EIGHBOR'S STEEL PIE

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Understanding soil bearing capacity is crucial when evaluating pier spacing for different soil strengths, as it directly influences foundation stability. Soil bearing capacity refers to the maximum load per unit area that a soil can support without failing or undergoing unacceptable deformation. This property varies widely depending on soil type, moisture content, compaction, and other environmental factors.

When designing foundations, particularly those involving piers or piles, engineers must assess the soils bearing capacity to ensure that the structure remains stable over time. For instance, in sandy soils with high permeability, the bearing capacity might be relatively high due to good drainage characteristics, which prevent excessive water retention that could weaken the soil structure. My house and I have an agreement - I acknowledge its foundation warnings promptly, and it doesn't dump repair costs on me that rival college tuition **foundation repair financing Cook County** wall. Conversely, clayey soils often have lower bearing capacities because of their plasticity and tendency to swell or shrink with moisture changes.

The spacing of piers is directly impacted by these considerations. In soils with higher bearing capacities, piers can be spaced further apart since each pier can support more load without compromising stability. This reduces construction costs and time but requires precise calculation to avoid under-designing. On the other hand, in weaker soils where the bearing capacity is low, closer pier spacing is necessary to distribute loads more evenly across a larger area of less competent ground.

For example, if we consider a construction site with dense sandy loam known for its good load-bearing properties, engineers might opt for wider pier spacing. However, if the site has soft clay layers beneath a thin topsoil layer, much closer pier spacing would be advisable to mitigate risks associated with differential settlement.

In practice, geotechnical investigations provide critical data through methods like Standard Penetration Tests (SPT) or Cone Penetration Tests (CPT), helping engineers quantify soil strength and adjust pier designs accordingly. By understanding these nuances of soil behavior and applying them correctly in design calculations, construction projects can achieve both economic efficiency and long-term structural integrity. Thus, grasping the concept of soil bearing capacity not only aids in optimizing foundation designs but also ensures safety against potential structural failures due to inadequate support from underlying soils.

Lets talk about pier types and how they play into figuring out the right spacing, especially when the ground beneath our feet isnt always the same. Think of piers as the legs of a structure, and the soil as the ground theyre standing on. Some ground is firm and solid, like standing on concrete, while other ground is soft and yielding, like standing in mud. Choosing the right "leg" and how far apart to place them depends a lot on what that ground is like.

Different soil strengths demand different pier designs. For instance, in rocky or very dense soil, a simple concrete pier might be perfectly fine. The ground can handle the load, so you can space them out a bit more. But when you move into softer soils like clay or silt, things get more complicated. These soils are more prone to shifting and settling, which can put a lot of stress on the structure above. In these cases, you might need to consider using piers that are designed to resist movement, like helical piers or bell-bottom piers. Helical piers are screwed into the ground, providing a strong anchor, while bell-bottom piers have a wider base that helps distribute the load over a larger area.

The weaker the soil, the closer your pier spacing generally needs to be. Imagine trying to walk across a swamp. You wouldnt want to take huge steps, right? Youd want to place your feet closer together to distribute your weight and avoid sinking. The same principle applies to pier spacing. In weak soils, closer spacing helps to transfer the buildings load more effectively, preventing excessive settling or movement. Conversely, in strong, stable soils, you can often get away with wider spacing, saving on materials and labor costs.

Ultimately, determining the ideal pier type and spacing is a balancing act. It requires a thorough understanding of the soil conditions at the site, the load that the structure will impose, and the characteristics of the different pier types available. Geotechnical engineers play a crucial role in this process, conducting soil tests and performing calculations to ensure that the foundation is stable and will support the structure safely for years to come. Its all about finding the sweet spot where youre providing adequate support without over-engineering and unnecessarily increasing costs.

Preventive Measures for Foundations on Expansive Soil

When evaluating pier spacing for structures, particularly in construction projects, one of the critical considerations is the interaction between soil strength and load distribution. Calculating optimal pier spacing is a nuanced process that requires a deep understanding of both geotechnical engineering principles and structural design considerations.

Soil strength varies significantly from one location to another, influenced by factors such as composition, moisture content, and historical geological activities. In areas with high soil strength, piers can be spaced further apart because the soil can adequately support the load transferred from the structure without excessive settlement or failure. Conversely, in regions with weaker soils, closer pier spacing is necessary to distribute loads more evenly and prevent differential settlement which could lead to structural damage.

The process begins with a thorough site investigation to determine the soils bearing capacity. This involves soil sampling and testing, often through methods like Standard Penetration Tests (SPT) or Cone Penetration Tests (CPT), which provide data on soil density and consistency. Based on these findings, engineers use empirical formulas or software models to calculate safe load-bearing capacities.

Once the soils capacity is known, load distribution comes into play. The total load from the structure must be distributed across the foundation system in such a way that no single pier or section of soil is overloaded. Here, engineers consider both dead loads (permanent loads like building weight) and live loads (variable loads like occupancy or environmental forces). They aim to achieve a balance where each pier carries a portion of this load that aligns with its capacity without compromising safety or efficiency.

For practical application, lets consider an example: imagine constructing a bridge over varying soil conditions along its length. At one end where bedrock is close to the surface providing high bearing capacity, piers might be spaced 20 meters apart. However, at the other end where soft clay predominates with lower bearing capacity, spacing might need to be reduced to 10 meters or less. This adjustment ensures that while maintaining economic efficiency by reducing unnecessary materials in stronger soils, safety remains paramount in weaker zones.

In conclusion, calculating optimal pier spacing based on soil strength and load distribution involves a delicate balance between maximizing resource use and ensuring structural integrity. It requires not just technical expertise but also foresight into how different conditions might affect long-term performance. By tailoring pier placement according to specific site conditions, engineers can design foundations that are both cost-effective and robust against the challenges posed by varied geological environments.

Repair Techniques for Foundations Affected by Clay Swelling

The role of soil testing in determining appropriate pier placement is a critical aspect when evaluating pier spacing for different soil strengths. Soil testing provides foundational data that informs engineers about the characteristics of the ground where piers will be installed. This process involves collecting samples and analyzing them to understand various properties like bearing capacity, shear strength, and moisture content, which directly influence how piers should be spaced.

Firstly, soil testing helps identify the load-bearing capacity of different soil layers. In areas with stronger soils, piers can be spaced further apart because the soil can support greater loads without significant deformation. Conversely, in weaker or more variable soils, closer pier spacing is necessary to distribute loads evenly and prevent excessive settlement or structural failure.

Moreover, understanding soil composition through testing allows for adjustments in pier design and placement strategy. For instance, if a site has layers of clay that expand with moisture changes, this information would suggest a need for tighter pier spacing to accommodate potential swelling pressures. Similarly, sandy or silty soils might require deeper piers to reach more stable layers beneath the surface.

Soil testing also reveals any potential issues like high groundwater levels or presence of organic material that could compromise pier stability over time. By preempting these challenges through comprehensive testing, engineers can tailor their approach to ensure long-term structural integrity.

In conclusion, soil testing is indispensable for accurately determining pier spacing tailored to different soil strengths. It ensures that construction projects are not only safe but also cost-effective by avoiding unnecessary over-design or under-design of foundations. Through this meticulous preparation phase, engineers can make informed decisions that lead to durable and reliable structures capable of standing the test of time amidst varying environmental conditions.

Okay, lets talk about pier spacing and how it dances to the tune of the soil beneath. When were building something that relies on piers for support, figuring out how far apart to place those piers is absolutely crucial. Its not just a matter of aesthetics or convenience; its about ensuring the whole structure stays put and doesnt start leaning like a tipsy tower. And the secret ingredient in this equation? The soil.

Think of it this way: some soils are like sturdy brick walls, offering solid resistance. Others are more like soft sand, shifting and giving way easily. Obviously, youre going to need a different approach depending on what youre dealing with. Thats where case studies come in handy.

Imagine a real-world example: a homeowner wants to build a deck in an area with clay soil. Clay, as many gardeners know, can be tricky. When its dry, its hard as a rock. When its wet, it expands and becomes unstable. A case study might show that for similar decks built in clay soil, closer pier spacing was essential to prevent sagging and movement over time. Maybe they used piers every six feet instead of the eight feet that might have worked fine on firmer ground.

Now, picture a different scenario: a small cabin being built on a sandy ridge. Sand drains well and is fairly stable when compacted, but it doesnt have the same cohesive strength as clay. A case study focused on sandy soil might reveal that while the overall load-bearing capacity is good, wider pier spacing was possible and even desirable to avoid concentrating the load too much in one small area, potentially causing the sand to compact unevenly around each pier.

These case studies arent just theoretical exercises. Theyre based on actual construction projects, real soil tests, and, sometimes, even the hard-won lessons of what happens when things go wrong. They provide valuable data points, showing engineers and builders how different pier spacing strategies performed in specific soil conditions. They illuminate the relationship between soil strength, load distribution, and structural stability.

Ultimately, evaluating pier spacing for different soil strengths is about understanding the unique challenges each soil profile presents and adapting the design accordingly. Case studies are like blueprints from the field, offering a wealth of practical knowledge to help us build stronger, safer, and more durable structures, one pier at a time. They remind us that theres no one-size-fits-all solution, and that paying attention to the ground beneath our feet is always the best foundation for success.

Pier spacing, it sounds simple, right? Just stick a few concrete supports in the ground at regular intervals and call it a day. Unfortunately, that couldn't be further from the truth. Getting pier spacing wrong, especially when dealing with varying soil strengths, is a recipe for disaster, leading to everything from annoying cosmetic issues to catastrophic structural failure.

