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Alternative Waste Aggregates in Road Base Materials

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Abstract

This paper addresses the need to use limestone rock aggregates, Granulated Blast Furnace Slag (GBS) waste materials together with recycled aggregates waste dust as a replacement for primary crushed rock aggregates in road base materials.

Using these materials at high volume will generate a new market for waste producers and waste management companies and will reduce the burden of landfill and the associated environmental and social impacts.

The re-use of wastes in high-value applications and reduced primary aggregate consumption will increase resource efficiency in the field of pavement construction. This work will have a direct impact on two quality of life indicators: "consumption of primary aggregates per unit value of construction" and "ratio of secondary to primary aggregate consumption".

In this study up to 10-20 % of the primary aggregates were replaced with dust recycled waste materials. Early laboratory results indicate that, this approach can also offer outstanding increase in the road base material stiffness and produce cost savings.

Keywords

Road base, Limestone rock aggregates, Recycled aggregates, Road base materials

1. Introduction

This study is aimed at gaining competitive advantage from developing a range of road base materials that can be produced and laid with high recycled aggregate content. Alternatively the technology could also be used for encapsulating hazardous wastes prior to landfill disposal to protect the natural environment.

Highways authorities are increasingly demanding new sustainable products from their supply chain partners. Therefore, if successful, this work will deliver a very low carbon footprint road base solution suitable for light to high trafficked roads and highways areas. To implement this technology in practice will require no additional cost as the use of conventional road base material laying and mixing is sufficient.

This proposition will be targeted initially at local roads offering a sustainable solution and helping local highway authorities to address the need to increase recycling, particularly of highway related waste materials.

There is evidence within Europe of road base materials containing waste coarse aggregates offering significant cost savings over road base materials containing expensive crushed rock aggregates. For example Tarmac ltd in the UK have already launched road base materials with waste coarse and dust aggregates aimed at boosting recycling and providing environmental savings.

Pavement is a key structural element in all highways, roads, walkways, industrial enterprises and airports. It is a foundation that sustains the operational loads generated from traffic, and transfers them to the supporting soil via unbound road base material without any structural failures or unacceptable settlements.

The main uses of unbound road base materials are beneath the blacktop or concrete wearing and base courses in highways and road pavements, forming the sub-base, and if required capping. Capping is essentially an improvement of the formation and is usually considered part of the earthworks.

The function of unbound materials or road base materials can be summarised as to: a) provide a working platform for construction traffic, b) provide a drainage layer, c) contribute to the structural performance of the finished blacktop or concrete finished pavement and d) to act as a frost protection blanket.

Currently the UK aggregate market is estimated at 270 million tonnes, recycled and secondary 65 millions and demolished and crushed waste of 40 million tonnes (Robinson, 2000; Dunster, 2001; Shi, 2004). Unbound road base materials for pavement absorbing more than 135 million tonnes of coarse aggregates. In the last 10 years the rate of using waste and secondary aggregates in unbound road base materials are significantly increased and certain attention being given to the use of Steel Slag (SS) and Blast Furnace Slag (BFS) (www.aggregain.org.uk March 2006).

It is clear that the partial replacement of primary aggregates with waste crushed rock lime stone dust and Granulated Blast Furnace Slag (GBS) dusts can make a significant contribution towards reducing current reliance on primary aggregate extraction whilst, the available amounts of waste stockpiles will be minimised. Therefore, the impact of this work is potentially very significant in two ways; first, reducing the extraction of primary aggregates will reduce the environmental impacts of quarrying and any associated social nuisance, and second, developing high value markets for significant waste stream by using alternative aggregates from rock aggregates crushing waste dust, steel slag and blast furnace slag wastes.

Literature review in this area has shown that, steel slag is being used as bound and unbound aggregate in road sub-base; bitumen bound base (road base) and surface (wearing) courses (Arm, 2003; Andre's, 2001; Murphy, 1997). Applications of BFS include aggregate used for highway capping and sub-base layers; bitumen bound base (road base), binder base and surface wearing courses (Geisler, 1994; Monaco and Wu, 1994).

