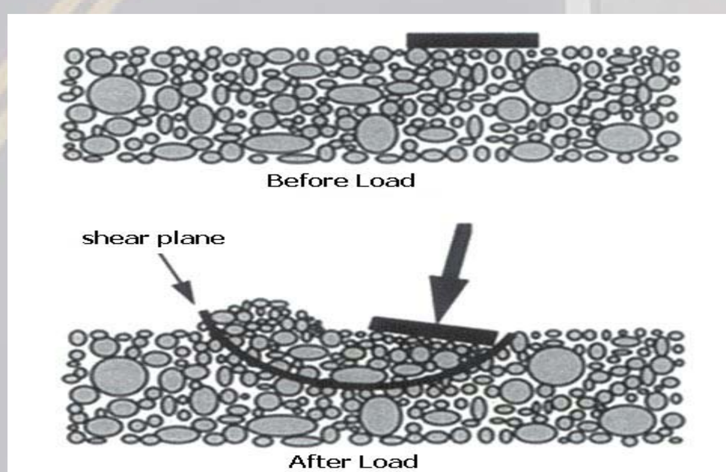
THE PREMIER AGGREGATE

THE CURE FOR PERMANENT PAVEMENT DEFORMATION

SUPERPAVE BITUMINOUS MIXTURES UTILIZING IRON AND STEEL MAKING SLAG AGGREGATES

Challenge:

Asphalt pavements with low shear strength can lead to permanent deformation or “rutting” of the pavement by repeated wheel loading as seen below. While many state highway agencies have recognized the value of utilizing angular material to fortify the aggregate structure of asphalt mixtures, the Federal Highway Administration (FHWA), through the Strategic Highway Research program (SHRP), combined these efforts and established a formal angularity requirement for use in Superpave Mix Designs. It is essential that the aggregate structure (in Hot Mix Asphalt), comprised of fine and coarse aggregates, provide enough shear strength to resist repeated load applications. It has been well documented that cubical, rough textured aggregates provide greater resistance than rounded, smooth textured aggregates, even though they may possess the same inherent strength.



Solutions:

In developing the specifications for the Superpave Mix Design, FHWA researchers surveyed pavement experts to determine which aggregate properties were most important. There was a general consensus that aggregate properties played the central role in overcoming permanent deformation. Those properties are coarse aggregate angularity; fine aggregate angularity; flat, elongated particles; and clay content. As we discuss the requirements of these physical properties you will note that Blast Furnace Slag Aggregates meet or exceed all of them.

Coarse Aggregate Angularity

This property ensures a high degree of aggregate internal friction and rutting resistance. FHWA designated the Coarse Aggregate Angularity (CAA) be measured using ASTM D-5821 “Standard Test Method for Determining the Percent of Fractured Particles in Coarse Aggregate”.

Course Aggregate Angularity Criteria

Traffic	Depth from Surface	
Million ESALs	< 100 mm	> 100 mm
<0.3	55/-	-/-
<1	65/-	-/-
<3	75/-	50/-
<10	85/8	60/-
<30	95/90	80/75
<100	100/100	95/90
≥100	100/100	100/100

Note: 1) “85/80” denotes that 85% of the course aggregate has one or more fractured faces and 80% has two or more fractured faces.
2) Blast Furnace Slag Aggregates contain 100% two or more fractured faces.

Fine Aggregate Angularity

The Fine Aggregate Angularity (FAA) property was also specified in order to promote a high degree of internal friction and rutting resistance. It was defined as the percent air voids present in loosely compacted aggregate smaller than 2.36 mm (AASHTO T 304, Test method for “Uncompacted Void Content of Fine Aggregate”). Higher void contents can be indicative of greater shear strength, resulting in increased rut resistance.

Fine Aggregate Angularity Criteria

Traffic	Depth from Surface	
Million ESALs	< 100 mm	> 100 mm
<0.3	-	-
<1	40	-
<3	40	40
<10	45	40
<30	45	40
<100	45	45
≥100	45	45

Criteria are percent air voids in loosely compacted fine aggregate.