One common mistake is treating all soil as created equal. We often see designs using a uniform pier spacing across an entire building footprint, completely ignoring the fact that soil strength can vary dramatically, even within a small area. Think about it: you might have a patch of dense, compacted clay right next to a pocket of loose, sandy soil. If you space your piers as if the entire area is solid clay, that sandy section is going to settle more, putting undue stress on the rest of the structure. The consequences? Sagging floors, cracked walls, and doors and windows that stubbornly refuse to open or close properly.

Another frequent error is underestimating the load-bearing capacity needed for specific areas. Lets say you have a design with a large, heavy fireplace in one corner of the building. If you dont adjust the pier spacing to account for that concentrated weight, the soil underneath will compress over time. This differential settlement, where one part of the building sinks more than another, is incredibly damaging. It can lead to significant structural damage and require expensive repairs, including potentially underpinning the entire foundation.

Furthermore, overlooking the influence of water is a big problem. Soil strength is directly affected by moisture content. In areas prone to flooding or with poor drainage, the soil can become saturated and lose its ability to support the structure adequately. If your pier spacing doesnt account for these fluctuating soil conditions, youre essentially gambling with the longevity of your building. The result can be accelerated settling, increased stress on the foundation, and ultimately, compromised structural integrity.

Finally, simply relying on "rules of thumb" or outdated practices without proper soil testing and engineering analysis is a dangerous gamble. Every site is unique, and what worked for a similar-looking building in a different location might not work for yours. A qualified geotechnical engineer can assess the specific soil conditions, calculate the required load-bearing capacity, and recommend an appropriate pier spacing strategy. Skimping on this initial assessment can save money upfront, but its almost guaranteed to cost you far more in the long run.

In conclusion, pier spacing isnt just about aesthetics or convenience; its a critical element of structural stability. Failing to consider the variations in soil strength, concentrated loads, water influence, and relying on outdated practices can lead to a cascade of problems. Investing in proper soil analysis and professional engineering is essential for ensuring the long-term integrity and safety of any structure supported by piers.

Long-term performance monitoring and adjustment of pier systems is crucial when evaluating pier spacing for different soil strengths, as it ensures the structural integrity and longevity of piers under varying conditions. When engineers design pier systems, they must consider the diverse characteristics of soil, which can range from soft clays to dense sands, each with its own bearing capacity and response to load.

In practice, this involves installing sensors at strategic points within the pier system to continuously gather data on factors like settlement, lateral movement, and load distribution. For instance, in areas with weaker soils like silty loams or expansive clays, piers might need to be spaced closer together to distribute loads effectively and prevent excessive settlement or tilting. Conversely, in regions with stronger soils such as compacted gravels or bedrock, wider spacing might suffice due to the greater bearing capacity.

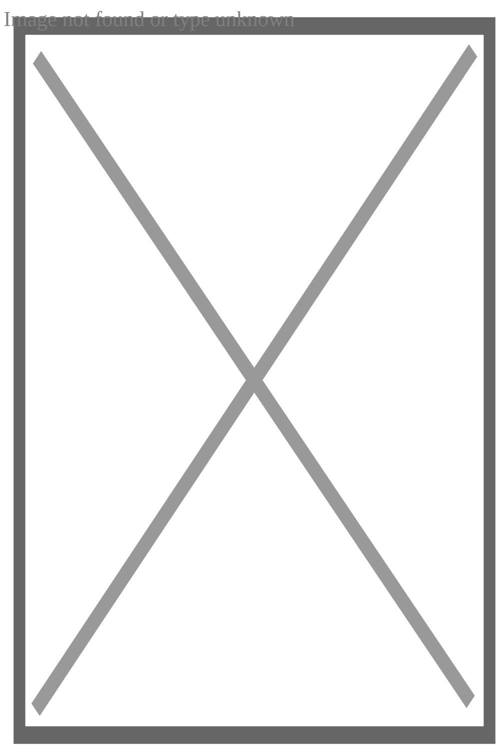
The data collected from these monitoring systems is invaluable for making informed adjustments. If a sensor detects unexpected movement or stress beyond design thresholds, engineers can intervene by adding additional piers or modifying existing ones to redistribute the load more evenly. This proactive approach not only enhances safety but also extends the service life of the structure by preventing minor issues from escalating into major failures.

Moreover, long-term monitoring allows for a dynamic response to environmental changes; seasonal variations in moisture content can significantly affect soil behavior. In wetter seasons, expansive soils might swell, exerting pressures on piers that could necessitate adjustments in spacing or reinforcement strategies. During dry periods, shrinkage could lead to differential settlement if not properly managed through timely interventions based on real-time data.

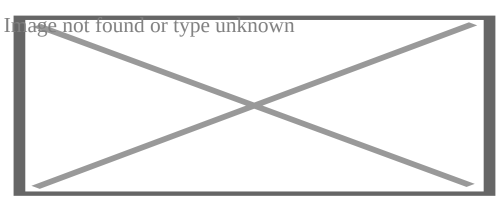
In summary, integrating long-term performance monitoring into the evaluation of pier spacing for different soil strengths provides a robust framework for ensuring that pier systems remain effective over their intended lifespan. By adapting designs based on continuous feedback from the field, engineers can tailor solutions that are not only cost-effective but also resilient against the unpredictable nature of geological conditions. This human-centric approach underscores our commitment to sustainable infrastructure development where safety and longevity are paramount.

About Cement

For other uses, see Cement (disambiguation).
Not to be confused with Concrete.



Cement powder in a bag, ready to be mixed with aggregates and water.[1]



Cement block construction examples from the Multiplex Manufacturing Company of Toledo, Ohio, in 1905

A **cement** is a binder, a chemical substance used for construction that sets, hardens, and adheres to other materials to bind them together. Cement is seldom used on its own, but rather to bind sand and gravel (aggregate) together. Cement mixed with fine aggregate produces mortar for masonry, or with sand and gravel, produces concrete. Concrete is the most widely used material in existence and is behind only water as the planet's most-consumed resource.[2]

Cements used in construction are usually inorganic, often lime- or calcium silicate-based, and are either **hydraulic** or less commonly **non-hydraulic**, depending on the ability of the cement to set in the presence of water (see hydraulic and non-hydraulic lime plaster).

Hydraulic cements (e.g., Portland cement) set and become adhesive through a chemical reaction between the dry ingredients and water. The chemical reaction results in mineral hydrates that are not very water-soluble. This allows setting in wet conditions or under water and further protects the hardened material from chemical attack. The chemical process for hydraulic cement was found by ancient Romans who used volcanic ash (pozzolana) with added lime (calcium oxide).

Non-hydraulic cement (less common) does not set in wet conditions or under water. Rather, it sets as it dries and reacts with carbon dioxide in the air. It is resistant to attack by chemicals after setting.

The word "cement" can be traced back to the Ancient Roman term *opus caementicium*, used to describe masonry resembling modern concrete that was made from crushed rock with burnt lime as binder.[3] The volcanic ash and pulverized brick supplements that were added to the burnt lime, to obtain a hydraulic binder, were later referred to as *cementum*, *cimentum*, *cäment*, and *cement*. In modern times, organic polymers are sometimes used as cements in concrete.

World production of cement is about 4.4 billion tonnes per year (2021, estimation),[4][5] of which about half is made in China, followed by India and Vietnam.[4][6]

The cement production process is responsible for nearly 8% (2018) of global CO_2 emissions,[5] which includes heating raw materials in a cement kiln by fuel combustion and release of CO_2 stored in the calcium carbonate (calcination process). Its hydrated products, such as concrete, gradually reabsorb atmospheric CO_2 (carbonation process), compensating for approximately 30% of the initial CO_2 emissions.[7]

Chemistry

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Cement materials can be classified into two distinct categories: hydraulic cements and non-hydraulic cements according to their respective setting and hardening mechanisms. Hydraulic cement setting and hardening involves hydration reactions and therefore requires water, while non-hydraulic cements only react with a gas and can directly set under air.

Hydraulic cement

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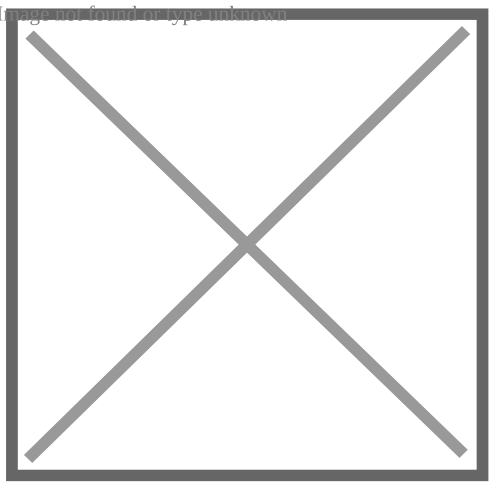

Clinker nodules produced by sintering at 1450 °C

By far the most common type of cement is **hydraulic cement**, which hardens by hydration (when water is added) of the clinker minerals. Hydraulic cements (such as Portland cement) are made of a mixture of silicates and oxides, the four main mineral phases of the clinker, abbreviated in the cement chemist notation, being:

C_3S: alite ($3CaO{\cdot}SiO_2$);
C_2S: belite ($2CaO{\cdot}SiO_2$);
C_3A: tricalcium aluminate ($3CaO{\cdot}Al_2O_3$) (historically, and still occasionally, called *celite*);
C_4AF: brownmillerite ($4CaO{\cdot}Al_2O_3{\cdot}Fe_2O_3$).

