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Limited Availability of Cementitious Materials Could Impact the Value Chain

By Dr. Vassiem Sheikh

In 1824, Joseph Aspdin filed a patent on hydraulic cement that he called "portland cement" because its color resembled the stone quarried on the Isle of Portland near the British coast. Aspdin's production method involved the careful proportioning of limestone and clay, pulverizing them, and burning the mixture into clinker, which was then ground into finished cement.

Today, raw materials—limestone with small quantities of clay and sand—usually come from a quarry located near the manufacturing plant. The materials are blended in the correct proportions, ground together, and heated in an industrial furnace called a kiln to form clinker. Kilns reach temperatures of 1450°C (2640°F). Once cooled, the clinker is ground with a small amount of gypsum to produce portland cement.

The availability of suitable raw materials, particularly limestone, shale, chalk, and clay, is critical to cement making. Raw materials must meet stringent quality requirements and be available in large quantities and exploited economically. Cement manufacturing is a highly energy-intensive process that results in the production of carbon dioxide (CO_2). CO_2 is mainly produced when the calcareous raw material is calcined to produce calcium oxide.

Supplementary cementitious materials (SCMs) are industrial by-products or natural products that develop hydraulic properties when mixed with portland cement. Their chemical composition is of similar nature to portland cement—calcium silicates and aluminates—although proportions of constituents vary. In general, cementitious materials are used to replace clinker in blended cements that allow a reduction in CO_2 and provide additional benefits in terms of cement performance. Their use also provides additional benefits in terms of enhancing the performance of ready-mix concrete. These include improvements in workability, lower heat of hydration, compressive strength, and enhanced long-term durability.

Major Sources of Industrial and Natural Cementitious Materials

Granulated Blast-Furnace Slag from Pig Iron Production

Production of high-quality iron in an efficient furnace is the basis for good blast-furnace slag. After being tapped from the furnace, the slag is cooled, with the cooling rate of the molten material determining its physical and chemical characteristics. There are two primary methods of cooling. One is to leave the slag to air cool on a stockpile over many days, producing a material that is ideal for processing as an aggregate. Alternatively, instantaneous cooling by quenching with large volumes of cold water produces a material that has, subject to processing, good cementitious properties. This material is normally referred to as granulated blast-furnace slag (GBFS) and is either used as a direct replacement of clinker or ground to be used as a direct addition to ready-mix concrete.

Fly Ash from Coal-Fueled Power Stations

Fly ash material solidifies while suspended in the exhaust gases and is collected by electrostatic precipitators or filter bags. Because the particles solidify while suspended in the exhaust gases, fly ash particles are generally spherical in shape and range in size from 0.5 µm to 100 µm. They consist mostly of silicon dioxide (SiO_2), aluminium oxide (Al_2O_3), and iron oxide (Fe_2O_3). They are also pozzolanic in nature and react with calcium hydroxide and alkali to form calcium silicate hydrates (cementitious compounds).

Two classes of fly ash are defined by ASTM C618: Class F fly ash and Class C fly ash. The main difference between these classes is the amount of calcium, silica, alumina, and iron in the ash. Engineering properties and development of strength over time are different depending on the chemical composition of the fly ash. The chemical properties of the fly ash are largely influenced by the chemical content of the coal burned (that is, anthracite, bituminous, and lignite).

Pozzolans from Volcanic Ash Deposits

Owing to its pozzolan properties, fly ash is used as a replacement for portland cement in concrete. The use of fly ash as a pozzolanic ingredient was recognized as early as 1914. Before its use was lost to the Dark Ages, Roman structures such as aqueducts or the Pantheon used volcanic ash (which possesses similar properties to fly ash) as pozzolan in their concrete. As pozzolan greatly improves the strength and durability of concrete, the use of ash is a key factor in their preservation.