Previous study also has shown that SS and BFS posses self binding properties (Maria, 2003; Pal *et al*., 2003; Wang and Emery, 2004), *and the early stages development of their stiffens and load carrying capacities properties (when they are used as unbound base materials for highway pavement applications) are not fully explored and understood by their users.*

Recognising the increasing need felt by the unbound and slightly bound pavement engineering practice to advance to more functional specifications for base and sub-base materials, this research application was set up with two aims:

To make the initial results for establishing of the early stage mechanical behaviour of road base materials containing high level of waste crushed rock and GBS dust available in the UK and,

To further the understanding of the stress dependent mechanical behaviour of road base containing GBS hydraulically bound base materials.

2. Laboratory Research Work: Material Types and Mix Descriptions

The critical part of controlling the high volume recycled rock and GBS waste dust aggregates in road base technology lies with developing road base materials that are able to be fully compacted using conventional laying and compaction equipments whilst providing a long shelf-life (workability) and yet be able to set quickly following compaction. The narrative below refers to previous work completed by LJMU and Tarmac Ltd in the UK, funded by the Department of Trade Industry in the UK, DTI and illustrates the type of activity required to develop road base materials containing waste limestone and GBS aggregates dust technology.

With the overall aim of studying the initial results for establishing of the early stage mechanical behaviour of road base materials containing high level of waste limestone and GBS dusts and to further the understanding of the stress dependent mechanical behaviour of GBS hydraulically bound road base materials, it was considered essential to choose initially a wide range of road base materials as shown in Table 1 below, that would display most clearly the benefits or disbenefits of the high level of waste materials.

Four triaxial samples from each of the mixes shown in Table 1 were prepared according to the British Standard and tested for the evaluation of Resilient Modulus, Mr, using the triaxial facility at Liverpool John Moores University.

Table 1: Material Types

Material Type/ Mix No.	Mix descriptions
Mix 1	Stancombe[1] Type 1 – Control
Mix 2	Stancombe Type 1 + 10% Limestone dust
Mix 3	Stancombe Type 1 + 20% Limestone dust
Mix 4	Stancombe Type 1 + 20% limestone dust + 5% GBS (granulated blast furnace slag)
Mix 5	Stancombe Type 1 + 20% Limestone dust + 10% GBS

[1] Stancombe = limestone rock aggregate (primary aggregates) used for road base materials in the UK

Samples have been compacted in layers at their optimum moisture contents directly into 150 mm diameter circular moulds with a height of 300 mm.

3. Results and Discussions

Figures 1 and 2 below show the triaxial testing results of the 5 mixes. All the mixes were manufactured at their optimum moisture contents and stored in the laboratory at a temperature of approximately 20C^{o} for 28 days before testing.

In Figure 1 and at a deviator stress of 73 kPa the addition of 10 % lime stone dust (all dust used in this research work is made from 0.0-4mm size materials) to the limestone control mix yields improvements in resilient stiffness (Mr) of 8 %, whereas adding 20 % lime stone dust yield a reduction in the stiffness modulus 37.5 %, showing that the increase in the amount of dust in the control mix above 10% limestone dust reduces the density of internal interlocking status of the micro structure of the road base materials.

At the other deviator stress the same finding holds true where the mix with lime stone + 10 % limestone dust shows a varying rate of increase in the resilient modulus values, whereas the mixes with limestone + 20 % limestone dust shows significant reduction in the resilient modulus at all the deviator stress covered in the testing programme.

Figure 2, shows an outstanding increase in the resilient modulus of the following mixes compared with the limestone control mix and the limestone mix with 20% limestone dust;

Limestone + 20 % limestone dust + 5 % GBS,

Limestone + 20 % limestone dust + 10 % GBS,

They all achieved more than 215% improvement in their Mr values compared with the mix which contains limestone + 20 % limestone dust. A closer look at these mixes suggested that they are concrete-like mixes and further testing and investigation is currently undertaken ay LJMU to explain the gain in their compressive and flexural strengths together with full chemical, XDR, XRF and ESM analysis.