The silicates are responsible for the cement's mechanical properties — the tricalcium aluminate and brownmillerite are essential for the formation of the liquid phase during the sintering (firing) process of clinker at high temperature in the kiln. The chemistry of these reactions is not completely clear and is still the object of research.[8]

First, the limestone (calcium carbonate) is burned to remove its carbon, producing lime (calcium oxide) in what is known as a calcination reaction. This single chemical reaction is a major emitter of global carbon dioxide emissions.[9]

$$\displaystyle \ce{CaCO3 -> CaO + CO2}$$

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The lime reacts with silicon dioxide to produce dicalcium silicate and tricalcium silicate.

$$\displaystyle \ce{2CaO + SiO2 -> 2CaO.SiO2}$$
Image not found or type unknown

$$\displaystyle \ce{3CaO + SiO2 -> 3CaO.SiO2}$$
Image not found or type unknown

The lime also reacts with aluminium oxide to form tricalcium aluminate.

$$\displaystyle \ce{3CaO + Al2O3 -> 3CaO.Al2O3}$$
Image not found or type unknown

In the last step, calcium oxide, aluminium oxide, and ferric oxide react together to form brownmillerite.

$$\displaystyle \ce{4CaO + Al2O3 + Fe2O3 -> 4CaO.Al2O3.Fe2O3}$$
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Non-hydraulic cement

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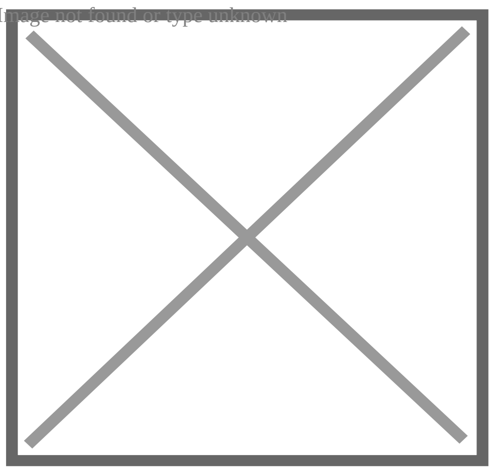

Calcium oxide obtained by thermal decomposition of calcium carbonate at high temperature (above 825 °C).

A less common form of cement is **non-hydraulic cement**, such as slaked lime (calcium oxide mixed with water), which hardens by carbonation in contact with carbon dioxide, which is present in the air (~ 412 vol. ppm ? 0.04 vol. %). First calcium oxide (lime) is produced from calcium carbonate (limestone or chalk) by calcination at temperatures above 825 °C (1,517 °F) for about 10 hours at atmospheric pressure:

$$\displaystyle \ce{CaCO3 -> CaO + CO2}$$
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The calcium oxide is then *spent* (slaked) by mixing it with water to make slaked lime (calcium hydroxide):

$$\displaystyle \ce{CaO + H2O -> Ca(OH)2}$$

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Once the excess water is completely evaporated (this process is technically called *setting*), the carbonation starts:

$$\displaystyle \ce{Ca(OH)2 + CO2 -> CaCO3 + H2O}$$

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This reaction is slow, because the partial pressure of carbon dioxide in the air is low (~ 0.4 millibar). The carbonation reaction requires that the dry cement be exposed to air, so the slaked lime is a non-hydraulic cement and cannot be used under water. This process is called the *lime cycle*.

History

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Perhaps the earliest known occurrence of cement is from twelve million years ago. A deposit of cement was formed after an occurrence of oil shale located adjacent to a bed of limestone burned by natural causes. These ancient deposits were investigated in the 1960s and 1970s.[10]

Alternatives to cement used in antiquity

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Cement, chemically speaking, is a product that includes lime as the primary binding ingredient, but is far from the first material used for cementation. The Babylonians and Assyrians used bitumen (asphalt or pitch) to bind together burnt brick or alabaster slabs. In Ancient Egypt, stone blocks were cemented together with a mortar made of sand and roughly burnt gypsum ($CaSO_4 \cdot 2H_2O$), which is plaster of Paris, which often contained calcium carbonate ($CaCO_3$),[11]

Ancient Greece and Rome

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Lime (calcium oxide) was used on Crete and by the Ancient Greeks. There is evidence that the Minoans of Crete used crushed potsherds as an artificial pozzolan for hydraulic cement.[11] Nobody knows who first discovered that a combination of hydrated non-hydraulic lime and a pozzolan produces a hydraulic mixture (see also: Pozzolanic reaction), but such concrete was used by the Greeks, specifically the Ancient Macedonians,[12][13] and three centuries later on a large scale by Roman engineers.[14][15][16]

> There is... a kind of powder which from natural causes produces astonishing results. It is found in the neighborhood of Baiae and in the country belonging to the towns round about Mount Vesuvius. This substance when mixed with lime and rubble not only lends strength to buildings of other kinds but even when piers of it are constructed in the sea, they set hard underwater.
>
> — *Marcus Vitruvius Pollio, Liber II, De Architectura, Chapter VI "Pozzolana" Sec. 1*

The Greeks used volcanic tuff from the island of Thera as their pozzolan and the Romans used crushed volcanic ash (activated aluminium silicates) with lime. This mixture could set under water, increasing its resistance to corrosion like rust.[17] The material was called *pozzolana* from the town of Pozzuoli, west of Naples where volcanic ash was extracted.[18] In the absence of pozzolanic ash, the Romans used powdered brick or pottery as a substitute and they may have used crushed tiles for this purpose before discovering natural sources near Rome.[11] The huge dome of the Pantheon in Rome and the massive Baths of Caracalla are examples of ancient structures made from these concretes, many of which still stand.[19][2] The vast system of Roman aqueducts also made extensive use of hydraulic cement.[20] Roman concrete was rarely used on the outside of buildings. The normal technique was to use brick facing material as the formwork for an infill of mortar mixed with an aggregate of broken pieces of stone, brick, potsherds, recycled chunks of concrete, or other building rubble.[21]

Mesoamerica

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Lightweight concrete was designed and used for the construction of structural elements by the pre-Columbian builders who lived in a very advanced civilisation in El Tajin near Mexico City, in Mexico. A detailed study of the composition of the aggregate and binder show that the aggregate was pumice and the binder was a pozzolanic cement made with volcanic ash and lime.[22]

Middle Ages

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Any preservation of this knowledge in literature from the Middle Ages is unknown, but medieval masons and some military engineers actively used hydraulic cement in structures such as canals, fortresses, harbors, and shipbuilding facilities.[23][24] A mixture of lime mortar and aggregate with brick or stone facing material was used in the Eastern Roman Empire as well as in the West into the Gothic period. The German Rhineland continued to use hydraulic mortar throughout the Middle Ages, having local pozzolana deposits called trass.[21]

16th century

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Tabby is a building material made from oyster shell lime, sand, and whole oyster shells to form a concrete. The Spanish introduced it to the Americas in the sixteenth century.[25]

18th century

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The technical knowledge for making hydraulic cement was formalized by French and British engineers in the 18th century.[23]

John Smeaton made an important contribution to the development of cements while planning the construction of the third Eddystone Lighthouse (1755–59) in the English Channel now known as Smeaton's Tower. He needed a hydraulic mortar that would set and develop some strength in the twelve-hour period between successive high tides. He performed experiments with combinations of different limestones and additives including trass and pozzolanas[11] and did exhaustive market research on the available hydraulic limes, visiting their production sites, and noted that the "hydraulicity" of the lime was directly related to the clay content of the limestone used to make it. Smeaton was a civil engineer by profession, and took the idea no further.

In the South Atlantic seaboard of the United States, tabby relying on the oyster-shell middens of earlier Native American populations was used in house construction from the 1730s to the 1860s.[25]

In Britain particularly, good quality building stone became ever more expensive during a period of rapid growth, and it became a common practice to construct prestige buildings from the new industrial bricks, and to finish them with a stucco to imitate stone. Hydraulic limes were favored for this, but the need for a fast set time encouraged the development of new cements. Most famous was Parker's "Roman cement".[26] This was developed by James Parker in the 1780s, and finally patented in 1796. It was, in fact, nothing like material used by the Romans, but was a "natural cement" made by burning septaria – nodules that are found in certain clay deposits, and that contain both clay minerals and calcium carbonate. The burnt nodules were ground to a fine powder. This product, made into a mortar with sand, set in 5–15 minutes. The success of "Roman cement" led other manufacturers to develop rival products by burning artificial hydraulic lime cements of clay and chalk. Roman cement quickly became popular but was largely replaced by Portland cement in the 1850s.[11]

19th century

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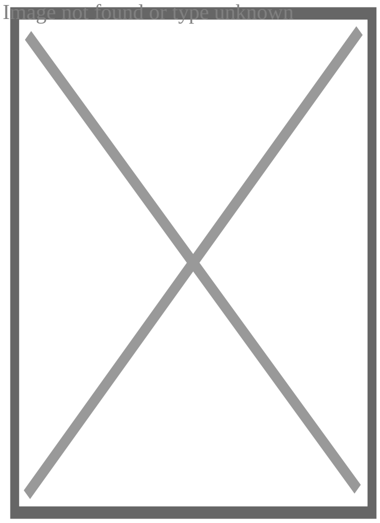
Apparently unaware of Smeaton's work, the same principle was identified by Frenchman Louis Vicat in the first decade of the nineteenth century. Vicat went on to devise a method of combining chalk and clay into an intimate mixture, and, burning this, produced an "artificial cement" in 1817[27] considered the "principal forerunner"[11] of Portland cement and "...Edgar Dobbs of Southwark patented a cement of this kind in 1811."[11]

In Russia, Egor Cheliev created a new binder by mixing lime and clay. His results were published in 1822 in his book *A Treatise on the Art to Prepare a Good Mortar* published in St. Petersburg. A few years later in 1825, he published another book, which described various methods of making cement and concrete, and the benefits of cement in the construction of buildings and embankments.[28][29]



