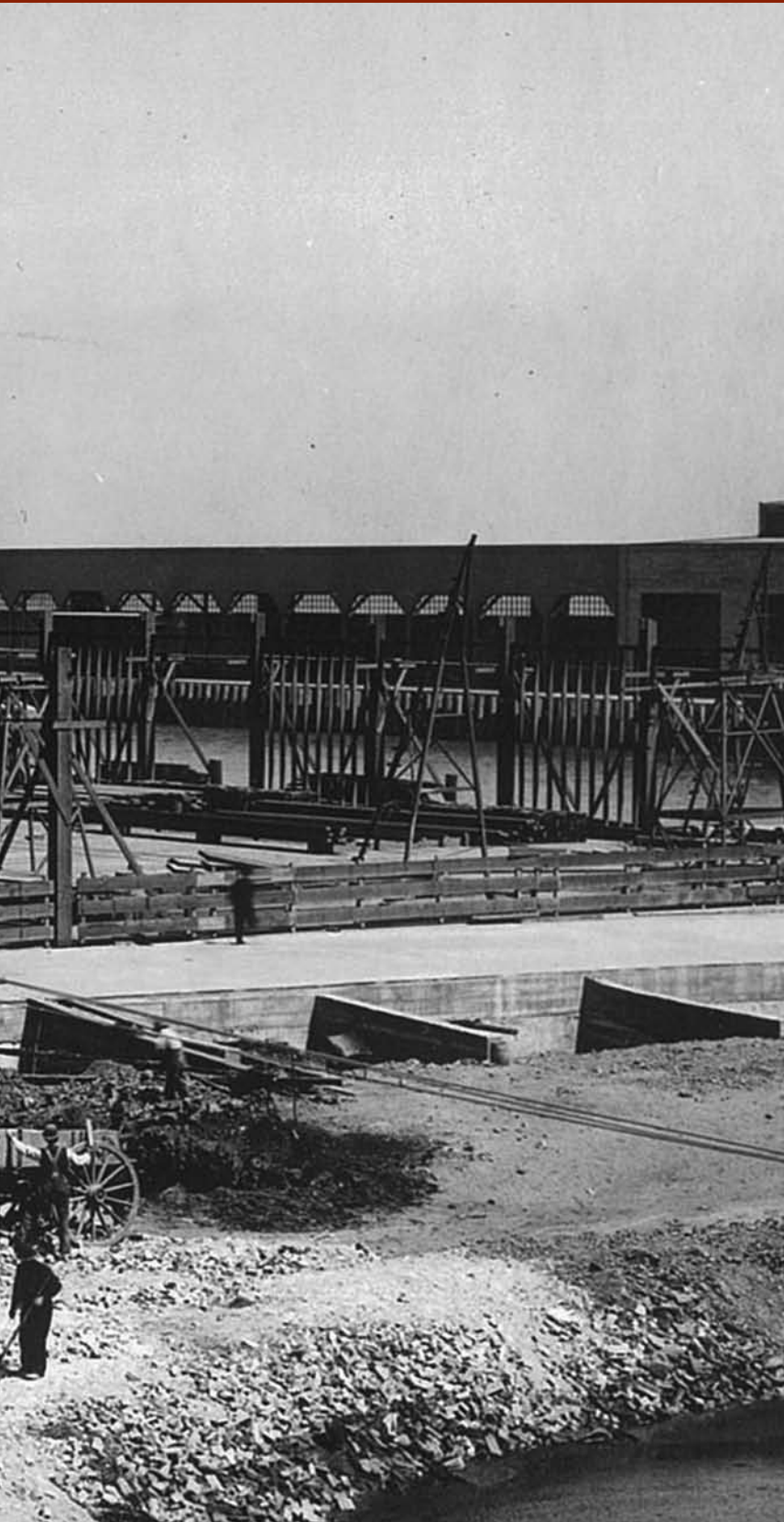


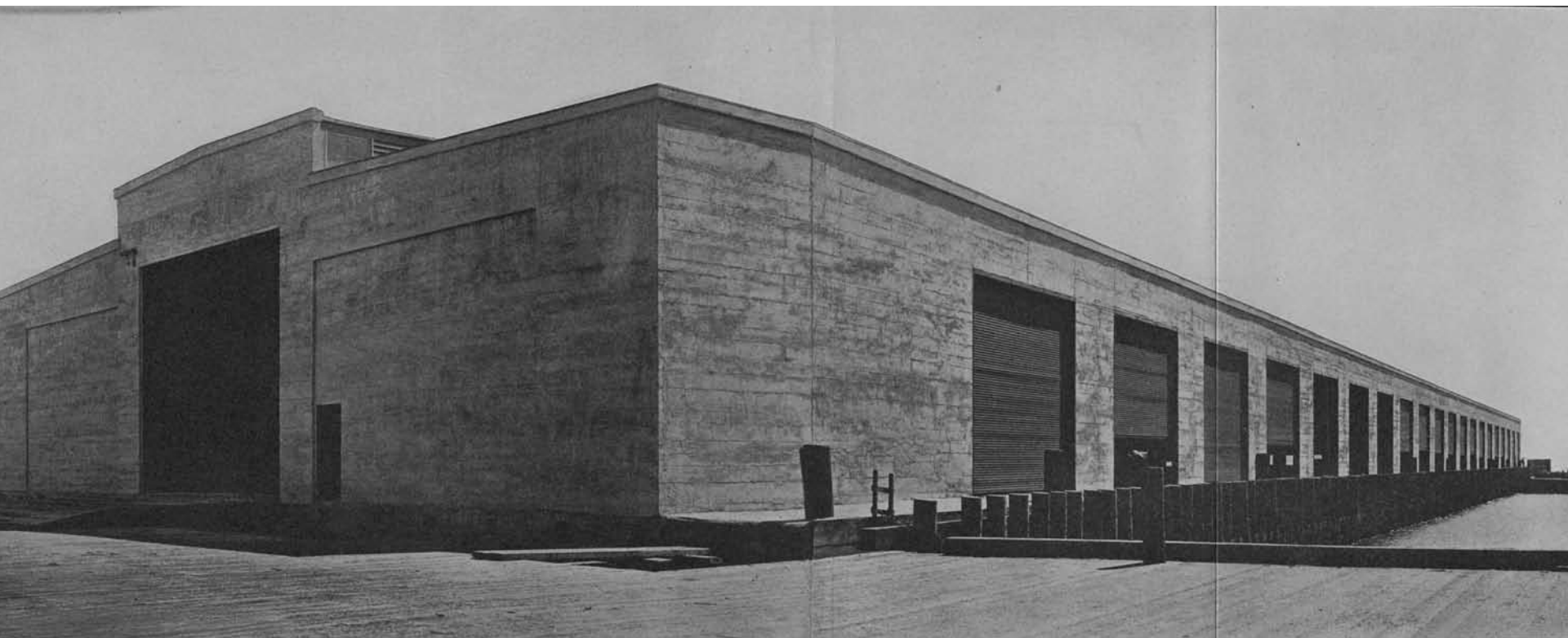
ENGINEERING





The history of the port of San Francisco is part of a worldwide story that is thousands of years old. Ports built by the Cretans at Pharos in Egypt by 1600 B.C., by the Greeks near Athens by 458 B.C., by Alexander the Great at Alexandria around 332 B.C., and by the Romans in many locations around the Mediterranean Sea and beyond before the fifth century A.D. were, in many cases, far more substantial and elaborate than those built since the industrial revolution: “Most of the ancient harbors were built upon a scale of solidity and architectural grandeur seldom or never attempted in modern times.”¹ Among the most famous examples is the port of Alexandria with its levees, piers, and giant lighthouse on the island of Pharos.

