The Evolution of Lightweight Concrete

FROM ANCIENT USES TO MODERN PERLITE INNOVATIONS

Figure 1 Ancient Roman concrete consisting of chunks of volcanic tuff and brick bound together by a volcanic ash-lime mortar Image: Roy Kaltschmidt, Berkeley Lab

Executive Summary

Lightweight concrete has been used since early construction history because it reduces dead load, improves thermal performance, and enables structures that would be difficult to achieve with heavier materials. From the Romans' use of natural lightweight aggregates to modern engineering needs, the motivation has remained largely the same. Expanded perlite became part of this broader development in the mid-20th century, offering a practical, reliable lightweight aggregate for both insulating and structural applications. Since its establishment, the ***Perlite Institute*** has contributed to this field by supporting testing efforts, sharing technical knowledge, and helping define good practice. This brochure outlines the historical progression of lightweight concrete and the way perlite-based solutions have evolved within that wider context.

Concrete History - Ancient Times

The origins of concrete can be traced back to around 6,500 BC in Syria and Jordan, where the earliest known structures were built[1]. Centuries later, the Ancient Romans transformed construction with Opus Caementicium (Roman concrete), introducing volcanic ash into their mixtures to achieve exceptional strength and durability (ESCSI, 1970). More than 2,300 years ago, they also pioneered lightweight concrete, a material that made possible some of the Empire's most iconic achievements, including the Pantheon Dome, the Colosseum, and the Port of Cosa. At the Port of Cosa on Italy's west coast, constructed in 273 BC, Roman engineers replaced traditional sand and gravel with natural lightweight volcanic aggregates such as pumice and scoria. This innovation created marine structures that withstood the forces of the sea for over two millennia before being abandoned due to abrasion and siltation.

The Colosseum, the monumental amphitheater of ancient Rome with a seating capacity of 50,000, was constructed between 75 and 80 A.D. Its foundation was built with lightweight concrete that incorporated crushed volcanic lava as aggregate, an innovation that provided both strength and reduced weight. In a similar way, the walls of the structure were formed using porous, crushed bricks as aggregates, while the spaces and vaults between the walls were constructed from porous tufa stone[2]. This sophisticated use of lightweight materials not only enhanced durability but also made possible the scale and architectural brilliance of one of Rome's most iconic landmarks (Grygar, 2014).

Figure 2 . First lightweight aggregates used in concrete mixtures: pumice (top), tufa stone (middle), and scoria (bottom).

[1] The International Association of Certified Home Inspectors - InterNACHI®, https://www.nachi.org/history-of-concrete.htm

[2] A light, sedimentary rock composed of calcium carbonate that forms at normal temperatures from water rich in dissolved calcium

