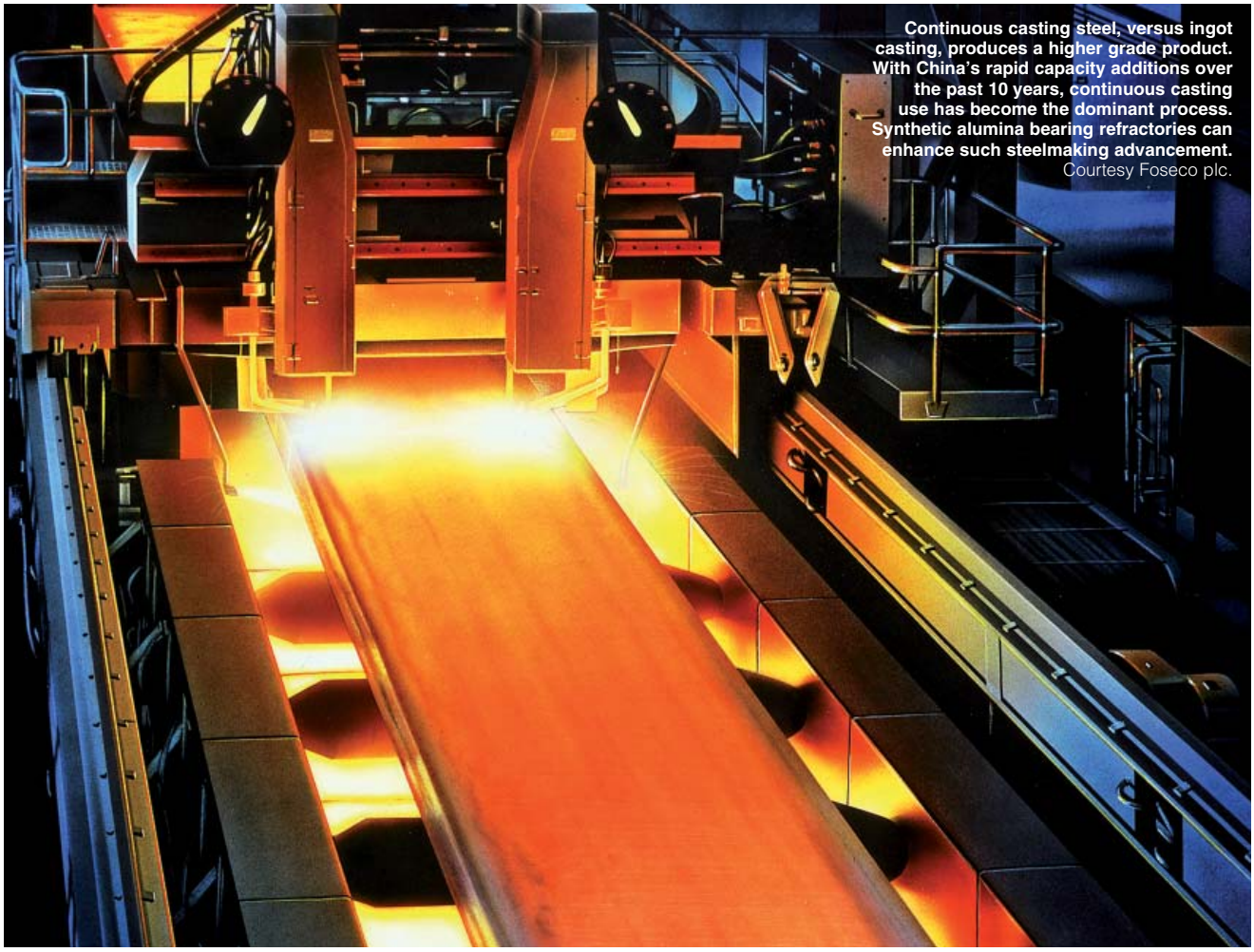


Continuous casting steel, versus ingot casting, produces a higher grade product. With China's rapid capacity additions over the past 10 years, continuous casting use has become the dominant process. Synthetic alumina bearing refractories can enhance such steelmaking advancement. Courtesy Foseco plc.

