International Journal of Technical Research and Applications e-ISSN: 2320-8163,
www.ijtra.com Volume 7, Issue 1 (JANUARY-FEBRUARY 2019), PP. 37-42

ENVIRONMENTAL PROBLEMS RELATED TO POOR STORM WATER CONTROL ON THE UNPLANNED HILLSIDE BUILT ENVIRONMENT OF BOTSWANA
- IN THE CASE OF PELENG, LOBATSE -

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***Abstract*— Hillside built environment of Peleng faces a great challenge in channeling storm water in the right paths so as to prevent it from damaging resident's properties and ruining the environment. Peleng has suffered and continue to suffer from poor storm water control evident by reports on soil erosion, landslides and damaged buildings by floods. The paper then analyzed the link between poor storm water control and these environment problems and proposed mitigation.**

***Index Terms*—Poor Storm Water Control, Environmental problems, Hillside, Regulations, Built Environment**

I. INTRODUCTION

Sloping land is a form of catalyst for storm water runoffs on the hillside built environment. That being the case it is pertinent to have a good storm water control in the sloping land. Good storm water control can be attained by good planning before commencement of residential construction. Since Peleng is a squatter settlement none of these planning was done before residents found refuge in this neighborhood. Where prior planning is exercised storm water drains are normally constructed along the sides of the roads or underneath. However in Peleng the government tried to later construct storm water drains, but due to narrow roads and houses being closer to the roads the efforts were only futile. The attempt left the area with narrow storm water drains in some places, and absolutely no storm water drains in other areas. Another attempt by the government was construction of a water retaining wall above the built up area, but the problem still persist. That being the case the consequences of poor storm water control such as soil erosion, landslides and damaged buildings by floods still persist but mitigation is pending. The paper then discuss and analyses this problems to prove that poor storm water control exacerbate the problems caused by floods from storm water. The study shall also propose a mitigation in the form of standards or guidelines to be followed in order to minimize the impacts related to poor storm water drainage.

II. LITERATURE REVIEW

In India to protect the environment in hill towns various regulations related to cutting of slopes, tree preservation, drainage pattern, protection against landslides and earthquakes, rain water harvesting, preservation of natural features and elements and top soil protection and erosion control are enforced in different hill towns (Kumar and Pushplata, 2013). Kalabamu, et al (2016) did a study on Lobatse and produced Lobatse town profile covering numerous issues concerning Lobatse. Among the issues discussed was poor implementation of development standards and lack of funding and how it has resulted in the continued experience of poor storm water drainage which ultimately leads to flooding, particularly in low income areas like Peleng. The study also discovered that some of the access had no provision for drainage which implied that either (i) there is poor application of standards, or (ii) or neglect of storm water management in low income areas, Kalabamu, et al (2016). The study was broad, it did not address hillside development or other storm water control systems besides storm water drainage. Another study which discussed the need to improve storm water control in Botswana although without addressing hillside developments nor Peleng specifically, was in Gwebu (2003) where the study analyzed the Environmental problems among low income urban residents of Old Naledi neighborhood in Gaborone, Botswana. The study discussed the importance of supplying the community with storm water drainage among other basic infrastructure and mentioned that lack of this facilities have instilled a negative feeling in the residents' towards the quality of their houses.

Fig.1. Area surveyed showing roads, plot boundaries and footprints of units per each plot

I. BACKGROUND/HISTORY

The problem caused by storm water runoffs have long persisted in Peleng, and it is evident by the efforts of Lobatse Town Council in trying to minimize the flow of water into residents plots by erecting about 400mm dwarf wall just above the last plots on top of the habited hill area. The purpose of the wall was to block storm water from entering residents' plots and channeling it to unhabited areas. Although it was a good initiative, the residents reported that the wall only blocks small amount of storm water and that it is too low hence it does not block other dangers like the rocks which sometimes fall from above due to landslides caused by heavy rains. Fig.2 shows the images of the storm water retaining wall on top of the habited area.

Fig.2. Images showing storm water retaining wall

II. METHODOLOGY AND AIM

The research method used to investigate these problems was through 160 house to house site inspection and inquiry from residents with open and close ended questionnaires. The investigation findings were then categorized as per the 3 slopes categories which were slope 4º & below, slope 5º-9º and slope 10º-13º. Slope 14º & above was not developed hence it is not included. To determine these slopes site coordinates obtained from Botswana department of surveys and mapping were plotted on Revit software to create a model of the hillside. Then Dynamo Visual Programming was used to determine different slope categories. Map with plots and footprints of houses was then superimposed on top of the slope map to identify plots per each slope category and presented as in Fig.1. For the accuracy of these analyses equal number of answered questionnaires per each slope category for poor storm water control, soil erosion, landslide, damaged buildings and knocked down trees were recorded in graphs and the results were tabulated.

