

Shepherd Building Group

*The sagging cathedral gallery shows the effects of age and poor foundations.*

## ENGINEERING

# Saving a stone prayer

**750-year-old York Minster saved from crumbling by new techniques of repair and restoration**

by F. C. Livingstone

On Easter Eve in the year 627, in a small wooden church built especially for the occasion, King Edwin of Northumbria became the region's first Christian monarch. Today the humble site is that of the mighty Cathedral at York, which physically as well as historically depends for its existence on the foundation of that early Anglo-Saxon church.

In recent years, York Minster, after seven centuries, has been in grave danger of falling down. That it probably will not is the result of by far the largest restoration job ever attempted on a British cathedral, an effort that may cost more than \$5 million in privately donated funds by the time it is completed.

The minster's troubles date all the way back to Edwin's wooden church which, late in the seventh century was replaced with a stone one, but still on relatively light foundations. Some 300 years later this church was destroyed in the Norman invasion. In 1070, Thomas of Bayeaux, first Norman archbishop of York, ordered a much larger minster built on the site. The task took 30 years, and again used the foundations of the little Saxon church that had come before.

The present minster, which is the largest medieval cathedral in England, was two centuries in construction, beginning under the aegis of Archbishop Walter de Grey in 1220. And again, it used the foundations of its modest predecessor.

As a result, engineers estimate that the foundations of York Minster are overloaded by as much as 25,000 tons. Nor does it help any that the original Saxon foundations, upon which everything else has pyramided, consist of masonry supported by timbers that have long since rotted away.

The cathedral's misfortunes first became glaringly apparent in 1964, during a series of periodic inspections by a team of observers led by Bernard Feilden, a fellow of the Royal Institute of British Architects, who also has the title of York Minster's official Surveyor of the Fabric.

The inspectors noted that the structure's two west towers, each nearly 200 feet high, had reached so sorry a state that they were literally in danger of crumbling. At the time, engineers put the blame on vibrations caused by the rumbling of nearby heavy traffic; High Petergate, a main traffic artery, passes only 50 yards from the west end of the



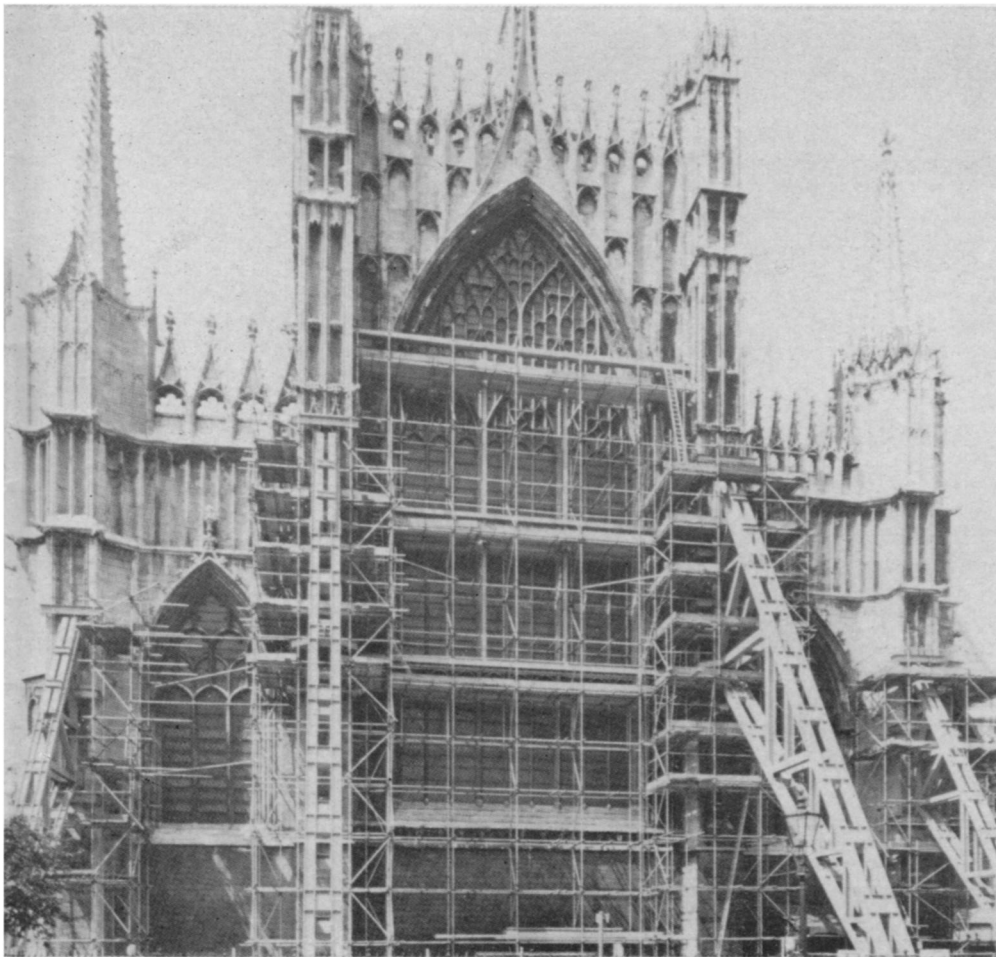
*Crack in a tower wall 120 feet up.*

minster, and another road runs immediately outside the minster walls.

