PERFORMANCE OF STEEL SLAG FOR WEARING COURSE COMPARED WITH CONVENTIONAL WEARING COURSE

MANOUCHEHR SHOKRI

A project report submitted in partial fulfillment of the
requirements for the award of the degree of
Master of Engineering (Civil- Transportation and Highway)

Faculty of Civil Engineering
Universiti Teknologi Malaysia

JUNE 2014

This project report is dedicated to my parents
for their endless support and encouragement

ACKNOWLEDGEMENT

I would like to express my gratitude to all those who gave me a helping hand to complete this thesis. Special thanks goes to my supervisor, Dr. Md. Maniruzzaman B. A. Aziz for his support in this research project and would like to acknowledge SHELL, Singapore for donation of testing asphalt binders. Special thanks dedicated to HoD of JGP Professor Dr. Mohd Rosli Hainin and Dr. Norhidayah Abdul Hassan for their cooperation and permitting to work in highway laboratory at weekends. Many thanks are also due to technicians of UTM and individuals who offered their helps directly or indirectly. who is most responsible for helping me complete the thesis as well as challenging research it. Gratitude also dedicated to all my friends. Thanks for all the helps and supports during all the way upon completing thesis.

Last but not least, I would like to extend my deepest and sincere appreciation to my beloved family especially my parent who are always support me, encourage me and listen to me along my research. They are my source of inspiration and my greatest refuge.

ABSTRACT

Transportation and highway orientation are going to use from sustainable material and recycling material. As the amount of disposed industrial waste material is increasing in road construction, researchers are exploring the use of waste materials which could preserve natural resources and save the environment. One of these sustainable materials is Steel-furnace slag, which is a synthetic aggregate produced as a consequence of the electric arc furnace (EAF). Steel slag was select due to its characteristics, which are almost similar to conventional aggregates, and the fact that it is easily obtainable as a by-product from the steel industry. The same gradations of mixtures would produce using normal crushed aggregate as control samples. This project was carried out to evaluate the performance of EAF steel slag aggregate in AC 14-wearing course mix, where the conventional granite aggregate was replaced with steel slag. In addition the following mix design and performance characterization of the bituminous and aggregates (steel slag aggregates and conventional aggregates) were evaluated in this project through creep tests, Resilient modulus tests at various temperatures, texture depth, skid resistance. The bitumen 60-70 PEN was used and percentage of Steel Slag was considered 0, 30, 50 and 100% for each sample. All the mixtures with EAF Steel slag have satisfied the requisites for acceptance in the road sector technical standards, thus resulting as suitable for use in the construction of road infrastructures. Samples made from steel slag showed considerably better results than conventional aggregate. Therefore, operation of steel slag would reduce land fill, save natural resources and improve the strength of pavement to sustain a higher volume of vehicles. on the other hand, laboratory test result results illustrates better performance against deformation characteristics, skid resistance, stripping of the binder and lateral movement of material compare with conventional wearing course.

ABSTRAK

Pengangkutan dan orientasi lebuh raya akan menggunakan dari bahan mampan dan bahan kitar semula. Oleh kerana jumlah bahan buangan industri dilupuskan semakin meningkat dalam pembinaan jalan raya , penyelidik sedang mengkaji penggunaan bahan-bahan buangan yang boleh memelihara sumber semula jadi dan menyelamatkan alam sekitar. Salah satu bahan-bahan lestari ini sanga keluli- relau, yang merupakan agregat sintetik dihasilkan sebagai akibat daripada relau arka elektrik (EAF). Keluli sanga menjadi pilihan kerana ciri-ciri, yang hampir sama dengan agregat konvensional, dan hakikat bahawa ia adalah mudah diperolehi sebagai produk daripada industri keluli. Penggredan sama campuran akan menghasilkan menggunakan agregat dihancurkan adalah sebagai sampel kawalan. Projek ini telah dijalankan untuk menilai prestasi EAF keluli sanga agregat dalam AC 14- memakai campuran tertentu, di mana agregat granit konvensional telah digantikan dengan keluli sanga. Selain reka bentuk campuran berikut dan pencirian prestasi bitumen dan agregat (agregat sanga keluli dan agregat konvensional) telah dinilai dalam projek ini melalui ujian rayapan , ujian modulus Berdaya Tahan pada pelbagai suhu, kedalaman tekstur, rintangan tergelincir. Bitumen 60-70 PEN telah digunakan dan peratusan Keluli Sanga dianggap 0, 30 , 50 dan 100% untuk setiap sampel. Semua campuran dengan EAF Keluli Sanga telah memenuhi syarat untuk penerimaan dalam piawaian teknikal sektor jalan raya, sekali gus sesuai untuk digunakan dalam pembinaan infrastruktur jalan raya . Sampel dibuat daripada keluli sanga menunjukkan keputusan yang jauh lebih baik daripada agregat konvensional. Oleh itu , operasi keluli sanga akan mengurangkan pengisian tanah, menjimatkan sumber semula jadi dan meningkatkan kekuatan turapan untuk mengekalkan jumlah yang lebih tinggi pada kenderaan. Sebaliknya, keputusan hasil ujian makmal menunjukkan prestasi yang lebih baik terhadap ciri-ciri rekabentuk, rintangan tergelincir, pelucutan daripada pengikat dan pergerakan sisi bahan dibandingkan dengan kursus pemakaian konvensional.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AASHTO	-	American Association of State Highway and Transportation Officials
ASTM	-	American Society for Testing and Materials
JKR	-	Jabatan Kerja Raya
TMD	-	Theoretical Maximum Density
UTM	-	Universal Testing Machine
EAF	-	Electric Arc Furnace
BOF	-	Basic Oxygen Furnace
SS	-	Steel Slag
HMA	-	Hot Mix Asphalt
OBC	-	Optimum Bitumen Content
BS	-	Britsh Standard
ACV	-	Aggregate Crushing Value
LAVV	-	Los Angeles Abrasion Value
AIV	-	Aggregate Impact Value
MTD	-	Mean Texture Depth

