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Controlled Low-Strength Material (CLSM)

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Features

- Controlled Low-Strength Material (CLSM)
- Concrete Throughout The Ages:The Invention of Portland Cement

Several terms of CLSM are currently used to describe this material, including flowable fill, controlled density fill, flowable mortar, plastic soil-cement, soil-cement slurry, K-Krete, and other names.

A self-compacted, cementitious structural fill or backfill that flows like a liquid, supports like a solid and self-levels without tamping or compaction having an unconfined compressive strength of 1,200 Psi or less.

History

In 1964, the U.S. Bureau of Reclamation documented the first known use of Controlled Low-Strength Material (CLSM). Plastic soil-cement, as the Bureau called it, was used as pipe bedding on over 515 kilometers of the Canadian River Aqueduct Project in Northwestern Texas. Since 1964, CLSM has become a popular material for projects such as structural fill, foundation support, pavement base, and conduit bedding.

Since 1979, the Iowa Department of Transportation has used CLSM to structurally modify more than 40 substandard bridges by converting them into culverts. CLSM is also used to fill large voids such as old tunnels and sewers. In a Milwaukee project, 635 cubic meters of CLSM were used to fill an abandoned tunnel.

Several terms of CLSM are currently used to describe this material, including flowable fill, controlled density fill, flowable mortar, plastic soil-cement, soil-cement slurry, K-Krete, and other names. Most current CLSM applications require unconfined compressive strengths of 200 psi (1.4 MPa) or less. This lower strength requirement is necessary to allow for future excavation of CLSM.

The fluidity/flowability and self-compacting properties of CLSM mixtures make CLSM an economical alternative to compacted granular material due to savings of labor and time during placing. CLSM is also an all-weather construction material—it will displace any standing water left in a trench—making it an ideal material for many projects.

CLSM will not settle or rut under loads, making the material an ideal pavement base. Additionally, CLSM can be placed quickly and support traffic load within hours of placement-minimizing repair time and allowing a rapid return to traffic. CLSM may be equal to or less than the cost of using standard compacted backfill. CLSM also makes an excellent bedding material for pipe, electrical, telephone, and other types of conduits because the mixture easily fills voids beneath the conduit and provides uniform support.

Uses of CLSM includes the following

- **Backfill** – Sever & Utility Trenches, Bridge Abutments, Conduit Encasement, Pile Excavation, Retaining Walls and Road Cuts.

- **Structural Fill** – Foundation Sub-base, Subfooting, Floor Slab Base, pavement Bases and Conduit Bedding

- **Others Uses as Fill** – Abandoned Mines, Underground Storage Tanks, Wells, Abandoned Tunnels Shaft and Sewers, Basements and Underground Structures, Voids Under Pavements, Erosion Control and Thermal Insulation with high air content flowable fill.

CLSM Requirement & Design

A typical CLSM mix contains cement, water and fine aggregate but fly ash and admixtures can also be added in varying proportion to meet specific performance requirements.

Raw Materials & Requirement:

a. Cement: Portland cement shall meet the requirements or conform to ASTM C150 - Standard Specification for Portland cement, Type I, II, V or a combination thereof. Typical cement range from 30 to 120 kg/m3, depending upon strength and hardening-time requirements. Increasing cement content will normally increase strength and reduce hardening time.

B. Fine Aggregate (Sand): Fine aggregate can meet the requirements of ASTM C33 Specification but CLSM is more economical to produce with local aggregates as long as the materials are not expansive or reactive. Typical aggregates range for CLSM from 1500 to 1800 kg/m3
Aggregates used successfully in CLSM mix includes:

- Pea gravel with sand
- Native sand soils with more than 10% passing a 75µ m(#200) sieve
- Quarry waste product (generally 10mm-3/8" minus aggregates)
- Silty sands with up to 20% fines passing a 75µm(#200) sieve have proven satisfactory

C. Water: Water used in mixing shall be free of oil, salt, acid, alkali, sugar, vegetable matter, or other substances injurious to the finished product. Water contents typically range from 193 to 344 kg/m3

D. Fly Ash: Fly Ash shall conform to ASTM C 618, Class C or F. Class C, can use up to 210 kg/m3 and Class F, can use up to 1200 kg/m3 where fly ash serves as the aggregate filler

E. Admixture: Chemical admixtures shall meet the requirement that conform to ASTM C494 or to ASTM C226-Air entraining admixture.

Below are CLSM mix designs used by various ready mixed concrete associations and departments of transportation. Most of the organizations have several different mix designs to satisfy different fill strength and flowability requirements. Amounts shown are pounds per cubic yard of fill.

Ohio Ready Mixed Concrete Association

	Mix1	Mix2	Mix3
Cement	50	100	50
Water	500	500	500
Fly ash	250	250	__
Fine aggregate	2,910	2,850	3,160

Michigan Ready Mixed Concrete Association

	Mix1	Mix2	Mix3
Cement	70	100	100
Water	420	420	750
Fly ash	500	900	2,000
Fine aggregate	2,600	2,100	__

National Ready Mixed Concrete Association

	Mix1	Mix2	Mix3
Cement	60	190	280
Water	475	460	440
Fly ash	290	300	300
Fine aggregate	2,770	2,680	2,650

Iowa Department of Transportation

Cement	100
Water	584
Fly ash	300
Fine aggregate	2,600

South Carolina Department of Highways and Public Transportation

	Mix1	Mix2	Mix3	Mix4
Cement	50	100	50	100
Water	458	460	375	375
Fly ash	300	400	300	400
Fine aggregate	2,850	2,700	3,070	2,910

