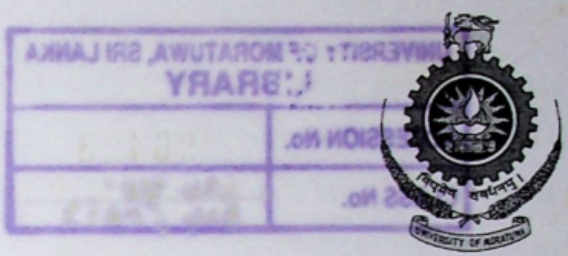
(69)

LIBRARY
UNIVERSITY OF MORATUWA, SRI LANKA
MORATUWA

LB/DON/28/2011
DCE 03/67



RIGID PAVEMENT DESIGN WITH RECYCLED CONCRETE AGGREGATE FOR LOW VOLUME ROADS

This Thesis Submitted to the Department of Civil Engineering of the University of Moratuwa in Partial Fulfillment of the Requirement Towards the Degree of Master of Science

SUPERVISED BY

Dr. W.K. Mampearachchi

Co – Supervisor

Prof S.M.A. Nanayakkara

Department of civil Engineering

University of Moratuwa, Sri Lanka

January 2008

624"08"
624(043)
TH

University of Moratuwa
96428

96428
+
CD-ROM

UNIVERSITY OF MORATUWA
LIBRARY

96428

DECLARATION

"I declare that this is my own work and this thesis 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 expect where the acknowledgement is made in the text"

Signature: ..... Date: 16.07.2010

J.K.U. Gayani

Department of Civil Engineering

University of Moratuwa

DECLARATION

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

Signature: ..... Date: 16/07/10

Dr. W.K. Mampearachchi

Department of Civil Engineering

University of Moratuwa

DEDICATION

TO MY MOTHER AND FATHER

For their continuous dedication and encouragement for my advancement

ACKNOWLEDGEMENTS

The author gratefully acknowledges the research supervisor, Dr. W.K. Mampearachchi, senior lecturer of the department of Civil Engineering for his invaluable guidance and support throughout the research period.

Sincere gratitude is extended particularly to Prof. Ramzdeen, Professor of the department of Building Economics for granting necessary funds from European Union for this study. And also the sincere thanks go to Prof. Bandara for providing the coordination and advices throughout the project.

Author wishes to express thanks to co-supervisor Prof. S.M.A. Nanayakkara who constantly gave his comment and ideas for the improvement of the project during the testing phase.

The support rendered by my fellow student Waruna Jayasooriya and others are also greatly appreciated.

The support given by Prof. W.P.S. Dias (Head, Department of Civil Engineering), and Prof. Bandara (Research Coordinator, Department of Civil Engineering) is acknowledged gratefully. All the other lectures are thanked for the positive attitude they adopted in promoting research in the department of Civil Engineering.

In addition technical officers of the Department of Civil Engineering, Mr. S.P. Madanayake, Mr. S. L. Kapuruge and laboratory assistants Mr. L. Perera and Mr. H.N Fernando and technical assistant Mr. B.S.P.A. Mendis are very much appreciated for their support given to carry out the experimental programme throughout this project.

Finally, the author wishes to thank all those who contributed undying support throughout the year to the completion of this project successfully.

ABSTRACT

The aim of this project is to determine the strength characteristic of recycled aggregates that can be used as an alternative material for rigid pavement construction.

The main consideration of any pavement design is to provide structural alternatives that are feasible both technically and economically. This can be achieved by specifying pavement layer thickness with proper types of materials based on the extent traffic, environmental conditions and life cycle cost analysis.

Since traffic is regarded as the key design parameter, traffic analysis was done for seventeen provincial roads. That analysis was carried out to find vehicle composition, magnitude of the axle loads, axle configuration and frequency of load repetitions.

An experimental campaign was implemented in order to monitor the recycled aggregate properties before utilizing them as a rigid pavement construction material. Properties of recycled aggregate were determined in terms of (i) particle size distribution (ii) particle density (iii) porosity and absorption (IV) particle shape (v) strength and toughness.

Then the development of concrete mix design was done. In this study, various physical and mechanical properties of concretes were examined. The concrete properties were determined by doing the workability test, compressive test, flexural strength and modulus of elasticity test.

Then suitable thicknesses for provincial roads were proposed based on the traffic volume and the recycled aggregate concrete properties.

TABLE OF CONTENTS

	PAGE
DECLARATION OF CANDIDATE	i
DECLARATION OF SUPERVISOR	ii
DEDICATION	iii
ACKNOWLEDGEMENTS	iv
ABSTRACT	v
TABLE OF CONTENTS	vi
LIST OF FIGURES	viii
LIST OF TABLES	x
CHAPTER 1: INTRODUCTION	1
1.1 BACKGROUND	1
1.2 OBJECTIVE	3
1.3 METHODOLOGY	3
1.3 SCOPE OF THE REPORT	4
CHAPTER 2: LITREATURE REVIEW	5
2.1 DEFINITIONS OF CONSTRUCTION WASTE	5
2.2 WASTE COMPOSITION IN SRI LANKA	6
2.3 RECYCLED AGGREGATE CONCRETE APPLICATION	7
2.3.1 RIGID PAVEMENT CONSTRUCTION	8
2.4 LITERATURE REVIEW OF RECYCLED AGGREGATE CONCRETE	12
2.4.1 REVIEWS ON RECYCLED PROCESS	12
2.4.2 BARRIERS IN PROMOTING USE OF RA AND RAC	16
2.4.3 RECYCLED AGGREGATE AS AN ALTERNATIVE MATERIAL FOR NATURAL AGGREGATE IN CONCRETE	18
CHAPTER 3: TRAFFIC ESTIMATION OF LOW VOLUME ROADS	24
3.1 TRAFFIC ANALYSIS	24
3.2.1 TRAFFIC DISTRIBUTION OF PROVINCIAL ROADS	24
CHAPTER 4: EXPERIMENTAL INVESTIGATIONS	31
4.1 DETERMINATION OF RECYCLED MATERIAL PROPERTIES	31
4.1.1 GRADATION OF RECYCLED AGGREGATE	31
4.1.2 DENSITY OF RCM	35

