

**DEVELOPMENT OF A GUIDELINE TO DETERMINE
STRUCTURAL CAPACITY OF DEMOLITION WASTE AS A
ROAD CONSTRUCTION MATERIAL**

V.W.P.JAYASOORIYA

(08-8017)



University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations

Thesis Submitted in Partial Fulfillment of the Requirement for the Degree of Master of
Science

Department of Civil Engineering

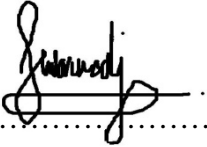
University of Moratuwa

Sri Lanka

January 2011

DECLARATION BY CANDIDATE

“I declare that this is my own work and this thesis/dissertation does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any University or other institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text”



.....

Date: 30th November 2010

V.W.P.Jayasooriya

Department of Civil Engineering

University of Moratuwa



University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.lib.mrt.ac.lk

DECLARATION BY SUPERVISOR

..

“I have supervised and accepted this thesis for the submission of the degree”

.....

Date:

Dr. W.K.Mampearachchi

Department of Civil Engineering

University of Moratuwa



University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.lib.mrt.ac.lk

DEDICATION

To My Dear

Father, Mother and to my wife Imesha

For their continuous dedication and encouragement for my advancement



University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.lib.mrt.ac.lk

ACKNOWLEDGEMENT

I wish to thank a few people for aiding in bringing this research to completion. I gratefully acknowledge my supervisor, Dr. W.K.Mampearachchi, for giving me the opportunity to undertake this research study and providing valuable advice and support throughout the research period. I would like to acknowledge and appreciate the advice given by Professor J.M.S.J Bandara, coordinator of my research and Dr (Mrs). H.L.D.M. A. Judith, Road Development Authority, Sri Lanka.

Sincere gratitude is extended to particularly to Prof. R. Rameezdeen, for granting necessary funds from European Union for this study. Fellow students Mrs. J.K.U.Gayani and Mr. W.P.H Gunarathne helped collect data and offered suggestions for improving this manuscript.

The support has given by Prof.W.P.S. Dias (Former Head, Department of Civil Engineering) is acknowledged.

I owe a very special gratitude to research students at the Transportation Engineering Division of the Department of Civil Engineering, University of Moratuwa for giving me the support throughout the research.

I would like to take this opportunity to extend my heartfelt appreciation to all the academic and non academic staff of the University of Moratuwa, who has assisted me in numerous occasions.

V.W.P.Jayasooriya

ABSTRACT

The use of demolition waste as pavement base material is a promising but unproven technique for road rehabilitation and construction. A survey was conducted by Building Economics Department of university of Moratuwa found that demolition waste is infrequently used in this application due primarily to a lack of practical knowledge about the engineering properties of the material. Therefore, this research was aimed at evaluating the physical properties, strength parameters, and durability characteristics of demolition waste to use as pavement base material.

The study included extensive laboratory and prototype model testing. Laboratory tests included flakiness index value, elongation index, aggregate impact value, Los Angeles abrasion value test, California bearing ratio, unconfined compressive strength and durability evaluations. Prototype modeling was utilized to compare demolition waste with respect to general base materials. It included a plate load test and dynamic cone penetrometer. The prototype model demonstrated that the demolition waste base layer was susceptible to stiffness changes due primarily to changes in moisture.

Prototype model results have been verified using 'Everstress' back-calculation software and it can be shown that the layer coefficient of CCM is equivalent to 0.134. And also this material shows a very high variability with respect to conventional base materials i.e. DGAB. Therefore it is recommended to use this material as a base material for a traffic load of 20kN or less. And it will perform a strong correlation as given in design charts & tables.

Finally it was possible to evaluate a structural capacity of demolition waste and develop a design chart to replace dense graded aggregate base course from demolition waste base layer for construction of roads. Therefore it is recommended to introduce demolition waste material instead of conventional base material based on the developed design guidelines.