Synthetic alumina steels show

Higher grade, higher value steel products are in increasing demand. *Yoke Fong* urges that refractory producers should address reformulations of their mixes and that upgrading refractory mixes using synthetic alumina is an important step for steel advancement

THE PRODUCTION OF clean steel is necessary for the production of the highest quality end products, such as automotive sheet steel and oilfield seamless tubing. The steelmaking focus is on the separation of impurities from the metal. Clean steel practices concentrate on ladle operations, tundish metallurgy, mould flow control, slag practices and more.

These clean steel techniques seek to minimise inclusions, or non-metallic oxide impurities, which impair the workability and mechanical properties of steel. Highest quality steel requires ultimate technology application and an important part of this is refractory upgrade to higher performing materials.

The accompanying panel outlines some of the chief refractory raw materials. Synthetic alumina enhances the overall performance of refractories in order to meet today's extreme service demands in Asia and elsewhere around the globe. Premium steel production requires refractories that are capable of withstanding greater heat, challenging erosion and wear conditions, and enduring more intense thermal cycles.

Upgrading refractory mixes with more homogenous, pure and dense synthetic

alumina provides longer service life under these high temperature conditions. Value-adding refractories with synthetic and premium alumina can provide longer refractory life, lower refractory consumption and cleaner steel.

Upgrading refractory formulations

Almatis premium aluminas are used to upgrade the performance of existing refractories to meet the more demanding requirements of today's steel and non-ferrous industries. The synthetic minerals of choice for dense refractories are:

- tabular alumina
- magnesia rich and alumina rich spinels
- calcium aluminate cements
- calcium hexaluminate bonite
- calcined and reactive alumina

Choosing the right combination of refractory raw materials will optimise the performance of refractory formulations.

- coarse aggregates are used to build the refractory foundation.
- fine aggregates are used to fill the intermediate voids between the coarse aggregate.
- matrix fines fill the micron size voids without adding excess liquid. The amount used impacts flow, and sets the properties for castables.
- binders hold the formulations together until thermal sintering occurs.
- additives are used as water reducing agents such as dispersants, deflocculants and plasticisers. They are also used as retarders or accelerators to control setting behaviour of the refractory formulation.

High quality tabular and spinel aggregates offered by Almatis in coarse and fine fractions are instrumental in achieving chemical and thermal shock resistance owing to their dense structure, closed porosity, and consistent particle size distribution.

Spinel is a performance booster for alumina refractories, providing higher hot strength and better slag resistance. When pre-formed alumina rich sintered spinel is utilised in severe service applications, such as steel ladles at 15% to 30% of a low or ultra low cement castable, slag and metal penetration is practically eliminated and erosion wear is greatly reduced. Formulations that contain spinel deliver a clear performance advantage with longer lining life and greater cost effectiveness.

Matrix fines in the Almatis portfolio, such as ground aggregates and reactive and ground calcined aluminas, range in particle size from 0.4 to 75 microns. They strongly determine the flow, strength and setting behaviour of a refractory castable.

Optimising the combination of matrix fines in a formulation greatly reduces the water demand by filling the voids within the combination of synthetic mineral structures. The mono-modal reactive aluminas provide full flexibility in designing the refractory matrix particle size distribution.

The multi-modal reactive aluminas can further enhance the performance by optimizing the particle size distribution with super-fine components that have been intensively homogenized while being manufactured.

In true high performance refractories suited for temperatures greater than 1,400°C, reactive aluminas and ground tabular and spinel aggregates typically replace standard calcined aluminas and silica fume in order to attain the performance requirements.

Dispersing aluminas are an Almatis

Refractory raw materials

Bauxite

Bauxite is a natural aggregate of aluminium-bearing minerals. The main use of bauxite is for producing aluminium but 10% of the world's bauxite is used for refractories as calcined bauxite. Calcined bauxite is minimally 85% Al_2O_3 and is used in refractories of high alumina content (70-90% alumina).