4.1.3 WATER ABSORPTION OF RCM 36

4.1.4 AGGREGATE IMPACT VALUE 36

4.2 DEVELOPMENT OF MIX DESIGN FOR RCA CONCRETE 37

4.3 IMPROVEMENT OF THE PROPERTIES OF FRESH AND HARDENED RCA BY USING ADMIXTURE 49

4.4 COMPARISON OF NORMAL AGGREGATE CONCRETE PROPERTIES AND RECYCLED AGGREGATE CONCRETE PROPERTIES 51

CHAPTER 5: DETERMINATION OF PAVEMENT DEMENTION 52

5.1 DETERMINATION OF A SUITABLE PAVEMENT WIDTH FOR RIGID PAVEMENT BASED ON THE MAXIMUM AXLE LOAD IN PROVINCIAL ROAD 52

5.2 DETERMINATION OF MINIMUM REQUIRED PAVEMENT THICKNESS FOR RAC AND NAC 55

5.3 SELECTION OF SUITABLE THICKNESS FOR PROVINCIAL ROADS 57

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS 66

6.1 CONCLUSIONS 66

6.2 RECOMMENDATIONS 69

REFERENCES

APPENDICES

LIST OF FIGURES

Figure 2.1	Waste quantification process	6
Figure 2.2	Sri Lankan demolition waste compositions	7
Figure 2.3	Rigid pavement layout	8
Figure 2.4	Pumping action failure of the slab	9
Figure 2.5	Recycling Portland cement concrete flow chart	15
Figure 3.1	Axle distribution of Chillaw - Iranawila - Nainamadama Rd	25
Figure 3.2	Axle distribution of Bathuluoya - Dewalahandiya Rd	26
Figure 3.3	Axle distribution of Udupila (Delgoda) of Kirillawala - Udupila Rd	26
Figure 3.4	Axle distribution of Neluwa-Kadihingala- Dellawa- Morawaka Rd	27
Figure 3.5	Axle distribution of Panawala - Maniyangana Rd	27
Figure 3.6	Axle distributions of large buses	28
Figure 3.7	Axle distributions of medium good vehicles	28
Figure 4.1	Sieve analysis test result of RCM (Overall Gradation)	32
Figure 4.2	Sieve analysis test result of RCM (Coarse Fraction Gradation)	33
Figure 4.3	Sieve analysis test result of sand	34
Figure 4.4	Relationship between std.deviation and characteristic strength	37
Figure 4.5	Relation between compressive strength and free water/ cement ratio	39
Figure 4.6	Estimated wet density for fully compacted concrete	40
Figure 4.7	Recommended % of fine aggregate as a function of free w/c ratio for various values of workability and max.agg.sizes	41
Figure 4.8	Slump test	43
Figure 4.9	Flexural strength test	44

Figure 4.10 Strength development of RCM concrete 48

Figure 5.1 Stress variation according to slab width 53

Figure 5.2 Critical wheel path 53

Figure 5.3 Stress variation for different Elastic Modulus for 52 kN axle load 55

Figure 5.4 Required flexural strength to limit the stress ratio to 0.5 56

Figure 5.5 Modulus of subgrade reaction vs CBR value 57

Figure 5.6 Loads vs. Stress relationship for a slab thickness of 100mm 59

Figure 5.7 Loads vs. Stress relationship for a slab thickness of 125mm 59

Figure 5.8 Loads vs. Stress relationship for a slab thickness of 137.5mm 60

Figure 5.9 Loads vs. Stress relationship for a slab thickness of 150mm 60

Figure 5.10 Result of fatigue tests on concrete from different sources 62

LIST OF TABLES

Table 3.1	Vehicle composition as a percentage value from the AADT	24
Table 3.2	Axle load distribution of Panawala Maniyangana Road	25
Table 3.3	ESA variation of each vehicle categories	29
Table 3.4	ESA variation of each vehicle categories in Class A-B roads	30
Table 4.1	Sieve analysis test result for RCM (Overall Gradation)	32
Table 4.2	Sieve analysis test result for RCM (Coarse Fraction)	33
Table 4.3	Sieve analysis test result for sand	34
Table 4.4	Recycled material properties	35
Table 4.5	Probability factor K	38
Table 4.6	Strength of normal concrete mixes at 0.5 w/c ratio	38
Table 4.7	Approximate free water content required to give various levels of workability	40
Table 4.8	Concrete mix design form for mix- B-1	45
Table 4.9	Mix proportions for RAC	47
Table 4.10	Fresh and harden concrete properties with RA	47
Table 4.11	Compressive strength data	48
Table 4.12	Improved concrete properties using admixture	50
Table 4.13	Comparison of concrete properties for normal aggregate and recycled aggregate	51
Table 5.1	Vehicle composition for different ADT in provincial roads	61
Table 5.2	Cumulative fatigue percent due to the vehicles in provincial roads	63
Table 5.3	Stresses for subgrade CBR of 8.5	64
Table 5.4	Stresses for subgrade CBR of 12	64
Table 5.5	Stresses for subgrade CBR of 20	65
Table 5.6	Stresses for subgrade CBR of 36	65
Table 5.7	Pavement thickness for different ADT	65