As restoration began on the west towers, the rest of the cathedral came under careful scrutiny for other signs of damage. And in autumn of 1967 it was discovered that the massive square center tower, almost as tall as the western towers and 67 feet on a side, was cracking badly. In addition, stress due to movement of the tower was causing distortion in other parts of the structure. Right angles were no longer true, horizontal lines such as window sills and mouldings were sagging more and more.

A source of major concern was the minster's huge east window, one of the largest expanses of stained glass in the world. Created between 1405 and 1408 by John Thornton of Coventry, it is perhaps the minster's most prized feature. Together with the cathedral's 116 other colored windows, it comprises nearly half of all the medieval stained glass still surviving in Britain. So valued is the window that it was entirely removed in 1939 and held in safekeeping for the duration of World War II.

When the cracked tower was discovered, it was feared that the distor-



*Swathed in I-beams and scaffolding, York Minster's east front awaits repair.*

tion might crack the precious panes. Heavy panels of translucent plastic and braces of heavy timber were placed inside and outside to protect them.

But the major effort of the restoration has been a huge steel girdle installed invisibly around the center tower, within the walls, to hold the tower together and prevent further distortion. Because the finished restoration work had to be completely invisible, installing the girdle meant drilling dozens of horizontal holes, each 67 feet long, through the solid stone tower walls. In these were installed almost two-thirds of a mile of high-tension stainless steel reinforcement.

**Before the drilling** could even begin, however, samples of the minster's limestone were probed with ultrasonic vibrations in a laboratory to see what kind of hole-making equipment would be needed. Aided by the tests, the engineers were able to use a high-speed rotary drill capable of boring a two-inch-diameter hole at speeds up to one foot per minute.

Just before the drilling started, further movements in the upper regions of the tower were detected by strain gauges capable of recording movements as small as half a millimeter. The drill-

ing thus proceeded in utmost urgency. To their frustration, the engineers were not able to use the boring equipment at its maximum speed, because the 67-foot-long holes had to be guided within a tolerance of one inch.

**Observers from** other church and historic buildings are constantly watching the work at York, to pick up ideas for their own use. And the girdle technique has provided some. Among the sophistications required to keep the work invisible has been the removal of 10-inch-diameter plugs of masonry at each end of each proposed bore hole. The plugs, replaced after drilling, offer a starting point for the drill at the beginning of the hole, and prevent the chipped area caused by the emerging drill head from being visible on the surface.

The towers, unfortunately, have not been the only areas in York Minster to suffer. Feilden's inspectors discovered, in their narthex-to-apse investigation of the cathedral, that the huge roof timbers, including some monster beams spanning 48 feet and weighing in the region of five tons, were in a bad state of decay. Several hundred cubic feet of new timber will be required, and the biggest timbers simply cannot be re-

placed with wood at all; such vast boards have not been available in England for years.

**The villain there** is the death-watch beetle, a small wood-boring insect that makes a clicking noise thought by the superstitious to presage death. The harmless-looking insect, one of a group aptly known as powder-post beetles, has caused so much damage that many of the large timbers are completely unsalvageable. Those will be replaced by reinforced concrete beams, designed by the Shepherds Building Group.

To both prevent further damage and protect the restoration, it is necessary as well to provide a completely new foundation, extending under the entire minster which is 486 feet long and ranges up to 223 feet wide. The nave alone is 104 feet across. The new foundation is being placed below the old Norman one, where that exists. The minster will literally float from now on. The new foundation entails construction of two huge rafts, the lower one below the water-table level. Hydraulic systems on the two rafts will carry the full weight of the cathedral, while valves will control the release of water below the lower raft.

All this restoration work and excavation has provided archaeologists with a series of side finds. The diggings have revealed traces of the Roman occupation of York, including a well-preserved fragment of their legionary fortress, which, in fact, stood on the spot even before King Edwin's wooden church. The north wall of the stone Saxon church has been found, as has the whole transept of the Norman minster.

When the restoration of York Minster is completed, it will be able to stand safely on its own 97,000 square feet for the first time in its 750-year history.

**With work** on the minster itself proceeding, the Ministry of Housing and Local Government has published a report recommending another \$5 million, this time in public funds, to restore the rest of York city. Among the proposals which should ease the strain on the cathedral is a daytime ban on all vehicles in the central streets after early deliveries are made. The streets would be paved wall-to-wall to provide more walking space for pedestrians.

Funds for the preservation and enhancement of York within the city walls could come from a five percent surcharge on hotel bills and a six-cent increase in admission charges to local historic sights. Except for the work on the cathedral, the report claims, "all that has been done to rescue historic York in the past 20 years has been first aid. The task is now to diagnose and prescribe for the disease." ◇