SOIL EROSION AND SEDIMENT YIELD AT CONSTRUCTION SITE - A CASE STUDY

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Soil Erosion and Sediment Yield at Construction Site - A Case Study

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Humbly dedicated especially to my family members for continuous support, love and care:

My beloved Father and Mother,

Law Puong Chui

Wong Kiu Chuo

My siblings,

Law Chai Lit

Law Lit Ling

My Wife,

Ling Siew Ching

To my Supervisor and Co-supervisor

Prof Dr Ir Law Puong Ling

Dr Siti Noor linda Taib

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ABSTRACT

Malaysia is currently undergoing rapid development towards urbanization and there has been an increasing concern over soil erosion and sedimentation issues. This is because the dynamic nature of soil erosion and sedimentation process depend on several factors, which include locality, climate, management, land use and cover, and also the extent of exposure of bare soil during construction activities. In order to estimate on-site and off-site impacts by soil erosion and transport of pollutant out of site, the mapping and computing methods with various variables would produce information that can be applied in the construction activities. In this research, soil erosion and sediment assessments were carried out for cut-and-fill activities at Samalaju Industrial Park, Bintulu, Sarawak. In this research, two equations called Revised Universal Soil Loss Equation (RUSLE) and Modified Universal Soil Loss Equation (MUSLE) equations were used to provide an assessment on soil erosion and sediment yield during pre-construction, during construction and post-construction periods.

Based on the results obtained, RUSLE values (soil erosion rates) show that soil erosion rates can be categorized as moderately high, especially during construction and operation phases. On the other hand, MUSLE values (sediment yield per storm event) also show that the highest sediment yield occurred during construction and operation phases. However, the amount of deposited sediment would vary from year to year. This situation could be due to the changes in rainfall patterns. The computed sedimentation data would provide a clear picture and understanding on the amount of sediment

deposited on site. To minimize potential erosion and sedimentation rates, there is a need to implement Best Management Practices (BMPs) for maximum protection of environment. In this research, it can be concluded that useful tools and methods for management of construction activities are the prime considerations to minimize soil erosion rate and sediment yield. Besides, there is a need to carry out regular inspection and maintenance on mitigation or control measures.

ABSTRAK

Pada masa kini, Malaysia di bawah pembangunan yang pesat dan isu-isu hakisan tanah dan pemendapan semakin menjadi sehingga menimbulkan kebimbangan. Ini disebabkan terdapat beberapa factor yang menyumbangkan sifat dinamik hakisan tanah dan proses pemendapan iaitu iklim setempat, faktor pengurusan, penggunaan tanah dan perlindungan dan juga termasuk pendedahan tanah semasa aktiviti pembinaan. Untuk memperolehi penilaian data di dalam tapak dan juga kesan di luar tapak oleh hakisan tanah dan pengaliran bahan pencemar keluar dari tapak, kaedah pemetaan dan pengkomputeran dengan pelbagai pembolehubah boleh menghasilkan maklumat semasa aktiviti pembinaan. Penilaian hakisan tanah dan pemendapan telah dijalankan untuk aktiviti-aktiviti pembinaan tapak potong dan mengisi di Taman Perindustrian Samalaju, Bintulu Sarawak. Dalam projek ini, dua persamaan yang ringkas iaitu persamaan RUSLE dan MUSLE telah digunakan dengan memberi ideal yang jelas dan juga boleh digunakan sepanjang tempoh pembinaan untuk menilai potensi kadar hakisan tertentu dan juga kesan pemendapan bagi tapak projek.

Berdasarkan keputusan, nilai RUSLE menunjukkan bahawa kadar hakisan tanah boleh dikategori dalam sederhana tinggi terutama semasa dalam fasa pembinaan dan fasa operasi. Di samping itu, nilai MUSLE juga menunjukkan bahawa pemendapan yang tertinggi berlaku semasa dalam fasa pembinaan dan fasa operasi. Walau bagaimanapun, terdapat pengubahan untuk pemendapan dari setahun ke setahun. Keadaan ini disebabkan oleh perubahan pelbagai corak hujan dari tahun ke tahun. Dengan adanya anggaran kasar bagi pemendapan boleh memberi gambaran yang jelas dan memahami

jumlah pemendapan yang yang didepositkan keluar dari tapak. Dengan adanya jankaan pemendapan data langkah-langkah kawalan boleh disediakan boleh mengurangkan potensi hakisan tanah dan pemendapan dalam usaha untuk memaksimumkan perlindungan alam sekitar.

Sementara itu, langkah-langkah kawalan yang sesuai mesti disediakan untuk mengurangkan potensi hakisan tanah dan pemendapan melalui analisis data dengan perbandingan di antara kawasan kawalan dan kawasan tidak kawalan. Oleh itu, kaedah kaedah dan pengunaan peralatan yang berkean merupakan pertimbangan yang utama untuk pengurusan aktiviti pembinaan untuk mengurangkan kadar hakisan tanah dan hasil pemendapan dan meningkatkan perlindungan alam sekitar. Selain itu, untuk mendapatkan pernilaian hasil yang berkesan, pemeriksaan dan penyelenggaran yang kerap mestilah dilaksanakan.