Source: Wikipedia

Figure 3 The Colosseum in Rome

Source: Wikipedia

Figure 4 The Pantheon's great dome

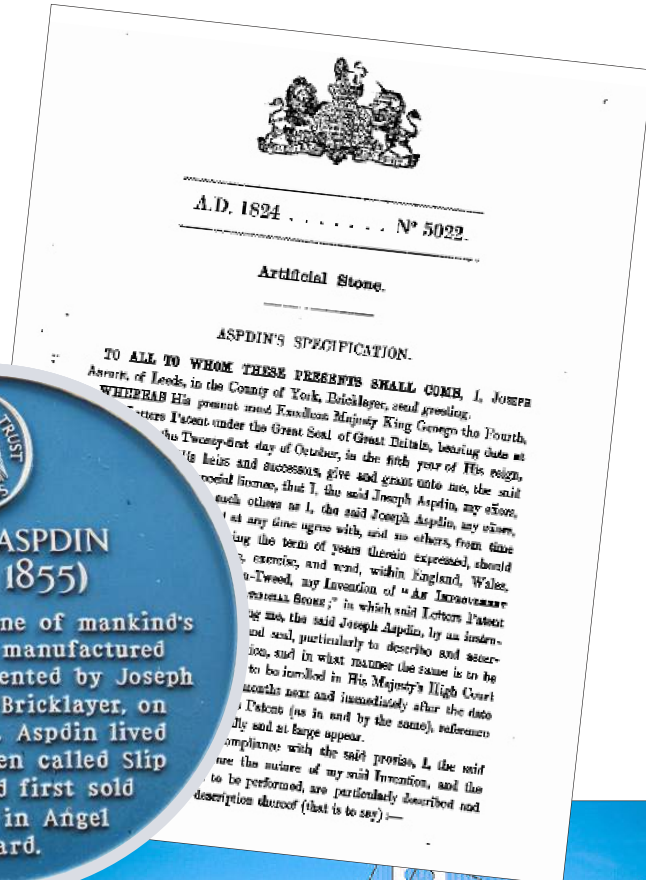
The Pantheon in Rome, completed in 128 A.D., stands as the earliest and most remarkable example of innovative concrete construction, featuring the world's first lightweight concrete dome (Thienel et al., 2020). Recognized as the first advanced concrete structure in history, and still fully functional today, the Pantheon demonstrates the ingenuity of Roman engineering. Its dome, with a diameter of 43.3 meters—a record that stood unchallenged for 2,000 years—was built using lightweight concrete with carefully selected aggregates of varying densities. Heavier materials were placed at the base, where stresses were greatest, while progressively lighter aggregates were used toward the top, where loads were lower. This ingenious method created a structure of extraordinary strength and reduced weight, ensuring both durability and stability. Remarkably, the Pantheon continues to serve its purpose nearly two millennia later, a timeless testament to the durability of lightweight concrete.

Source: Wikipedia

Figure 5 The Pantheon dome. The coffered dome has a central oculus as the main source of natural light.

The Era of Cement – the Genesis of Portland Cement

In 1824 Joseph Aspdin, an English bricklayer, intermixed pulverized raw limestone and pulverized impure siliceous materials in varying percentages (ESCSI, 1970). He then subjected these mixtures to the high temperatures of coke fires and pulverized the resultant clinkers. Aspdin determined the raw compounding required for maximum strength and removed the dangerous inconsistencies of the older Roman cements. This was the birthday of Portland Cement, so called because when hardened it resembled a popular building stone quarried on the Isle of Portland, off the coast of England.


A.D. 1824 . . . . Nº 5022.

Artificial Stone.

ASPDIN'S SPECIFICATION.

TO ALL TO WHOM THESE PRESENTS SHALL COME, I, JOSEPH ASPDIN, of Leeds, in the County of York, Bricklayer, send greeting.

WHEREAS His present most Excellent Majesty King George the Fourth,

Figure 6 Plaque commemorating Joseph Aspdin in the yard where he lived (left), and first page of Aspdin patent (right)

