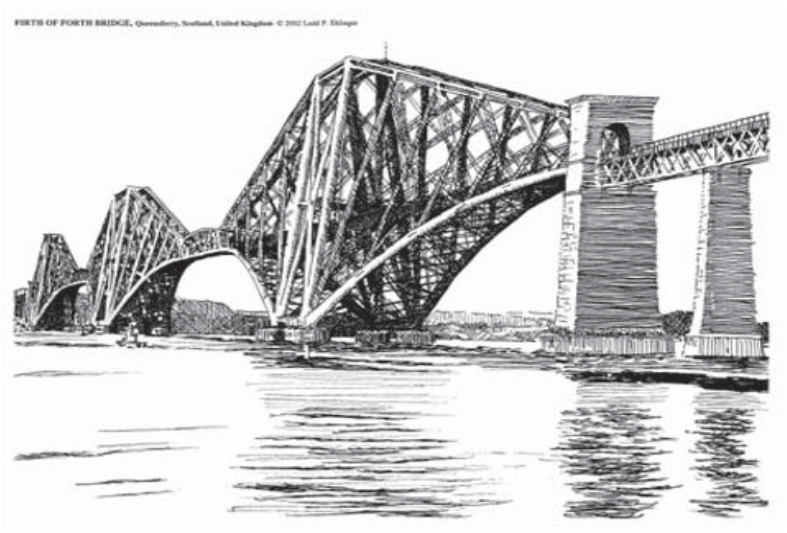
ARCHITECTURE

EHLINGER & ASSOCIATES FIRST QUARTER 2002



FIRTH OF FORTH BRIDGE

This issue's limited edition print of a sketch by Ladd P. Ehlinger is of the Firth of Forth Bridge at Queensferry, Scotland, U.K., located about 8 miles north of Edinburgh. This railroad bridge is considered by many, including the writer, to be the "Holy Grail of Civil Engineering". This is because this bridge was the first cantilever bridge to be built of steel, a relatively new material in 1885 when the bridge construction was initiated, and it is as pure an expression of a cantilever bridge that one can find even though it was the first. The writer first learned of this bridge as a six year old, amusing himself reading an extensive article about it in his father's childhood *Book of Knowledge* (the junior Encyclopaedia Britannica), printed ca. 1917. Contained in that article were progress construction photos, and an explanation of the theory of the cantilever, including the engineering math underlying it. This exposure sparked a lifelong interest in structures and construction, and the desire to actually see the bridge and ride across it — which finally occurred in October 2001.

Scotland's east coast is interrupted by fjords such that a 46 mile train ride from Edinburgh to Dundee took a half a day. One had to ride ferries over the Firth of Tay and the Firth of Forth. There was a tremendous demand for bridges to shorten the trip.

There had been another bridge begun over the Firth of Forth (means mouth of the Forth River in Gaelic) designed by Sir Thomas Bouch, the chief engineer for the North British Railway. Bouch had completed a suspension bridge over the Firth of Tay, north of the Forth River. He was constructing the foundations for a similar suspension bridge over the Firth of Forth, when on the 28th of December 1879, the Tay bridge collapsed in a violent storm, with the loss of 75 lives. Even though Bouch had received a knighthood for its design, he was disgraced by the collapse, and died 3 months later.

There was then tremendous public concern over the suspension type design of the Forth bridge as a result of the collapse of the Tay bridge. A competition was held and a cantilever concept was submitted by Benjamin Baker and Sir John Fowler, the chief engineers. They were awarded the contract on the 21st of December 1882. The three X-braced towers were erected their entire height by Queen Victoria's Golden Jubilee in 1887, and the cantilever "arms" trusses were hung out and the bridge completed in 1890 by Sir William Arrol Co. contractors. 57 men died in the construction before it opened on the 5th of March 1890.