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BMPs	-	Best Management Practices
C	-	Cover-Management Factor
CN	-	Curve Number
CPESC	-	Certified Professional in Erosion and Sediment Control
DID	-	Department of Irrigation and Drainage
ESC	-	Erosion and Sediment Control
ESCP	-	Erosion and Sediment Control Plan
ha	-	Hectare
HSGs	-	Hydrologic Soil Groups
I	-	Intensity of Rainfall
I_a	-	Initial Abstraction
IDF	-	Rainfall Intensity, Duration and Frequency Curve
j	-	Joule
K	-	Soil Erodibility
LS	-	Slope Length and Steepness Factor
MUSLE	-	Modified Universal Soil-Loss Equation

N-P-K	-	Nitrogen-Phosphorus-Potassium
NWQSM	-	National Water Quality Standard of Malaysia
OM	-	Organic Matter Content
p	-	Erosion Control Practice Factor
Q_P	-	Peak Flow
R	-	Rainfall/Runoff Erosivity
RUSLE	-	Revised Universal Soil-Loss Equation
SSTS	-	Soil Stabilization for Temporary Slopes
t	-	Tonnes
t_c	-	Time of Concentration
t_o	-	Time of Overland Flow
TRMs	-	Turf Reinforcement Mats
t_t	-	Time of Travel
USDA	-	United States Department of Agriculture
USLE	-	Universal Soil-Loss Equation
V	-	Volume of Runoff
WEPP	-	Water Erosion Prediction Project
yr	-	Year

CHAPTER 1

INTRODUCTION

1.1 Background of study

Soil is subjected to natural weathering and erosion. Natural, geologic, erosion by water, wind and ice has been occurring at relatively slow rate since the earth was formed. But the construction activities and large earth-moving projects enhance the erosion dramatically, mainly by exposing large areas of soil to rain and running water. If this runoff is not treated properly, it will cause serious siltation of nearby watercourses. In many developed countries including Malaysia, soil is highly susceptible to erosion due to the demand of development. Therefore, construction site erosion and sediment controls are the main challenging problems for engineers in real-world environmental management issues (Theakston, 1988).

In Malaysia, there has been an increasing concern over soil erosion consequences of deforestation related to land conversion for highway, logging activities, industrial or urbanization purposes (Brooks, Richard & Spencer, 1993). Therefore, construction engineers and landscape architects have a number of 'tools'

at their disposal to keep soil onsite. These erosion and sediment control practitioners are required to identify the most appropriate and cost-effective best management practices (BMPs) for their erosion control plan.

In nature, there are two major types of erosion, i.e. by water and wind. For Malaysian environment, water is the most significant erosion due to high mean of annual rainfall, storm frequency and density (Department of Irrigation and Drainage, 2001). Besides, according to (Schueler & Lugbill, 1990) in construction development, it has been found that sediments from construction sites typically consist of larger percentage of smaller particles such as silt and clay than the parent soil. This is because of the small size of the unconsolidated particles from construction in storm water runoff that are displaced easily than the larger particles in compacted soil.

Therefore, there are six principles to be considered in preparation of a Erosion and Sediment Control Plan (ESCP) which include planning considerations, vegetative stabilization, physical stabilization, diversion of runoff, flow velocity reduction, and sediment Trapping/Filtering need to be implemented for erosion and sediment control (ESC) activities during construction development (Md Noh, 2006). The utilization of ESCP for construction development areas becomes compulsory since October 2005 after being endorsement by the National Council for Local Government. For every development projects with greater 1 hectare has to submit ESCP and Earthwork Plan to DID for review and endorsement prior to granting of approval by Local Authority. For area that is less than 1 ha, ESC measures shall be embedded in the Earthwork Plan allowing small scale development to waive full ESCP submission.

1.2 Problem Statement

Recently urban development was particularly rapid in Malaysia. There are further hillside development has been rapid in the last two decades in Malaysia and has causing in acute environmental problem in many locations (Department of Environment, 2008). Apart from urban expansion, development has also occurred in inland hilly areas as well as near coastlines and on islands for industrial purposes like at Bintulu region Samalaju Industrial Parks. Planning and achieving sustainable development in such environment is particularly important in regard to erosion and sedimentation, slope stability management, drainage, and flash flood (Department of Irrigation and Drainage, 2001). An adverse environmental effect of urban growth in Malaysia has been frequent occurrence of excessive soil losses from sites cleared of vegetation but awaiting development and from construction sites. There has also been deterioration in a number of water courses (Department of Environment, 1995).

There are two major type of erosion, by wind and by water. Under Malaysian conditions, erosion by water is the most significant due to high mean annual rainfall, storm density and frequency. Higher rates of erosion will occur when the vegetation cover is disturbed or removed. Once the vegetation is cleared, interception of rainfall will be greatly reduced. This will result in a drastic increase in surface runoff velocity and volume. Increase runoff (especially on hilly terrains) will certainly cause substantial soil erosion. Erosion by running water may take place in the form of rill or gully erosion, notably in loose sandy granitic soils or reworked residual soils (University of Malaya Consultancy Unit, 2003).