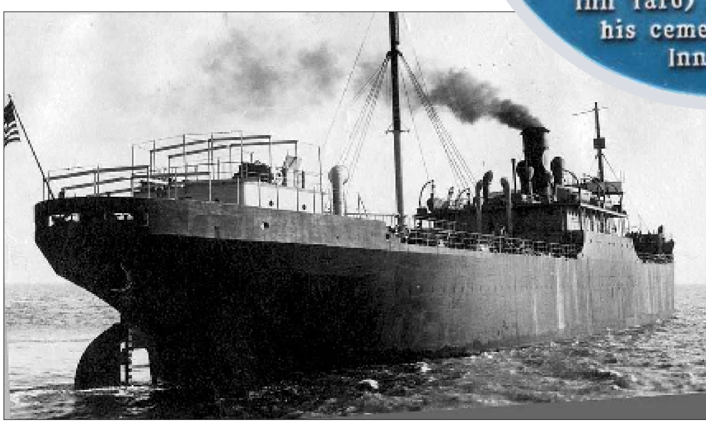

Source: Wikipedia

Figure 7 SS Selma, oil tanker ship made from concrete

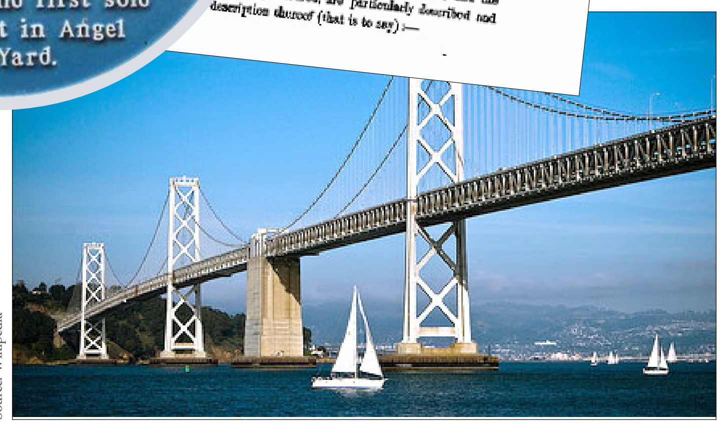

Source: Wikipedia

Figure 8 The western section of the San Francisco–Oakland Bay Bridge

The Interbellum Era / USA Lightweight Concrete Ocean-Going Ships

During World War I, the United States Navy, through the Emergency Fleet Building Corporation, pioneered the use of Expanded Shale lightweight aggregates in shipbuilding. This innovation led to the construction of lightweight concrete ships as part of the wartime program. In 1918, the SS *Atlantus*, the first 3,000-ton concrete vessel, was launched[3]. The following year, the *Selma*—a 7,500-ton tanker measuring 434 feet in length, 43 feet in beam, and with a 26-foot draft fully loaded—entered service. In total, 14 lightweight concrete ship hulls were built during World War I (ESCSI, 1970). The success of this technology carried forward into World War II, when 104 lightweight concrete supply ships were constructed, with cargo capacities ranging from 3,200 to 140,000 tons. These vessels showcased the durability, versatility, and strategic value of lightweight concrete in large-scale maritime applications.

The Interbellum Era / USA: Lightweight Concrete Decks in Bridges

In the 1920s, expanded slate aggregates were first introduced in lightweight concrete for bridge construction. Over the following decades, this innovation proved highly successful—by the mid-20th century, more than 200 lightweight concrete bridges had been built across the United States.

One of the most iconic applications was in the San Francisco–Oakland Bay Bridge (Piechaczek et al., 2025). By using lightweight concrete in the upper deck floor, engineers reduced the structure's weight by 25 pounds per square foot—an impressive total of 31.6 million pounds. This not only lowered the cost of the superstructure but also reduced foundation stresses under seismic loads, ultimately cutting the project budget by approximately $3 million.

[3] https://www.concreteships.org/ships/ww1/atlantus/

The Interbellum Era / USA: Structural Lightweight Concrete in Buildings

The early 1920s marked the beginning of structural lightweight concrete in the United States. In 1920, the Haydite Company in Kansas City, Missouri, established the first commercial expanded shale plant for producing bricks and concrete (ESCSI, 1970). Just two years later, in 1922, the gymnasium addition at Westport High School in Kansas City became the first structural lightweight concrete building in history. Although expanded shale aggregates cost nearly twice as much as sand and gravel, they proved highly cost-effective by reducing foundation engineering requirements and overall deadweight loads.

A few years later, in 1928–1929, lightweight concrete was used in the first major high-rise project: the 14-floor addition to the Southwestern Bell Telephone Company office in Kansas City. Originally planned as an 8-floor addition with normal-weight concrete, the switch to lightweight concrete enabled a taller expansion. With no ready-mix plants available at the time, the material was mixed directly on site, demonstrating both innovation and practicality.

Source: skyscrapercenter.com/©Terri Meyer Boake

Expanded Perlite Era: Perlite Lightweight Concrete

The development of perlite expansion technology in the late 1940s marked the beginning of a new era in lightweight construction materials. In 1949, the Perlite Institute (PI) was founded to advance knowledge and promote applications of this unique mineral.