Beginning in 1909, all piers were built of concrete, but the decision to erect transit sheds of modern fireproof materials—steel and concrete—or heavy timber was a function of anticipated use and the availability of funds. Pier 34, shown here under construction in 1910, was built of bolted heavy timber at the same time that Piers 36, 38, and 40 were built of concrete.



Above: The engineering department of the Board of State Harbor Commissioners (BSHC) was a leader in the adoption of new structural technologies during a period of rapid innovation. Beginning in 1909, the port built all of its piers and bulkhead wharves and most of its transit sheds of a newly accepted material—reinforced concrete. Pier 40, shown here in 1910, was among this generation.

Opposite top: The port of San Francisco is part of a long tradition of port engineering and design that began in antiquity, utilizing seawalls, wharves, and piers. One predecessor was the port of Claudius at Ostia, built in the mid-first century A.D., which accommodated ships carrying break-bulk cargo with long, narrow piers and shelters on the piers. A major difference was the stone construction and architectural embellishment of the ancient ports.

The impressiveness of these early ports notwithstanding, the physical character of the port of San Francisco north of China Basin has more in common with two-thousand-year-old ports—and with ports built between antiquity and the twentieth century—than it does with ports developed since about 1970. The fundamental requirement of both ancient ports and the port of San Francisco in the late nineteenth and early twentieth centuries was to provide a berth for a seagoing vessel in order to load and unload passengers and cargo. This was accomplished by the labor of numerous workers and with the assistance of cargo-handling machinery of varying levels of sophistication and complexity.

Until about 1960, ships always tied up at the same kinds of places—manmade platforms built alongside or projecting into navigable water. In the United States, these platforms are generally called wharves when they are parallel to the shoreline and piers when they project out from the shoreline into the water, although piers can also be called wharves. Many ancient piers were curved, but some were straight. Records from the ancient port of Eleusis near Athens document a “mole or jetty [pier], straight in plan, . . . probably intended for the discharge and loading of

vessels laid alongside it.”²

Piers and other port structures in antiquity were built according to methods that were still used in San Francisco in the twentieth century. Like the builders of the San Francisco seawall, the Greeks erected harbor walls and piers in the simple but effective manner of throwing rubble into the water “until the mound reached water level, where it was leveled off and the masonry blocks were built up above.”³ Like many structures on the San Francisco waterfront, Roman structures were built on wooden piles that were either positioned along the shore or driven into navigable water away from shore. The Romans probably built “wooden quays and jetties”—i.e., wharves and piers—in Britain.⁴ These were similar to the wood wharves and piers of nineteenth-century ports in the United States. According to a historian of the port of New York, “Until the mid-nineteenth century, many maritime building methods had not changed significantly since antiquity. Techniques first described by the Roman architect and engineer Marcus Vitruvius in the first century B.C.E. were still employed for constructing seawalls.”⁵

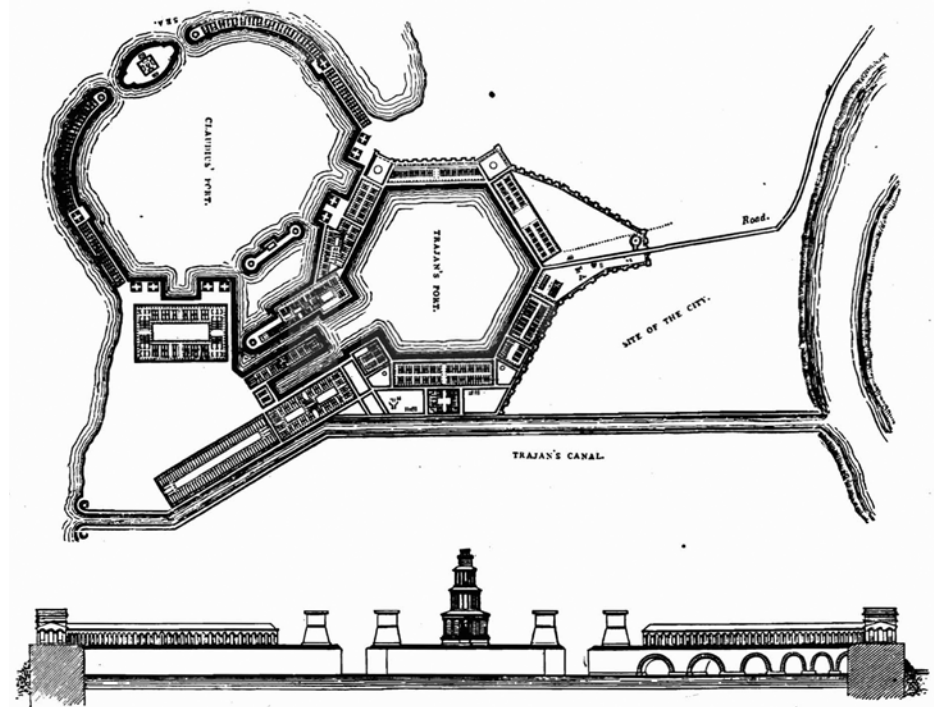
For many centuries, the universal means of loading and unloading ships involved heavy

