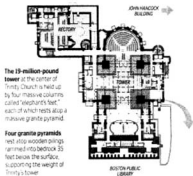


Architect H.H. Richardson had to build a stone church on swampland. His clever 19th-century solution still carries its weight today.

# A church on stilts

## Built on terra precarius

Long considered a landmark of 19th-century American architecture, Boston's Trinity Church is also a feat of engineering, perching thousands of tons of granite atop some 4,500 wooden pilings pounded into the marshy Back Bay.



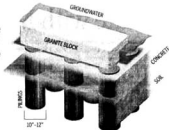
The 19-million-pound tower at the center of Trinity Church is held up by four massive columns called "elephant's feet," each of which rests atop a massive granite pyramid.

Four granite pyramids rest atop wooden pilings driven into bedrock 35 feet below the surface, supporting the weight of Trinity's tower.

### GRANITE, WOOD, AND MUD

Groundwater four feet deep was continually pumped out of the construction site as more than 2,000 35-foot-long pilings were pounded in below Trinity's 90-foot-square center. Finishing the four granite pyramids took about a year and a half.

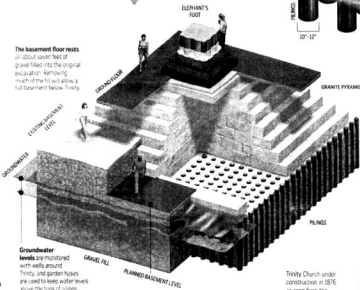
Wet pilings remain strong indefinitely because water prevents the growth of wood-eating bacteria. To ensure stability, pilings are about twice as thick as they need to be to support the structure.



Two feet of concrete keeps the wooden pilings in place, but stops one inch below their tops, so the pilings themselves hold the building's weight.

Granite blocks weighing one to four tons each were stacked into pyramids 17 feet high and 35 feet wide at the base.

The basement floor rests on about seven feet of gravel filled into the original excavation, removing much of the fill soil above a full basement below Trinity.



Groundwater levels are monitored with wells around Trinity, and garden hoses are used to keep water levels above the tops of pilings.

SOURCES: Trinity Church in the City of Boston; "A Description of Trinity Church" by Henry H. Richardson; "A History of the City of Boston" by Henry H. Richardson; "The City of Boston" by Henry H. Richardson.

Trinity Church under construction in 1876 as seen from the intersection of Boylston and Dartmouth streets.

By Tim Hayes

and Christopher

Boston's Back Bay was a reeking fen in the mid-19th century, 450 acres of brackish mudflats and sewage runoff that flooded twice a day at high tide. It was a breeding ground for diseases and insects as well as a source of chronic stench at low tide.

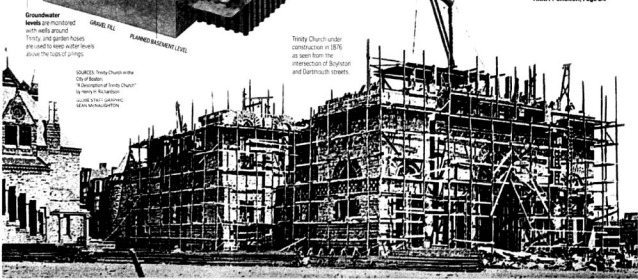
But, for a growing city of 130,000 confined to a narrow peninsula, this fen was the western frontier, inspiring a massive land-reclamation project that went against a basic axiom of construction: You shouldn't build anything important in a swamp.

By the time famed architect H. H. Richardson was commissioned to build the new Trinity Church in 1871, the newly filled land beneath Copley Square was what one observer called "a desert of dirt, dust, mud and wind." On this soft ground, Richardson was to build a stone church whose central tower alone weighed an estimated 19 million pounds.

Yet, today, while other Back Bay and South End property owners battle rot that has sometimes dangerously weakened the pilings that hold their buildings up, Richardson's masterpiece shows us a scratch from 130 years perched on swampland.

This summer, an extensive inspection of many of the 4,500 spruce logs driven

TRINITY CHURCH, Page D4



# A church on stilts: Solution for Trinity still carries its weight

► **TRINITY CHURCH**  
Continued from Page D1

into the ground to support the church revealed no significant deterioration or shifting of the church's weight. In fact, the engineers concluded that Richardson's piling system was twice as strong as it needed to be to hold up one of the most architecturally significant buildings in the country.

"[Trinity] is a hell of an engineering project and an unbelievable building," said Patrick Watson-Hogan, project executive for Shawmut, the construction company overseeing the piling inspection and building renovation.

The good news about Trinity Church is small comfort for people who own hundreds of other buildings built on the filled land. Over the decades, public works projects such as tunnel digging have caused sudden drops in underground water levels, leaving wooden support pilings exposed to air and rot. Rotten pilings can cause the building to sink, cracking foundations or even buckling walls — and replacing the pilings can cost \$250,000 for a single rowhouse.