From its earliest years, the Institute documented the use of perlite in lightweight concrete through a series of pioneering publications:

- Perlite Concrete Physical Testing Program, 1952[4]

This is the first perlite concrete report. The document was prepared in 1952 by the Robert W. Hunt Company (Chicago) for the Perlite Institute. It records an extensive physical testing program on perlite concrete, covering aggregate characterization, mix designs, tensile and compressive strength, bond to reinforcement, shrinkage, modulus of elasticity, roof slab load tests, and durability evaluations. The report presents raw test results (without interpretation) intended for use by the Perlite Institute's technical committee and member companies.

- Report on Roof and Ceiling Construction with Perlite Concrete Roof and Perlite Plaster Ceiling on Open Web Steel Joists and Steel Beam, 1953[5].

This report was issued in 1953 by Underwriters' Laboratories, Inc. for the Perlite Institute. It documents a fire endurance, hose stream, and excess load test on a roof and ceiling assembly using perlite concrete roof decks and perlite plaster ceilings on open-web steel joists and beams. The study concluded that such assemblies provide three-hour fire resistance for the roof deck and two-hour protection for the supporting steel beams.

- Report on Floor and Ceiling Assembly with Concrete Over Steel Form Units with Provisions for Electrical Wiring Supported by a Steel Beam and Protected with Perlite Acoustical Plaster, 1958 doc[6].

This report was prepared in 1958 by Underwriters' Laboratories, Inc. for F.E. Schundler & Co., Joliet, Illinois, and Granco Steel Products Co., Granite City, Illinois. It covers a fire endurance and hose stream test on a floor–ceiling assembly of expanded shale concrete over steel form units, with electrical raceways and beams protected by perlite acoustical plaster. The results showed the assembly achieved a 3-hour fire rating for the floor–ceiling and 4-hour protection for the supporting steel beam.

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[4] Perlite Concrete Physical Testing Program for PERLITE INSTITUTE, 1952. Available at the Members Only area of the Perlite Institute webpage (https://www.perlite.org/)

[5] Report on Roof and Ceiling Construction with Perlite Concrete Roof and Perlite Plaster Ceiling on Open Web and Steel Beam, 1953. Available at the Members Only area of the Perlite Institute webpage (https://www.perlite.org/)

[6] Report on Floor and Ceiling Assembly with Concrete Over Steel Form Units with Provisions for electrical Wiring Supported By a Steel Beam and Protected with Perlite Acoustical Plaster,1958. Available at the Members Only area of the Perlite Institute webpage (https://www.perlite.org/)

■ Thermal Conductivity of Perlite Concrete,1963[7].

This document is a composite technical file on perlite concrete and insulation, compiled for the Perlite Institute. It consists of:

- First product specifications and technical data sheets for perlite concrete aggregate and loose-fill insulation (with ASTM references, physical properties, installation guidelines, and R/U-value tables).
- A research paper by Ludwig Adams (1969, Cryogenic Technology) on the thermal conductivity of perlite concrete under varying density, temperature, and moisture conditions.
- A reroofing applications article (1992, Roofer Magazine) describing the use of perlite insulating concrete in reroofing systems.
- A Pittsburgh Testing Laboratory report (1963) with compressive strength and density tests on perlite concrete mixes.
- A Pennsylvania State College Engineering Research report (1952) on guarded hot-box heat transfer tests of concrete block walls filled with perlite insulation

These foundational documents established the technical credibility of perlite-based construction products and paved the way for their widespread adoption worldwide.

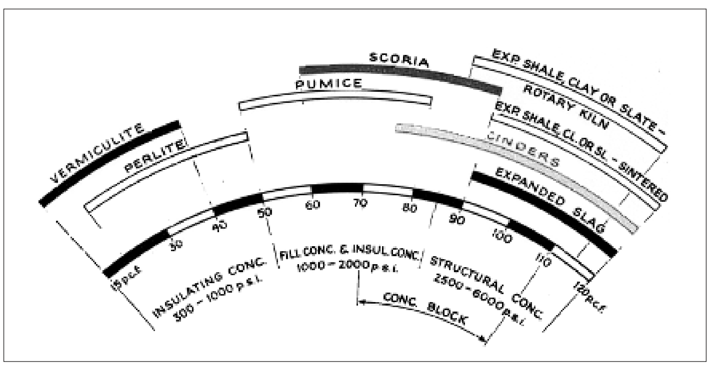

Figure 10. Weight spectrum of lightweight concretes (ESCSI, 1970).