Global Cement and Cementitious Materials Market

The market for cementitious materials is driven to a large extent by the demand for cement, and the world demand for cement is projected to rise 4.5% per year to 5.2 billion metric

Table 1. World Cement Demand (million metric tons)				% Annual Growth	
Cement Demand by Region	Year 2009	Year 2014	2019(f)	2009-2014	2014-2019
North America	115	136	168	3.4%	4.3%
Western Europe	163	126	142	–5.0%	2.4%
Asia-Pacific	2149	3158	3940	8.0%	4.5%
Central & South America	119	153	190	5.2%	4.4%
Eastern Europe	105	120	139	2.7%	3.0%
Africa/Mid East	358	467	611	5.5%	5.5%
TOTAL	3009	4160	5190	6.7%	4.5%

SOURCE: https://www.worldcement.com/europe-cis/27082015/global-demand-cement-billion-tons-449/

tons in 2019. The majority of the gains are in the Asia-Pacific and Middle East regions, driven by an increase in construction activity in developing countries such as India, Vietnam, and Indonesia. The Chinese market continues to be the largest contributor to growth, accounting for more than 50% of the global cement demand.

For the United States, the Portland Cement Association forecasts growth of approximately 3.5% in cement consumption annually over the next three years. But the domestic growth rate calculation is heavily influenced by the federal government, and it will take many months before fiscal stimulus and government infrastructure spending plans become clear. California, the Gulf Coast, and the Eastern coastal regions will likely import the majority of cement in the next few years. These regions could also see the ratio of SCMs rise much faster than inland regions.

Globally, the SCM market is forecast to grow at approximately 4 to 5% per annum. It was valued at $79.2 billion in 2014, over $90 billion in 2017, and should reach $100 billion by 2020. However, a key strategic concern for the cement and concrete industries is that cementitious materials supplies are limited, and in some markets demand is exceeding supply.

Approximately 450 MT of blast-furnace slag is produced annually worldwide; however, only part of this is granulated to produce roughly 300 MT of GBFS. The primary producers are China and Japan, which generate more than 50% of the world's production. The strong demand for GBFS in many global markets has had a dramatic effect on prices, with free-on-board prices recently reaching historical highs.

It is expected that until 2030, imported GBFS will remain available because China has a significant surplus. Other places in the world also have availability. There are potential advantages in the quality of imported GBFS. For example, Chinese GBFS has a higher reactivity than some European sources. On the other hand, a reliance on imports also introduces a security-of-supply risk. Already, China has started to use GBFS for its domestic cement industry and begun using its market position to increase price.

With respect to fly ash, approximately 500 MT is produced annually worldwide—60% of which is generated in India and China—and approximately 300 MT is usable ash. In Europe and the United States, fly ash production is being affected by the closure of many coal-fueled power plants. One of the United Kingdom's eight remaining coal power plants is expected to cease generating electricity in 2018, and the government has laid out new rules that are intended to force the closure of all remaining coal-fueled power plants by 2025. A similar scenario is unfolding in Northern Europe, where plants are either being closed or switched to biomass—leading to an overall shortage of

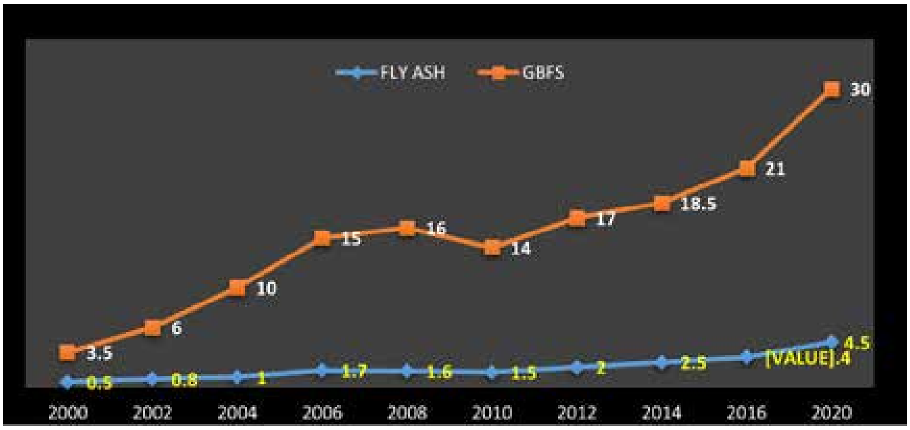

Figure 1. Seaborne Trading of Fly Ash and Slag (MMT)
SOURCE: SCB Europe

fly ash on the continent. This has impacted U.S. markets, which have been large importers of fly ash from Europe.