Reference for CLSM Mix Design

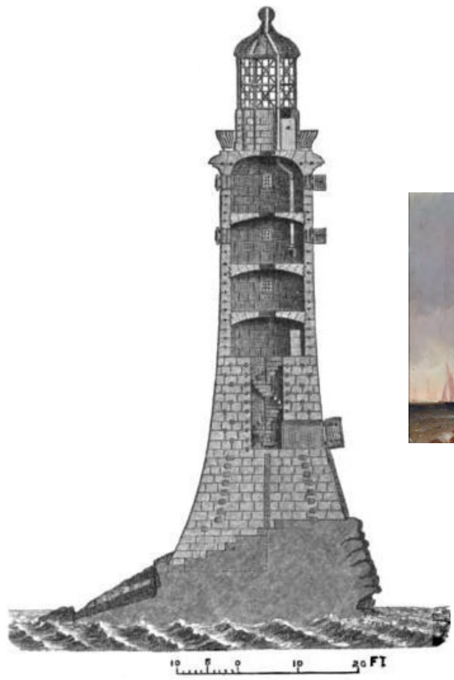
Joseph Aspdin (1778-1855)

Portland Cement, one of mankind's most important manufactured materials, was patented by Joseph Aspdin, a Leeds Bricklayer, on 21 October 1824.

Experiments With New Cements 1670-1824

There was very little use of concrete by the British until the 18th century, with the notable exception in the 1670s of the construction of a breakwater or mole at Tangier, a British outpost on the North African coast. There, Henry Shere, a young engineer, supervised the mole's construction, based on one at Genoa.

In 1756 a Leeds engineer, John Smeaton, was commissioned to build the third lighthouse on the Eddystone Rocks in the English Channel 14 miles south-west of Plymouth. The two previous lighthouses had been constructed of timber, one had burnt down and the other had blown away in a gale.



SECTION OF SMEATON'S LIGHTHOUSE.

Smeaton soon realized that the only practical method was to build with blocks of stone, but this presented the problem of how to bind them together to form a rigid monolithic structure. The cements generally available in 1756 were weak and slow setting, and as the blocks would be constantly soaked by the sea, the mortar would be washed away before it could harden.

Smeaton began testing mortars from different parts of the country. He found that lime mortar would set under water if the limestone used in its manufacture contained clay (which provided the silica and alumina). But lime mortar did not itself solve the problem and he eventually settled on a mixture of burnt limestone from South Wales and an Italian trass. Smeaton's experiments were the first scientific investigations and paved the way to modern cements.

Towards the end of the 18th century there was revival of interest in developing new types of cement, with many formulations which, in essence, were little better than Smeaton's attempts Perhaps the best known was a cement discovered by accident by a vicar, the Rev. James Parker of Northfleet in Kent, who threw a pebble collected from the beach onto his fire, where it was thoroughly calcined. After some experiments he developed a cement which he patented in 1796 under the name 'Roman' cement because, it is suggested, he believed he had discovered how to make the cement of ancient times.

The pebbles, which were nodules of septaria or cement stone from the London clay, contained lime, silica, and alumina, and were burnt in kiln before being crushed to produce the Roman cement. Large quantities were collected from the beaches in Thames Estuary and other places to make a cement that remained popular until the middle of the 19t century.

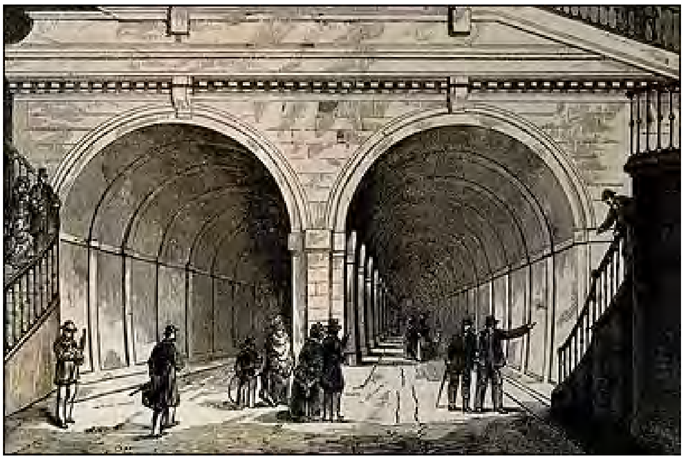
The Invention of Portland Cement

A great milestone in the history of concrete was the invention of Portland cement by Joseph Aspdin. Following his researches in Wakefield he took out a patent on 21 October 1824 for the manufacture of the world's first Portland cement, which he claimed to have been making since 1811. He chose this name because, when set, he thought it resembled Portland stone in colour and not, as people often think, because it was made in Portland.

Aspdin's was undoubtedly the most superior cement of its day, but since that time considerable improvements have been made in the cement-making process, so that today's Portland cement resembles that produced by Aspdin in name and basic ingredients only.

He established his first cement works around 1828 at Kirkgate in Wakefield. So far as can be ascertained, only one building incorporating Aspdin's cement still survives

Aspdin's younger son, William, left home about this time to seek his fortune 200 miles to the south in London. He set up a cement works at Rotherhithe, to the east of London, at a time when Isambard Kingdom Brunel was having problems constructing the Thames Tunnel.



Brunel carefully placed several tons of his cement into the river when the tunnel roof collapsed. This sealed the break and Brunel was able to pump the brick-built tunnel dry and then reline parts of it with mortar made with Portland cement. Despite the problems with its construction, this was the world's first significant underwater tunnel.

In 1852, Aspdin moved to Gateshead, and set up what was probably the largest cement works in the world at that time. In 1860 he started cement manufacture in Germany, where he died four years later.

The cement-making process was improved by Isaac Johnson who managed a cement works in Swanscombe and later, in 1856, took over Aspdin's abandoned works in Gateshead. He raised the temperature at which the cement was fired, and is regarded by many as the father of modern Portland cement.

Concrete Through The Ages; British Cement Association