The intent of the study then is to discuss the problems associated with poor storm water control as per the residents` reports and to validate that poor access contribute to the problems by analyzing to find the relationship. The study will then propose mitigation through perusal of the existing Botswana building regulations to identify its inadequacies concerning poor storm water control and where it can be improved to make the situation better.

III. PROBLEMS RELATED TO POOR STORM WATER CONTROL ON THE HILLSIDE

Residents of Peleng reported many problems that are caused by uncontrolled storm water runoff. The improper control of storm water runoff can be defined as poor storm water control. Among the problems mentioned by residents is that there is too much storm water runoffs into their plots and that this water comes with waste and stones, accumulates around the house, exposes pipes and rocks, take trees down, removes vegetation and soil, and also damages the buildings. The problems were then categorized and analyzed. Fig.3 shows that poor storm water control situation is worse on slope 5º-9º category.

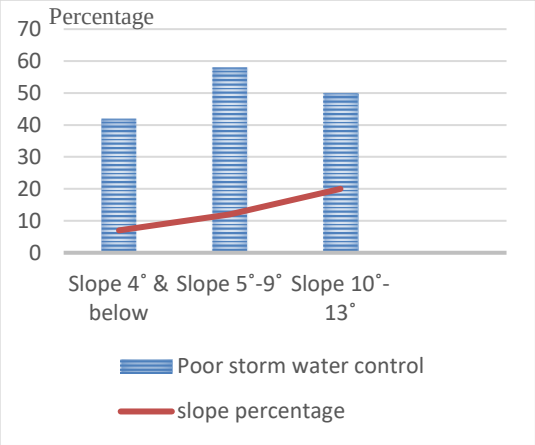

Fig.3. Record of Poor Storm Water Control

TABLE.1. Number and percentage of Poor Storm Water Control problems reported by residents

Types of problem	No. of reports	Percentage
Soil erosion	125	78%
Landslide	14	9 %
Floods damaging building	47	29 %

A. Soil Erosion

Erosion occurs when soil is left exposed to rain or wind energy, raindrops hit exposed soil with great energy and easily dislodge the soil particles from the surface (Pimentel, 2006). In the hillside it`s worse because the loose particles are immediately washed away by flowing water due to gravity. Accelerated soil erosion by water is about 56% and wind erosion is responsible for about 28% (Agyarko et al, 2012). Fig.4 shows that erosion is higher in slope 5º-9º than in slope 10º-13º category. This is because the upper hillside has a retaining wall to minimize the flow of water.

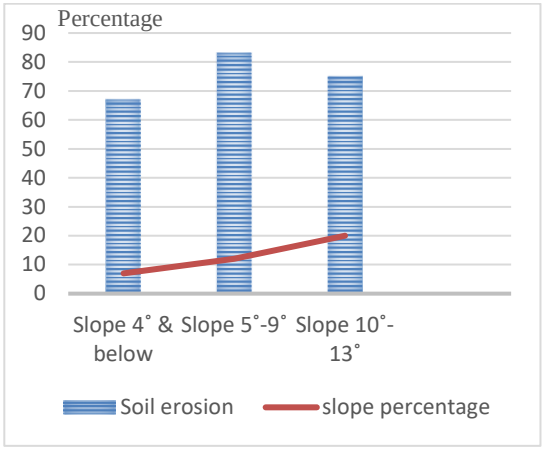

Fig.4. Record of Soil erosion

Fig.5. Images showing effects of soil erosion

B. Landslides

Landslides are not too common in Peleng as it's a rocky hillside but a few were reported by the residents. Majority of the residents reported that the rocks were coming from above the hill and sometimes destroying their houses. Other residents reported that due to landslides their boundary walls collapsed because there are no retaining walls as in Fig.7. Fig.6 indicates that the upper slope experienced more landslides because of its steepness and rocky topography.

