aggregate gradation chart

ASTM C-33 Standard Specification for Concrete Aggregate										
Table 2 Grading Requirements for Coarse Aggregate										
Size Number	Nominal Size	Amounts Finer Than Each Laboratory Sieve (Square Openings)								
		Percentage by Weight								
	Square Openings	2”	1”-1/2”	1”	3/4”	1/2”	3/8”	No.4	No.8	No.16
4	1-1/2” to 3/4”	100	90 to 100	20 to 55	0 to 15	—	0 to 5			
467	1-1/2” to No.4	100	95 to 100	—	35 to 70	—	10 to 30	0 to 5		
57	1” to No.4	—	100	95 to 100		25 to 60		0 to 10	0 to 5	
6	3/4” to 3/8”	—	—	100	90 to 100	20 to 55	0 to 15	0 to 5		
67	3/4” to No.4	—	—	100	90 to 100		20 to 55	0 to 10	0 to 5	
7	1/2” to No. 4	—	—	—	100	90 to 100	40 to 70	0 to 15	0 to 5	
8	3/8” to No. 8	—	—	—	—	100	85 to 100	10 to 30	0 to 10	0 to 5

Suggested Stockpiling Practice to Minimize Concrete Mixing Water Absorption by Coarse Aggregate

All coarse aggregates having 24 hour water absorption values greater than about 2.0% and not having this absorption satisfied when incorporated into concrete mixtures can extract water from the mixtures and may result in stiffening and plastic cracking. ACI 221 R-96, Section 3.3 references saturation of porous aggregate and recommends proper wetting of aggregate stockpiles. However, NSA goes a step further with the following recommended procedures to minimize the effect of plastic shrinkage cracking.

NSA recommends the BF slag aggregate supplier pre-soak the aggregate in an effort to aid the concrete producer with fully saturating the aggregate. NSA also recommends following ACI 221, Guide for Use of Normal Weight Aggregates in Concrete.

To minimize such absorption while in the concrete mixture the coarse aggregate should be thoroughly saturated while being stockpiled and allowed to drain for approximately 12 hours before being incorporated into the concrete mixture.

Water sprinklers should provide sufficient volume of water so as to completely soak all parts of the stockpile and be able to percolate through the pile so that noticeable water run-off is discharged from the aggregate pile. This should be carefully monitored so as not to create excess discharge.

Aggregate should be sampled for moisture content prior to the pour. The concrete aggregate should have sufficient moisture content to meet its absorption value, established by testing performed by a certified lab or a DOT. Excess moisture can be adjusted in the concrete mixing process in order to achieve desired slump.

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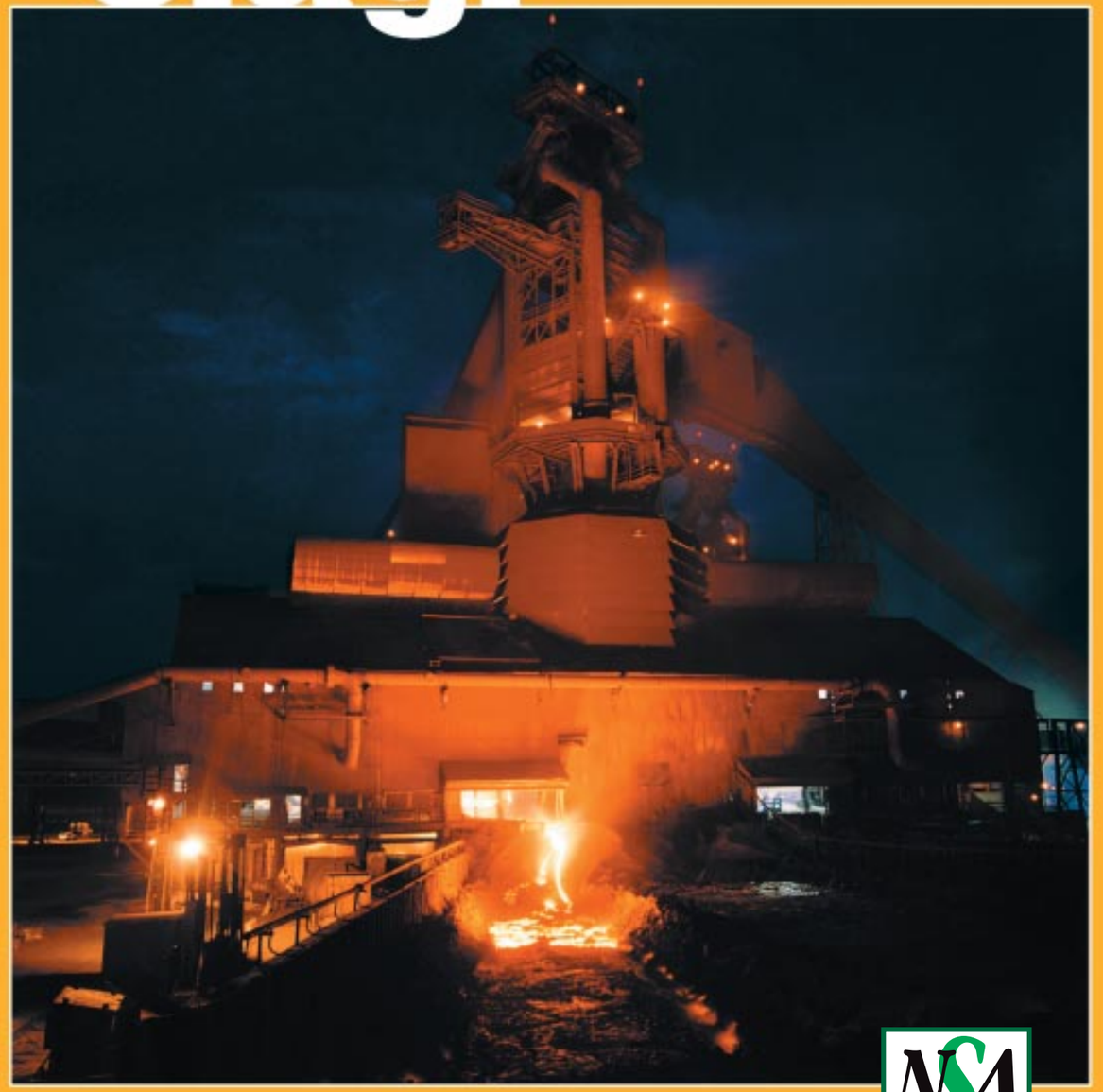
Blast Furnace slag:

The Aggregate of choice for Portland Cement Concrete



definition

Blast Furnace Slag and Air-Cooled Blast Furnace Slag are defined in ASTM C-125 as:

blast furnace slag - the nonmetallic product, consisting essentially of silicates and aluminosilicates of calcium and other bases, that is developed in a molten condition simultaneously with iron in a blast furnace.

air-cooled blast furnace slag - the material resulting from solidification of molten blast-furnace slag under atmospheric conditions, subsequent cooling may be accelerated by application of water to the solidified surface.

texture and shape

Air-cooled blast furnace slag crushes to angular, roughly cubical pieces with a minimum of flat or elongated pieces. The texture ranges from the vesicular pitted surfaces through all degrees of roughness to smooth, conchoidal fractures for the denser slags. This rough vesicular nature of slag gives it a greater surface area than smoother aggregates of equal volume, the feature that provides an excellent bond with Portland cement.

specific gravity

The bulk specific gravity-dry basis--of air-cooled slag generally falls in the range of 2.0 to 2.5. Due to the cellular nature of slag, it is recommended that the bulk specific gravity be used rather than the apparent specific gravity for purposes of computing yield or estimating quantities and the saturation surface dry (SSD) specific gravity if used for concrete mixture design.

weight per cubic foot

The unit weight varies with: (a) size and grading of the slag, (b) method of measuring and (c) bulk specific gravity of the slag. Typical weight (compacted) of crushed and screened air-cooled blast furnace slag, graded as ordinarily used in concrete is usually in the range of 70-85 lbs. per cu. ft. Most specifications for graded aggregates (other than macadam sizes for which the minimum weight is 65 lbs) require that slag should weigh not less than 70 lbs. per cubic foot when measured dry and compacted.

This characteristic of a comparatively low weight per cubic foot as compared to the other types of aggregate makes slag economically advantageous in concrete.

absorption

Absorption ranges from 1% to 5%. Water calculated as absorption is somewhat higher for air -cooled blast furnace slag as compared to other commercial aggregates. Care must be taken during the absorption test to determine the saturated surface dry (SSD) condition because of the vesicular nature of air- cooled blast furnace slag pieces.

durability

Slag is highly resistant to the action of weathering. It will withstand an unusual number of cycles of the sodium sulfate soundness test (ASTM Designation C 88). Freezing and thawing or wetting and drying tests, also have little or no effect. High temperatures have very little effect on slag, nor is it disassociated by heat, as it is formed in the blast furnace at about 2700° F. Slag shows a slow but very uniform expansion 5.3 x 10-6 per degree F., up to its melting point (2100° to 2600° F). This figure is normally accepted as the coefficient of thermal expansion for cement mortar and steel, hence, slag, when combined with these ingredients, to form reinforced concrete, affords a high degree of compatibility.

resistance to abrasion

An outstanding feature for air-cooled blast furnace slag is its toughness and resistance to polishing under traffic, the feature that contributes to non-skid highways.