TABLE OF CONTENTS

DECLARATION BY CANDIDATE	I
DECLARATION BY SUPERVISOR	II
DEDICATION	III
ACKNOWLEDGEMENT	IV
ABSTRACT	V
TABLE OF CONTENTS	VI
LIST OF FIGURES	IX
LIST OF TABLES	XI
LIST OF ACRONYMS	XII
CHAPTER 1	
INTRODUCTION	1
1.1 GENERAL	1
1.2 OBJECTIVES	2
1.3 SIGNIFICANCE OF THE RESEARCH	3
1.4 THESIS OVERVIEW	4
CHAPTER 2	
LITERATURE REVIEW	5
2.1 INTRODUCTION.....	5
2.2 CONSTRUCTION & DEMOLITION (C&D) WASTE.....	5
2.2.1 CONSTRUCTION (PROCESS) WASTE.....	5
2.2.2 PROPERTIES OF PROCESS WASTE.....	6
2.2.3 DEMOLITION WASTE.....	8
2.2.4 DEMOLITION METHODS.....	8
2.2.5 PROPERTIES OF DEMOLITION WASTE IN SRI LANKA.....	10

2.3 CONSTRUCTION & DEMOLITION MATERIAL APPLICATIONS.....	14
2.4 QUALITY CONTROL REQUIREMENT	16
2.5 SUMMARY	17

CHAPTER 3

EXPERIMENTAL INVESTIGATIONS	18
3.1 INTRODUCTION	18
3.2 LABORATORY EXPERIMENTS	18
3.2.1 CHARACTERIZATION TESTING ON PROCESS WASTE	18
3.2.2 CHARACTERIZATION OF PROCESS WASTE	22
3.2.3 STRENGTH TESTING	22
3.2.4 TESTING ON DEMOLITION WASTE	26
3.2.5 GRADATION OF CCM	27
3.2.6 PREDICTION ON SAMPLE SELECTION BASED ON CBR VALUE	28
3.2.7 PARTICLE SHAPE VARIATION	32
3.2.8 DURABILITY TESTING	34
3.2.9 CALIFORNIA BEARING RATIO	40
3.3 EVALUATION OF STRUCTURAL COEFFICIENT OF CCM	44
3.3.1 PLATE LOAD TESTING ON PROTOTYPE MODEL	44
3.3.2 TESTING SCHEDULE	45
3.3.3 STATIC PLATE LOAD TESTING ON PROTO TYPE MODEL	49
3.3.4 IDENTIFICATION OF FAILURE LOAD	50
3.4 DEVELOPMENT AND VERIFICATION OF PLATE-LOAD DEFLECTIONS.....	54
3.4.1 GENERAL	54
3.4.2 DEVELOPMENT OF BACK-CALCULATION PROGRAM	54
3.4.3 BASIC ASSUMPTIONS AND INPUT DATA	57
3.5 LAYER COEFFICIENT OF CCM (BASED ON AASHTO GUIDELINE)	58
3.6 DEVELOPMENT OF DESIGN CHART	59
3.6.1 SELECTION OF BEST-FIT LINE	60
3.7 SUMMARY	62