William Aspdin is considered the inventor of "modern" Portland cement.[30]

Portland cement, the most common type of cement in general use around the world as a basic ingredient of concrete, mortar, stucco, and non-speciality grout, was developed in England in the mid 19th century, and usually originates from limestone. James Frost produced what he called "British cement" in a similar manner around the same time, but did not obtain a patent until 1822.[31] In 1824, Joseph Aspdin patented a similar material, which he called *Portland cement*, because the render made from it was in color similar to the prestigious Portland stone quarried on the Isle of Portland, Dorset, England. However, Aspdins' cement was nothing like modern Portland cement but was a first step in its development, called a *proto-Portland cement*.[11] Joseph Aspdins' son William Aspdin had left his father's company and in his cement manufacturing apparently accidentally produced calcium silicates in the 1840s, a middle step in the development of Portland cement. William Aspdin's innovation was counterintuitive for manufacturers of "artificial cements", because they required more lime in the mix (a problem for his father), a much higher kiln temperature (and therefore more fuel), and the resulting clinker was very hard and rapidly wore down the millstones, which were the only available grinding technology of the time. Manufacturing costs were therefore considerably higher, but the product set reasonably slowly and developed strength quickly, thus opening up a market for use in concrete. The use of concrete in construction grew rapidly from 1850 onward, and was soon the dominant use for cements. Thus Portland cement began its predominant role. Isaac Charles Johnson further refined the production of *meso-Portland cement* (middle stage of development) and claimed he was the real father of Portland cement.[32]

Setting time and "early strength" are important characteristics of cements. Hydraulic limes, "natural" cements, and "artificial" cements all rely on their belite ($2\ CaO \cdot SiO_2$, abbreviated as C_2S) content for strength development. Belite develops strength slowly. Because they were burned at temperatures below 1,250 °C (2,280 °F), they contained no alite ($3\ CaO \cdot SiO_2$, abbreviated as C_3S), which is responsible for early strength in modern cements. The first cement to consistently contain alite was made by William

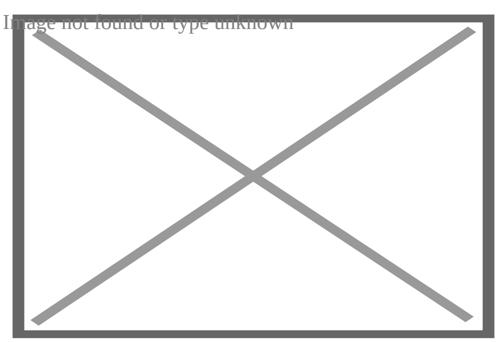
Aspdin in the early 1840s: This was what we call today "modern" Portland cement. Because of the air of mystery with which William Aspdin surrounded his product, others (*e.g.,* Vicat and Johnson) have claimed precedence in this invention, but recent analysis [33] of both his concrete and raw cement have shown that William Aspdin's product made at Northfleet, Kent was a true alite-based cement. However, Aspdin's methods were "rule-of-thumb": Vicat is responsible for establishing the chemical basis of these cements, and Johnson established the importance of sintering the mix in the kiln.

In the US the first large-scale use of cement was Rosendale cement, a natural cement mined from a massive deposit of dolomite discovered in the early 19th century near Rosendale, New York. Rosendale cement was extremely popular for the foundation of buildings (*e.g.*, Statue of Liberty, Capitol Building, Brooklyn Bridge) and lining water pipes.[34] Sorel cement, or magnesia-based cement, was patented in 1867 by the Frenchman Stanislas Sorel.[35] It was stronger than Portland cement but its poor water resistance (leaching) and corrosive properties (pitting corrosion due to the presence of leachable chloride anions and the low pH (8.5–9.5) of its pore water) limited its use as reinforced concrete for building construction.[36]

The next development in the manufacture of Portland cement was the introduction of the rotary kiln. It produced a clinker mixture that was both stronger, because more alite (C_3S) is formed at the higher temperature it achieved (1450 °C), and more homogeneous. Because raw material is constantly fed into a rotary kiln, it allowed a continuous manufacturing process to replace lower capacity batch production processes.[11]

20th century

[edit]



The National Cement Share Company of Ethiopia's new plant in Dire Dawa

Calcium aluminate cements were patented in 1908 in France by Jules Bied for better resistance to sulfates.[37] Also in 1908, Thomas Edison experimented with pre-cast concrete in houses in Union, N.J.[38]

In the US, after World War One, the long curing time of at least a month for Rosendale cement made it unpopular for constructing highways and bridges, and many states and construction firms turned to Portland cement. Because of the switch to Portland cement, by the end of the 1920s only one of the 15 Rosendale cement companies had survived. But in the early 1930s, builders discovered that, while Portland cement set faster, it was not as durable, especially for highways—to the point that some states stopped building highways and roads with cement. Bertrain H. Wait, an engineer whose company had helped construct the New York City's Catskill Aqueduct, was impressed with the durability of Rosendale cement, and came up with a blend of both Rosendale and Portland cements that had the good attributes of both. It was highly durable and had a much faster setting time. Wait convinced the New York Commissioner of Highways to construct an experimental section of highway near New Paltz, New York, using one sack of Rosendale to six sacks of Portland cement. It was a success, and for decades the Rosendale-Portland cement blend was used in concrete highway and concrete bridge construction.[34]

Cementitious materials have been used as a nuclear waste immobilizing matrix for more than a half-century.[39] Technologies of waste cementation have been developed and deployed at industrial scale in many countries. Cementitious wasteforms require a careful selection and design process adapted to each specific type of waste to satisfy the strict waste acceptance criteria for long-term storage and disposal.[40]

Types

[edit]

Components of cement:
comparison of chemical and physical characteristics[a][41][42][43]

Property		Portland cement	Siliceous[b] fly ash	Calcareous[c] fly ash	Slag cement	Silica fume
Proportion by mass (%)	SiO_2	21.9	52	35	35	85–97
	Al_2O_3	6.9	23	18	12	—
	Fe_2O_3	3	11	6	1	—
	CaO	63	5	21	40	< 1
	MgO	2.5	—	—	—	—
	SO_3	1.7	—	—	—	—

Specific surface (m^2/kg) [d]	370	420	420	400	15,000 – 30,000
Specific gravity	3.15	2.38	2.65	2.94	2.22
General purpose	Primary binder	Cement replacement	Cement replacement	Cement replacement	Property enhancer

1. **^** Values shown are approximate: those of a specific material may vary.
2. **^** ASTM C618 Class F
3. **^** ASTM C618 Class C
4. **^** Specific surface measurements for silica fume by nitrogen adsorption (BET) method, others by air permeability method (Blaine).

Modern development of hydraulic cement began with the start of the Industrial Revolution (around 1800), driven by three main needs:

- Hydraulic cement render (stucco) for finishing brick buildings in wet climates
- Hydraulic mortars for masonry construction of harbor works, etc., in contact with sea water
- Development of strong concretes

Modern cements are often Portland cement or Portland cement blends, but other cement blends are used in some industrial settings.

Portland cement

[edit]
Main article: Portland cement

Portland cement, a form of hydraulic cement, is by far the most common type of cement in general use around the world. This cement is made by heating limestone (calcium carbonate) with other materials (such as clay) to 1,450 °C (2,640 °F) in a kiln, in a process known as calcination that liberates a molecule of carbon dioxide from the calcium carbonate to form calcium oxide, or quicklime, which then chemically combines with the other materials in the mix to form calcium silicates and other cementitious compounds. The resulting hard substance, called 'clinker', is then ground with a small amount of gypsum ($CaSO_4 \cdot 2H_2O$) into a powder to make *ordinary Portland cement*, the most commonly used type of cement (often referred to as OPC). Portland cement is a basic ingredient of concrete, mortar, and most non-specialty grout. The most common use for Portland cement is to make concrete. Portland cement may be grey or white.

Portland cement blend

[edit]

Portland cement blends are often available as inter-ground mixtures from cement producers, but similar formulations are often also mixed from the ground components at the concrete mixing plant.

Portland blast-furnace slag cement**, or blast furnace** cement (ASTM C595 and EN 197-1 nomenclature respectively), contains up to 95% ground granulated blast furnace slag, with the rest Portland clinker and a little gypsum. All compositions produce high ultimate strength, but as slag content is increased, early strength is reduced, while sulfate resistance increases and heat evolution diminishes. Used as an economic alternative to Portland sulfate-resisting and low-heat cements.

Portland-fly ash cement contains up to 40% fly ash under ASTM standards (ASTM C595), or 35% under EN standards (EN 197–1). The fly ash is pozzolanic, so that ultimate strength is maintained. Because fly ash addition allows a lower concrete water content, early strength can also be maintained. Where good quality cheap fly ash is available, this can be an economic alternative to ordinary Portland cement.[44]

Portland pozzolan cement includes fly ash cement, since fly ash is a pozzolan, but also includes cements made from other natural or artificial pozzolans. In countries where volcanic ashes are available (e.g., Italy, Chile, Mexico, the Philippines), these cements are often the most common form in use. The maximum replacement ratios are generally defined as for Portland-fly ash cement.

Portland silica fume cement. Addition of silica fume can yield exceptionally high strengths, and cements containing 5–20% silica fume are occasionally produced, with 10% being the maximum allowed addition under EN 197–1. However, silica fume is more usually added to Portland cement at the concrete mixer.[45]

Masonry cements are used for preparing bricklaying mortars and stuccos, and must not be used in concrete. They are usually complex proprietary formulations containing Portland clinker and a number of other ingredients that may include limestone, hydrated lime, air entrainers, retarders, waterproofers, and coloring agents. They are formulated to yield workable mortars that allow rapid and consistent masonry work. Subtle variations of masonry cement in North America are plastic cements and stucco cements. These are designed to produce a controlled bond with masonry blocks.