China and Guyana have historically been the world's major calcined bauxite suppliers for refractories owing to their bauxite's purity and higher bulk density.

Guyanese bauxite quality is superior, but higher cost, infrastructure limitations and mine privatization attempts have reduced production by 50% over the past 20 years. China is the world's major supplier of calcined bauxite for refractories.

Brown fused alumina

Brown fused alumina (BFA) is produced by fusing bauxite in an electric furnace. BFA's major use is in abrasives but substantial quantities are used globally in refractories. BFA is typically 96-98% alumina and is a raw material for "high alumina" refractories.

The slow cooling of a BFA block allows major impurity segregation, thus challenging product consistency and quality. China has come to dominate global BFA supply due to low pricing and wide availability up to this point – but this is changing.

Tabular alumina

Tabular alumina is termed a synthetic raw material as it is produced from a very pure calcined alumina in a highly controlled process. It derives its name from the large, flat, tablet-like corundum crystals that give it great hardness and density.

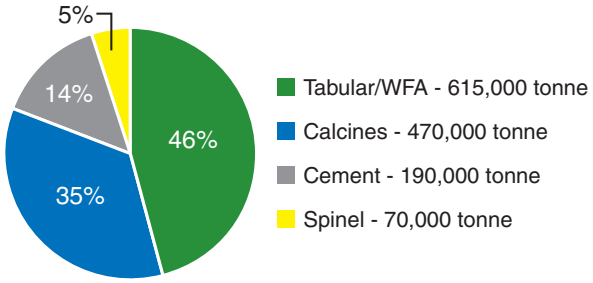
Tabular alumina is 99.5% Al_2O_3. First produced in 1935 for improved furnace refractories, tabular alumna's development was focused entirely on superior refractory performance. Its superior refractoriness, thermal shock-, creep-, and abrasion resistance have made tabular alumina the dominant synthetic high purity Al_2O_3 aggregate.

Owing to its highly controlled manufacturing process Almatis' premium T60/T64 tabular alumina has very homogenous properties, such as low impurity level, high bulk specific gravity, and low open porosity. With less variability, we believe, it is superior to natural alumina materials. It is used to produce "extra-high alumina" refractories, which provide higher refractoriness, better wear resistance, longer lining life and greatly enhanced cost effectiveness.

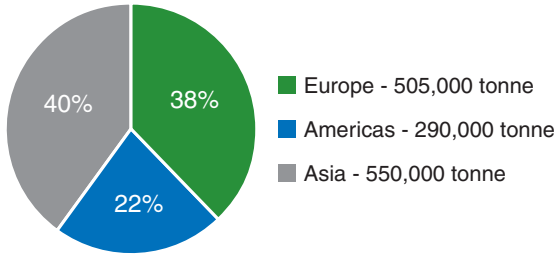
Synthetic high alumina raw materials

Estimated Range: kg/tonne crude steel production	
Japan	1.3 – 1.5
Europe (EU 15)	1.3 –1.5
Americas	1.3 –1.5
Russia, Eastern Europe, Other Europe	0.2 – 0.6
China, India, Other Asia	0.2 –0.6

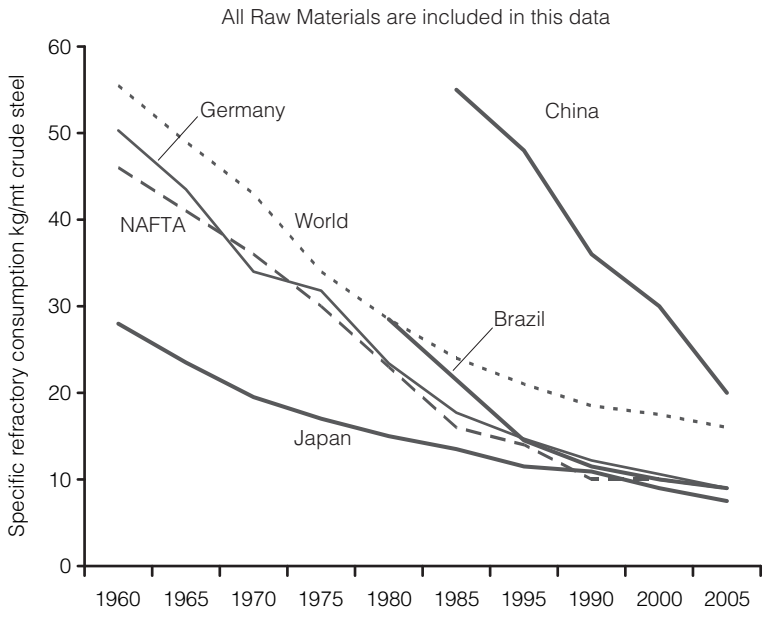
Market size for synthetic high alumina raw materials - 1,350,000 tonne



