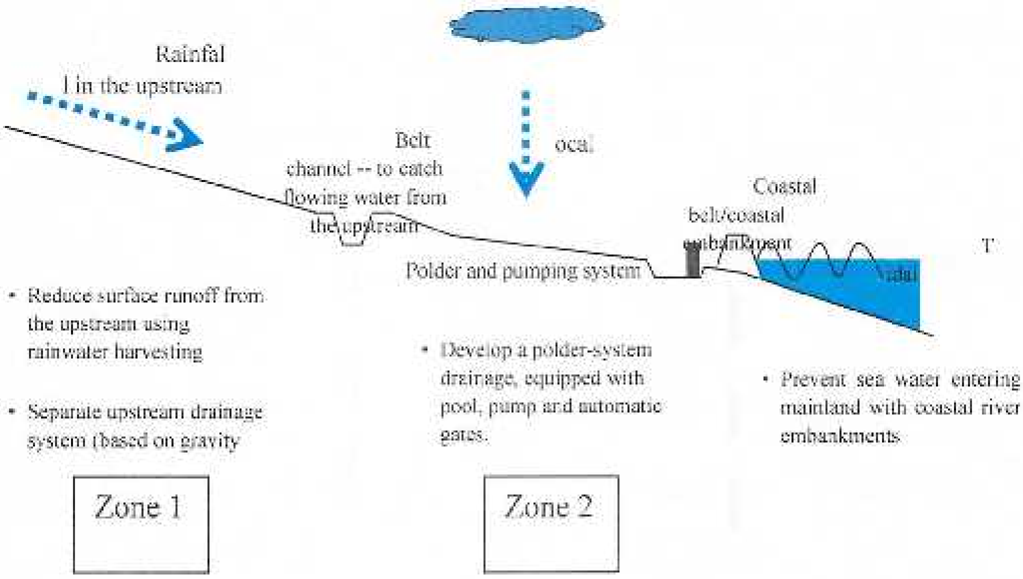

Figure 8. Concept of Drainage System in Semarang (Bappeda Semarang, 2007).

The Coastal Belt is connected to the river dyke that is extended upstream until the tip of the tidal influence. Therefore the tidal water cannot enter the lower area (Zone 2). This embankment is built with such a height that can anticipate the influence of tides. While the surface runoff from local rainfall at zone 2 is keep being collected in polder system and then pumped to the sea. To prevent the intrusion of sea water into the land (especially at the time of the tides), a coastal belt or coastal embankment is constructed along the coastal line. In addition, the coastal belt is also able to be used for another function, such as toll road (Ikateksi Undip, 2013). Figure 9 depicts the layout of proposed drainage system in Semarang.