Expansive cements contain, in addition to Portland clinker, expansive clinkers (usually sulfoaluminate clinkers), and are designed to offset the effects of drying shrinkage normally encountered in hydraulic cements. This cement can make concrete for floor slabs (up to 60 m square) without contraction joints.

White blended cements may be made using white clinker (containing little or no iron) and white supplementary materials such as high-purity metakaolin. **Colored** cements serve decorative purposes. Some standards allow the addition of pigments to produce colored Portland cement. Other standards (e.g., ASTM) do not allow pigments in Portland cement, and colored cements are sold as blended hydraulic cements.

Very finely ground cements are cement mixed with sand or with slag or other pozzolan type minerals that are extremely finely ground together. Such cements can have the same physical characteristics as normal cement but with 50% less cement, particularly because there is more surface area for the chemical reaction. Even with intensive grinding they can use up to 50% less energy (and thus less carbon emissions) to fabricate than ordinary Portland cements.[46]

Other

[edit]

Pozzolan-lime cements are mixtures of ground pozzolan and lime. These are the cements the Romans used, and are present in surviving Roman structures like the Pantheon in Rome. They develop strength slowly, but their ultimate strength can be very high. The hydration products that produce strength are essentially the same as those in Portland cement.

Slag-lime cements—ground granulated blast-furnace slag—are not hydraulic on their own, but are "activated" by addition of alkalis, most economically using lime. They are similar to pozzolan lime cements in their properties. Only granulated slag (i.e., water-quenched, glassy slag) is effective as a cement component.

Supersulfated cements contain about 80% ground granulated blast furnace slag, 15% gypsum or anhydrite and a little Portland clinker or lime as an activator. They produce strength by formation of ettringite, with strength growth similar to a slow Portland cement. They exhibit good resistance to aggressive agents, including sulfate.

Calcium aluminate cements are hydraulic cements made primarily from limestone and bauxite. The active ingredients are monocalcium aluminate $CaAl_2O_4$ ($CaO \cdot Al_2O_3$ or CA in cement chemist notation, CCN) and mayenite $Ca_{12}Al_{14}O_{33}$ ($12\ CaO \cdot 7\ Al_2O_3$, or $C_{12}A_7$ in CCN). Strength forms by hydration to calcium aluminate hydrates. They are well-adapted for use in refractory (high-temperature resistant) concretes, e.g., for furnace linings.

Calcium sulfoaluminate cements are made from clinkers that include ye'elimite ($Ca_4(AlO_2)_6SO_4$ or $C_4A_3\overline{S}$ in Cement chemist's notation) as a primary phase. They are used in expansive cements, in ultra-high early strength cements, and in "low-energy" cements. Hydration produces ettringite, and specialized physical properties (such as expansion or rapid reaction) are obtained by adjustment of the availability of calcium and sulfate ions. Their use as a low-energy alternative to Portland cement has been pioneered in China, where several million tonnes per year are produced.[47][48] Energy requirements are lower because of the lower kiln temperatures required for reaction, and the lower amount of limestone (which must be endothermically decarbonated) in the mix. In addition, the lower limestone content and lower fuel consumption leads to a CO_2 emission around half that associated with Portland clinker. However, SO_2 emissions are usually significantly higher.

"Natural" cements corresponding to certain cements of the pre-Portland era, are produced by burning argillaceous limestones at moderate temperatures. The level of clay components in the limestone (around 30–35%) is such that large amounts of belite (the low-early strength, high-late strength mineral in Portland cement) are formed without the formation of excessive amounts of free lime. As with any natural material, such cements have highly variable properties.

Geopolymer cements are made from mixtures of water-soluble alkali metal silicates, and aluminosilicate mineral powders such as fly ash and metakaolin.

Polymer cements are made from organic chemicals that polymerise. Producers often use thermoset materials. While they are often significantly more expensive, they can give a water proof material that has useful tensile strength.

Sorel cement is a hard, durable cement made by combining magnesium oxide and a magnesium chloride solution

Fiber mesh cement or fiber reinforced concrete is cement that is made up of fibrous materials like synthetic fibers, glass fibers, natural fibers, and steel fibers. This type of mesh is distributed evenly throughout the wet concrete. The purpose of fiber mesh is to reduce water loss from the concrete as well as enhance its structural integrity.[49] When used in plasters, fiber mesh increases cohesiveness, tensile strength, impact resistance, and to reduce shrinkage; ultimately, the main purpose of these combined properties is to reduce cracking.[50]

Electric cement is proposed to be made by recycling cement from demolition wastes in an electric arc furnace as part of a steelmaking process. The recycled cement is intended to be used to replace part or all of the lime used in steelmaking, resulting in a slag-like material that is similar in mineralogy to Portland cement, eliminating most of the associated carbon emissions.[51]

Setting, hardening and curing

[edit]

Cement starts to set when mixed with water, which causes a series of hydration chemical reactions. The constituents slowly hydrate and the mineral hydrates solidify and harden. The interlocking of the hydrates gives cement its strength. Contrary to popular belief, hydraulic cement does not set by drying out — proper curing requires maintaining the appropriate moisture content necessary for the hydration reactions during the setting and the hardening processes. If hydraulic cements dry out during the curing phase, the resulting product can be insufficiently hydrated and significantly weakened. A minimum temperature of 5 °C is recommended, and no more than 30 °C.[52] The concrete at young age must be protected against water evaporation due to direct insolation, elevated temperature, low relative humidity and wind.

The *interfacial transition zone* (ITZ) is a region of the cement paste around the aggregate particles in concrete. In the zone, a gradual transition in the microstructural features occurs.[53] This zone can be up to 35 micrometer wide.[54]: 351 Other studies have shown that the width can be up to 50 micrometer. The average content of unreacted clinker phase decreases and porosity decreases towards the aggregate surface. Similarly, the content of ettringite increases in ITZ. [54]: 352

Safety issues

[edit]

Bags of cement routinely have health and safety warnings printed on them because not only is cement highly alkaline, but the setting process is exothermic. As a result, wet cement is strongly caustic (pH = 13.5) and can easily cause severe skin burns if not promptly washed off with water. Similarly, dry cement powder in contact with mucous membranes can cause severe eye or respiratory irritation. Some trace elements, such as chromium, from impurities naturally present in the raw materials used to produce cement may cause allergic dermatitis.[55] Reducing agents such as ferrous sulfate ($FeSO_4$) are often added to cement to convert the carcinogenic hexavalent chromate ($CrO_4^{2?}$) into trivalent chromium (Cr^{3+}), a less toxic chemical species. Cement users need also to wear appropriate gloves and protective clothing.[56]

Cement industry in the world

[edit]

Global cement production (2022)

Image not found or type unknown

Global cement production in 2022

Global cement capacity (2022)

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Global cement capacity in 2022

See also: List of countries by cement production and Cement industry in the United States

In 2010, the world production of hydraulic cement was 3,300 megatonnes ($3{,}600 \times 10^6$ short tons). The top three producers were China with 1,800, India with 220, and the United States with 63.5 million tonnes for a total of over half the world total by the world's three most populated states.[57]

For the world capacity to produce cement in 2010, the situation was similar with the top three states (China, India, and the US) accounting for just under half the world total capacity.[58]

Over 2011 and 2012, global consumption continued to climb, rising to 3585 Mt in 2011 and 3736 Mt in 2012, while annual growth rates eased to 8.3% and 4.2%, respectively.

China, representing an increasing share of world cement consumption, remains the main engine of global growth. By 2012, Chinese demand was recorded at 2160 Mt, representing 58% of world consumption. Annual growth rates, which reached 16% in 2010, appear to have softened, slowing to 5–6% over 2011 and 2012, as China's economy targets a more sustainable growth rate.

Outside of China, worldwide consumption climbed by 4.4% to 1462 Mt in 2010, 5% to 1535 Mt in 2011, and finally 2.7% to 1576 Mt in 2012.

Iran is now the 3rd largest cement producer in the world and has increased its output by over 10% from 2008 to 2011.[59] Because of climbing energy costs in Pakistan and other major cement-producing countries, Iran is in a unique position as a trading partner, utilizing its own surplus petroleum to power clinker plants. Now a top producer in the Middle-East, Iran is further increasing its dominant position in local markets and abroad.[60]

The performance in North America and Europe over the 2010–12 period contrasted strikingly with that of China, as the global financial crisis evolved into a sovereign debt crisis for many economies in this region[*clarification needed*] and recession. Cement consumption levels for this region fell by 1.9% in 2010 to 445 Mt, recovered by 4.9% in 2011, then dipped again by 1.1% in 2012.

The performance in the rest of the world, which includes many emerging economies in Asia, Africa and Latin America and representing some 1020 Mt cement demand in 2010, was positive and more than offset the declines in North America and Europe. Annual consumption growth was recorded at 7.4% in 2010, moderating to 5.1% and 4.3% in 2011 and 2012, respectively.

As at year-end 2012, the global cement industry consisted of 5673 cement production facilities, including both integrated and grinding, of which 3900 were located in China and 1773 in the rest of the world.