ASTM C-33 **Standard Specification for Concrete Aggregate** states that air-cooled blast furnace slag is excluded from the abrasion requirements as measured by ASTM C-131 **Standard Test Method for Resistance to Degradation and Abrasion of Small-size Coarse Aggregate by Abrasion and Impact in the L.A. Machine**.

This is due to the rough edges of the cubicle-shaped slag breaking off under the impact of the steel balls constituting the test charge in the L.A. machine.

The quality test for air-cooled blast furnace slag as a measure of resistance to degradation and abrasion is its density that is measured by the jigged or rodded unit weight as described in ASTM C- 29 Standard Test Method for Bulk Density and Voids in Aggregate.

alkali silica reaction (ASR)

ASTM C 1260 **Test Method for the Potential Reactivity of Aggregates** is a rapid and severe test to determine if the silica content of aggregate reacts deleteriously with the alkalis in Portland cement. Air-Cooled Blast Furnace Slag is innocuous to ASR reaction.

"D" cracking

Portland Cement Concrete (PCC) made with Air-Cooled Blast Furnace Slag does not exhibit "D" Cracking unlike highly absorptive natural aggregates.

applications

- Highway Paving
- Structural Foundation
- Footing and Walls
- Flatwork, Driveways, and Sidewalks
- Industrial Floors
- Bridge Columns and Decks
- Slip Form Curbs

features and benefits

FEATURE	BENEFIT
Aggregate weight advantage	20% savings potential in coarse aggregate cost
Excellent aggregate / mortar Bond Higher level of absorbed water contributes to more complete hydration	10% cement savings potential resulting from higher compression strength
Durability * No alkali silica reaction (ASR) * Resistant to freezing and thawing damage	Lower life-cycle cost
Concrete weight advantage	6% increase in concrete truck carrying capacity and reduced transportation cost
Chert free aggregate and resistant to scaling due to de-icing salt	Aesthetically and cosmetically preferred

compression & flexure strength

Portland Cement Concrete (PCC) with air-cooled blast furnace slag as the coarse aggregate exhibits flexure strength equivalent to and compressive strength up to 10% greater than Portland Cement Concrete made with natural aggregates.

blast furnace slag concrete mix designs*

Pavement Designs Air Entrained								
Sks. / CY	4	4.5	5	5.5	6	6.5	7	7.5
Portland Cement	244	275	306	336	367	397	428	458
Slag Cement	132	148	164	181	197	214	230	247
Natural sand	1,262	1,222	1,182	1,142	1,102	1,062	1,022	982
#57 slag	1,760	1,760	1,760	1,760	1,760	1,760	1,760	1,760
A.E.	6%	6%	6%	6%	6%	6%	6%	6%
W / R	Using Manufacturers' Recommendations							
Water - gal/CY	34	34	34	34	34	34	34	34

Standard Design - Air Entrained						
Sks. / CY	4	4.5	5	5.5	6	6.5
Portland Cement	244	275	305	336	367	397
Slag Cement	132	148	165	181	197	214
Natural sand	1,406	1,392	1,352	1,312	1,274	1,234
#57/#67 slag	1,565	1,565	1,565	1,565	1,565	1,565
A.E.	5.5%	5.5%	5.5%	5.5%	5.5%	5.5%
W / R	Using Manufacturers' Recommendations					
Water gal/CY	34	34	34	34	34	34

Pump Design Air Entrained					
Sks. / CY	5	5.5	6	6.5	7
Portland Cement	305	336	367	397	428
Slag Cement	165	181	197	214	230
Natural sand	1,482	1,442	1,404	1,364	1,326
#57 slag	1,465	1,465	1,465	1,465	1,465
A. E.	5%	5%	5%	5%	5%
W / R	Using Manufacturers' Recommendations				
Water gal/CY	34	34	34	34	34

Chemical Properties

Silica	SiO_2	33% - 42%	Sulfur*	S	1% - 3%
Alumina	Al_2O_3	10% - 16%	Iron Oxide	FeO	0.3% - 2%
Calcium Oxide	CaO	36% - 45%	Manganese Oxide	MnO	0.2% - 1.5%
Magnesium Oxide	MgO	3% - 16%	*Principally in the form of Calcium sulfide		

*Proportioning of materials should be verified by trial mixes.