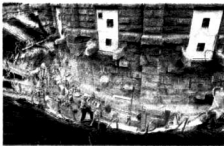
But Trinity's success is not merely the result of good fortune that ground water never drained away. Instead, Richardson — an architect known for his intricate

Romanesque facades and careful attention to detail — designed his church with the distant future in mind, building in backup systems that would support the church long after his generation was gone.

The filling of the Back Bay was a 30-year process, began in 1857 and made possible by a railway built between downtown Boston and the gravel pits at Needham 9 miles away. For three decades, trains ran every 45 minutes, with men and steam shovels working 24 hours a day to fill the entire area with at least 20 feet of gravel, an effort that required almost twice as much earth as that being displaced by Boston's current Big Dig project.

Construction of the Trinity Church was part of a bold attempt to create a public space in the heart of the emerging neighborhood. Later, the Boston Public Library would join the church in Copley Square, but the builders of Trinity had few places to look for engineering tips on such a large-scale project.

And Richardson was quite aware that he was a pioneer. Builders of modern Back Bay structures such as the Hancock Tower drive steel pilings right down into the bedrock 30 or more feet below the ground-water line,



In a view from street level, workers inspect the exposed 19th-century pilings under Trinity Church in Boston.

anchoring the building in stone. But engineers in the 1870s didn't have the technology for such construction methods, forcing Richardson to improvise.

"The nature of the ground on which the building was to stand brought problems for the solution of which no familiar precedent existed," writes Richardson in "A Description of Trinity Church," his account of the project.

Richardson decided to provide more support for Trinity than was theoretically needed, just to guard against any unforeseen difficulties, over-engineering the foundation to such a degree that little

short of an earthquake could shake it. Workers drove 4,500 wooden piles — each 35 feet long and 10 to 12 inches in diameter — into the ground upon which the church would eventually rest, all sunk so that they were resting directly on the bedrock. The space around the top 2 feet of the pilings was then filled in with concrete to prevent shifting.

During construction, which began in 1873, Richardson noted even the minutest details to demonstrate to history the pains he went to in ensuring the stability of the church:

"Every pile was watched, numbered, its place marked on a plan at a large scale, and a record made of the weight of the hammer with which it was driven, the distance that the pile sank at the last three blows, and the height from which the hammer fell."

The biggest danger to the foundation of any old Back Bay build-

ing is a rotting away of the wood pilings, which is caused by oxidation when water levels drop and allow the wood to come into contact with air. For Trinity, workers leveled the tops of the piles well below the average water level to keep them wet. According to the structural engineers currently examining the foundation, Trinity's piling system is so overbuilt that more than half of the diameter of every piling could rot away and the church still wouldn't be in danger. In addition, Trinity has its own on-site monitoring wells, so if the ground-water level gets low, church officials simply leave garden hoses running into the wells for a few weeks to bring the levels back up.

"The theory is that when they first put this building together, they actually planned on the redundancy in their design, and that's what protected the building," said Watson-Hogan of Shawmut.

But the leadership of Trinity Church is taking no chances. About three years ago, 13 test pits were dug adjacent to different parts of the church to do an initial screening for piling-rot and to see how stable the water levels have been. The results showed that the water table varied by about 8 inches across the entire site, but only the pilings on the east end, where the water was the lowest, showed any kind of rot. Workers on the current Trinity excavation project are exposing every pile around the edge of the east wing and repairing any that show signs of trouble.

Knowing they have a solid

foundation, church officials can focus on ongoing renovations, intended to beautify the visible parts of the magnificent building, which has been a national historical landmark for more than 30 years.

The church's construction "was all kind of state-of-the-art for 1877, and to do [the current renovations], it turns out that it's all state-of-the-art for 2003," said Trinity Church spokesman David Trueblood. "Getting ready for this project, they went through and used... a newly developed system that uses lasers to make exact measurements of structures so you get an absolute, infinitesimal-detailed picture. We have much, much better drawings now of what the place is as built than the engineers had who built it."

The renovation-in-progress is uncovering all sorts of little peccadilloes that never would pass engineering standards today, but that don't seem to have had any adverse effects. For instance, there are numerous places where the foundation stones don't quite line up on top of the piles. The understanding is that most of the piles were pounded in before the builders were exactly sure where the building was going to go or what its final dimensions would be.

"My feeling is that the architects kind of waded their arms and said, 'Make it like this,' and then the artisans would get up and they would actually make it, and you got somewhere in between vision and reality," Trueblood said. "But there are no cracks at all in this whole thing, so whatever is down there has worked perfectly for 126 years."