physical labor by large numbers of workers. In ancient times, workers were usually slaves. In the late nineteenth and early twentieth centuries, workers were gangs of longshoremen. In order for workers to handle the cargo, it was generally broken down into units that one person could maneuver. In ancient times, amphorae (distinctive ceramic jugs with handles and pointed bottoms) were common containers for liquid cargoes such as olive oil and wine; marine archeologists have found many of them. In the nineteenth and twentieth centuries, sacks, barrels, crates, and bales were common types of packages. In contrast with bulk cargo—for example, grain or coal dumped into large bins, or oil poured into tanks—cargo carried in these small packages is called break-bulk cargo.

Even in ancient times, waterfront work had the benefit of machinery. Until the beginning of the industrial revolution in the eighteenth century, waterfront technology was simple and did not change much, consisting of pulleys, basic cranes, screw-pumps, and slings. This equipment was essential for constructing port structures, loading and unloading ships, and building and repairing ships.

At every era in the history of ports, there was a direct and inseparable connection between the design of port facilities, the availability of cargo-handling technology, the size of ships, and the character and practices of labor. At all times, a pier had to be at least as long as the ships that it served and wide enough to accommodate both the means of moving cargo and the cargo itself, as well as large numbers of workers. One known example of a Roman merchant ship was 120 feet long. Because slaves performed most of the waterfront work during Greek and Roman times, labor was cheap, and there was little incentive to use or improve cargo-handling technology. Pier sheds to cover the cargo were not built or were not common in antiquity, but the Romans built shelters between piers, called *cellae*, to protect ships at berth.

After the fall of the Roman Empire in the fifth century A.D., regular shipping in Europe disappeared except in Scandinavia, and there was virtually no development of ports for centuries. According to J. P. M. Pannell's historical study of civil engineering, "By the twelfth and thirteenth centuries, trade in Europe was again



flourishing; quays and jetties were coming into use for convenience in loading and unloading ships” in Britain and around the Mediterranean and Baltic regions.⁶ Venice became the center of trade routes that stretched to China. Port operations were sophisticated: “Shipping regulations of this period show that an elaborate system of inspections, loading rules, and construction regulations were effectively enforced.”⁷ Medieval

Above: San Francisco and most other ports of the nineteenth and twentieth centuries followed the relatively inexpensive model of port design that entailed seawalls, wharves, and piers. In northern Europe, where the tides are unusually high, far more elaborate and expensive ports were built that used locks, gates, and pumps to contain water in basins at low tide, such as the London and St. Katharine Docks planned in 1893.



The design of the port of San Francisco followed a type common in the United States and best represented by New York, with its seawall, landfill behind the seawall, and rows of finger piers. New York's Department of Docks was created in 1870, seven years after the BSHC; its master plan of 1871 predated San Francisco's of 1877.

port technology was probably similar to that of the Roman Empire.

