australasian (iron & steel) slag association

QUICK REFERENCE GUIDE 3 - 2014

Steel Furnace Slag

INTRODUCTION

Steel furnace slag (SFS) is the co-product of the basic oxygen steel making process (BOS). The slag is removed from the vessel after the exothermic refinement of molten iron and recycled steel in the presence of fluxes and oxygen.

SFS is a co-product of the conversion process of molten iron to steel in basic oxygen steelmaking within an integrated steelworks. A chemical reaction occurs within the vessel after the oxygen lance is lowered, a protective slag layer forms with the addition of lime. When the reaction has been completed, the steel and slag are separated and molten slag is poured into pits where the slag is cooled with water sprays before haulage for processing. See *A Guide to the Use of Iron and Steel Slag in Roads* for further information.

TYPICAL PHYSICAL PROPERTIES

Table 1 - Typical Physical Properties of SFS.

Typical Physical Properties- Aggregate	Steel Furnace Slag
Bulk Density (t/m^3)(loose)	1.5-1.8
Dry Strength (kN)	260-300
Wet Strength (kN)	240-280
Wet/Dry Variation (%)	5-15
Water Absorption (%)	2-4
LA Abrasion	15-20
Polished Aggregate Friction Value (PAFV)	54-60
Sodium Sulfate Soundness (%)	<1
Physical Property- 20 mm Road base	
Maximum Dry Density (kg/m^3)[2]	2.4-2.6
Optimum Moisture Content (%)[1]	10-12

Notes:
[1]OMC depends on the components of the mix.
[2]MDD based on 100% standard compaction.

SFS has a dark grey colour, with a particle density that is 20% greater than basalt and harder than blast furnace slag (BFS). This product crushes into a cubical shape and has the potential for expansion if not adequately weathered. Weathering is typically achieved by periodic watering, monitoring and internal stockpile management procedures developed by suppliers of SFS aggregates. Requirements for free lime limits, where provided, should be met before supply.

TYPICAL APPLICATIONS

Advantages offered by SFS include the availability of free lime which has been recognised with the development of self - cementing, heavy duty pavements. Unconfined compressive strength (UCS) > 5 MPa has been achieved at 28 days. Also, as a tough, durable material, SFS has excellent skid resistance properties, making it an ideal aggregate for pavement surfacing applications. Resistance to rutting makes SFS particularly applicable for heavily trafficked corners and stopping zones.

Typical uses for SFS are:

- Sealing/asphalt aggregate
- Pavement base and sub-base layers
- Engineering construction
- Sub-soil drainage

The main typical applications for the use of SFS come under the following specifications as shown in Table 2 below:

Table 2 - Applicable SFS Specification.

SFS Type	RMS/VicRoads
Unbound	R71
Bound	R73
Select Fill	R44
Aggregate	R33

ASPHALT

SFS has many properties that make it suitable for use in asphalt. It is a hard, dense, durable and well-shaped aggregate that has a strong affinity for bitumen. The skid resistance and anti-polishing properties make it an ideal aggregate for asphalt surfacing including open grade, dense grade and stone mastic asphalt.

As SFS may contain small amounts of potentially expansive products such as burnt lime and dolomite, sufficient moisture and time must be provided to enable hydration of these materials to avoid expansion.

PAVEMENTS & ENGINEERING

Bound Steel Slag Pavements

The working time for a bound pavement is typically the time measured from the commencement of blending the binder to the material to be bound, to the completion of the compaction of the bound material within the pavement. The use of material within its working time is of critical importance when bound pavement materials are placed in layers. Working time is not simply the time within which the materials placed are workable, but rather the time within which layering of bound pavement can occur without risk of de-bonding/lamination or loss of ultimate pavement strength.

The nominated working time is the lesser value of the Maximum Dry Density (MDD) and the Unconfined Compressive Strength (UCS).

Layering of bound pavements within relevant material working times will still require the underlying surface to be scarified (not profiled or milled) in some way. This is essential to remove the smooth surface created by either smooth drum rolling or rubber tyre polishing created by trucks tipping on the lower surface.

Moisture Content

Slag blended pavements are less sensitive to moisture than conventional materials.

Unbound Steel Slag Pavements

SFS can be successfully utilised in unsealed roads and industrial hardstand areas.

For unbound applications, each site or project should be reviewed to ensure that the SFS used is fit for purpose for the given application. Construction guidelines should be considered on a site-by-site basis to ensure all relevant site conditions are addressed. Whilst weathering of SFS is undertaken to limit potential material expansion, SFS may not be suitable for use in some applications.