Global demand by region



Refractory consumption in steel making



tailor-made high performance additive system for castables. They solve two challenges with one product: dispersion of fines in the castable mix and steering of the setting time which optimizes the installation of the end customer product into steel applications. This provides very reliable behaviour of refractory products on the steel mill site.

Improving or upgrading refractory formulations to optimise steel quality is the primary driver for greater use of synthetic alumina. Higher performance refractories with extended service life also lower the refractory consumption per tonne of steel.

Synthetic alumina products are used for ladle linings, shrouds, stoppers, lances, porous plugs, well blocks and blast furnace runner troughs.

Tight market for calcined bauxite and BFA

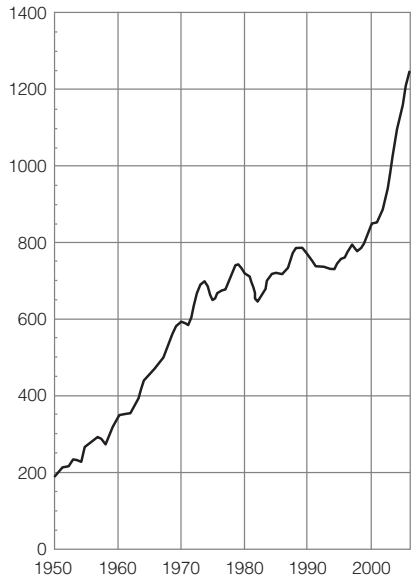
The current supply dynamics of calcined bauxite and BFA provide additional impetus for refractory reformulations. The government of China has applied controls that limit the supply of both of these materials.

Environmental tightening has forced the closure of vertical shaft and beehive kilns used for calcined bauxite production. Rotary kilns are replacing them but driving up production costs. China's high demand for bauxite for aluminium production, which has grown near 35% year to date, is intense competition for calcined bauxite feed.

Moreover, Chinese aluminium consumption is still in its developing stage with 6.7 kg per capita consumption versus 28-30 kg per capita in the USA and Japan.

Industrial Minerals concluded in its March 2007 issue that "the market for bauxite-based refractories is considered on a downwards trajectory. This is because technological shifts over the last decade have resulted in the expanded use of higher performance refractories, bringing about a market decline in the consumption of refractories per tonne of steel produced." This provides improved cost effectiveness and, most importantly, cleaner steel.

World crude steel production, 1950 to 2006 (m. tonnes)



Source: IISI

Brown fused alumina suffers similar shortages of supply and rising prices. For over a decade, China has supplied the majority of the world's BFA demand. The bauxite kiln closures and strong Chinese demand for aluminium metal is tightening the calcined bauxite feedstock needed to produce BFA.

The cost to produce a tonne of BFA climbed $60/tonne during mid-2007 driving prices up by a further $19/tonne. Many Chinese BFA producers are shutting down their operations and price increases of 10-20% were projected by some in 2007 [*and for bauxite and BFA, have come to fruition since this article was written – see Prices p.84-85*].

Strong market pull

In 2006, 1,244m. tonnes of steel were produced worldwide. Global steel production grew 9% in 2006, and in 2007 rose by 7.5% to 1,343.5m. tonnes.