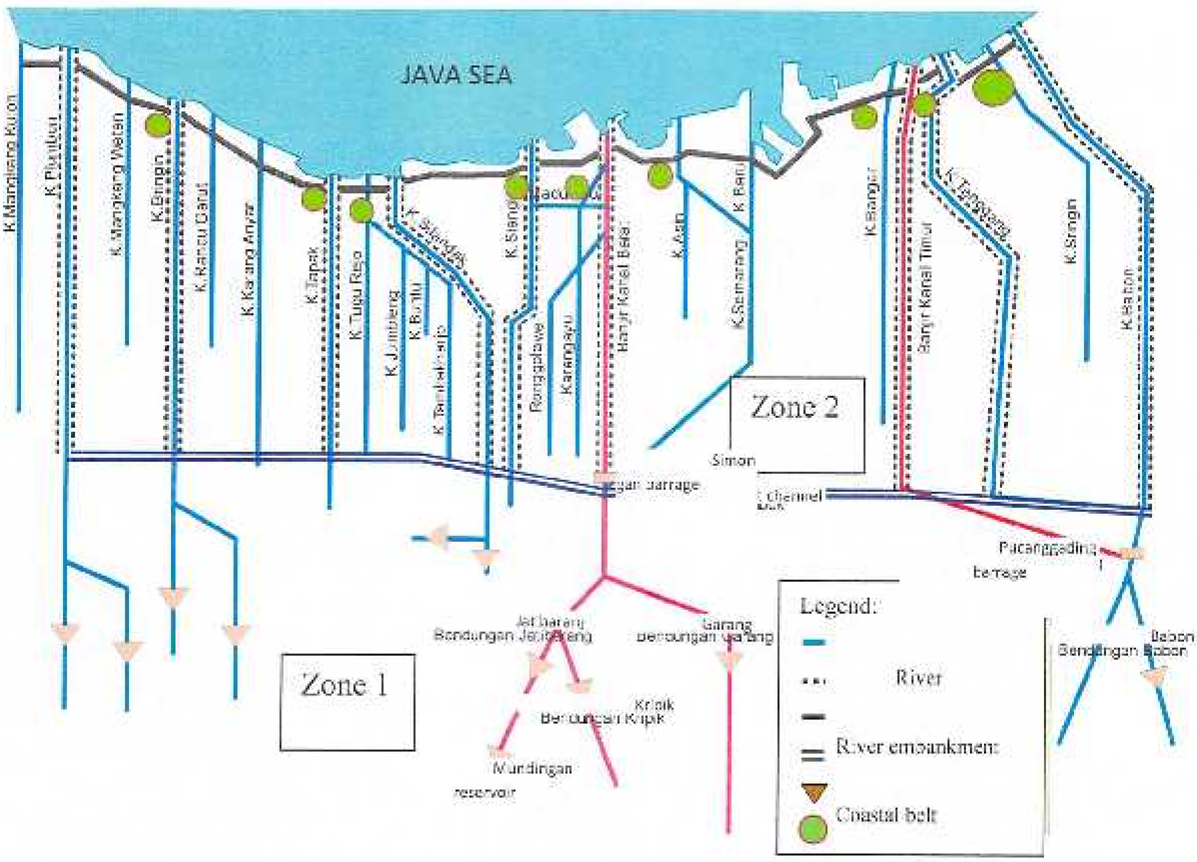

Figure 9. Layout of Proposed Drainage System in Semarang (Bappeda Semarang, 2007)

Pavement Preservation

Pavement preservation is a proactive approach to maintain the pavement remains in good condition by performing preventive maintenance on the parts that were preliminary damage, to avoid any further damage which will require more expensive maintenance. Pavement preservation is carried out immediately after preliminary/minor damage is observed on the pavement. This helps the effort to make the road surface in order to always be in an impermeable condition, so that if there is inundation water, the road may have resistance to not to be damaged.

Besides to maintain pavement surfaces remain in good condition and watertight, pavement preservation should also involve any activities that keep the drainage system in functioning condition (such as eliminating grass on the shoulder and waste in the side ditch). Therefore, the implementation of road preservation should be done by contractors who are bound by performance-based contract (PBC) in order to ensure that it can run better and more sustain.

Protection on Soils and Unbound Materials

Generally, pavement structures are designed to be impermeable to water that comes from above (rainwater), so that it can protect the material below the pavement surface (unbound materials and soil). However, the pavement structure is very vulnerable to weakening by water coming from the side (of the damaged drainage channels) or from below (high groundwater). Moreover, in the event of flooding, the water pooled on the surface will infiltrate into the subsurface through road damage (cracks/potholes) and/or the shoulder of the road, so that it could weaken the bearing capacity of the foundation layer to withstand against traffic loads.

To overcome this, the interface between the layers could be covered with materials such as geo-membrane or water-repellent materials. Geo-membrane material is costly when used in large quantities, although it provides almost lifetime protection against water infiltration. Another material, called water-repellent material, for example Terrasil (Zydex, 2010) began more popular as an alternative of geo-membrane. Terrasil is a liquid chemical substance containing various substances such as Organo Silane. This modifier material enables to bind silica in the soil, thus forming a kind of nano-membrane that cannot be penetrated by water. The use of Terrasil could reduce the permeability of the soil from 10^{-5} cm/s to 10^{-7} cm/s. In addition to being a material that can reduce the influence of water, Terrasil also can reduce the loss of soil bearing capacity due to wet soil (Zydex, 2010). Figure 10 shows the application of Terrasil to the soil. In Figure 10 (a), the channel without application of Terrasil was filled by water. In a short time, water in the channel will seep into the walls of the channel, so that the water in the channel will dry up since all water infiltrate into the soil through the walls of the channel. Different finding is shown in Figure 10 (b) which the soil kept being dry after several hours. This is occurred after the walls of the channel were sprayed by a solution composed of Terrasil and water (the ratio of Terrasil to water is 1:400).

(a) Soils without Terrasil (b) Soils with Terrasil

Figure 10. Application of Terrasil as Water-repellent (Wasis et al., 2012)

To protect the soil from water infiltrating from the surface due to flooding, it is necessary to wrap around the pavement layers with Terrasil solution. Illustration of this process can be seen in Figure 11. To obtain the best protection, the following procedure can be performed: (i) compact the soil until 95% of density at optimum water content; (ii) apply/spray Terrasil

Solution by 2 cycles. The first application of Terrasil solution makes 90% - 95% of soil surface be impermeable. While the second one will make 100% of the surface soil becomes impermeable, including micro cracks, (iii) allow for a minimum of 24-hour curing time, before the next layer can be overlaid.