Beginning in the fifteenth century, changes began to take place that affected the development of ports over the next five hundred years. As Pannell explains, “The Renaissance and its almost inevitable consequence, the Industrial Revolution, brought about a great development of ports, and this became extremely rapid in the eighteenth century.”⁸ The most important

changes were the increasing size of ships and the longer distances that they traveled—across oceans and out of sight of land for long periods.

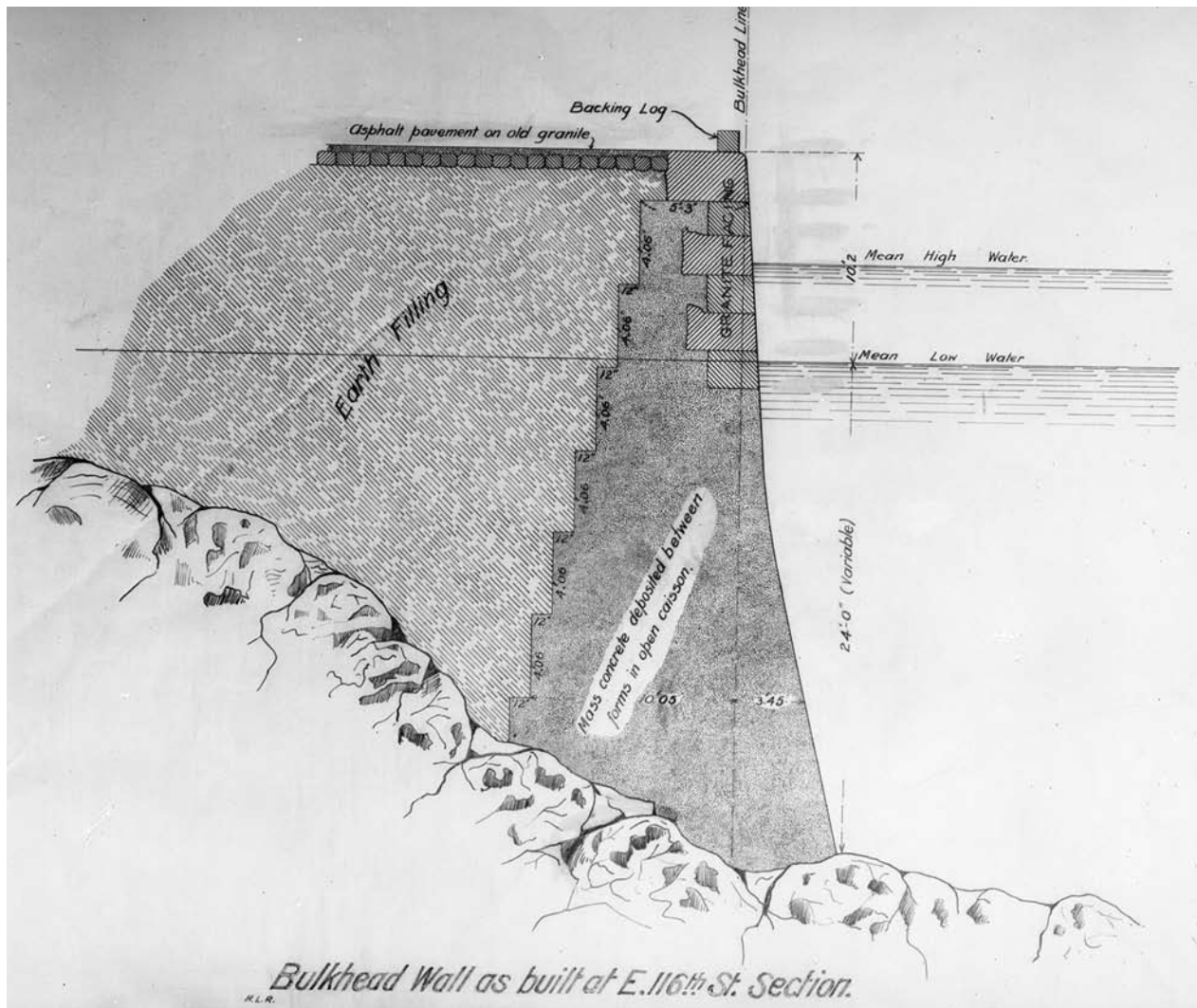
In the seventeenth and eighteenth centuries, the use of larger ships led to a need for deeper harbors in northern Europe, where tides were much higher than in the Mediterranean. This, in turn, gave rise to the development of new types of port facilities that provided berths of sufficiently deep water by means of locks, gates, dredged basins, and pumps, as well as wharves, piers, levees, and shoreline walls. Complexes of these facilities, called docks, captured deep water at high tide for the loading, unloading, or repair of ships. Docks were extremely expensive and required innovative structural and mechanical technologies, as well as centralized planning and control by the city or state. Le Havre, London, Liverpool, Hamburg, and Antwerp were among the ports developed early and extensively with docks.

