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Faculty of Engineering

**A STUDY ON SILT AND CLAY PARTICLES SETTLING CHARACTERISTICS IN CHANNELS**

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**Bachelor of Engineering with Honours**
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# A STUDY ON SILT AND CLAY PARTICLES SETTLING CHARACTERISTICS IN CHANNELS

KENNY ADAMS AJANG

This project is submitted in partial fulfillment of
the requirements for the Degree of Bachelor of Engineering with
Honours (Civil Engineering)

Faculty of Engineering
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*To my parents, my siblings*

*and*

*my love,  Rani*

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# ABSTRACT

This research project focuses on the design, development (fabrication) and performance tests of a channel model regarding to its usage in civil engineering construction site to transport flowing water as well as reducing the suspended solids (silt and clay). The model consist of two components a) the channel or drainage which will be the main collecting point for the surface runoff and b) the sedimentation trap at which the main sedimentation activities of suspended solids particles will take place. In this experimental research, it was found that at influent SS level of 300 mg/L and flow velocity at 0.096 m/sec (Q = 5 x $10^{-5}$ $m^3$/sec), the channel would experience a depositional rate of approximately 12.0%, at influent SS level of 300 mg/L and flow velocity at 0.121 m/sec, (Q = 8.33 x 10-5 m3/sec), the channel would operate in an erosion stage, whereby approximately 26.0% sediments would be added into the flow, and at influent SS level of 465 mg/L, the depositional rate would approximately be 16.13% at velocity = 0.096 m/sec (Q = 5 x $10^{-5}$ $m^3$/sec) to 5.38% at velocity = 0.121 m/sec (Q = 8.33 x 10-5 m3/sec) over a distance of 2 meters respectively.

# ABSTRAK

Projek penyelidikan ini merupakan satu hasil kerja yang menumpukan kepada rekaan, pembangunan dan ujian kecekapan bagi model parit atau terusan berkenaan aplikasinya untuk menyalirkan air serta mengurangkan kelodak dan lumpur di tapak pembinaan, terutamanya bagi bidang Kejuruteraan Sivil. Model ini terdiri daripada dua komponen iaitu a) terusan atau parit di mana ia berfungsi sebagai pusat pengumpulan dan laluan bagi air yang dilepaskan dari tapak pembinaan dan b) perangkap kelodak dan lumpur di mana proses utama sedimentasi akan berlaku. Berdasarkan eksperimen yang telah dijalankan, didapati bahawa peratus kecekapan penyingkiran lumpur dan tanah liat dari air kelodak bagi kepekatan ampaian 300 mg/L dan halaju 0.096 m/saat (Q = 5 x $10^{-5}$ $m^3$/s) adalah 12.0% manakala bagi kepekatan ampaian 300 mg/L dan halaju 0.121 m/s, (Q = 8.33 x 10-5 m3/s), model terusan akan mengalami hakisan dan sebanyak 26.0% lumpur dan tanah liat disingkirkan. Bagi kepekatan ampaian 465 mg/L, peratus kecekapan penyingkiran lumpur dan tanah liat adalah kira – kira 16.13% pada halaju 0.096 m/s (Q = 5 x $10^{-5}$ $m^3$/s) dan sebanyak 5.38% disingkirkan pada halaju 0.121 m/s (Q = 8.33 x $10^{-5}$ $m^3$/s) sepanjang jarak 2 meter.

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| | | |
|---|---|---|
| C | - | Concentration |
| $C_{in}$ | - | Influent Concentration |
| G | - | Gram |
| k | - | Conversion factor |
| h | - | Depth |
| L | - | Liter |
| m | - | Meter |
| ml | - | Milliliter |
| mm | - | Millimeter |
| min | - | Minutes |
| JKR | - | Jabatan Kerja Raya |
| n | - | Manning's Coefficient of Roughness |
| P | - | Wetted Perimeter |
| Q | - | Flow rate/ Discharge |
| R | - | Hydraulic Radius |
| sec | - | Second |
| SS | - | Suspended Solids |
| y | - | Water Depth Normal to the Bottom of Channel |
| V | - | Velocity |
| µ | - | Micro |

| | | |
|---|---|---|
| $\pi$ | - | pi |
| USCS | - | Unified Soil Classification System |
| $f_g$ | - | Force of gravity |
| $\rho_p$ | - | Density of discrete particle |
| $V_p$ | - | Volume of discrete particle |
| $f_b$ | - | The buoyant force |
| $\rho_w$ | - | water density |
| $f_{net}$ | - | Net force |
| $f_d$ | - | Drag force |
| $\upsilon$ | - | Velocity of discrete particle |
| $C_D$ | - | Coefficient of drag |
| $A_p$ | - | cross sectional area of the particle perpendicular to the direction of movement |

