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Response of Partially Covered Road Embankments and its Environmental Impact

Khamaruzaman Wan Yusof[1], Syed Muzzamil Hussain Shah[2], Zahiraniza Mustaffa[3], and Ahmad Mustafa Hashim[4]

[1, 2, 3, and 4]Civil Engineering Department, Universiti Teknologi PETRONAS, Malaysia

[1]khamaruzaman.yusof@petronas.com.my

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Abstract. Tropical regions have always suffered soil loss by water which deteriorates the surrounding environment in several ways. This paper focuses on one of an issue that under the tropical rainfall event how the newly constructed bare highway affects the water turbidity and total suspended solids in a water channel. The study was based on a pilot scale field test which was constructed in compliance with the real field conditions. The study was limited to the tropical rainfall event of 40 mm/hr, native grass cover, sandy loam, and for the road side slope of 1V:1.5H (~ 30°). To determine the turbidity and total suspended solids (TSS), three plots were observed with the different percentage of covers namely, no cover (plot A-control plot), 50% of the grass covered surface (plot B), and 30% of the grass covered surface (plot C). The purpose of the study was to observe the influence of these three plots on the dependent variables that is turbidity and TSS. The study summarizes that the presence of cover is adequate enough to cope with this issue to an extent. The results obtained showed that the bare soil surface performed worst under the rainfall intensity of 40 mm/hr for both the dependent variables. The maximum turbidity values observed from plot B and plot C were 30% and 90.25% respectively of the maximum turbidity value obtained from plot A. Similarly, the maximum TSS values observed from plot B and plot C were 35.21% and 63.76% respectively of the maximum TSS value observed from plot A.

Introduction

In spite of its limited periphery roads cannot be disregarded while comparing the soil loss with the agricultural activities [1]. The soil loss observed from the exposed embankments is similar to that of observed from the parched lands [2]. By the year 2050, the urban community is expected to reach the globe by 9.5 billion and most of the increment is anticipated in the developing regions like Asia and Africa which are susceptible to water contamination. Roads construction is among the vital source of soil loss which aids the sedimentation process by flowing towards the water channel in the form of surface runoff [3]. Not only the construction activities but the public works, logging activities and agricultural activities are considered equally responsible for the occurrence of soil loss [4]. Road construction induces higher erosion rates as it usually remains bare and uncovered which makes it exposed to the rain drop impact [5] that ultimately influences the natural surrounding [6]. On the contrary, the need of roads is necessary for the economic development of the country [7]. Therefore, to lessen the soil loss phenomenon, immediate surface cover is required to protect the exposed soil surface once the road construction phase is completed [8]. Fig. 1 shows the view of newly constructed bare road embankment affected by the rain drop impact.

Figure 1. Newly constructed embankment [2].

Intimately, 50 to 80 percent of the sediment load which contribute to the stream channels is mainly by soil erosion from the road surfaces [9] that not only aggravate the water carrying capacity of the channel but also affects the aquatic life [10]. A study reported that the construction spoils observed from a newly constructed highway in China were found to be 2-5 million m^3 per 100 km [7]. In the last few tenners the rapid development activities are held accountable for the worsening of the water bodies [11, 12] therefore, this issue has been much prioritized due to its influence to the water channels which deteriorate the channel capacity of the streams and worsen the water quality in the sense of severe turbidity and the presence of suspended particles [13].

There are two tracts through which the sediments reaches the water body that is either by mass failure or by surface erosion. Mass failure occurs in the areas having sharp inclinations and slopes whereas; surface erosion is very common in the areas of stable slopes which usually occur from roads, filled slopes, and cut slopes [14]. The impact of surface erosion allows the extraneous sediments to deposit in the water body [15] which affects the survival of aquatic habitats [16].

With the passage of time surface erosion reduces from the roads compared to its time of construction, as the top soil surface gradually erodes away which exposes the soil beneath that erodes at slow tempo may be due to its different properties [17]. Unpaved roads are the major source of surface runoff which does not allow water to infiltrate and leads to the land degradation by detaching the individual soil particle that flows with the generated runoff [1]. Moreover, the logging roads are considerd responsible both for the sediments deposition in the water body and for the influx of the toxic contaminants to the water channel through road vehicles [18]. Specifically, to mitigate this problematic issue from the exposed road side slope areas immediate soil protection is required.