As coal-fueled power generation diminishes, so does the amount of ash produced. Between 2015 and 2016, as more ash was recovered from landfills—even while some was still disposed—there was a switch from net disposal to net recovery from landfills. In 2016, the UK market required more ash than was produced by power stations or recovered from landfill, and the UK is currently importing ash. In 2017, approximately 250,000 metric tons were imported, compared to 75,000 tons just 2 years earlier.

It has been estimated that there are well in excess of 50 million tons of fly ash deposits in the United Kingdom associated with coal-fueled power stations—either those still in operation or a legacy from power stations that have been shut down. Such deposits have a potential strategic long-term benefit for the UK construction industry. The overall shortage of fly ash in some markets has also opened up new opportunities for the use of pozzolans as a direct replacement for fly ash.

Although fly ash and GBFS are considered the main cementitious materials, there has been a recent increase in the use of ternary blends with both fly ash and GBFS. This combination of both materials in certain proportions in ready-mix concrete has shown superior performance in terms of the workability of fresh concrete to the improved long-term properties of hardened concrete.

Global Seaborne Trading of Cement and Cementitious Materials

According to a recent report by CW Research, more than 174 million tons of cement/SCMs were shipped by seagoing vessels in 2016, up 1.3% compared to the 171.9 million tons shipped by sea in 2015. Its latest research shows that low shipping rates have stimulated seaborne trade. Moreover, the increased imports in key markets where cement production has leveled out (such as the United States) also motivated higher seaborne cementitious trade volumes in 2016 compared to 2015.

Globally, gray cement continues to be the cementitious commodity most heavily traded by sea. In 2016, gray cement comprised over half of the sea-based cementitious trade (a category that includes gray cement, white cement, slag, clinker, and fly ash). Clinker (including both white and gray) accounted for 33% of total seaborne cementitious trade in 2016, followed by ground blast furnace slag with a 12% share of the trade. Far less traded, white cement and fly ash accounted for 3% and less than 2%, respectively, of total seaborne trade of cementitious materials.

On the main trade routes and regions, Asia-Pacific absorbs 51% of the total seaborne trade of cementitious materials. Due to proximity and pricing considerations, the largest volumes of cementitious materials were traded within this region, with almost 90 million tons shipped in 2016.

The cost of shipping cementitious materials is a key factor in competitively supplying a customer with fly ash or slag. Today, in most cases, the expense of shipping is greater than the product cost itself and is dependent on bunker (fuel) rates, ship size, and most importantly, the market conditions on the required trading route.

Growing Demand for Fly Ash and Slag

Cementitious materials are commonly used in different stages of the cement and concrete production processes, and the demand for both fly ash and slag is growing. However, due to the lack of availability of these products in some mature markets in the world, the key challenge for the construction industy will be to ensure that sufficient cementitious materials are made available for them to meet their environmental and performance targets.

In Europe and some U.S. coastal states, domestic fly ash production will decline further over the next five years. There are two ways of compensating for this shortage—by recovering fly ash from stockpiles/landfills and beneficiating it using proven technology, or by importing fly ash from other countries where it is available.

Similarly, GBFS production has declined due to the reduction in steel production, which constitutes a vulnerability in the availability of GBFS. This overall global shortage has dramatically increased prices, and it is expected that prices will continue to rise. Importing cementitious materials from countries where there are ample quantities available—that is, India and China—will always be a potential solution to meet shortages. However, there are economic factors to consider, such as freight rates. Moving forward, all stakeholders in the value chain need to be aligned and share a long-term vision for sourcing cementitious materials. ❖

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