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GGBFS cement is routinely specified in concrete to provide protection against both sulphate attack and chloride attack

Saudi Readymix has used 100,000 tn of slag since 2013 reducing our CO_2 emissions by almost 100,000 tn of CO_2

Ground Granulated Blast- Furnace Slag

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Main uses and its wide range of usage in enhancing the durability of concrete

Ground granulated blast-furnace slag (GGBFS) or Slag Cement is obtained by quenching molten iron slag (a by-product of iron and steel-making) from a blast furnace in water or steam, to produce a glassy, granular product that is then dried and ground into a fine powder. GGBFS is used to make durable concrete structures in combination with ordinary portland cement and/or other pozzolanic materials. It has been widely used in Europe, and increasingly in the United States and in Asia (particularly in Japan and Singapore) for its superiority in concrete durability, extending the life span of buildings from fifty years to a hundred years.

Two major uses of GGBFS are in the production of quality-improved slag cement, namely Portland Blast furnace cement (PBFC) and high-slag blast-furnace cement (HSBFC), with GGBFS content ranging typically from 30 to 70%; and in the production of ready-mixed or site-batched durable concrete.

Concrete made with GGBFS cement sets more slowly than concrete made with ordinary Portland cement, depending on the amount of GGBFS in the cementitious material, but also continues to gain strength over a longer period in production conditions. This results in lower heat of hydration and lower temperature rises, and makes avoiding joints easier, but may also affect construction schedules where quick setting is required.

Use of GGBFS significantly reduces the risk of damages caused by alkali–silica reaction (ASR), provides higher resistance to chloride ingress — reducing the risk of reinforcement corrosion — and provides higher resistance to attacks by sulfate and other chemicals.

GGBFS cement is routinely specified in concrete to provide protection against both sulphate attack and chloride attack. It has now effectively replaced sulfate-resisting Portland cement (SRPC) on the market for sulfate resistance because of its superior performance and greatly reduced cost compared to SRPC.

To protect against chloride attack, GGBFS is used at a replacement level of 50% in concrete. Instances of chloride attack occur in reinforced concrete in marine environments and in road bridges where the concrete is exposed to splashing from road de-icing salts. In most projects GGBFS is now specified in structural concrete for bridge piers and abutments for protection against chloride attack. The use of GGBFS in such instances will increase the life of the structure by up to 50% had only Portland cement been used, and precludes the need for more expensive stainless steel reinforcing.

It is also routinely used to limit the temperature rise in large concrete pours. The more gradual hydration of GGBFS cement generates both lower peak and less total overall heat than Portland cement. This reduces thermal gradients in the concrete, which prevents the occurrence of micro cracking which can weaken the concrete and reduce its durability.

Concrete containing GGBFS cement has a higher ultimate strength than concrete made with Portland cement. It has a higher proportion of the strength-enhancing calcium silicate hydrates (CSH) than concrete made with Portland cement only, and a reduced content of free lime, which does not contribute to concrete strength. Concrete made with GGBFS continues to gain strength over time, and has been shown to double its 28-day strength over periods of 10 to 12 years. Since it is a by-product of steel manufacturing process, its use in concrete is recognized by Leadership in Energy and Environmental Design (LEED) etc. as improving the sustainability of the project and will therefore add points towards LEED certification. In this respect, GGBFS can also be used for superstructure in addition to the cases where the concrete is in contact with chlorides and sulfates. This is provided that the slower setting time for casting of the superstructure is justified.

Based on early experiences, modern designers have found that these improved durability characteristic help further reduce life cycle costs and lower maintenance costs and by replacing a portion of portland cement in a concrete mixture is a useful method to make concrete better and more consistent. Among the measurable improvements are:

- **Better concrete workability**
- **Easier finishability**
- **Higher compressive and flexural strengths**
- **Lower permeability**
- **Improved resistance to aggressive chemicals**
- **More consistent plastic and hardened properties**
- **Lighter color**

Above: Boyne Bridge M1 motorway
Concrete Piers contain GGBS, resulting in a lighter more aesthetic appearance.