Research Method

The study was conducted at Universiti Teknologi PETRONAS (UTP), Malaysia. A side slope with the gradient of ~ 30° was observed under the simulated rainfall conditions with the different percentage of land covers. The rainfall intensity opted for the experimental run was 40 mm/hr (the average rainfall event) for which the rainfall data of Perak, Malaysia (2005-2011) was attained and analyzed. Each plot (2 meters length x 6 meters width) was served under the similar simulated rainfall conditions, soil type, and slope inclination for estimating the water turbidity and TSS values from the bare soil surface, 50% of the grass covered surface, and 30% of the grass covered surface. The study area was sheltered by a roof and covered with the plastic so that the plots can be protected in case if the natural rainfall occurs as shown in Fig. 2. The rainfall intensity was adjusted to 40 mm/hr on the flow meter which was kept noticed so that it assures that the rainfall conditions remained constant throughout the experimental phase. A container was placed at the bottom of each plot so that the water samples can be collected after every 15 min for a period two hours. The water samples were collected in the labeled plastic bottles from all the plots so that the samples cannot be mixed with each other. The individual sample collected was used both for determining the turbidity and TSS values. The samples were then taken to the lab for further processing.

The water samples collected were quite turbid however to compute the turbidity values the dilution of 1 in 50 was used. From the each diluted sample, three samples were collected to determine the water turbidity by using the turbidity meter as shown in Fig. 3 (a & b). For estimating the TSS values, the filter papers were first washed and cleaned which were then placed in the oven at 105° for 24 hours. The dried filter papers were then weighed and labelled. The water samples collected during the experimental runs were then diluted (the dilution used was 1 in 10). Three samples were then taken from the each diluted sample. The filter papers containing suspended particles were dried again for 1 hour and placed in the desiccators for 20 min. The dried filter papers were then weighed and the difference was observed. This gave the average TSS value, obtained at different time intervals as shown in Fig. 3 (c & d).

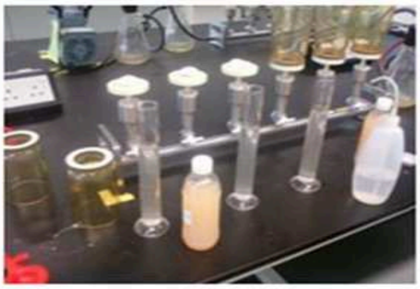
Plot A – Bare soil surface (Control plot) | *Plot B – 50% of the grass covered surface* | *Plot C – 30% of the grass covered surface*

Figure 2. Bare soil surface, 50% of the covered surface, and 30% of the covered surface.

Diluting the water sample (a)

Turbidity meter (b)

The dried filter papers weighed (c)



1 in 10 dilutions for TSS (d)

Figure 3. Estimation of turbidity and total suspended solids.

Results and Discussions

The results obtained from plot A were drastic for both the dependent values. The impact of moderate rainfall event of 40 mm/hr dislodged the soil particles, which were carried away by the surface runoff to the bottom channel under the force of gravity. Both the turbidity and TSS values were exceptional when compared with plot B, the reason for which is suggested that there was not provided any surface cover to protect the exposed soil and to distract the generated runoff which raised the turbidity values and the amount of suspended solids in the water channel. However, the maximum turbidity and TSS values obtained from plot A were found to be 1631.5 (NTU) and 69 (mg/L) respectively.

The results obtained from plot B were quite low both for the turbidity and TSS values when compared with the bare soil scenario. The maximum turbidity and TSS values obtained from plot B were 490 (NTU) and 24.3 (mg/L), respectively, which were only 30% and 35% of the maximum turbidity and TSS values obtained from plot A. This shows that even the partially covered soil surface is adequate enough to cope with the moderate rainfall event in reducing the soil loss which in turn reduced the turbidity and TSS.

The results attained from plot C were ineffective. 30% of the ground cover surface did not perform well in mitigating the turbidity and TSS values. However, the maximum turbidity and TSS values obtained from plot C were 1472.5 (NTU) and 44 (NTU) respectively which were quite near to the results obtained from plot A.

The turbidity values obtained from plot A and plot C nearly equated. The maximum turbidity value observed from plot C was found to be 1472.5 NTU which was only 1.10 times lower than the maximum turbidity value obtained from the bare soil surface. The reason for the proximity in the results is suggested that plot C was 70% exposed and only 30% covered. Moreover, the largely spaced grass patches allowed the detached fine soil particles to flow with the generated runoff which raised the turbidity values. Although, the soil loss was also observed from plot B but the closely spaced grass patches retained the soil particles from flowing away which acted as a filter and reduced the turbidity values.