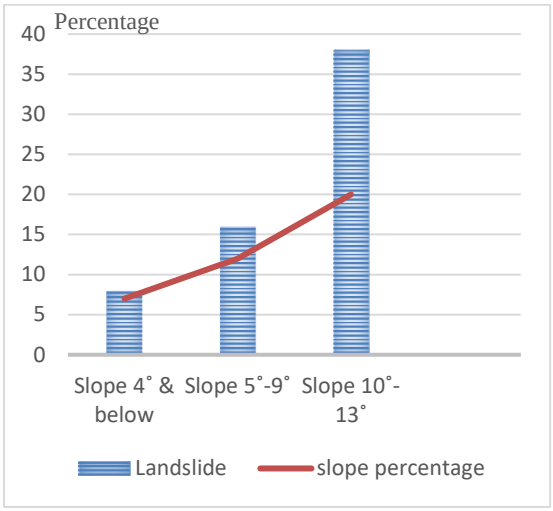

Fig.6. Percentage landslide reports per each slope category

Fig.7. Boundary walls collapsed due to landslides

C. Floods damaging the building

Residents reported that storm water runoffs from the top had exposed the base of their buildings, hence making their building weak and allowing water to enter inside their houses. Fig.8 indicates that floods damaged the building more in slope 5º -9º and slope 4º & below. Slope 10º-13º reported less damage of buildings by floods because there was a retaining wall and most of the foundation were built on top of the rocks.

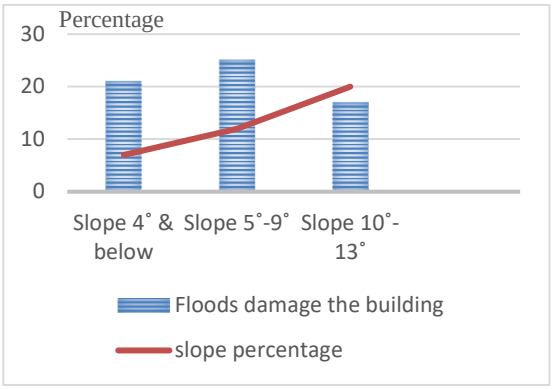

Fig.8. floods damage on buildings reports per each slope category

Fig.9. Images showing buildings damaged by floods

IV. ANALYSIS OF THE RELATIONSHIP BETWEEN POOR STORM WATER CONTROL AND THE HILLSIDE PROBLEMS

A. Relationship between poor storm water control and soil erosion

Analysis from fig.10 suggest that where there was poor storm water control, there was also high record of soil erosion. These is because the poor storm water control line is parallel to the soil erosion line. Slope 10º–13º degrees situation is better because of the water retaining wall that has been placed on the hillside just above this slope category.

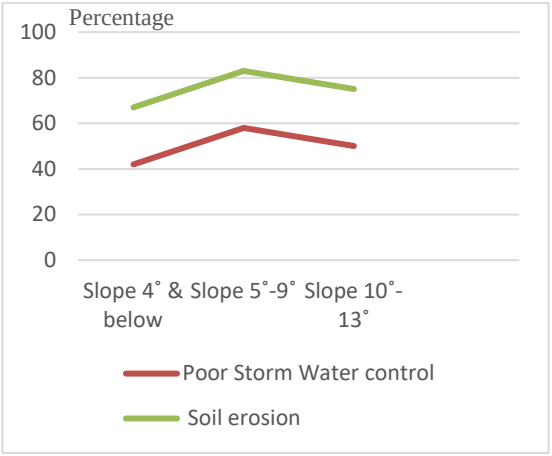

Fig.10. Percentage of Poor storm water control per each slope category in relation to soil erosion

B. Relationship between poor storm water control, and landslides

The analyses from fig.11 indicates that poor storm water control and landslide lines of slope 4º & below and slope 5º – 9º are parallel to each other until they reach slope 10º-13º where now the poor storm water control line goes down and the landslide line goes up. It can be derived from fig.11 that landslide situation is worse on the upper part of the hillside even though percentage of poor storm water control is low. This mean that there are many loose rocks on the upper side of the hill than on the built up area and their effect is felt more by the residents on the upper slope. Since the water retaining wall on the upper slope is too low, it is unable to block the rocks coming from the top of the hill.

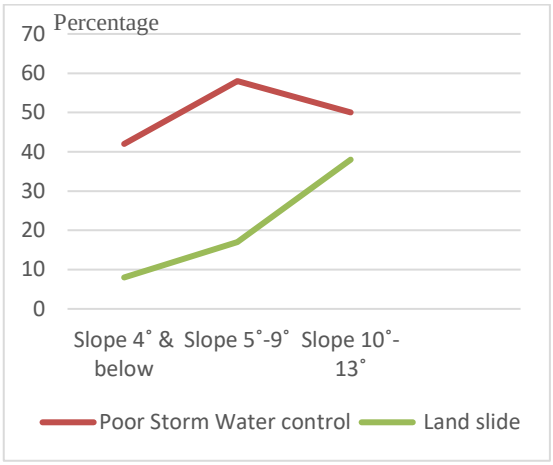

Fig.11. Percentage of Poor storm water control per each slope category in relation to soil erosion