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Nowadays the topic of steel slag is one of the most important issues especially in transportation and highway. The molten slag flows from the furnace into a pit area where it solidifies. The slag consists principally of a fused mixture of oxides of calcium, silica, iron, alumina and magnesia. Other benefits of using steel slag in asphalt concrete include the recycling of a waste product, thus reducing the volume of material placed in Oregon landfills. Steel slag, as waste material of steel production, has been used widely in road construction because it has high density and hardness similar to those of coarse aggregates.

In general conditions, steel slag aggregates can replace natural aggregates in approximately every situation. The exemption to this is where the density of the aggregate is a crucial design consideration as in cement (Holliday & Crofton-atkins, 1997).

Hot mix asphalt (HMA) concrete is a combination of aggregate and asphalt cement. The aggregate acts as the structural frame of the pavement and the asphalt cement as the glue of the mixture. The mineral aggregate, including coarse and fine particles in asphalt paving mixtures, encompasses approximately 90% of volume of HMA (Ahmedzade & Sengoz, 2009). Somehow the properties of the aggregate have straight and considerable effect on the performance of asphalt pavements.

The HMA industry has been pressured in recent years to add in a wide variety of waste materials into HMA pavements(Kamboozia, 2012).

The resulting large quantities of slags produced and their potential impact on the environment have encouraged materials scientists and civil engineers to explore technically noise, cost-effective and environmentally acceptable use of this material in civil and highway construction. Steel slag is industrially-produced artificial aggregate which, after suitable treatment, constitute an excellent material for manufacture of wearing course in the road construction industry(According to NR2C(2008), n.d.). The manufacture and its employ are friendly to the environment while contributing in the manufacture of safer highway. Somehow the most destructive effects on construction of road especially wearing course can be to consist fatigue, rutting, skid resistance, and texture depth.

Steel-slag is a byproduct of the steel industry, and is reported to exhibit great potential as a replacement for natural aggregates in road construction. Steel-slag is a waste material that can be recycled as a road construction material. Steel-slag aggregates have been reported to retain heat considerably longer than natural aggregates. In other hand the heat retention characteristics of steel-slag aggregates can be advantageous for HMA construction, as less gas (energy) is used throughout the execution of asphaltic concrete works. Based on high frictional and abrasion resistance, steel-slag is used commonly in industrial roads, intersections, and parking areas where high wear resistance is required (Ahmedzade et al., 2009).

1.2 Problem statement

Most of the aggregates are mined material, which lead towards the reduction of natural resources. Specifically the countries having limited resources of aggregate are in trouble, and thinking about to save their assets for their future generations. On the other hand, a large area of land is being utilized for the disposal of solid waste, producing by Industries, residential, commercial and other similar sources. In this study will speak and compare the specifications conventional design and steel slag

design, that the resilient module in steel slag mix design is higher than conventional mix design. Also the conventional mix design wearing course is so poor toward compare steel slag mix design, steel slag design with excellent interlock aggregate has considerable resistance on rutting and also steel slag has greater cohesive strength compare with conventional mix design

The rapid increase in traffic volume, heavy loading and environmental impact causes early damages to pavement, such as:

- inadequate skid resistance
- deformation of aggregates
- inadequate macro texture

The most important deformation and deteriorations of asphalt hot mix design can be fatigue, rutting, creep the materials, poor skid resistance for a crossing heavy vehicles and repeated of them. Because so performance of asphalt mix design always has been steady resistance about this deterioration, in the other hand uses from new material in construction of road such as steel slag especially in wearing course can help to goes up of resistance wearing course.