# CHAPTER 1

# INTRODUCTION

## 1.1 Introduction

Sedimentation and settling of silt and clay particles in a channel or earth drains is no small matter as this can cause various problems to arise, especially from the channel itself. Silt is produced by mechanical weathering of rock, as opposed by chemical weathering that results in clay. Silt refers to soil or rock particles of a certain very small range. On the Wentworth scale, silt particles fall between 0.004 and 0.063 mm (4 - 62.5 μm), larger than clay but smaller than sand. In actuality, silt is chemically distinct from clay, and their size ranges overlap. According to the Unified Soil Classification System (USCS), the sand-silt distinction is made at the 0.075 mm (75 μm) particle size (i.e. material passing the #200 sieve), and silts and clays are distinguished by their plasticity. Silt can occur as a deposit or as material transported by a stream or by a current in the ocean. Silt is easily transported in water and is fine enough to be carried long distances by air as 'dust'. Thick deposits of silt material resulting from *aeolian* deposition are often called *loess* (a German term) or *limon* (French). Silt and clay contribute to turbidity in river water.

## 1.2 Purpose of report

This research report was written in partial fulfillment of the requirements for the four years degree of civil engineering. The subject of this report is to document the final year research project about silt and clay particles settling characteristics in channels.

## 1.3 Objective

The objective of this research project is to carry out performance tests, especially silt and clay particles settling characteristics on a development roadside channel currently adopted by JKR Sarawak on a 1:10 scale.

## 1.4 Hypothesis

The recent findings shows that existing channels used in Malaysia, especially in Sarawak are not performing well up to the required standard as the channels encounters numerous problems. This is best explained by referring to the deposits of silt and clay, along with other types of pollutants that travels along the channel. Sedimentation may be classified into various types depending on the characteristics and concentration of the suspended materials. Particles whose size, shape and specific gravity do not change with time are referred to as discrete particles.

Silt and clay are discrete particles in dilute suspension, type-1 settling, are the easiest situation to analyze. If a silt or clay particle is suspended in water, it initially has two forces acting upon it. The force of gravity

$$f_g = \rho_p g V_p \qquad (1)$$

In which $\rho_p$ is the density of the particle, $g$ is the gravitational constant and $V_p$ is the volume of the particle. The buoyant force quantified by Archimedes

$$f_b = \rho_w g V_p \qquad (2)$$

Where $\rho_w$ is the water density. Since the forces are in opposite directions, there will be no net force when $\rho_p = \rho_w$, and on acceleration of particle in relation to the water will occur. If, however, the density of the particles differs from that of the water, a net force is exerted and the particle is accelerated in the direction of the force;

$$f_{net} = (\rho_p - \rho_w) g V_p \qquad (3)$$

This net force becomes the driving force for acceleration. Once motion has been initiated, a third force is created due to viscous friction. This force, called the drag force, is quantified by

$$f_d = C_D A_p \rho_w \upsilon^2/2 \qquad (4)$$

Where $C_D$ is the coefficient of drag, $A_p$ is the cross sectional area of the particle perpendicular to the direction of movement, and $\upsilon$ is the velocity of the particle. Because the drag force acts in the opposite direction to the driving force and increases as the square of velocity, acceleration occurs at a decreasing rate until a steady velocity is reached at a point where the drag force equals the driving force:

$$(\rho_p - \rho_w) g V_p = C_D A_p \rho_w \upsilon^2/2 \qquad (5)$$

For spherical particles,

$$V_p/A_p = 2d/3$$

Substituting into equation 1.5

$$\upsilon_t^{2} = 4g\,(\rho_p - \rho_w)\,d/\,(3C_D\rho_w) \qquad (6)$$

Expressions for $C_D$ change with characteristics of different flow regimes. For laminar, transitional and turbulent flow, the values of $C_D$ are:

$$C_D = 24/\mathrm{Re}\ \text{(laminar)} \qquad (7)$$

$$= 24/\mathrm{Re} + 3/\mathrm{Re}^{1/2} + 0.34\ \text{(transitional)} \qquad (8)$$

$$= 0.4\ \text{(turbulent)} \qquad (9)$$

Where Re is the Reynolds number

$$\mathrm{Re} = \Phi\upsilon_t\,\rho_w d/\,\mu \qquad (10)$$

Reynolds number less than 1.0 indicates laminar flow, while values greater than $10^4$ indicate turbulent flow. Intermediate values indicate transitional flow, the shape factor is added $\Phi$ to correct the lack of spherosity.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Overview