The concentration of TSS attained from plot A and plot C followed the similar scenario as observed for the turbidity for which the similar reason is suggested. However, the graph attained for TSS showed variations at different time intervals for which several reasons are suggested. Firstly, this could have happened as the soil loss occurred at different rates at different time intervals. Secondly, the settled particles could have settled in the bottom container depending on the particle density while collecting the water samples. Lastly, the surface water discharge received in the bottom container could have disturbed the particles in suspension during samples collection.

Fig. 4 shows the graph for turbidity incurred from all the plots under the moderate rainfall event of 40 mm/hr whereas; Fig. 5 shows the result obtained for TSS from all the plots under the same rainfall event.

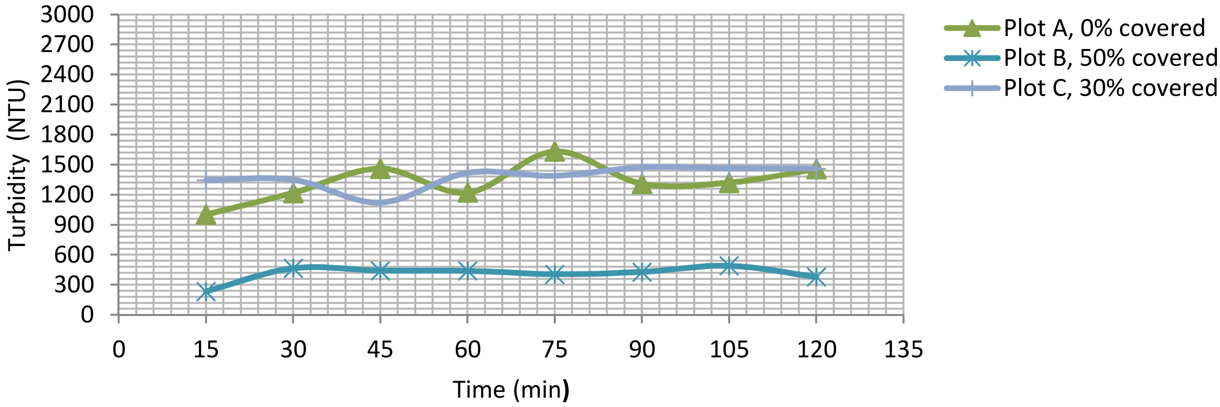


Figure 4. Turbidity values incurred from all the plots under the moderate rainfall event.

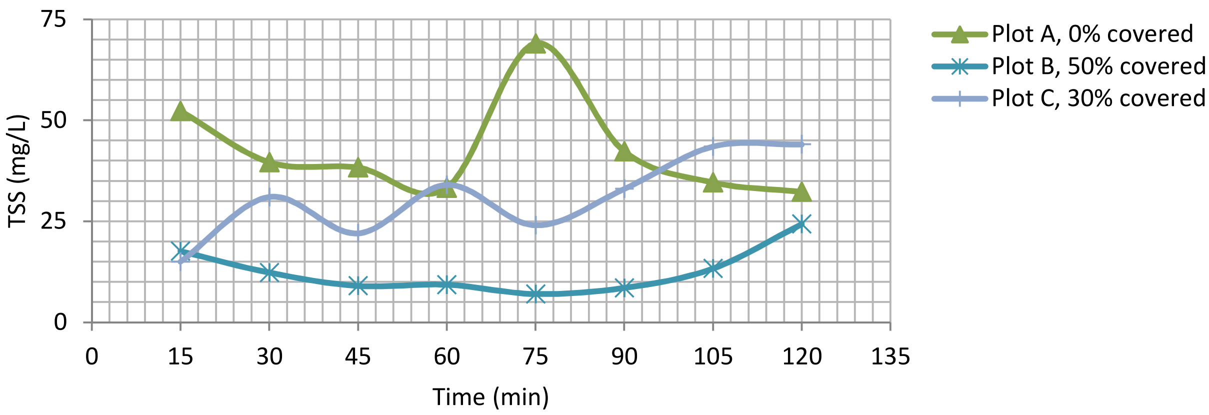


Figure 5. TSS values obtained from all the plots under the moderate rainfall event.

Summary and Concluding Remarks

Based on the results obtained from all the plots this study recommends that the areas where the average rainfall remains moderate must cover the newly constructed bare embankments with at least 50% of the grass covered surface so that it assures immediate protection to the soil loss and reduces the water turbidity and the presence of suspended solids to the water body. Moreover, 30% of the grass covered surface was just examined to notice its efficiency against the moderate rainfall event which did not work. Moreover, the grass growth rate was also observed for plot B, and Plot C. The observation made for plot B showed that the plot area was covered up to 80% within a period of 2 months only after commencing the study whereas; for plot C it hardly reached up to 40% and majority of the grass was observed to be dying.

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