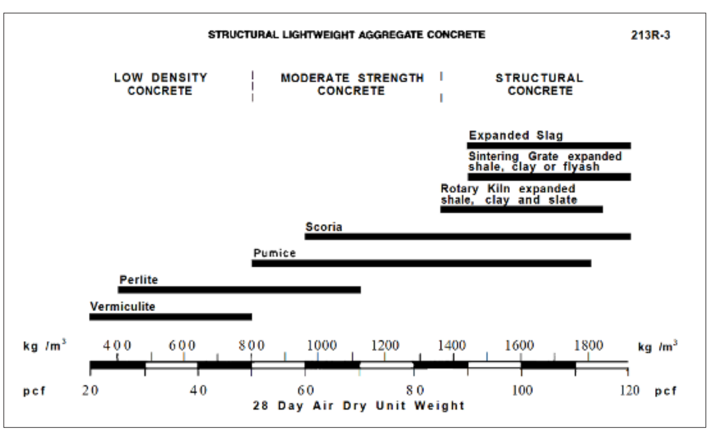

Figure 11 Approximate unit weight and use classification of lightweight concrete aggregates (Grygar, 2014)

Energy Saving Era: Perlite Lightweight Insulating Concrete

The 1973 oil crisis in Germany marked a turning point in building energy regulations. The newly introduced action towards energy saving required significant reductions in energy consumption, leading to the adoption of monolithic exterior walls made of lightweight concrete as a cost-effective thermal insulation solution (Economidou et al., 2020). From the 1990s onward, stricter thermal insulation regulations were progressively implemented—first in Germany, then across Europe and eventually in most developed countries. This regulatory shift significantly expanded the applications of *Perlite Lightweight Insulating Concrete* (LWIC) in modern construction.

Figure 12 Technical brochures of the Perlite Institute on mix design and physical, mechanical and thermal properties of lightweight perlite concrete. The brochures are available at the "Resource Library" area of the Perlite Institute webpage (https://www.perlite.org/)

Currently, advanced perlite-based concrete solutions have been developed for diverse functions:

■ Ultra-Lightweight Insulating Concrete (400–800 kg/m³): Ideal for roofs, terraces, and balconies. Find more information here (https://www.perlite.org/wp-content/uploads/2024/04/Perlite-Lightweight-Insulating-Concrete-Roofing.pdf)

■ Mediumweight Perlite Concrete (1,000–1,400 kg/m³): Used to reduce dead loads in floors, podiums, and precast elements. Find more information here: https://www.perlite.org/wp-content/uploads/2021/12/TransitMix-PerliteConcrete-SpecGuide.pdf)

■ Structural Perlite Concrete (1,600–1,800 kg/m³): High-strength formulations reaching up to 30 MPa. Find more information here: https://www.perlite.org/wp-content/uploads/2018/03/perlite-concrete-overview-metric.pdf

[7] Thermal Conductivity of Perlite Concrete, 1963. Available at the Members Only area of the Perlite Institute webpage (https://www.perlite.org/)

From ancient Roman marvels to today's high-performance building materials, lightweight concrete has consistently reshaped the way we build. The evolution of perlite-based solutions reflects not only advances in engineering but also society's growing commitment to sustainability, energy efficiency, and resilient construction. As global challenges demand lighter, stronger, and more environmentally responsible structures, perlite lightweight concrete stands ready to continue this legacy—offering architects, engineers, and builders an enduring material for the future.

For more information on applications, mix designs, and the physical, mechanical, or thermal properties of perlite concretes, please visit the *Perlite Institute* webpage, explore the *Resource Library*, or contact the Institute directly for specialized guidance and support.

BIBLIOGRAPHY

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[4] Piechaczek, M., Ostrowski, K. A., & Furtak, K. (2025). Lightweight Aggregate Concrete with Regard to Bridge Structures—State of the Art. Materials, 18(16), 1–46. https://doi.org/10.3390/ma18163874

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