1.3 Objectives

The aim of this study is to acquire sufficient knowledge of the characteristics of (EAF) steel slag as an aggregate for the design of HMA.

- To evaluate the use of different percentage of steel slag comparing with the replacement of the natural aggregates in wearing course in terms of texture depth, creep, resilient modules and skid resistance.

- To obtain a best HMA for wearing course and determine the feasibility of using steel slag aggregate in ACW14 by a suitable proportion of steel slag from the electric arc furnace (EAF), the natural aggregate and the bitumen binder.

1.4 Significance of study

From the study, the feasibility and performance of ACW 14 by using steel slag as aggregate replacement can be obtained. From the economic point of view, utilization of steel slag as road construction aggregate may reduce the cost of extracting and processing naturally occurring aggregates. The industry producing steel may also reduce their cost for treating and disposing the large number of steel slag stockpiles. In road construction, economic factor had played a major role to decide the qualities of pavement. Hundreds of millions Ringgit Malaysia allocated for road construction and maintenance work for every year. So when the performance of pavement may be increased, the maintenance cost for pavement may also reduce. From environment impact, utilization of steel slag aggregate may directly reduce on naturally occurring aggregate and the number of raw material extracting projects. Incorporating steel slag in road construction also can reduce the use of landfill area.

1.5 Scope of study

The scope of the study will be focus the performance of the Stone Mastic Asphalt (SMA) when aggregate is replaced with 0%, 30%, 50% and 100% steel slag. The steel slag were used is from Purata Keuntungan Sdn. Bhd located at Pasir GudangLaboratory Marshall mix design have been done in this study and all mix design was referred from JKR/SPJ/2008. The bitumen were be used is from 60/70. For control mix design, the aggregate were got from MRP Quarry locate at Ulu Choh, Pulai. The test that doing in this research is resilient modulus, creep test, skid resistance and texture depth. And then, the result will be compare with the control mix that used the common aggregate. This study only limited to laboratory test and not considered

field test. All the test and laboratory work were performed at Highway and Transportation Laboratory, Universiti Teknologi Malaysia.

REFERENCES

Ahmedzade, P., & Sengoz, B. (2009). Evaluation of steel slag coarse aggregate in hot mix asphalt concrete. Journal of hazardous materials, 165(1-3), 300–5. doi:10.1016/j.jhazmat.2008.09.105

Airey, G. D., Collop, A. C., & Thom, N. H. (2004). Mechanical Performance of Asphalt Mixtures Incorporating Slag and Glass Secondary Aggregates, (September).

Ameri, M. (2012). Evaluation of the Use of Steel Slag in Concrete, (Geopave 1993), 1–9.

Arenicz, R. M., Development, E. P., Steel, A., Services, M., Kembla, P., & Lecturer, S. (n.d.). NATIONAL SLAG, 1–11.

Asi, I. M. (2007). Evaluating skid resistance of different asphalt concrete mixes. Building and Environment, 42(1), 325–329. doi:10.1016/j.buildenv.2005.08.020

Behnood, a., & Ameri, M. (2012). Experimental investigation of stone matrix asphalt mixtures containing steel slag. Scientia Iranica, 19(5), 1214–1219. doi:10.1016/j.scient.2012.07.007

Chesner, W., Collins, R., & MacKay, M. (1998). User guidelines for waste and by-product materials in pavement construction. Retrieved from http://trid.trb.org/view.aspx?id=483842

Demand, T., & Models, F. (n.d.). No Title, 1–70.

Dippenaar, R. (2004). Industrial uses of slag — the use and re-use of iron and steelmaking slags, 57–70.

Faculty, M. (n.d.). Application of electric arc furnace slag, 436–444.

Framework, S., & Union, E. (n.d.). NR2C New Road Construction Concepts.

Green, J. J. (1998). National slag association, 20007(November).

Hafeez, I., Kamal, M. A., Ahadi, M. R., Shahzad, Q., & Bashir, N. (n.d.). Performance Prediction of Hot Mix Asphalt from Asphalt Binders, 2012, 104–113.

Hainin, M. R., Yusoff, N. I. M., Mohammad Sabri, M. F., Abdul Aziz, M. A., Sahul Hameed, M. A., & Farooq Reshi, W. (2012). Steel Slag as an Aggregate Replacement in Malaysian Hot Mix Asphalt. ISRN Civil Engineering, 2012, 1–5. doi:10.5402/2012/459016

Hamzah, M. O., & Yi, T. C. (2008a). Effects of Temperature on Resilient Modulus of Dense Asphalt Mixtures Incorporating Steel Slag Subjected to Short Term Oven Ageing, 36(December), 221–225.