In 1996, China produced 101.2m. tonnes of crude steel. By 2001 this had risen to 150.9m. tonnes, an increase of 49.1%. In 2006, China produced 422.7.m tonnes of crude steel, an increase of 317.7% in just ten years. China's share of world crude steel production has also increased significantly. In 1996, China became the largest steel producing country in the world for the first time, accounting for just 13.5% of production. In 2006, this share had risen to 34%, just above one third of all crude steel produced in the world.

However, 2007 saw a slowdown in China's steel output. The country's steel production in 2007 reached 489m. tonnes, a 15.7% increase on 2006. This represented a growth reduction from the 18.8% achieved in 2006, 26.8% in 2005, and 26.1% in 2004.

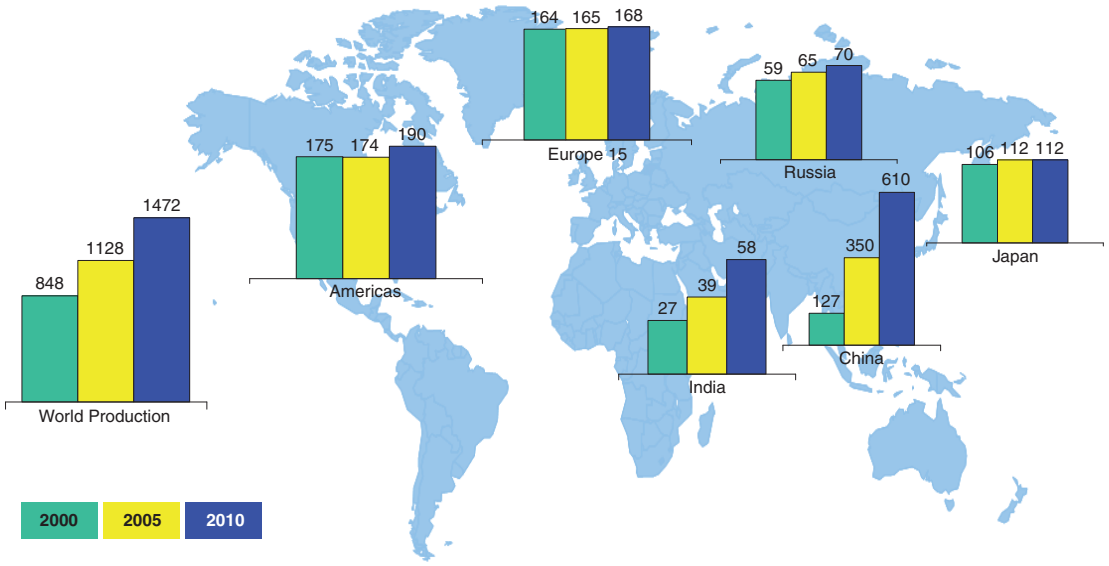
The slowdown in 2007 was most apparent during the last quarter, with an 8.6% growth rate. However, according to the International Iron and Steel Institute, China remains the driving force behind the still strong world production figures. Without China world crude steel production would have only grown at a mere 3.3%.

Global steel average growth rates

	2007	2008	2009	2010
China	13.6	10.0	7.8	7.2
India	4.6	5.0	3.8	6.4
Japan	(2.8)	0.0	0.0	0.0
Korea	1..0	0.8	1.2	3.4
Other Asia	1.9	2.2	5.6	8.5
Total Asia	**8.5**	**7.0**	**5.9**	**6.0**

Source: IISI

Global steel production (m. tonnes)



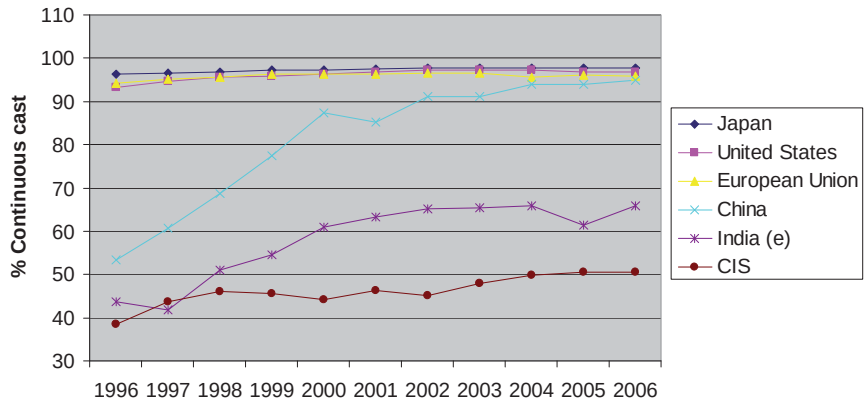
Source: IISI

Major steel producing countries (m. tonnes)