SFS can be placed in layers up to 300 mm thick, although for most unbound applications, 150-200 mm of material is generally adequate.

Placement

Construction joints occur where bound material is placed against previously placed bound material which is outside the bound material's working time. Where this occurs, a clean, compacted, vertical perpendicular surface should be cut to the full depth of the pavement layer thickness for both transverse and longitudinal construction joints. This will reduce the risk of plating effects on the pavement. All spoil material should be discarded and not incorporated back into the works.

Figure 1 - Longitudinal construction jointing.

Due to their rigidity, cracks occur in bound pavements. The risk of this occurring can be reduced by managing the correct location of joints, such as:

- Limiting the overall pavement widths;
- Ensuring joints are not in wheel paths; and
- Ensuring joints in sub-base layers are offset to joints in the base layer.

Figure 2 - Transverse construction joint.

ENVIRONMENTAL CONSIDERATIONS

Several comprehensive studies of SFS have shown this material and its leachate contains trace amounts of metal well below trigger levels for environmental investigation. The primary environmental risk when utilising SFS in road making applications is the potential for alkaline leachate to enter local waterways. This risk is minimal when SFS is incorporated into well-designed and constructed roads with adequate drainage and decreases over time as the material gains strength. Hours to days of direct stagnant contact with SFS are required for the pH of water to reach environmentally significant levels. Water sheeting off a road or hardstand area is not in contact with free lime contained in SFS for a long enough period to produce high pH run-off. An approach to using SFS around rivers and streams is to maintain a 5-10 m buffer either side of the normal waterway flow if unsure engineering design is adequate. Being a co-product of the steel manufacturing process, exemptions have been granted for use in road making. See *QRG 1* for further information.

CASE STUDIES

Case Study 1: Unsealed Rural Road at Misty Lane, Jamberoo NSW

Misty Lane is a 2 km privately owned and maintained rural road located in Jamberoo and used by 7 properties. This project required a 20 x 0 mm SFS road base, its main feature being that the slag product was used to achieve a low technical but high quality outcome.

It was found that there were little obvious problems with the SFS product after regular inspections. As the material took longer to harden, the surface which was initially pliable allowed for loose stone to be forced into the surface which increased compaction and subsequent road life for the local residents.

Figure 3 - SFS road base used at Misty Lane, Jamberoo.

Figure 4 - Close-up of SFS road base.

Case Study 2: Stabilised Steel Furnace Slag (SFS) Used in Lightly Bound Pavement Application

An unsealed hardstand for heavy equipment storage was constructed at Kooragang Island.

Figure 5 - 6 mm SFS minus dust used at Kooragang Island.

This project required SFS 6 mm minus dust blended with a binder to produce a UCS strength at 7 days accelerated using RMS Test Method T116 of between 1.0 and 1.5 MPa.

The SFS dust was blended with a binder in a computer-controlled pugmill then delivered to the site via truck and dog configurations. Material was placed and compacted using a grader and smooth drum roller with approximately 600 tonnes placed per day of production.

This material is to remain unsealed during service life and therefore required a smooth impermeable finish to meet the tight grade tolerance for control of surface storm water runoff.

LIFE CYCLE ANALYSIS (LCA)

The benefits of using the stabilised SFS dust for this application were numerous as follows:

- The stabilised SFS dust provided an effective solution to other investigated pavement designs being a traditional concrete pavement, or RMS specified heavily bound pavement, or using natural quarried road base materials with an increased pavement thickness. The quarried materials would also require a spray seal to provide the desired durability and storm water run-off properties.

The stabilised SFS dust was more than fit for purpose providing the client with:

- An impervious surface;
- Minimum dusting for an unsealed pavement;
- High bearing and tensile strength;
- Reduced pavement thickness;
- Along with benefitting the environment through recovery and recycling of an industry waste material, reducing the carbon footprint for this project and protecting natural resources and the environment from further degradation; and
- The hardstand has been in service for over 12 months with the client being very satisfied with the performance to date.

CONCLUSION

In terms of its competitive advantages in relation to other materials, iron and steel slag (ISS) products have been proven for use in various types of applications including: cement and concrete manufacture, civil works, road construction, rehabilitation and stabilisation of existing roads, car parks and pavements.

Economically, ISS products are comparative to other traditional resources but should be assessed on a case by case basis given the other performance and environmental advantages.

The Australasian (iron & steel) Slag Association continues to advocate for the current and potential uses of slag products as well as improving regulatory understanding of the benefits arising from slag use.

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