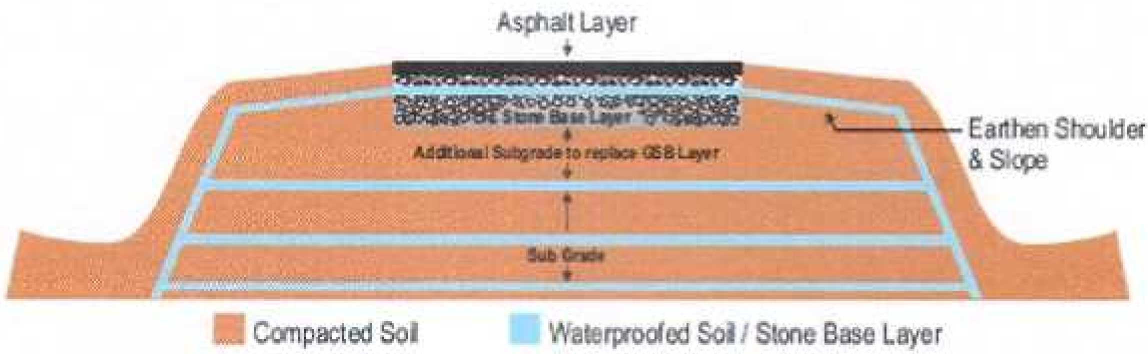

Figure 11. Schematic of the Application of Terrasil on Unbound Materials of Road Structure
(Zydex, 2010)

In addition to adaptation, it would be valuable to have more information about the regional affects of climate change, mapped against the location of critical infrastructure assets. Location of future flood risk and other climate change-related hazard is of critical importance (The Royal Academy of Engineering, 2011).

CONCLUDING REMARKS

Climate change may contribute many disasters, such as flooding, landslides and so on, in Indonesia and caused hazards on many infrastructures, includes roads. The damage occurred then caused many losses and casualties, however, the immediate action taken as a representation of adaptation activities, generally was not technically sound. In this paper, as parts of varied possible adaption, three approaches were proposed: re-design drainage system to prevent flooding at lower area using belt system (coastal belt and belt channel), pavement preservation in order to keep the pavement surface impermeable, and using water-repellent materials to withstand the soil and unbound materials under-layer against water.

REFERENCES

Bappeda Semarang (Semarang Regional Planning and Development Board). 2007. *Master Plan Sistem Drainage Kota Semarang.*

Bina Marga Jateng (Highway Offices of Central Java Province, Directorate General of Highways, Ministry of Public Works of the Republic of Indonesia). 2014. *The Photos documentation.*

Djoko Murjanto.2011. *Disaster Risk Management.* Proceeding of the 3 rd International Conference on Geotechnical Engineering for Disaster Mitigation and Rehabilitation 2011 combined with 5th International Conference on Geotechnical and Highway Engineering-Practical Aplications, Challenges and Oportunities. S.P.R. Wardani, J. Chu, S.C. Robert Lo, S. Iai, K.K. Phon Editors. World Scientific Publishing Co.Pte.Ltd.. ISBN-13 978-981-4365-15-4, ISBN-10 981-4365-15-7.

Global Environment Facilities. 2013. Climate Change Mitigation Strategy, www.thegef.org/gef/CC_mitigation_strategy, access on 22 February 2014.

Ikateksi Undip (Civil Engineering Alumni Association, Diponegoro University). 2013. *Sabuk Pantai Multifungsi di Kota Semarang.*

Kokusho, T. 2005. *Extreme events in Geohazards in Asia.*Proceeding of the International Conference on Geotechnical Engineering for Disaster Mitigation and Rehabilitation, Singapore World Scientific Publishing Co.Pte.Ltd. ISBN 981-256-469-1.

Latif, M. and Wiegandt, K. 2007. *Climate Change: The Point of No Return*, Haus Publishing Ltd., London.

National Research Council .2010. *Advancing the Science of Climate Change.* Washington, D.C.: The National Academies Press. ISBN 0-309-14588-0.

Secretary of State of Environment, Food and Rural Affairs. 2011. *Climate Resilient Infrastructure: Preparing for a Changing Climate.* London, UK.

BPS (Indonesian Central Statistics Agency). 2000. *Central Java Province in Numbers*, Semarang.

BPS (Indonesian Central Statistics Agency). 2005. *Central Java Province in Numbers*, Semarang.

BPS (Indonesian Central Statistics Agency). 2008. *Central Java Province in Numbers*, Semarang.

BPS (Indonesian Central Statistics Agency). 2013. *Central Java Province in Numbers*, Semarang.

The Royal Academy of Engineering. 2011. *Infrastructure, Engineering and Climate Change Adaptation – ensuring services in an uncertain future*, London, UK.

Wardani, S.P.R. and Muntohar A.S. 2013. *Lessons Learned from the Recent Natural Disasters in Indonesia.* Geotechnical, Geological and Earthquake Engineering, Geotechnical Prediction and Practice in Dealing With Geohazards, Springer Dordrecht Heidelbrg New York London. Jian Chu, Sri P.R. Wardani, Atsushi Iizuka Editors. ISSN 1573-6059, ISBN 978-94-007-5674-8, ISBN 978-94-007-5675-5 (e Book), DOI 10.1007/978-94-007-5675-5.

Wasis, H.F.H., Utami, H.S., Setiadji, B.H. and Purwanto, D. 2012. *The use of Terrasil for Soil Improvement*, Proceedings of the 15th FSTPT Symposium, Bekasi, Indonesia. (in Bahasa Indonesia)

Zydex. 2010. *Terrasil Brochure,* Zydex, India.