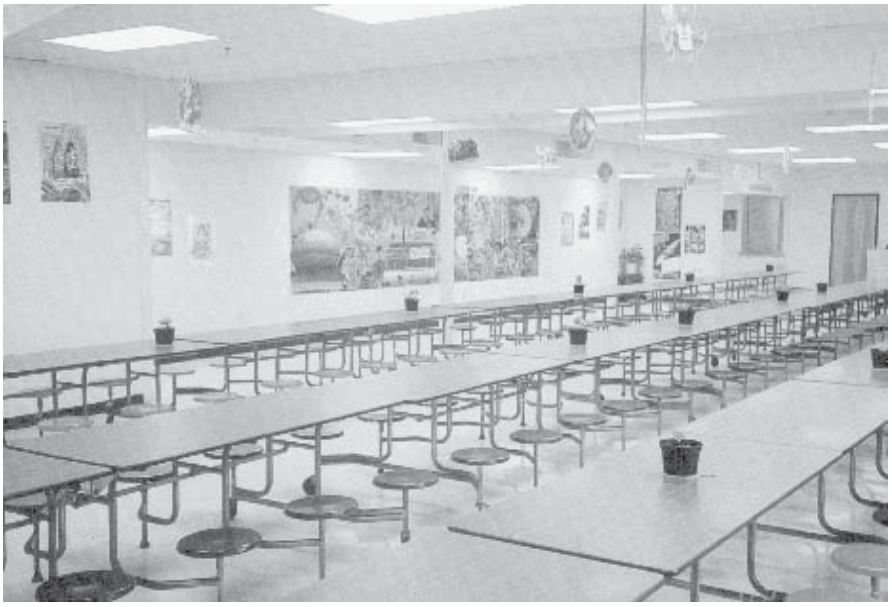
The *Book of Knowledge* had an illustration of the "arms" of the cantilever showing two men seated with their arms outstretched holding weights and a belt or strap over their heads to their hands. This illustrated that the slanting top members of the cantilever trusses are in tension and the curved bottom members are in compression. The main compression members of the bridge are steel tubes, the heaviest of which are 12 feet in diameter of 1-1/2" thick steel plate with internal stiffeners. The tension members are lattice girders easily distinguished from the tubes. The main towers are 331 feet high and are 120 feet apart at

their supports at the water and slope inward to 33 feet apart at the top. They are supported by 70' diameter piers built from wrought iron caissons that were sunk to bed rock for laying of limestone and concrete.

From pier to pier, the entire run of the cantilever portion of the bridge is 5,300 feet with the longest span 350 feet at the navigable channel, and the total length 8,276 feet. The bridge held the longest cantilever bridge record until 1917. The cantilever trusses were built without any falsework as shown in the photo taken during construction.

Unfortunately, not everyone liked the design of the bridge. The poet and artist William Morris called it "the supremest specimen

of all ugliness". Even the writer is impressed by the eerie appearance of the bridge — similar to a procession of dinosaurs tied head to tail, as elephants are sometimes. In any event, this bridge fully served its purpose and answered the concerns of those that had it built: it has been perfectly safe. It was designed for a wind loading of 56 PSF, while the Tay bridge had been designed only for 10 PSF



Andrew Wilson
Elementary School

These are some interesting shots - before and after - of the Cafeteria of the Andrew Wilson Elementary School that E&A recently redesigned, and which is almost 100% reconstructed. This building was originally built ca. 1913. The first floor was treated as a basement in the original design, with the construction being rather rough. The original design documents were incomplete with subsequent renovation documents also missing or incomplete.

Investigative disassembly was performed in certain areas to determine the exact nature of what was present, which yielded false results. The areas picked were areas where previous rehab work was done we didn't know about, that was done in such a way that it indicated that the slabs were ground supported.

The original foundation design was pile supported on the perimeter walls, and the interior column footings, with the slabs being indicated as ground supported or "floating" as in present day technical slang. This didn't worry us as our investigation agreed with it. However, when the slab was demolished in certain areas to install new plumbing, we discovered much to our surprise that at sometime, probably in the 1920's judging by the type of structural design, a new pile supported (on the existing footings) one-way reinforced concrete slab had been installed. In the picture at the left, you can see the reinforcing that was bent up out of the way as the new work was installed. This resulted in an "on the fly" analysis of the existing slab to determine its capacity, and how best to marry the new work to it. The lesson learned was to better pick the areas of investigative disassembly.