Hamzah, M. O., & Yi, T. C. (2008b). Effects of Temperature on Resilient Modulus of Dense Asphalt Mixtures Incorporating Steel Slag Subjected to Short Term Oven Ageing, 221–225.

Holliday, K. A. (1997). Steel Slag - The High Performance Industrial Aggregate, (October 1996), 1–23.

Holliday, K. A., & Crofton-atkins, P. (1997). Steel Slag - The High Performance Industrial Aggregate, (October 1996), 1–23.

Jones, R. T. (2004). Economic and environmentally beneficial treatment of slags in DC arc furnaces, 363–376.

Joulazadeh, M., & Joulazadeh, F. (2010). Slag; Value Added Steel Industry Byproducts. Archives of Metallurgy and Materials, 55(4). doi:10.2478/v10172-010-0017-1

Kamboozia, N. (2012). The Linear Visco-Elastic Behavior of Glasphalt Mixture under Dynamic Loading Conditions Visco-Elasticity, (Arabani 2011), 1–12.

Khan, Z. A., Malkawi, R. H., Al-ofi, K. A., & Khan, N. (2002). Review of Steel Slag Utilization in Saudi, 3(December).

Khanzadi, M., & Behnood, A. (2009). Mechanical properties of high-strength concrete incorporating copper slag as coarse aggregate. Construction and Building Materials, 23(6), 2183–2188. doi:10.1016/j.conbuildmat.2008.12.005

Liapis, I., & Likoydis, S. (2012). Use of Electric Arc Furnace Slag in Thin Skid–Resistant Surfacing. Procedia - Social and Behavioral Sciences, 48, 907–918. doi:10.1016/j.sbspro.2012.06.1068

Liz Hunt, P. E. &Glen. E. B. (2000). Steel Slag in Hot Mix Final Report

Liz Hunt, P. E. &Glen. E. B. (2012). Steel Slag in Hot Mix Final Report Research Article, Volume 201(ISRN Civil Engineering), 5.

Louzi, N. (2012a). Modification of Hot Asphalt Mixtures in Jordan and Syria by Using Steel Slag, 6(3), 279–292.

Louzi, N. (2012b). Modification of Hot Asphalt Mixtures in Jordan and Syria by Using Steel Slag, 279–292.

Mostafaee, S. (2011). A Study of EAF High-Chromium Stainless Steelmaking Slags Characteristics and Foamability.

Muniandy, R., Aburkaba, E., Mahdi, L., & Ehsan, S. D. (2012). Effects of Mineral Filler Particle Size and Type on Permanent Deformation of Stone Mastic, 50–64.

November, S. (2008). Performance Evaluation of Steel Slag as Natural Aggregates Replacement in Asphaltic Concrete, (November).

nsa_173-3_steel_slag_rr_ballast.pdf. (n.d.).

Slag, S., In, U., Mixes, A., & Emery, J. (n.d.). National Slag Association, (416), 1–11.

Sofilić, T., Mladenovič, A., & Sofilić, U. (n.d.). Characterization of The Eaf Steel Slag As Aggregate For Use In Road Construction.

Takahashi, T., & Yabuta, K. (2002). New Applications for Iron and Steelmaking Slag, 87(87).

Tang, Y. (2013). Effect of Slag Composition on Fatigue Life of High Speed Wheel Steel. Advanced Materials Research, 675, 264–269. doi:10.4028/www.scientific.net/AMR.675.264

The Basic Oxygen Steelmaking (BOS) Process. (n.d.).

TRB 2013 Annual Meeting Paper revised from original submittal. (2013), 1–11.

Wang, G., Wang, Y., & Gao, Z. (2010). Use of steel slag as a granular material: volume expansion prediction and usability criteria. Journal of hazardous materials, 184(1-3), 555–60. doi:10.1016/j.jhazmat.2010.08.071

Wang, Y., & Wang, G. (2011). Improvement of Porous Pavement.

Weymouth, T. S. (2006). Evaluation of Characterization Techniques for.

Wilson, D. J. (n.d.). Comparison of Skid Resistance Performance between Greywackes and Melter Slag Aggregates in New Zealand, 1–15.

Yildirim, I. Z., & Prezzi, M. (2011a). Chemical, Mineralogical, and Morphological Properties of Steel Slag. Advances in Civil Engineering, 2011, 1–13. doi:10.1155/2011/463638

Yildirim, I. Z., & Prezzi, M. (2011b). Chemical, Mineralogical, and Morphological Properties of Steel Slag. Advances in Civil Engineering. doi:10.1155/2011/463638