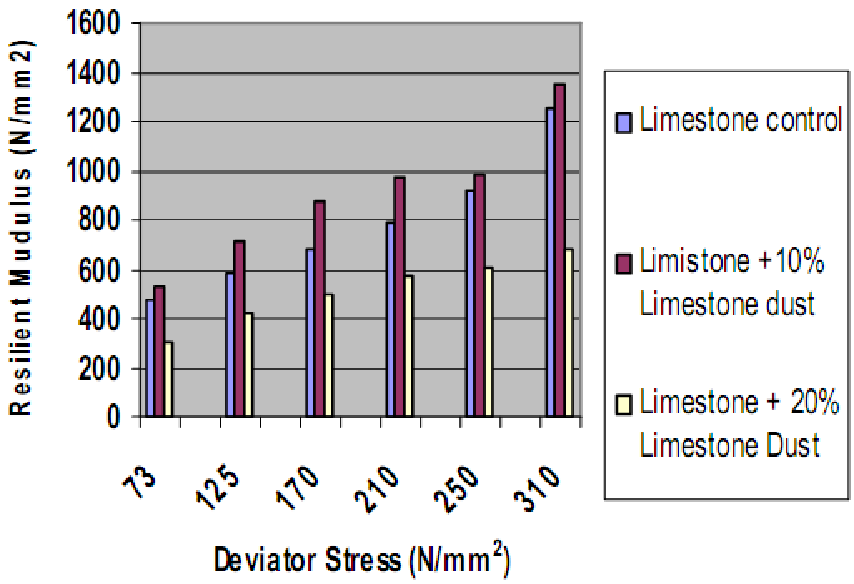

Figure 1: Resilient Modulus of the Mixes

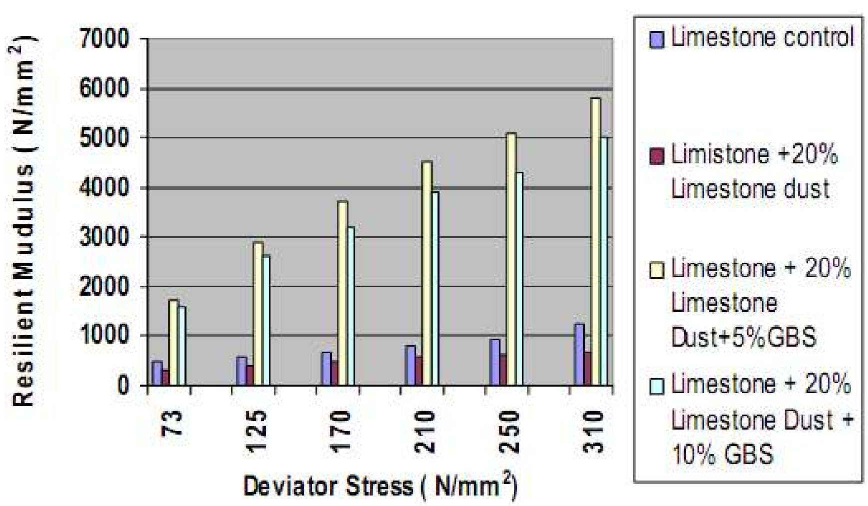

Figure 2: Resilient Modulus of the Mixes Containing Added Dust and GBS

4. Conclusions

1. The addition of 10 % lime stone dust to the control mix shows improvements in the mixes resilient stiffness (Mr) at all the levels of deviator stress. A value of 8 % improvements in the resilient modulus is noted at deviator stress 73. The rate of increase in the resilient stress is improved at stress deviators 125, 170 and 210 compared with the improvement in the resilient stress at deviator 73. This rate of improvement is low at stress deviator 250 and 310 compared with the values of gains in the resilient modulus at stress deviators 73, 125, 170 and 210.
2. The addition of 20 % lime stone dust yield a reduction in the stiffness modulus of 37.5 % at deviator stress of 73 N/mm^2 and significant reduction in the resilient stress at the rest of the deviator stress showing in the figure, showing that the increase in the amount of dust in the control mix above 10 % limestone dust reduces the density of internal interlocking status of the micro structure of the road base materials and thus produce a weaker road base materials than the control mix currently accepted by road engineers.
3. An outstanding increase in the resilient modulus of the following mixes compared with the limestone control mix and the limestone mix with 20 % limestone dust;

   Limestone + 20 % limestone dust + 5 % GBS,

   Limestone + 20 % limestone dust + 10 % GBS,

   They all achieved more than 215 % improvement in their Mr values compared with the mixes which contains limestone + 20 % limestone dust. A closer look at these mixes shows that they are all hydraulically bound concrete-like road base materials.

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