In the same period, long-distance travel resulted in the establishment of new ports around the world—in cities such as Rio de Janeiro, Cape Town, Bombay, and New York. San Francisco's rapid emergence as a port in the mid-nineteenth century was part of this same development. The city presented certain advantages: “At this time, two main factors determined the commercial success of a port: one, the physical shape of the harbor and its suitability for shipping and the other, the capacity of its immediate hinterland for the production and absorption of goods carried by sea. It is mainly by changes in these factors that ports have risen or fallen in importance.”⁹

In the nineteenth century, as United States ports were growing, the primary factors in the development of ports included the continuing increase in the size of ships in order to service commerce more efficiently; “the application of steam-power to cranes, pile-drivers, dredgers, and other plant; . . . improvements in materials, including concrete; . . . and a growing reliance on scientific and technological research to solve a variety of port problems.”¹⁰

UNITED STATES PORTS

In the years following the American Revolution, the principal ports of Boston, New York, Philadelphia, Baltimore, and Charleston built



New York's seawall, built from 1874 to 1916, was comparable to San Francisco's, built from 1878 to 1915. Both consisted of a stone and concrete wall with earth fill behind it.

new wharves and piers to serve expanded trade and growing populations. In each of these cities, the waterfront was built up with rows of wood piers projecting from the shoreline, designed to accommodate a vessel on each side. Warehouses were built along the shore facing the waterfront. The shoreline itself was provided with a man-made edge—a wall, wharf, or a combination of the two—so that the water was deep enough for ships to come right to the waterfront. Private interests undertook many of these developments independently, creating irregular and uncoordinated waterfronts.

The basic features of ports in the United States were established very early. In the 1630s, the Dutch built “small platforms and seawalls” at the tip of Manhattan, and in the 1650s, they erected an expanded seawall using pile-driving



Unlike San Francisco's seawall, New York's riverwall was faced in cut granite blocks. Its vertical face obviated the need for a bulkhead wharf; ships could come right to the wall, which served as the edge of a wharf along the shore. The granite face had a more finished appearance and was more expensive than San Francisco's rubble stone wall.



Left: Among the distinctions of the port of San Francisco was its greater vulnerability than most to shipworms or marine borers, creatures that could cripple a wooden pier in less than five years. Research and experimentation led to the adoption of wooden piles treated with creosote but did not eliminate the need for constant replacement of wooden piles.

Below: Damage from ship collisions was a chronic concern of the port. Engineers experimented with ways to minimize the cost of inevitable collisions, and maintenance workers continually repaired damage. Cheap wooden fenders absorbed much of the impact, rather than the expensive ship hulls or the unforgiving concrete piers.



Above: The deterioration of wooden piles was one of the most vexing problems for port engineers, chronically draining funds and inhibiting development. Experiments with alternatives included wooden piles encased in concrete that the port made in forms, shown here in 1910.

Right: After 1910, the most common and long-lasting piles were square in section. Made by the port, they were used for piers and were driven through the seawall to support the bulkhead wharf.