C. Relationship between poor storm water control and floods damaging the building

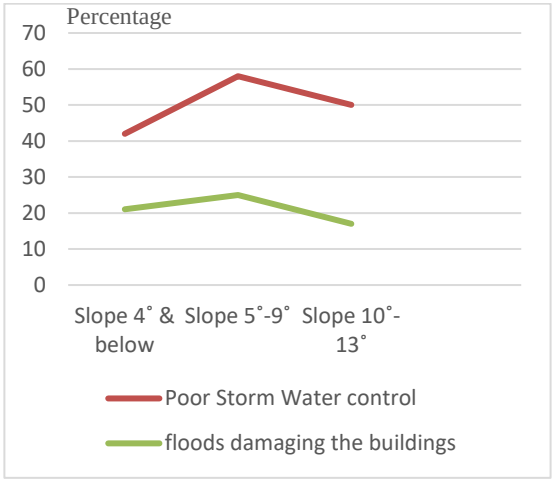

Fig.12. Percentage of Poor storm water control per each slope category in relation to soil erosion

TABLE.2. Indicate the storm water control inadequacies and the effects of poor storm water control

	Effects	of	Poor storm water management
Storm Water management inadequacies	Soil Erosion	Landslide	Floods damage on building and landscape
Poor Storm Water Drainage	o	x	o
Absence of Retaining Walls	o	o	o
Absence of Soft and Hard landscape	o	x	o

Key:
Affected by poor storm water inadequacies = o
Not affected by poor storm water inadequacies = x

Fig.12 indicates that there is higher percentage record of poor storm water drainage recorded as there is for floods damaging the building in slope 5^{o}-9^{o}. This relation indicates that when there is poor storm water control then floods damages the building. Fig.12 also indicates that water retaining wall on top of the hill has contributions in reducing the impacts of damage on the buildings as seen for slope 10^{o}-13^{o}.

V. MITIGATION PROPOSAL FOR POOR STORM WATER CONTROL

Storm water control can be a duty for the government as well as the residents. The government can assist by improving the plot external areas while the residents can improve the inside of their plots. To achieve this hillside storm water control and improvement strategies are proposed to be included in the Botswana Development Control Code (DCC).

A. Storm Water Drainage

According to DCC, 30% of building permits and certificates of occupancy shall not be issued prior to the installation and acceptance of the drainage facilities (MLH, 2013). To improve this regulation for already developed hillside neighborhood, in cases where the area was initially unplanned and lacks storm water drainage, and the roads are narrow to allow for drainage construction, residents shall give away the front piece of their land for drainage construction and shall be entitled to reasonable compensation. Residents shall also provide drainage concrete apron around the house to minimize damage of foundations by floods.

B. Retaining Walls

Retaining walls can be used to reduce slope disturbance (Seno and Ogura, 2018). For hillside regulations, the use of retaining walls shall be mandatory to minimize the impacts of landslide and soil erosion through blocking water and loose soil and rocks. Retaining walls shall also be constructed where there are changes in levels. Curb stones along the narrow roads shall be provided where there is no space for storm water drainage so that roads can aid in controlling storm water.

C. Soft and Hard Landscapes

The use of soft and hard landscape material shall be required to stabilize steep embankments, such as retaining walls, ground cover and trees (MLH, 2013). This regulation shall be mandatory for hillside developments. The landscape designs shall provide drainage channels draining into tree ports. Native shrubs and trees shall be retained on hillside terrain whenever possible to help reduce erosion (Seno and Ogura, 2018).

VI. CONCLUSION

Poor storm water control is a serious problem in the hillside of Peleng hence the study examined the link between environmental hillside problems and poor storm water control, then analyzed the reasons causing the problems and proposed forms of mitigation. Environmental problems and the dangers they cause were discussed in respect to Peleng residents` reports. It was discussed that soil erosion left the land bare and exposed rocks, landslides caused rocks to fall front the top of the hill and caused damage on the built environment, and that floods damaged the foundations of the buildings. The analysis indicated that soil erosion and floods damaging the building foundations were due to poor storm water drainage, lack of retaining walls and unlandscaped land. Analysis indicated the storm water retaining wall on the upper hillside contributed in reducing poor storm water control problems. Landslide was mainly due to poor retaining of slope disturbance. Improvements of regulations for storm water drainage, retaining walls and soft and hard landscapes were prosed as hillside building regulations to complement the inadequacies of Botswana Development control Code.

ACKNOWLEDGEMENTS

The author expresses their appreciation to Japan International Cooperation Agency (JICA) for the funding of this research, cooperating residents of Peleng for answering questionnaires and Botswana Department of Maps and Surveys for Peleng maps.

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