PERFORMANCE OF STEEL SLAG AS REPLACEMENT OF NATURAL AGGREGATE IN WEARING COURSE OF FLEXIBLE PAVEMENT

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Dedicated to my family specially my mother and father, to my brothers and sister,
my son and all my friends…
I really appreciate their support and encouragement
I miss you all...
Zulfiqar Ali

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ABSTRACT

A byproduct obtained from steel industry known as steel slag, is reflecting as a construction material throughout the world. Mainly there are two types of steel slag, Basic Oxygen Furnace (BOF) and Electric Arc Furnace (EAF) obtained from steel industry. Steel slag is further processed to obtain different grades of aggregate to be used in pavement construction. Not all but most of the physical properties of steel slag are similar to the natural aggregate. 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. Five dense graded mix designs were incorporated with penetration grade 80/100 bitumen binder. The EAF steel slag was used to replace granite aggregate at percentage of 0, 25, 50, 75 and 100%. The same gradation as used for natural aggregate was followed for steel slag aggregate also, in accordance with Jabatan Kerja Raya (JKR) specification. Marshall mix design was used to obtain the optimum bitumen content (OBC) for test samples. The asphaltic concrete samples were examined through sand patch test to evaluate the surface texture depth of five different asphalt concrete mixes. The same mixes were also evaluated to find out the skid resistance of samples. The overall results of samples containing steel slag show productive results as compare to the conventional aggregates. These results confirm the potential of steel slag aggregate, and appreciate the use of EAF steel slag for the construction of green pavements by saving natural resources of aggregate.

ABSTRAK

Satu hasil sampingan industri keluli yang dikenali sebagai keluli sanga, adalah bahan pembinaan di seluruh dunia. Terdapat dua jenis keluli sanga utama diperolehi daripada industry keluli iaitu, Relau Oksigen Asas (BOF) dan Elektrik Arc Relau (EAF). Steel sanga terus diproses lagi untuk mendapatkan gred yang berbeza daripada agregat yang akan digunakan dalam pembinaan turapan. Tidak semua tetapi kebanyakan sifat-sifat fizikal keluli sanga adalah sama dengan agregat semula jadi. Projek ini telah dijalankan untuk menilai prestasi EAF keluli sanga agregat dalam *AC 14-wearing course mix*, di mana agregat granit konvensional telah digantikan dengan keluli sanga . Lima padat reka bentuk campuran bergred telah digabungkan dengan penembusan gred 80/100 bitumen pengikat. EAF keluli sanga telah digunakan untuk menggantikan agregat granit pada peratusan 0, 25, 50 , 75 dan 100%. Penggredan sama seperti yang digunakan untuk agregat semulajadi diikuti untuk keluli sanga agregat juga boleh, selaras dengan Jabatan Kerja Raya (JKR) spesifikasi. Rekabentuk campuran *Marshall* telah digunakan untuk mendapatkan kandungan bitumen optimum (OBC) untuk sampel ujian. Sampel konkrit asfaltik telah diperiksa melalui ujian tampalan pasir untuk menilai kedalaman tekstur lima permukaan asfalt campuran konkrit yang berbeza. Campuran yang sama juga dinilai untuk mengetahui rintangan tergelincir sampel. Keputusan keseluruhan sampel yang mengandungi keluli sanga telah menunjukkan keputusan yang produktif berbanding dengan agregat konvensional. Keputusan ini mengesahkan potensi keluli sanga agregat, dan seterusnya menghargai penggunaan EAF keluli sanga untuk pembinaan laluan pejalan kaki hijau dengan menyimpan sumber semula jadi agregat.

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LIST OF ABBREVIATION

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	-	British Standard
ACV	-	Aggregate Crushing Value
LAAV	-	Los Angeles Abrasion Value
AIV	-	Aggregate Impact Value
MTD	-	Mean Texture Depth

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

Highway network is considered as the back bone of country's economy, because about 80% transit of passengers and goods depends on this mode of transportation. It facilitates the road users from there door steps to the terminals of other modes, industrial areas, commercial areas, institutional, even every type of land use area. Definitely for the construction of such a network, a huge quantity of material is required.