Earth drain or channel plays a great role in our daily lives. Apart from transporting water, it gives significant impact in flood control, especially in flood-prone areas in Malaysia. Our government has spent great amount of money in design, installation and maintenance of channels. This goes to show to us the importance of channels and it's only fair that we took our part in maintaining the functionality of channels. This chapter will review on impact of sedimentation and erosion on channels. Also included will be type of channels and design consideration.

## 2.2 Impact of sedimentation and erosion

"Sediment transporting capacity, curvature effects as well as compositions of channel beds and bank materials need to be considered by the engineer during the design process of channels. Neglecting these effects would normally result in instability problems because channel morphology changes with time" (Jurutera, May 2005). This shows that sedimentation plays a great role in the designing of a channel or earth drain. A stable or regime channel would best be describe as " a stable channel is an unlined earth canal for carrying water, the banks and bed of which are not scoured by the moving water and in which objectionable deposits of sediment do not occur" (Chang, 1988). Thus from the definition, small amount of erosion and sediment deposition may occur along the channel but for a long period of time, bank and bed will attain toward stability. Also by taking the consideration of the location of the constructed channel itself as it may be constructed not far from roads, highways and bridges, and cut-and-fill areas, sedimentation and erosion can have significant effect on surface waters and soil surface with silt and clay particles along with other pollutants.

Designed channels can also be simulated as same as river channels as both behaves almost identical towards erosion and sedimentations. According to Chang (1998), "river channel behavior often needs to be studied for its natural state and response to human regulation. Studies of river hydraulics, sediment transport and river channel changes may be through physical modeling, or mathematical modeling, or both". In economical aspects, mathematical modeling is more cost worthy and one of it is Fluvial-12 that has been gradually gaining popularity in designing stable section of channels. Physical modeling has been around long and been relied upon traditionally for river projects. The computer program Fluvial-12 is a mathematical model that is formulated and developed for water and sediment routing in natural and man-made channels and simulates the combined effects of flow hydraulics, sediment transport and river channel changes for a given flow period. This model is capable of predicting instability effects such as riverbed changes due to erosion and sedimentation during flood, thereby providing the necessary information for the design or bank protection work.

### 2.3 Types of channels

The general classifications for channels or open channels are:

A. Natural channels, which include all water courses that have been carved by nature through erosion; and

B. Artificial or improved channels, which are constructed or existing channels that have been significantly altered by human effort. Improved channels can be lined with grass, concrete, mortared rocks or rock riprap.

#### 2.3.1 Geometric Elements of Channel Section

Geometric elements are properties of a channel section that can be defined entirely by the geometry of the section and the depth of flow. These elements are very important and are used extensively in flow computations.

#### 2.3.2 Natural Channels

The ideal open channel is a stabilized water course developed by nature over time, characterized by stable bed and banks. The benefits of such a channel are:

A. Velocities are usually low, resulting in longer concentration times and lower downstream peak discharges. Available channel storage can decrease peak flows.

B. Maintenance needs are usually low because the channel is somewhat stabilized.

C. The channel provides a desirable green belt and recreational area adding significant social benefits.

Many natural channels have mild slopes, are reasonably stable, and are not in a state of serious degradation or aggradations. However, if a natural channel is to be used for carrying storm runoff from an urbanizing area, the altered nature of the runoff peaks and volumes from urban development can and will cause scour and erosion. Some on-site modification of the natural channel may be required to assure a stabilized condition.

### 2.3.3 Grass-Lined Channels

Grass channels are the most desirable of the various types of improved channels for the following reasons:

A. The grass can stabilize the body of the channel.
B. The grass consolidates the soil mass of the bed.
C. The grass will check the erosion and control the movement of soil particles along the channel bottom.

### 2.3.4 Concrete-Lined Channels

Concrete lined channels are designed to protect the channel from the erosive potential of high velocities. In addition to concrete-lined channels, other methods may be proposed to combat erosive velocities in channels and should be submitted for review.