CHAPTER 4

DEVELOPMENT OF GUIDELINE63

4.1 CURRENT PRACTICES63

4.2 REQUIRED PROPERTIES OF DGAB64

4.3 REQUIREMENT FOR CCM64

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS67

5.1 CONCLUSION67

5.2 FINDINGS67

5.3 RECOMMENDATION..... 69

REFERENCES.....71

APPENDIX A..... 75

APPENDIX B..... 77

APPENDIX C..... 83

APPENDIX D..... 86

APPENDIX E..... 88

APPENDIX F..... 93

APPENDIX G98



LIST OF FIGURES

FIGURE 2.1: WASTE QUANTIFICATION PROCESS.....	6
FIGURE 2.2: CONSTRUCTION WASTE COMPOSITION	7
FIGURE 2.3: SELECTIVE DEMOLITION OF STRUCTURES.....	9
FIGURE 2.4: SORTED BROKEN CONCRETE STOCKPILED SEPARATELY	9
FIGURE 2.5: DEMOLITION WASTE COMPOSITION.....	11
FIGURE 2.6: COMPONENTS OF A FLEXIBLE PAVEMENT.....	14
FIGURE 3.1: DRY DENSITY VS. MOISTURE CONTENT OF PROCESS WASTE.....	19
FIGURE 3.2: PARTICLE-SIZE DISTRIBUTION OF PROCESS WASTE	20
FIGURE 3.3: LIQUID LIMIT PLOT	21
FIGURE 3.4: SWELLING VARIATION WITH CUMULATIVE TIME OF PROCESS WASTE	23
FIGURE 3.5: 4-DAY SOAKED CBR TEST FOR PROCESS WASTE.....	24
FIGURE 3.6: CBR TEST FOR PROCESS WASTE AT OMC	25
FIGURE 3.7: COMPARISON OF WET SIEVING OVER DRY SIEVING FOR CCM.....	28
FIGURE 3.8: CBR VARIATION WITH DIFFERENT GRADATION FOR CCM SAMPLES.....	29
FIGURE 3.9: UPWARD AND DOWNWARD GRADATION VARIATION OF CCM SAMPLES.....	30
FIGURE 3.10: FLAKINESS INDEX TEST	33
FIGURE 3.11: ELONGATION INDEX TEST.....	33
FIGURE 3.12: MAGNESIUM SULFATE SOUNDNESS TEST FOR COARSE AGGREGATE OF CCM.....	35
FIGURE 3.13: MAGNESIUM SULFATE SOUNDNESS TEST FOR FINE AGGREGATE OF CCM	35
FIGURE 3.14: LAAV VARIATION WITH DIFFERENT CATEGORIES OF CCM	39
FIGURE 3.15: BEFORE LOS ANGELES ABRASION TEST	40
FIGURE 3.16: AFTER LOS ANGELES ABRASION TEST.....	40
FIGURE 3.17: 37.5MM MAXIMUM AGGREGATE CBR VARIATION WITH MC FOR CCM.....	41
FIGURE 3.18: 28MM MAXIMUM AGGREGATE CBR VARIATION WITH MC FOR CCM.....	42
FIGURE 3.19: 20MM MAXIMUM AGGREGATE CBR VARIATION WITH MC FOR CCM.....	42
FIGURE 3.20: CBR VARIATION WITH MC FOR CCM.....	43
FIGURE 3.21: PROTOTYPE EXPERIMENT SETUP.....	44
FIGURE 3.22: DYNAMIC CONE PENETROMETER TEST	46
FIGURE 3.23: GRADING CURVE FOR DGAB SAMPLE.....	47
FIGURE 3.24: FIXING OF LOADING ARRANGEMENT	48
FIGURE 3.25: DIAL GAUGE ARRANGEMENT FOR DEFLECTION READINGS	48
FIGURE 3.26: SETTLEMENT WITH DIFFERENT LAYER THICKNESSES FOR 20kN	50
FIGURE 3.27: IDENTIFICATION OF FAILURE LOAD FOR DGAB	53

FIGURE 3.28: IDENTIFICATION OF FAILURE LOAD BASED ON DEFLECTION BASINS	53
FIGURE 3.29: ILLUSTRATION OF BACK-CALCULATION TO ESTIMATE LAYER MODULUS.....	55
FIGURE 3.30: COMMON ELEMENTS OF BACK-CALCULATION PROGRAMS	55
FIGURE 3.31: THE BACK-CALCULATION PROCESS	56
FIGURE 3.32: DESIGN CHART FOR REPLACEMENT OF DGAB	61
FIGURE 4.1: FLOW CHART OF DESIGNING PROCEDURE.....	66



