vic roads

TECHNICAL NOTE

Steel Furnace Slag Aggregate 09

INTRODUCTION

This Technical Note provides information on the properties of steel furnace slag aggregate and potential uses in roadworks.

Steel furnace slag (SFS) aggregate is a by-product of the steel making process. Use of this product in the road industry represents an opportunity to supplement finite quarry resources with this manufactured material. Industrial slags are recognised as a potential source of recycled material for use in various applications for roadworks through Austroads Guide to Pavement Technology Part 4E: *Recycled Materials* (1).

PRODUCTION

There are two main methods used to produce steel by refining pig iron and steel scrap, with a resultant slag by-product.

The basic oxygen steel (BOS) process uses oxygen blown into a steelmaking vessel charged with molten pig iron creating exothermic reaction, to produce large quantities of BOS slags at steelworks at Port Kembla (NSW) and Whyalla (SA).

The electric arc furnace (EAF) process uses high voltage current to melt the steel scrap charge and produces smaller quantities of EAF steel slag at steelworks at Melbourne, Sydney and Newcastle.

Both methods involve the removal of excess carbon, silicon and other elements not needed in modern steels. This process of removal is aided by the addition of lime as part of the flux which serves to combine the unnecessary constituents contained in source material (i.e. resulting in the production of slag) from the molten steel. Both BOS slag and EAF slag are considered as SFS aggregate.

SFS is different to Iron Blast Furnace Slag (BFS) which is a by-product of the iron making process using blast furnaces. BFS slag is not discussed in this Technical Note.

The SFS produced from the steel making furnaces is typically air cooled, forming a solid rock type material, and has similar appearance and properties to igneous rock. The steel slag is crushed to size and is normally produced through a range of sizes up to about 75mm.

Both BOS and EAF steel slag have similar physical and chemical properties, typical properties are detailed in Austroads Guide Part 4E - *Recycled Materials*. Steel slag has a density higher than igneous rock, with guidance values for density provided in the Austroads Guide (1). Typical chemistry for BOS and EAF slags after appropriate conditioning and weathering can be obtained from the Australasian (iron & steel) Slag Association (2).

The chemical composition of SFS aggregate may vary slightly within the steel making practice and the quality of steel being produced. The range of variation can be significantly lower than for natural aggregates.

CHARACTERISTICS OF STEEL SLAG

The physical and mechanical properties of SFS aggregate have similarity with properties of natural hard rock aggregates.

The features of steel slag aggregates are as follows:

- Strong and very durable.
- Excellent cubical shape which creates very strong interlocking properties as well as minimizing potential shear failures.
- High resistance to abrasion and impact, which provides increased serviceability advantages
- High skid resistance due to high polished aggregate friction values
- Strong affinity to bituminous binder due to its high alkalinity
- Recovered by-product, reducing mining of virgin aggregate resources
- Typically denser than natural rock aggregate.

Figure 1 – Steel Furnace Slag Aggregate [2]

EXPANSION AND CONDITIONING

Expansion

During the steel making process small percentages of un-hydrated lime inclusions can remain undissolved in the steel slag.

SFS aggregates exhibit a volume expansion which is managed by conditioning the aggregate using water. The volume expansion of SFS aggregate is primarily caused by a reaction between the un-hydrated (free) lime in the slag and water to produce calcium hydroxide.

Volume expansions of up to 10 to 20% have been reported for overseas slags, which were consistent with relatively higher free lime contents. Recent investigations in Australia have reported lower free lime contents in the order of 3 to 4% and therefore lower expansion values of up to about 2%. The testing for volumetric expansion of steel slag differs from country to country. As such, test methods developed by using local slag should be adopted for the acceptable limits for percentage of expansion.

Conditioning

Due to its expansive nature, SFS aggregates must be allowed to undergo a conditioning (weathering) process to reduce the quantity of free lime to acceptable limits prior to use in road construction. In order to achieve this, SFS aggregate should be allowed to stand in stockpiles exposed to the weather for a period of one to three months for all types of applications. This conditioning period must be applied from the time that the slag is in its final size.