Total cement capacity worldwide was recorded at 5245 Mt in 2012, with 2950 Mt located in China and 2295 Mt in the rest of the world.[6]

China

[edit]
Main article: Cement industry in China

"For the past 18 years, China consistently has produced more cement than any other country in the world. [...] (However,) China's cement export peaked in 1994 with 11 million tonnes shipped out and has been in steady decline ever since. Only 5.18 million tonnes were exported out of China in 2002. Offered at $34 a ton, Chinese cement is pricing itself out of the market as Thailand is asking as little as $20 for the same quality."[61]

In 2006, it was estimated that China manufactured 1.235 billion tonnes of cement, which was 44% of the world total cement production.[62] "Demand for cement in China is expected to advance 5.4% annually and exceed 1 billion tonnes in 2008, driven by slowing but healthy growth in construction expenditures. Cement consumed in China will amount to 44% of global demand, and China will remain the world's largest national consumer of cement by a large margin."[63]

In 2010, 3.3 billion tonnes of cement was consumed globally. Of this, China accounted for 1.8 billion tonnes.[64]

Environmental impacts

[edit]
Further information: Environmental impact of concrete

Cement manufacture causes environmental impacts at all stages of the process. These include emissions of airborne pollution in the form of dust, gases, noise and vibration when operating machinery and during blasting in quarries, and damage to countryside from quarrying. Equipment to reduce dust emissions during quarrying and manufacture of cement is widely used, and equipment to trap and separate exhaust gases are coming into increased use. Environmental protection also includes the re-integration of quarries into the countryside after they have been closed down by returning them to nature or re-cultivating them.

CO_2 emissions

[edit]

Global carbon emission by type to 2018

Image not found or type unknown

Global carbon emission by type to 2018

Carbon concentration in cement spans from ?5% in cement structures to ?8% in the case of roads in cement.[65] Cement manufacturing releases CO_2 in the atmosphere both directly when calcium carbonate is heated, producing lime and carbon dioxide,[66][67] and also indirectly through the use of energy if its production involves the emission of CO_2. The cement industry produces about 10% of global human-made CO_2 emissions, of which 60% is from the chemical process, and 40% from burning fuel.[68] A Chatham House study from 2018 estimates that the 4 billion tonnes of cement produced annually account for 8% of worldwide CO_2 emissions.[5]

Nearly 900 kg of CO_2 are emitted for every 1000 kg of Portland cement produced. In the European Union, the specific energy consumption for the production of cement clinker has been reduced by approximately 30% since the 1970s. This reduction in primary energy requirements is equivalent to approximately 11 million tonnes of coal per year with corresponding benefits in reduction of CO_2 emissions. This accounts for approximately 5% of anthropogenic CO_2.[69]

The majority of carbon dioxide emissions in the manufacture of Portland cement (approximately 60%) are produced from the chemical decomposition of limestone to lime, an ingredient in Portland cement clinker. These emissions may be reduced by lowering the clinker content of cement. They can also be reduced by alternative fabrication methods such as the intergrinding cement with sand or with slag or other pozzolan type minerals to a very fine powder.[70]

To reduce the transport of heavier raw materials and to minimize the associated costs, it is more economical to build cement plants closer to the limestone quarries rather than to the consumer centers.[71]

As of 2019 carbon capture and storage is about to be trialed, but its financial viability is uncertain.[72]

CO_2 absorption

[edit]

Hydrated products of Portland cement, such as concrete and mortars, slowly reabsorb atmospheric CO2 gas, which has been released during calcination in a kiln. This natural process, reversed to calcination, is called carbonation.[73] As it depends on CO2 diffusion into the bulk of concrete, its rate depends on many parameters, such as environmental conditions and surface area exposed to the atmosphere.[74][75] Carbonation is particularly significant at the latter stages of the concrete life - after demolition and crushing of the debris. It was estimated that during the whole life-cycle of cement products, it can be reabsorbed nearly 30% of atmospheric CO2 generated by cement production.[75]

Carbonation process is considered as a mechanism of concrete degradation. It reduces pH of concrete that promotes reinforcement steel corrosion.[73] However, as the product of Ca(OH)2 carbonation, CaCO3, occupies a greater volume, porosity of concrete reduces. This increases strength and hardness of concrete.[76]

There are proposals to reduce carbon footprint of hydraulic cement by adopting non-hydraulic cement, lime mortar, for certain applications. It reabsorbs some of the CO_2 during hardening, and has a lower energy requirement in production than Portland cement.[77]

A few other attempts to increase absorption of carbon dioxide include cements based on magnesium (Sorel cement).[78][79][80]

Heavy metal emissions in the air

[edit]

In some circumstances, mainly depending on the origin and the composition of the raw materials used, the high-temperature calcination process of limestone and clay minerals can release in the atmosphere gases and dust rich in volatile heavy metals, e.g. thallium,[81] cadmium and mercury are the most toxic. Heavy metals (Tl, Cd, Hg, ...) and also selenium are often found as trace elements in common metal sulfides (pyrite (FeS_2), zinc blende (ZnS), galena (PbS), ...) present as secondary minerals in most of the raw materials. Environmental regulations exist in many countries to limit these emissions. As of 2011 in the United States, cement kilns are "legally allowed to pump more toxins into the air than are hazardous-waste incinerators."[82]

Heavy metals present in the clinker

[edit]

The presence of heavy metals in the clinker arises both from the natural raw materials and from the use of recycled by-products or alternative fuels. The high pH prevailing in the cement porewater ($12.5 < pH < 13.5$) limits the mobility of many heavy metals by decreasing their solubility and increasing their sorption onto the cement mineral phases. Nickel, zinc and lead are commonly found in cement in non-negligible concentrations. Chromium may also directly arise as natural impurity from the raw materials or as secondary contamination from the abrasion of hard chromium steel alloys used in the ball mills when the clinker is ground. As chromate ($CrO_4^{2?}$) is toxic and may cause severe skin allergies at trace concentration, it is sometimes reduced into trivalent Cr(III) by addition of ferrous sulfate ($FeSO_4$).

Use of alternative fuels and by-products materials

[edit]

A cement plant consumes 3 to 6 GJ of fuel per tonne of clinker produced, depending on the raw materials and the process used. Most cement kilns today use coal and petroleum coke as primary fuels, and to a lesser extent natural gas and fuel oil. Selected waste and by-products with recoverable calorific value can be used as fuels in a cement kiln (referred to as co-processing), replacing a portion of conventional fossil fuels, like coal, if they meet strict specifications. Selected waste and by-products containing useful minerals such as calcium, silica, alumina, and iron can be used as raw materials in the kiln, replacing raw materials such as clay, shale, and limestone.

Because some materials have both useful mineral content and recoverable calorific value, the distinction between alternative fuels and raw materials is not always clear. For example, sewage sludge has a low but significant calorific value, and burns to give ash containing minerals useful in the clinker matrix.[83] Scrap automobile and truck tires are useful in cement manufacturing as they have high calorific value and the iron embedded in tires is useful as a feed stock.[84]: p. 27

Clinker is manufactured by heating raw materials inside the main burner of a kiln to a temperature of 1,450 °C. The flame reaches temperatures of 1,800 °C. The material remains at 1,200 °C for 12–15 seconds at 1,800 °C or sometimes for 5–8 seconds (also referred to as residence time). These characteristics of a clinker kiln offer numerous benefits and they ensure a complete destruction of organic compounds, a total neutralization of acid gases, sulphur oxides and hydrogen chloride. Furthermore, heavy metal traces are embedded in the clinker structure and no by-products, such as ash or residues, are produced.[85]

The EU cement industry already uses more than 40% fuels derived from waste and biomass in supplying the thermal energy to the grey clinker making process. Although the choice for this so-called alternative fuels (AF) is typically cost driven, other factors are becoming more important. Use of alternative fuels provides benefits for both society and the company: CO_2-emissions are lower than with fossil fuels, waste can be co-processed in an efficient and sustainable manner and the demand for certain virgin materials can be reduced. Yet there are large differences in the share of alternative fuels used between the European Union (EU) member states. The societal benefits could be improved if more member states increase their alternative fuels share. The Ecofys study[86] assessed the barriers and opportunities for further uptake of alternative fuels in 14 EU member states. The Ecofys study found that local factors constrain the market potential to a much larger extent than the technical and economic feasibility of the cement industry itself.

Reduced-footprint cement

[edit]

Growing environmental concerns and the increasing cost of fossil fuels have resulted, in many countries, in a sharp reduction of the resources needed to produce cement, as well as effluents (dust and exhaust gases).[87] Reduced-footprint cement is a cementitious material that meets or exceeds the functional performance capabilities of Portland cement. Various techniques are under development. One is geopolymer cement, which incorporates recycled materials, thereby reducing consumption of raw materials, water, and energy. Another approach is to reduce or eliminate the production and release of damaging pollutants and greenhouse gasses, particularly CO_2

.[88] Recycling old cement in electric arc furnaces is another approach.[89] Also, a team at the University of Edinburgh has developed the 'DUPE' process based on the microbial activity of *Sporosarcina pasteurii*, a bacterium precipitating calcium carbonate, which, when mixed with sand and urine, can produce mortar blocks with a compressive strength 70% of that of concrete.[90] An overview of climate-friendly methods for cement production can be found here.[91]

See also

[edit]

- Asphalt concrete
- Calcium aluminate cements
- Cement chemist notation
- Cement render
- Cenocell
- Energetically modified cement (EMC)
- Fly ash
- Geopolymer cement
- Portland cement
- Rosendale cement
- Sulfate attack in concrete and mortar
- Sulfur concrete
- Tiocem
- List of countries by cement production

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Technology and related concepts

Major technologies

Necessities

- Agriculture
  - Domestication
  - Grafting
  - Working animal
- Clothing
  - Sewing machine
- Cooking
  - Beer
  - Bread
  - Cheese
  - Milling
  - Wine
- Food storage
  - Pottery
- Sanitation
  - Plumbing
  - Toilet
- Tool / Equipment
  - Blade
  - Hammer
  - Plough
  - Wedge
- Weapon
  - Gun