University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.lib.mrt.ac.lk

LIST OF TABLES

TABLE 2.1: CONSTRUCTION WASTE COMPOSITION.....	7
TABLE 2.2: DEMOLITION WASTE COMPOSITION	11
TABLE 2.3: AGGREGATE GRADING, BINDER CONTENT AND THICKNESS REQUIREMENTS	16
TABLE 3.1: DRY DENSITY VARIATION OF SIX SAMPLES OF PROCESS WASTE	19
TABLE 3.2: PARTICLE-SIZE DISTRIBUTION OF PROCESS WASTE	20
TABLE 3.3: LIQUID LIMIT TEST DATA FOR PROCESS WASTE.....	21
TABLE 3.4: PLASTIC LIMIT TEST DATA FOR PROCESS WASTE.....	21
TABLE 3.5: SWELLING TEST RESULTS OF PROCESS WASTE	23
TABLE 3.6: 4 DAY SOCK CBR TEST FOR PROCESS WASTE	24
TABLE 3.7: CBR TEST FOR PROCESS WASTE AT OMC	25
TABLE 3.8: DIFFERENCE IN WET-SIEVE & DRY-SIEVE PASSING FOR CCM.....	27
TABLE 3.9: CBR VARIATION WITH DIFFERENT GRADATIONS	31
TABLE 3.10: GRADATION DIFFERENCE OF CCM.....	32
TABLE 3.11: FLAKINESS & ELONGATION TEST OF CCM	33
TABLE 3.12: SOUNDNESS TEST OF COARSE AGGREGATE OF CCM.....	36
TABLE 3.13: SOUNDNESS TEST OF FINE AGGREGATE OF CCM	37
TABLE 3.14: LAAV TESTING CATEGORIES CITED IN ASTM C 131.....	38
TABLE 3.15: LOS ANGELES ABRASION VALUE TEST FOR DIFFERENT CATEGORIES OF CCM	39
TABLE 3.16: 37.5MM NOMINAL MAXIMUM AGGREGATE CBR VARIATION WITH MC FOR CCM..	41
TABLE 3.17: 28MM NOMINAL MAXIMUM AGGREGATE CBR VARIATION WITH MC FOR CCM.....	42
TABLE 3.18: 20MM NOMINAL MAXIMUM AGGREGATE CBR VARIATION WITH MC FOR CCM.....	43
TABLE 3.19: MC VARIATION FOR DIFFERENT MAXIMUM AGGREGATE SIZES OF CCM	44
TABLE 3.20: USED MATERIAL PROPERTIES FOR BASE PREPARATION.....	47
TABLE 3.21: LAYER THICKNESS WITH BASE MATERIAL	48
TABLE 3.22: PLATE LOAD DEFLECTION READINGS FOR 20 kN LOAD	50
TABLE 3.23: IDENTIFICATION OF FAILURE LOAD FOR DGAB.....	52
TABLE 3.24 : MATERIAL UNIT WEIGHT	57
TABLE 3.25 : ASSUMED POISSON’S RATIO.....	57
TABLE 3.26: BACK-CALCULATION BY EVERCALC- SUMMARY OUTPUT.....	58
TABLE 3.27: LAYER COEFFICIENT OF CCM.....	59
TABLE 3.28 : SUMMARY OF COMPARISON.....	60
TABLE 3.29: REQUIRED CCM THICKNESS FOR REPLACEMENT OF DGAB.....	61

LIST OF ACRONYMS

AASHTO	American Association of State Highway and
DGAB	Aggregate Base Course
AIV	Aggregate Impact Value
ASTM	American Society for Testing and Materials
BS	British Standard
C & D	Construction & Demolition
CBR	California Bearing Ratio
CCM	Crushed Concrete Material
CNSA	Cumulative Number of Standard Axles
C-S-H	Calcium Silicate Hydrate
DCP	Dynamic Cone Penetrometer
DGAB	Dense Graded Aggregate Base
ESAL	Estimated Standard Axle Load
FEM	Finite Element Model
LAAV	Los Angeles Abrasion Value test
MC	Moisture Content
MDD	Maximum Dry Density
NA	Natural Aggregate
OMC	Optimum Moisture Content
PCC	Portland Cement Concrete
RCA	Recycled Concrete Aggregate
RDA	Road Development Authority

SSCM Standard Specification for Construction Material of Roads and Bridges

UCS Unconfined Compressive Strength



University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.lib.mrt.ac.lk