UNIVERSITI TEKNOLOGI MARA

SEDIMENT TRANSPORT PREDICTION DUE TO IN-STREAM MINING BY EVOLUTIONARY POLYNOMIAL REGRESSION METHOD

NADIATUL ADILAH BT AHMAD ABDUL GHANI

Thesis submitted in fulfillment
of the requirements for the degree of
Doctoral of Philosophy
(Civil Engineering)

Faculty of Civil Engineering

May 2019

ABSTRACT

This study investigates the use of Evolutionary Polynomial Regression (EPR) technique in genetic programming to predict sediment transport due to in-stream mining. EPR is a data-driven hybrid regression technique and has been used successfully in solving numerous problems in civil engineering that include sewer failure, water distribution in pipelines, groundwater management, water quality model, floodplain, coastal and also sewage sludge prediction. However, this technique has not been fully explored in establishing sediment transport model. In this technique symbolic models were first constructed by integrating the best features of numerical regression. Four established models were selected to predict sediment transport on Malaysian rivers using 390 data from twelve selected rivers in Malaysia. This extensive database was obtained from the Department of Irrigation and Drainage (DID), Ministry of Natural Resources & Environment, Malaysia and previous studies.

Analysis has shown below average performance for all equations when tested on local river data. Rigorous testing of the independent variables from the selected equations, have found significant predictors for use in the newly derived equation. The identified predictors found to be of significance are U^*/V (ratio of shear velocity to velocity of flow), R/d_{50} (ratio of hydraulic radius to particle mean size), B/y (ratio of width to flow depth and U^*/ω_s (ratio of shear velocity to fall velocity of sediment particle). Development of model makes use of 273 data (training sets) from twelve rivers in Malaysia. Out of this number, 64% of the predicted data fall within the discrepancy ratio of 0.5 - 2.0 to the measured data. While 70% of the data used for validation fall within the acceptable limit. Upon establishing the best model, new set of data with a limitation of range were selected. Only 256 data were selected from 390 data used which are 64% from total data. Based from this new set of data range, 666 new models were developed using this technique. The best proposed sediment transport model for the first group range can be defined as a function U^*/V (ratio of shear velocity to velocity of flow), R/d_{50} (ratio of hydraulic radius to particle mean size). Balance 134 data which is fall outside the range was used to develop second model for a different range of data. A robustness study was performed in order to validate the generalization ability of the developed EPR model. The percentage of sensitivity analysis for every four input parameters shows input value d_{50}, particle mean size gives the most significant to EPR Model with 4.08%. The less significant variables to this model is shear velocity, U^*, with 0.23%. Results obtained from the EPR model was compared with those obtained from four other available sediment transport prediction models. Analyses have found that EPR model features predictive potential to solve highly nonlinear sediment data. Comparative analysis of the proposed model with the established sediment transport models using regression technique and modified Graf were carried out. In conclusion, the model developed using the Evolutionary Polynomial Regression technique had been validated using 82 data and it yielded the best results compared to the other models with most of the prediction data plotted 100% in difference ratio.

ACKNOWLEDGEMENT

All praise to Allah, the Almighty God for the mercy and blessings bestowed on me during my lifetime and for giving me the strength and endurance to complete this research.

My sincere gratitude goes to my supervisor Professor Ir Dr Hajah Junaidah Ariffin for her guidance, kindness and faith in my abilities without which it would have been impossible to complete this research. Indeed, I have learned and benefited a lot from her. Her invaluable and inspirational inputs have contributed significantly to the improvement of my work. I am also very grateful to my co-supervisor Dr Norashikin Ahmad Kamal who contributed constant encouragement and stimulating ideas towards this research.

I would like to extend my appreciation to all the staff in the Department of Civil Engineering, Universiti Teknologi Mara (Shah Alam) for the rendered services. Not forgotten are my colleagues (Dr Saerah, Dr Azlinda, Dr Zamsalwani and Dr. Dura) who are always helpful and cooperative throughout the study.

Thank you to my parents, Haji Ahmad Abdul Ghani Abdul Aziz and Hajah Paridah Ibrahim, my in laws, Haji Abu Bakar Abdullah and Hajah Ubaidah Othman, and other family members for their support and love without which the thesis would have not been completed. They have always been there to set me on the right path, for which I am utterly grateful. Their sacrifice gives me courage and becomes my driving force that propels me to success.

Special dedication to Ir Hajah Fatimah Mohd Noor, who provided reviewing and proofreading services for this thesis. Her contribution and moral support throughout this study will never be forgotten. Thank you also to Mr Kamarul Azlan and the late Associate Professor Dr Norhan Abdul Rahman for continuous support and encouragement which flourish my perseverance to continue and finish this journey. Big thanks are also dedicated to my beloved friends, Ina, Ami, Kak Yati, Aleng, Kak Intan, Shairul and Ciksue, especially to Kak Roky from Universiti Malaysia Pahang who constantly shared ideas, advices and motivation during critical situation.

I am also deeply indebted to my beloved husband, Abdul Shahid Abu Bakar who deserves more praises than I can put down in words for his ardent love, prayers, patience, and encouragement during my study. Certainly, I am thankful to my kids Aishya Nabila, Aafiya Najla and Ayman Najmi, whose love becomes my utmost strength to complete this study.

My regards and blessings are also dedicated to everyone who supported me in any respect during the completion of the research. Finally, I thank my mighty God for the many blessings in my life, especially the strength and sheer endurance bestowed upon me in completing this research. Thank you, all.

Alhamdulillah

"If you can dream it, you can do it."- Walt Disney

TABLE OF CONTENTS

CHAPTER ONE
INTRODUCTION

1.1 Research Background

Flow in river, stream and creek bring along soil, sand and sediment together. The particle of sediment, soil and sand transports in rivers will give an impact that change shape and river characteristics. During rainy day, soil from the surrounding area is eroded and washed into streams or rivers. The conditions of heavy flow will transported the sediment and larger particle to be suspended compare to the low flow condition. This phenomena make the rivers are more muddy-looking during storms because lots of sediments was transporting.

Sediment is defined as soil transported by wind or water. Sediments can be small particles of rock, shells, silt, mud, vegetation and other material. Sedimentation is a process by which sediments settle and build up and sometimes known as acceration. This process eventually changes the shape of a river and its embankment, continually altering its cross-section. It will also change it longitudinal profile, course of flow and pattern through the processes of sediment transport, scour and deposition. Therefore, it is important to understand the principles of sediment transport for the appliance to the solution of engineering and environmental problems related with natural events and human activities in order to sustain cultural and economic developments along an alluvial river.

Currently, there are a few different models used to identify the sedimentation process and to calculate the sediment transport. In most literatures, researchers tend to treat the suspended load and the bed load separately for calculating the sediment transport. However, more recent work have begun to rely on the total bed load calculation using complex analytical methods, such as the Artificial Neural Networks (Ab. Ghani et al., 2011; Nagy et al., 2002), Multiple Linear Regression Methods (Sinnakaudan et al., 2006) and the latest is genetic programming (Kumar et al., 2014; Chang et al., 2012).

Some available sediment transport equations are developed by Ackers & White (1973), Graf (1971), Karim (1998) and Van Rijn (1984). However, these existing