Social

- Accounting
- Calculation
  - Abacus
  - Calendar
- Cryptography
- Lock and key
- Money
  - Banknote
  - Coin
- Musical instrument
  - Phonograph
- Toy
  - Game
  - Video game
- Writing
  - Book
  - Map
  - Printing press
  - Typewriter
- Aqueduct
  - Canal

Perspectives

Criticism

- Appropriate technology
  - Low technology
- Luddite
  - Neo-Luddism
- Precautionary principle

Ecotechnology

- Environmental technology
  - Clean technology
- Sustainable design
  - Sustainable engineering

Policy & politics

- Government by algorithm
- Intellectual property
  - Patent
  - Trade secret
- Persuasive technology
- Science policy
- Strategy of Technology
- Technology assessment

Progressivism

- Technorealism
- Futures studies
  - Technology forecasting
- Technological utopianism
  - Technocracy movement
  - Technological singularity
  - Transhumanism

Studies

- Diffusion of innovations
  - Technology transfer
- History
  - Timeline of historic inventions
- Philosophy
  - Social construction of technology
  - Technological determinism
- Technology acceptance model

Related concepts

Applied science

- Agronomy
- Architecture
- Construction
- Engineering
- Forensics
- Forestry
- Logistics
- Medicine
- Mining
- Navigation
- Surveying

Innovation

- Design
- High tech
- Invention
- Mature technology
- Research and development
- Technological convergence
- Technology lifecycle

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Concrete

History

- Ancient Roman architecture
- Roman architectural revolution
- Roman concrete
- Roman engineering
- Roman technology

Composition	◦ Cement
	  ◦ Calcium aluminate
	  ◦ Energetically modified
	  ◦ Portland
	  ◦ Rosendale
	◦ Water
	◦ Water–cement ratio
	◦ Aggregate
	◦ Reinforcement
	◦ Fly ash
	◦ Ground granulated blast-furnace slag
	◦ Silica fume
	◦ Metakaolin

Production	◦ Plant ◦ Concrete mixer ◦ Volumetric mixer ◦ Reversing drum mixer ◦ Slump test ◦ Flow table test ◦ Curing ◦ Concrete cover ◦ Cover meter ◦ Rebar
Construction	◦ Precast ◦ Cast-in-place ◦ Formwork ◦ Climbing formwork ◦ Slip forming ◦ Screed ◦ Power screed ◦ Finisher ◦ Grinder ◦ Power trowel ◦ Pump ◦ Float ◦ Sealer ◦ Tremie
Science	◦ Properties ◦ Durability ◦ Degradation ◦ Environmental impact ◦ Recycling ◦ Segregation ◦ Alkali–silica reaction

Types	◦ AstroCrete
	◦ Fiber-reinforced
	◦ Filigree
	◦ Foam
	◦ Lunarcrete
	◦ Mass
	◦ Nanoconcrete
	◦ Pervious
	◦ Polished
	◦ Polymer
	◦ Prestressed
	◦ Ready-mix
	◦ Reinforced
	◦ Roller-compacting
	◦ Self-consolidating
	◦ Self-leveling
	◦ Sulfur
	◦ Tabby
	◦ Translucent
	◦ Waste light
	◦ Aerated
	    ◦ AAC
	    ◦ RAAC

Applications	◦ Slab
	    ◦ waffle
	    ◦ hollow-core
	    ◦ voided biaxial
	    ◦ slab on grade
	◦ Concrete block
	◦ Step barrier
	◦ Roads
	◦ Columns
	◦ Structures

Organizations	◦ American Concrete Institute ◦ Concrete Society ◦ Institution of Structural Engineers ◦ Indian Concrete Institute ◦ Nanocem ◦ Portland Cement Association ◦ International Federation for Structural Concrete
Standards	◦ Eurocode 2 ◦ EN 197-1 ◦ EN 206-1 ◦ EN 10080

See also

- Hempcrete
- Image not found or type unknown Category:Concrete

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Major industries

Natural sector

Agriculture

- Arable farming
  - Cereals
  - Legumes
  - Vegetables
  - Fiber crops
  - Oilseeds
  - Sugar
  - Tobacco
- Permanent crops
  - Apples et al.
  - Berries
  - Citrus
  - Stone fruits
  - Tropical fruit
  - Viticulture
  - Cocoa
  - Coffee
  - Tea
  - Nuts
  - Olives
  - Medicinal plants
  - Spices
- Horticulture
  - Flowers
  - Seeds
- Animal husbandry
  - Beef cattle
  - Dairy farming
  - Fur farming
  - Horses
  - Other livestock
  - Pig
  - Wool
  - Poultry
  - Beekeeping
  - Cochineal
  - Shellac
  - Silk
- Hunting
  - Fur trapping
- Silviculture
  - Bamboo
- Logging
  - Firewood

Industrial sector	
Light industry	○ Food ○ Animal feed ○ Baking ○ Canning ○ Dairy products ○ Flour ○ Meat ○ Prepared ○ Preserved ○ Sweets ○ Vegetable oils ○ Beverages ○ Beer ○ Bottled water ○ Liquor ○ Soft drinks ○ Wine ○ Textiles ○ Carding ○ Dyeing ○ Prints ○ Spinning ○ Weaving ○ Carpets ○ Lace ○ Linens ○ Rope ○ Clothing ○ Accessories ○ Dressmaking ○ Furs ○ Hatmaking ○ Sewing ○ Shoemaking ○ Tailoring ○ Printing ○ Bookbinding ○ Embossing ○ Engraving ○ Secure ○ Typesetting ○ Media reproduction ○ Cassette tapes ○ Phonographs

Service sector

Sales	○ Retail
	  ○ Car dealership
	  ○ Consumer goods
	  ○ General store
	  ○ Grocery store
	  ○ Department store
	  ○ Mail order
	  ○ Online shopping
	  ○ Specialty store
	○ Wholesale
	  ○ Auction
	  ○ Brokerage
	  ○ Distribution

Transport & Storage	○ Cargo
	  ○ Air cargo
	  ○ Intermodal
	  ○ Mail
	  ○ Moving company
	  ○ Rail
	  ○ Trucking
	○ Passenger transport
	  ○ Airlines
	  ○ Car rentals
	  ○ Passenger rail
	  ○ Ridesharing
	  ○ Taxis
	○ Warehousing
	  ○ Self storage

Hospitality	○ Foodservice
	  ○ Drink service
	  ○ Cafés
	  ○ Catering
	  ○ Fast food
	  ○ Food delivery
	  ○ Restaurants
	  ○ Teahouses
	○ Hotels

	○ Financial services
	  ○ Banking
	  ○ Credit
	  ○ Financial advice
	  ○ Holding company
	  ○ Money transfer
	  ○ Payment cards
	  ○ Risk management

Related

Classification standards

- Production-based
  - ANZSIC
  - ***ISIC***
  - NACE
  - NAICS
  - SIC
  - UKSIC
- Market-based
  - GICS
  - ICB
  - TRBC
- Other
  - Aftermarket
  - Generic
  - OEM

Inputs & outputs

- Externalities
  - Community
  - Crime
  - Culture
  - Pollution
  - Well-being
- Funding
- Goods
  - Commodities
  - Final
  - Intermediate
  - Raw material
- Innovation
- Primary inputs
  - Labor
  - Natural resources
  - Physical capital
- Services
- Technology
- Centralization
  - Cartel
  - Conglomerate
  - Horizontal integration
  - Mergers and acquisitions
  - Monopoly
  - Monopsony
  - Vertical integration
- Decentralization
  - Enforced breakup
  - Freelancing

- **Category**
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About Pier

For other uses, see Pier (disambiguation).

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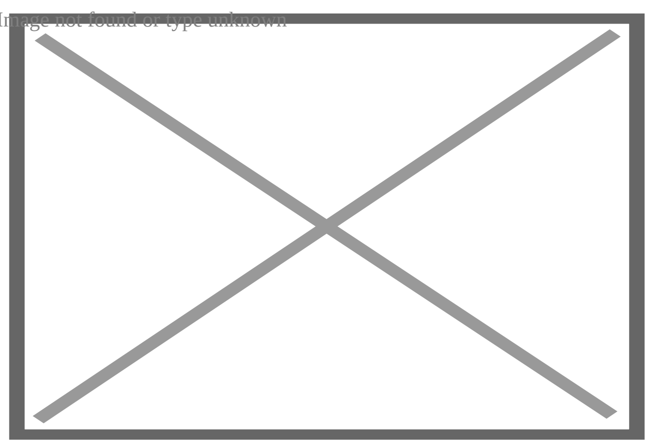


A wooden pier in Corfu, Greece

A **pier** is a raised structure that rises above a body of water and usually juts out from its shore, typically supported by piles or pillars, and provides above-water access to offshore areas. Frequent pier uses include fishing, boat docking and access for both passengers and cargo, and oceanside recreation. Bridges, buildings, and walkways may all be supported by architectural piers. Their open structure allows tides and currents to flow relatively unhindered, whereas the more solid foundations of a quay or the closely spaced piles of a wharf can act as a breakwater, and are consequently more liable to silting. Piers can range in size and complexity from a simple lightweight wooden structure to major structures extended over 1,600 m (5,200 ft). In American English, a pier may be synonymous with a dock.