Typical Fine Aggregate Angularity Values

Fine Aggregate	Typical Angularity
Blast Furnace Slag Sand	46+
Steel Furnace Slag Sand	46+
Washed Natural Sand	38-42
Dolomitic Sand	43+
Limestone Sand	43+

Superpave Mix Design allows blending of aggregates to meet the fine aggregate angularity criteria. Hence, in many cases it may be more cost effective to blend the most angular sand with a local rounded sand source to meet the angularity requirements as illustrated below:

Fine Aggregate Blending Analysis

(Based Upon Fine aggregate Angularity Requirement of 45)			(Based Upon Fine Aggregate Angularity Requirement of 45)		
SCENARIO #1			**SCENARIO #2**		
Blast Furnace (BF) Slag Sand	(49% air void) x 56% Blend = 27.4		Manufactured Sand	(46% air void) x 84% Blend = 38.6	
Natural Sand	(40% air void) x 44% Blend = 17.6		Natural Sand	(40% air void) x 16% Blend = 6.4	
	Total = 45.0			Total = 45.0	
Assumed Pricing:			Assumed Pricing:		
BF Slag Sand	$7.50/ton x 56% Blend	= $4.20	Manufactured Sand	$7.00/ton x 84% Blend	= $5.88
Natural Sand	$4.50/ton x 44% Blend	= $1.98	Natural Sand	$4.50/ton x 16% Blend	= $ .72
	Combined Price/ton = $6.18			Combined Price/ton = $6.60	

Note: Blast furnace and steel furnace slag sand's high angularity is attributed to its irregular particle shape which has also been beneficial in assisting customers in meeting Voids in Mineral Aggregate (VMA) requirements.

Superpave Mix Design

Along with the noted aggregate physical properties, The FHWA also established more stringent Voids in Mineral Aggregate (VMA), a Voids Filled with Asphalt (VFA), and a Restricted Zone that would theoretically reduce the amount of round sand used in the mixtures. The FHWA also noted a desire for an "S" shaped gradation curve that would go below the Restricted Zone and provide a coarser aggregate structure than previously used, although current research has indicated that some mixtures that go above or through the restricted zone have preformed successfully. The physical properties of Iron and Steel Making Slag Aggregates both meet or exceed the aggregate properties, but assist in attaining all of the mixture properties previously noted. Slag Aggregates have been used extensively for Superpave Mixtures (Surface, Intermediate, and Base) in the Midwest since the inception of Superpave. The following are examples of Superpave Mixtures currently in use:

MIXTURE: **SUPERPAVE (Illinois)**

MIXTURE: 9.5 mm-Surface Mixture

Equivalent Single Axle Loads (ESAL's): High Volume

MATERIALS:

LIQUID:			
	Percent: 5.6%	Type:	PG 64-22
AGGREGATE 1:	12.5 mm X 2.36 mm		
	Percent: 38.5%	Type:	BOF Slag Chip
AGGREGATE 2:	12.5 mm X 2.36 mm		
	Percent: 20.5%	Type:	Limestone Chips
AGGREGATE 3:	4.75 mm X 0		
	Percent: 26.0%	Type:	Limestone Sand
AGGREGATE 4:	4.75 mm X 0		
	Percent: 13.0%	Type:	BF Slag Sand
AGGREGATE 5:	Mineral Filler		
	Percent: 2.0%	Type:	Bag House Dust

MIXTURE PROPERTIES:

Number of Gyrations (N)

$N_{initial}$:

N_{Design}: 90

$N_{maximum}$:

Dust / Effective Asphalt Ratio: 0.7

Air Voids:	4%	
VMA:	15.6	(Criteria: 15 min)
VFA:	74.0	(Criteria: 65 – 78)
FAA:	45.8	

MIXTURE: **SUPERPAVE (Indiana)**

MIXTURE: 9.5 mm-Surface Mixture

Equivalent Single Axle Loads (ESAL's): 12.5 million

MATERIALS:

LIQUID:			
	Percent: 6.6%	Type:	PG 64-22
AGGREGATE 1:	12.5 mm X 2.36 mm		
	Percent: 32.0%	Type:	BF Slag Chip
AGGREGATE 2:	12.5 mm X 2.36 mm		
	Percent: 20.0%	Type:	Dolomite Chips
AGGREGATE 3:	4.75 mm X 0		
	Percent: 47.0%	Type:	BF Slag Sand
AGGREGATE 4:	Mineral Filler		
	Percent: 1.0%	Type:	Bag House Dust

MIXTURE PROPERTIES:

Number of Gyrations (N)

$N_{initial}$: 8

N_{Design}: 109

$N_{maximum}$:

Dust / Effective Asphalt Ratio: 1.2

Air Voids:	4%	
VMA:	15.5	(Criteria: 15 min)
VFA:	75.0	(Criteria: 65 – 78)
FAA:	47.8	