An acceptable method for conditioning SFS aggregates in Australia is to thoroughly water the slag one day per week over a four week period (or longer if appropriate) to create the "dry and wet" cycle.

Overseas literature also suggests that a protective film provided by a binder such as bitumen would eliminate or limit the amount of hydration of free lime in the slag. It is generally accepted that the critical free lime content in a specific SFS aggregate, after which no further hydration occurs, is about 3%. It is therefore important that conditioning measures are undertaken to limit or reduce the content or the effect of free lime in SFS aggregate before use in roadworks.

DENSITY

Steel furnace slag is a heavier material than natural rock types such as basalt, granites or limestone. A given volume or area of application would require a greater tonnage of SFS aggregate than traditional rock aggregates. Attention should be given to cartage of SFS aggregates to ensure trucks carry a legal load.

APPLICATIONS FOR STEEL SLAG

The following list provides some applications of steel slag aggregates in roadworks.

- Sprayed sealing and asphalt applications
- Skid resistant sealing aggregate
- Base and subbase pavement construction
- Hard stand areas
- Construction fills
- Subsurface drainage filter materials
- Grit blasting.

SFS aggregate is not suitable as a coarse aggregate in concrete manufacture due to possible expansion problems.

Asphalt and Sprayed Sealing

Steel slag aggregates have been successfully used in both asphalt and sprayed seal applications.

Due to better strength, abrasion and impact resistance than natural aggregates, steel slag aggregates are particularly suitable for use in areas subjected to heavy vehicle loads and high shear stress.

The excellent cubical shape and high affinity for bitumen provides potential for reduced risk of stripping for sprayed seals. SFS aggregate also has synergy with natural materials. A blend of SFS aggregate and natural materials as a asphalt layer also can be an option when SFS aggregate is unavailable for total quantities.

Steel slag aggregates typically have a high polished stone value (58 to 63 PSV) which can be used where a high friction surface of sprayed seal or asphalt is required.

Pavement Construction

SFS aggregate can be used as a pavement material.

The crushed SFS can be used as is, or blended with other materials (e.g. granulated blast furnace slag, flyash, or insitu granular materials) to produce a material similar to crushed rock. This material can be suitable for sub-base layers, and may be suitable as a base layer. Crushed slag mixes must be registered in accordance with VicRoads Code of Practice RC500.02 *Registration of Crushed Rock Mix Designs* (3) prior to use on any VicRoads works.

In some cases, the crushed slag can display cementitious properties with sufficient unconfined compressive strength to meet the requirements for cement treated crushed rock. However, excessive unconfined compressive strength should be avoided.

The material is less sensitive to water than some natural aggregates and should be compacted close to saturation point. The material can be ripped and remixed and will again achieve a lightly bound layer.

Construction Fills

Steel slag can be used in fills and is provided uncrushed so that the material develops good mechanical interlock when compacted.

Unweathered SFS should not be used as a fill material where expansion may create subsequent problems, i.e. near structures or rigid works such as reinforced earth walls, behind abutments, under concrete slabs or other confined spaces.

SPECIFIC REQUIREMENTS

If you are considering using steel furnace slag aggregate on your project, contact Technical Consulting for specialist advice.

REFERENCES

1. Austroads Guide to Pavement Technology Part 4E: Recycled Materials. Sydney 2009, available at www.austroads.com.au.
2. Australasian (iron & steel) Slag Association, A guide to the use of iron and steel slag in roads, Wollongong 2002, available at www.asa-inc.org.au.
3. VicRoads Code of Practice RC500.02 Registration of Crushed Rock Mix Designs, available at www.vicroads.vic.gov.au

CONTACT OFFICERS

For further information on Steel Furnace Slag Aggregate, please contact the following officers:

Graeme Newman Phone: (03) 9881 8934
Email: Graeme.Newman@roads.vic.gov.au

Andrew Walker Phone: (03) 9881 8941
Email: Andrew.Walker@roads.vic.gov.au