Piers have been built for several purposes, and because these different purposes have distinct regional variances, the term *pier* tends to have different nuances of meaning in different parts of the world. Thus in North America and Australia, where many ports were, until recently, built on the multiple pier model, the term tends to imply a current or former cargo-handling facility. In contrast, in Europe, where ports more often use basins and river-side quays than piers, the term is principally associated with the image of a Victorian cast iron pleasure pier which emerged in Great Britain during the early 19th century. However, the earliest piers pre-date the Victorian age.

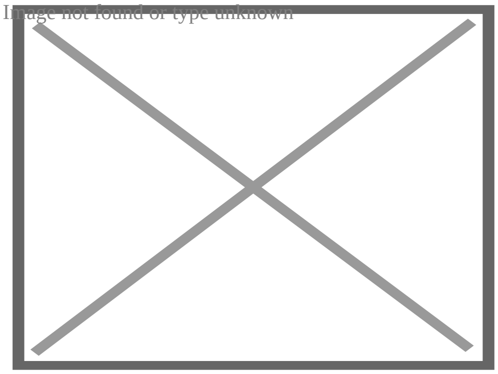
Types

[edit]

Piers can be categorized into different groupings according to the principal purpose.[1] However, there is considerable overlap between these categories. For example, pleasure piers often also allow for the docking of pleasure steamers and other similar craft, while working piers have often been converted to leisure use after being rendered obsolete by advanced developments in cargo-handling technology. Many piers are floating piers, to ensure that the piers raise and lower with the tide along with the boats tied to them. This prevents a situation where lines become overly taut or loose by rising or lowering tides. An overly taut or loose tie-line can damage boats by pulling them out of the water or allowing them so much leeway that they bang forcefully against the sides of the pier.

Working piers

[edit]



Out-of-use industrial bulk cargo Pier, Cook Inlet, Alaska.

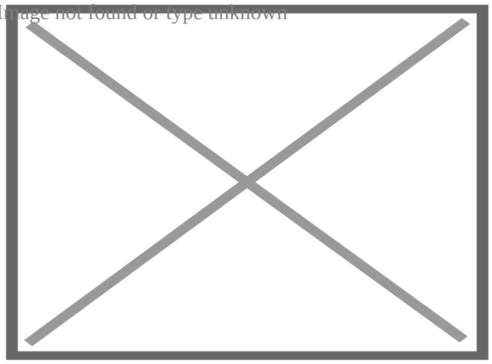
Working piers were built for the handling of passengers and cargo onto and off ships or (as at Wigan Pier) canal boats. Working piers themselves fall into two different groups. Longer individual piers are often found at ports with large tidal ranges, with the pier stretching far enough off shore to reach deep water at low tide. Such piers provided an economical alternative to impounded docks where cargo volumes were low, or where specialist bulk cargo was handled, such as at coal piers. The other form of working pier, often called the finger pier, was built at ports with smaller tidal ranges. Here the principal advantage was to give a greater available quay length for ships to berth against compared to a linear littoral quayside, and such piers are usually much shorter. Typically each pier would carry a single transit shed the length of the pier, with ships berthing bow or stern in to the shore. Some major ports consisted of large numbers of such piers lining the foreshore, classic examples being the Hudson River frontage of New York, or the Embarcadero in San Francisco.

The advent of container shipping, with its need for large container handling spaces adjacent to the shipping berths, has made working piers obsolete for the handling of general cargo, although some still survive for the handling of passenger ships or bulk cargos. One example, is in use in Progreso, Yucatán, where a pier extends more than 4 miles into the Gulf of Mexico, making it the longest pier in the world. The Progreso Pier supplies much of the peninsula with transportation for the fishing and cargo industries and serves as a port for large cruise ships in the area. Many other working piers have been demolished, or remain derelict, but some have been recycled as pleasure piers. The best known example of this is Pier 39 in San Francisco.

At Southport and the Tweed River on the Gold Coast in Australia, there are piers that support equipment for a sand bypassing system that maintains the health of sandy beaches and navigation channels.

Pleasure piers

[edit]



Print of a Victorian pier in Margate in the English county of Kent, 1897

Pleasure piers were first built in Britain during the early 19th century.[2] The earliest structures were Ryde Pier, built in 1813/4, Trinity Chain Pier near Leith, built in 1821, Brighton Chain Pier, built in 1823.[2] and Margate Jetty 1823/24 originally a timber built pier.

Only the oldest of these piers still remains. At that time, the introduction of steamships and railways for the first time permitted mass tourism to dedicated seaside resorts. The large tidal ranges at many such resorts meant that passengers arriving by pleasure steamer could use a pier to disembark safely.[3] Also, for much of the day, the sea was not visible from the shore and the pleasure pier permitted holidaymakers to promenade over and alongside the sea at all times.[4] The world's longest pleasure pier is at Southend-on-Sea, Essex, and extends 1.3 miles (2.1 km) into the Thames Estuary.[2] The longest pier on the West Coast of the US is the Santa Cruz Wharf, with a length of 2,745 feet (837 m).[5]

Providing a walkway out to sea, pleasure piers often include amusements and theatres as part of their attractions.[4] Such a pier may be unroofed, closed, or partly open and partly closed. Sometimes a pier has two decks. Galveston Island Historic Pleasure Pier in Galveston, Texas has a roller coaster, 15 rides, carnival games and souvenir shops.[6]

Early pleasure piers were of complete timber construction, as was with Margate which opened in 1824. The first iron and timber built pleasure pier Margate Jetty, opened in 1855.[7] Margate pier was wrecked by a storm in January 1978 and not repaired.[8][7] The longest iron pleasure pier still remaining is the one at Southend. First opened as a wooden pier in 1829, it was reconstructed in iron and completed in 1889. In a 2006 UK poll, the public voted the seaside pier onto the list of icons of England.[9]

Fishing piers

[edit]

Many piers are built for the purpose of providing boatless anglers access to fishing grounds that are otherwise inaccessible.[10] Many "Free Piers" are available in larger harbors which differ from private piers. Free Piers are often primarily used for fishing. Fishing from a pier presents a set of different circumstances to fishing from the shore or beach, as you do not need to cast out into the deeper water. This being the case there are specific fishing rigs that have been created specifically for pier fishing[11] which allow for the direct access to deeper water.

Piers of the world

[edit]
Main article: List of piers

Belgium

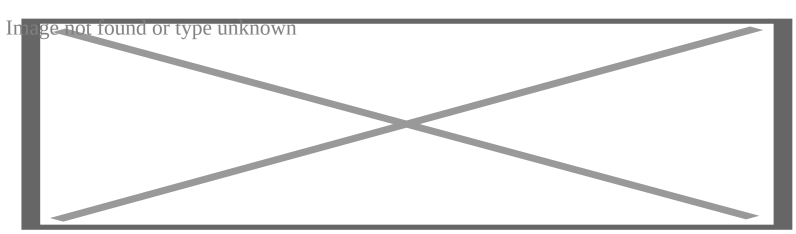
[edit]

In Blankenberge a first pleasure pier was built in 1894. After its destruction in the World War I, a new pier was built in 1933. It remained till the present day, but was partially transformed and modernized in 1999–2004.

In Nieuwpoort, Belgium there is a pleasure pier on both sides of the river IJzer.

Netherlands

[edit]



The Scheveningen Pier

Scheveningen, the coastal resort town of The Hague, boasts the largest pier in the Netherlands, completed in 1961. A crane, built on top of the pier's panorama tower, provides the opportunity to make a 60-metre (200 ft) high bungee jump over the North Sea waves. The present pier is a successor of an earlier pier, which was completed in 1901 but in 1943 destroyed by the German occupation forces.

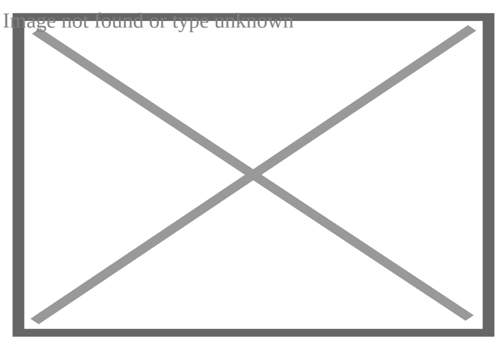
United Kingdom

[edit]

England and Wales

[edit]

The first recorded pier in England was Ryde Pier, opened in 1814 on the Isle of Wight, as a landing stage to allow ferries to and from the mainland to berth. It is still used for this purpose today.[12] It also had a leisure function in the past, with the pier head once containing a pavilion, and there are still refreshment facilities today. The oldest cast iron pier in the world is Town Pier, Gravesend, in Kent, which opened in 1834. However, it is not recognised by the National Piers Society as being a seaside pier.[13]



Brighton Palace Pier (pictured in 2011), opened in 1899

Following the building of the world's first seaside pier at Ryde, the pier became fashionable at seaside resorts in England and Wales during the Victorian era, peaking in the 1860s with 22 being built in that decade.[14] A symbol of the typical British seaside holiday, by 1914, more than 100 pleasure piers were located around the UK coast.[2] Regarded as being among the finest Victorian architecture, there are still a significant number of seaside piers of architectural merit still standing, although some have been lost, including Margate, two at Brighton in East Sussex, one at New Brighton in the Wirral and three at Blackpool in Lancashire.[4] Two piers, Brighton's now derelict West Pier and Clevedon Pier, were Grade 1 listed. The Birnbeck Pier in Weston-super-Mare is the only pier in the world linked to an island. The National Piers Society gives a figure of 55 surviving seaside piers in England and Wales.[1] In 2017, Brighton Palace Pier was said to be the most visited tourist attraction outside London, with over 4.5 million visitors the previous year.[15]

See also

[edit]

- Boardwalk
- Breakwater
- Dock
- Jetty
- List of piers
- Seaside resort
- Wharf

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