Below: The Rio-Antirion bridge
Constructed in 2004 is the world's longest cable-stayed bridge. Its foundations were constructed with a blended cement comprising 60% GGBS for a service life of 120 years. [RCPT values in real life testing were consistently under 300 C]

Concrete Throughout the Ages: From Prehistory to The Middle Ages

> *"In both Roman and Egyptian times it was re-discovered that adding volcanic ash to the mix allowed it to set underwater. Similarly, the Romans knew that adding horse hair made concrete less liable to crack while it hardened, and adding blood made it more frost-resistant."*

Prehistory

The first concrete-like structures were built by the Nabataea traders or Bedouins who occupied and controlled a series of oases and developed a small empire in the regions of southern Syria and northern Jordan in around 6500 BC. . They discovered the advantages of hydraulic lime, with some self-cementing properties, by 700 BC.

They later discovered the advantages of hydraulic lime -- that is, cement that hardens underwater -- and by 700 BC, they were building kilns to supply mortar for the construction of rubble-wall houses, concrete floors, and underground waterproof cisterns. The cisterns were kept secret and were one of the reasons the Nabataea were able to thrive in the desert.

3000 BC

Egypt

Around 3000 BC, the ancient Egyptians used mud mixed with straw to form bricks. Mud with straw is more similar to adobe than concrete. However, they also used gypsum and lime mortars in building the pyramids.

2000 BC

China

About this same time, the northern Chinese used a form of cement in boat-building and in building the Great Wall. Spectrometer testing has confirmed that a key ingredient in the mortar used in the Great Wall and other ancient Chinese structures was glutenous, sticky rice. Some of these structures have withstood the test of time and have resisted even modern efforts at demolition.

500 BC

Rome

"The Romans used concrete extensively from 300 BC to 476 AD, a span of more than seven hundred years. During the Roman Empire, Roman concrete (or opus caementicium) was made from quicklime, pozzolana and an aggregate of pumice."

By 600 BC, the Greeks had discovered a natural pozzolan material that developed hydraulic properties when mixed with lime, but the Greeks were nowhere near as prolific in building with concrete as the Romans. By 200 BC, the Romans were building very successfully using concrete, but it wasn't like the concrete we use today. It was not a plastic, flowing material poured into forms, but more like cemented rubble.

The Roman Pantheon

The Romans built most of their structures by stacking stones of different sizes and hand-filling the spaces between the stones with mortar. Above ground, walls were clad both inside and out with clay bricks that also served as forms for the concrete. The brick had little or no structural value and their use was mainly cosmetic. Before this time, and in most places at that time (including 95% of Rome), the mortars commonly used were a simple limestone cement that hardened slowly from reacting with airborne carbon dioxide. True chemical hydration did not take place. These mortars were weak.

For the Romans' grander and more artful structures, as well as their land-based infrastructure requiring more durability, they made cement from a naturally reactive volcanic sand called *harena fossicia*. For marine structures and those exposed to fresh water, such as bridges, docks, storm drains and aqueducts, they used a volcanic sand called *pozzuolana*.

These two materials probably represent the first large-scale use of a truly cementicious binding agent. Pozzuolana and harena fossicia react chemically with lime and water to hydrate and solidify into a rock-like mass that can be used underwater. The Romans also used these materials to build large structures, such as the Roman Baths, the Pantheon, and the Colosseum, and these structures still stand today.

As admixtures, they used animal fat, milk and blood -- materials that reflect very rudimentary methods. On the other hand, in addition to using natural pozzolans, the Romans learned to manufacture two types of artificial pozzolans -- calcined kaolinitic clay and calcined volcanic stones -- which, along with the Romans' spectacular building accomplishments, are evidence of a high level of technical sophistication for that time.

The Middle Ages

500 AD - 14th Century

After the Roman Empire, the use of burned lime and pozzolana was greatly reduced until the technique was all but forgotten between 500 and the 14th century.

Multiple sources; anonymous