	2006		2005	
	Rank	mmt	Rank	mmt
China	1	422.7	1	355.8
Japan	2	116.2	2	112.5
United States	3	98.6	3	94.9
Russia	4	70.8	4	66.1
South Korea	5	48.5	5	47.8
Germany	6	47.2	6	44.5
India	7	44.0	7	40.9
Ukraine	8	40.9	8	38.6
Italy	9	31.6	10	29.3
Brazil	10	30.9	9	31.6

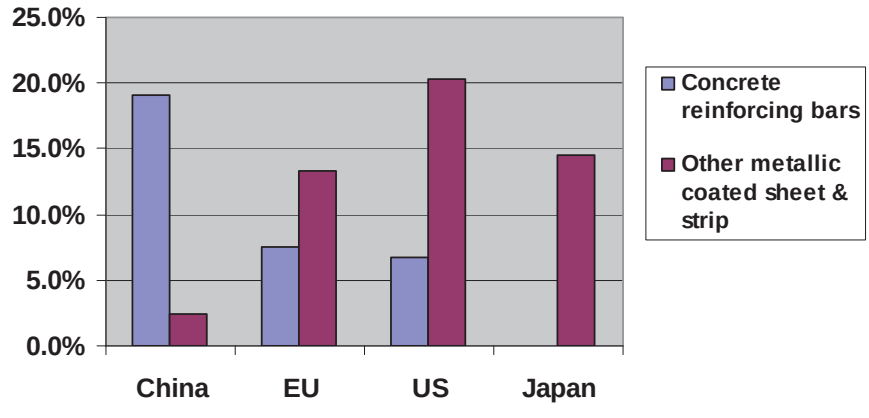
Source: IISI

Continuously cast steel output



Source: IISI

Steel product mix (% of total steel)



Source: IISI

The volume of China's steel output is world dominant. But the quality of the steel output is still climbing the technology curve. One measure of the evolution of a region's steel production is continuous casting use. Continuous casting steel, versus ingot casting, produces a higher grade product. With China's rapid capacity additions over the past 10 years, continuous casting use has become the dominant process and approaches that of the EU, US and Japan.

Still, China's output of steel products lags behind the EU, USA, and Japan with regard to steel cleanliness. China is not producing higher grades of low carbon automotive steels but proportionately more reinforcing bar and other low grade steels, as the figure demonstrates.

Concrete reinforcing bar consumes 19% of China's crude steel production whereas in the EU, USA, and Japan reinforcing bar only consumes 8%, 7%, and none respectively.

For "other metallic coated sheet and strip," which includes zinc coated automotive steels, the trend is opposite: China directs only 2% of its crude steel to these high- grade products while the EU, USA and Japan direct 13-20%.

To support the advance up the technology curve to higher grade, higher value steel products, refractory companies should address reformulations of their mixes. Refractory raw materials with less variability can provide more predictable and stable service. And while refractories are the consumables of steelmaking, protecting the metal-making vessels, the less they are consumed the less contamination, the more precise the process control and the less the cost of replacement.

Consistently cleaner steel production is the ultimate goal but cost savings add greatly to the benefits. Upgrading refractory mixes to synthetic alumina is an important step in reformulation for steel advancement.

Contributor: Yoke Fong, Commercial Director Refractories Asia, Qingdao Almatis Co., Ltd, Shanghai, China; adapted from her presentation at the 7th Chinese Industrial Minerals Conference, 9-11 October 2007, Dalian.