Natural aggregate in the form of boulders, gravels, and sand have been used for thousands of years for construction purposes. Significant modification of aggregate carried out during the Roman empire to construct their roads network and aqueducts. The invention of concrete, highly increased the demand of aggregate. Aggregate is an important material blended with a binder, serves as a reinforcement and increases the overall strength of the composite material.

For the construction of sustainable and green pavements, the factors like environmental, economic, technical and deficiency of proper construction material have diverted the attention of researchers to think about alternatives. In result they have explored variety of recycled materials can be used as aggregates, one of them is steel slag. This byproduct is obtained by two methods either from the conversion of iron to steel in the basic oxygen furnace BOF, or the melting of scrap in electric arc furnace EAF to make steel.

The worldwide production of steel reached up to 109.3million tones in 2007 with the increase of 7.6% as compared with previous years .Where China, Japan and United States, are the top producers of steel, and the topmost consumers are Singapore (1,200kg), Taiwan (over 970kg) and Korea (830kg) per capita (Nayak 2008). The production of three tonne of stainless steel yields about one tonne of steel slag. It has been reported that the worldwide production of steel slag, is about fifty million tons per year. Furthermore, in Europe, every year nearly 12 million tons of steel slag is produced (Ahmedzade and Sengoz 2009). In Germany the high cost of landfills resulted the recycling of steel slag as a building material. EAF had been introduced more than 40 years ago and today 70 % of steel slag is being used as a construction material (Apfel).

The use of steel slag as aggregate results both positive (wear resistant, skid resistant, rough textured, angular, well graded, stripping resistant) and negative (heavy, expansive). Considerable experience and researches since 1970 throughout the world has shown that the use of steel slag in asphaltic concrete minimizes number of problems experienced by conventional asphalt concretes and provides high stability, stripping resistant asphalt mixes with excellent skid resistance (Emery 1986).

Malaysia is also generating a sufficient amount of waste material in the form of steel slag. But it is not being utilized as a recycled material, since the steel slag has already been declared as a building material and not a waste material.

1.2 Problem Statement

The rapid increase in traffic volume, heavy loading and environmental impact cause early damages, which badly affect service life of the pavements. These damages like rutting, inadequate skid resistance due to polishing of aggregates, cause serious crashes by increasing the number of accidents day by day. Most of the physical and mechanical properties of steel slag are similar or better than natural aggregate. Therefore it is reflecting throughout the world as a construction material specially in the field of highway construction. As steel slag is a porous, highly rough textured and angular material, containing significant amount of iron which makes it sufficient hard, dense and abrasion resistant. These characteristics may reduce the early damages and enhance the structural and functional performance of the pavements by increasing the safety of road users.

Partial replacement of natural aggregate with steel slag in asphalt pavement mixes may provide satisfactory results. Otherwise the 100% steel slag requires higher amount of bitumen due to its high porosity and also cause volume expansion because of containing free spongy lime and magnesium.

With the development of highway construction industry, Malaysia may experience the reduction of aggregate resources near future, because a large land is being covered by disposing off the steel slag.

1.3 Aim and Objectives of the Study

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.

The objectives are:

i. To obtain a best HMA for wearing course AC14 by a suitable proportion of EAF steel slag, natural aggregate and the bitumen binder, this should perform much better as compare to natural aggregate.

ii. To evaluate and compare the performance of asphalt concrete mixes incorporated with different percentages of steel slag by replacing granite aggregate, in terms of macro-texture and skid resistance.

1.4 Scope of the Study

The scope of this study was to develop asphalt mixes by partial replacement of natural aggregate with 0, 25, 50, 75, and 100% of EAF steel slag. The mix types were completely of dense grade conforming the JKR AC14 gradation system. For all type of mixes 80/100 bitumen penetration grade was incorporated as a binder. The percentage of bitumen binder was increased 0.5% to 1% with the increment of steel slag, the reason was to obtain adequate optimum bitumen content as steel slag is porous material requires higher bitumen as compare to the natural aggregate.

For this research natural aggregate was obtained from Ulu Choh Sdn Bhd quarry Pulai Johor Bahru, Malaysia. EAF steel slag was obtained from Antara Steel Mill Sdn Bhd Pasir Gudang, Johor, Malaysia.

A range of physical and mechanical tests was carried out to examine the mixes in Highway and Transportation Laboratory, University Technology Malaysia Johor Bahru Campus.

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