ARCHITECTURE

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PONT DU GARD

Water played a huge role in the development and expansion of the Roman empire, as large a role as good roads for transportation did. In this issue's limited edition signed print by Ladd Ehlinger, we have a combination of a road and an aqueduct (conduit for water) that functions as a bridge over the River Gard, near Nimes, France.

Roman civilization placed great value upon the importance of water in both private and public life. Most private houses had bathrooms as we know them today, with tubs, lavatories and toilets, but the water ran constantly to flush the waste away. There were public baths as well, which we as a civilization do not have, where separate pools of cold, tepid and hot water were used for cleansing and relaxing. These pools were huge in size and also utilized constantly running water to flush them and keep them clean. There was no chlorination or other chemical treatment as we know it, so the constant flushing was a necessity along with very large quantities of water.

In addition, the Romans had no methodology of treating waste water or sewage, or even storm drainage that became contaminated by animal droppings, even though they were well aware that waste water fostered disease and should thus be separated from potable water.

Consequently, sources of clean, potable water and a means of preventing it from becoming contaminated by any source was absolutely necessary. Waste water was evacuated downstream and fresh water was sought as far upstream as possible. In the sixth century B.C., the Romans began using conduits to evacuate waste water and also to bring in clean water to the city. Mountain streams and springs in unpopulated areas were used as a source of fresh water to minimize the possibility of contamination. Channels, called 'specus', faced with stone rubble set in mortar were dug into high spots in the terrain and bridges supporting channels were used to span depressions, so that the channels were kept to a slight slope from the source of the water to the city. The water was kept as high as practicable in the air in order to keep the pressure of the water high, and to prevent theft and contamination. The channels that needed to be in the air were supported by tiers of stone or concrete arches for economy of support and minimum obstruction to traffic below.

The Roman architects seldom used pumps, though these had been invented by the hydraulic experts of Alexandria, Egypt centuries earlier, and the Romans were familiar with them. One of the few occasions when they used pumps was in the water supply for Lyons, France. Siphons were sometimes used for transsport over deep depressions or ravines also, but when this was done, multiple lead pipes of small diameter (9 or 10 of 1-1/2" diameter) were used in the depression linking the reservoirs on either side of the depression. The Romans were unable to make satisfactory cast iron pipe and valves to withstand the high pressures, so this method with small lead pipes and reservoirs was used.

The size of the 'specus' varied from 1-1/2' to 4' wide by 2' to 8' high, and was constant from the source of the water to the reservoirs that were built near the distribution destination. Some of these distribution reservoirs were huge vaulted caverns built underground, such as at Constantinople, with buildings built on top of them later.

Local distribution was initially sent from the 'specus' to large pipes made of stone that had holes drilled to create the conduit, brick vaulted channels or terra cotta pipe. From these conduits, distribution into the buildings was by small diameter lead pipes.

Incidentally, medical historians have speculated that a major reason for the demise of the Roman empire was that large segments of the population suffered madness from lead poisoning from the lead in the water distribution conduits being leached into the water. However, the Romans also had the practice of flavoring their wine with a tincture of lead and mercury, which was probably of much greater significance. Also, the wonderful roads that the Romans built, while facilitating the control and management of the empire, allowed the importation of disease to the capital at a very rapid rate. The technology to combat the diseases thus imported didn't exist. This is very similar to the phenomena of today where we see diseases spread rapidly by air travel.

The Pont du Gard was completed about 20 B.C. It was commissioned by the Emperor Agrippa and was part of a 25 mile long aqueduct designed to carry the waters of a spring near Uzes to Nimes, and to function as a bridge for people and vehicles.

The Pont du Gard has three rows of arches one above the other. The bottom row is the bridge that carries the road and has breakwaters facing upstream. It has six arches in all, with very wide openings - 52 feet to 70 feet by 66 feet high, as it crosses a swift flowing river. The second story is the same height as the first and has double the number of arches - 11 total. The third story breaks the rhythm of the lower stories. It is only 28 feet high and has 35 arches which comprise only half the area of the elevation. These top arches play a purely aesthetic part, as the conduit could have been placed directly on the second level or on a wall on the second level. This is the only decorative element of the entire bridge conceded by the architect. It is the only level that has mortar binding the stones together. The two lower stories are constructed of large stone blocks laid dry, with no mortar in the joints. Their treatment is so utilitarian that it has been raised to an aesthetic level. The keystones are elongated for emphasis. The corbelled stones just above the springline of the arches, that were used to support the wooden centering or falsework that the vaults were constructed upon, have been left in place as decoration. The whole composition harmonizes with the landscape in a very skillful way.

The writer was aware of the mortarless stone construction when the Pont du Gard was visited with his son, then 12 years old. It was a very windy day, with bright sun and cloudless sky. We were crossing the bridge, about midway when the drift sway, or lateral deflection of the bridge under the gusty wind loading became very noticeable. Thoughts of the mortarless joints being 'worked' by the swaying motion over the centuries, so that the joints were enlarged by the grinding action making sand in the joints, which further enlarged the joints, to the point of instability of the whole structure under wind loading contrasted with the realization that the bridge has safely been here for centuries. The thought of 'How much longer can the bridge take this motion?' was interrupted by two startling sonic BOOMS and then the sight of two French Mirage jets buzzing the bridge.

A very exciting visit!

MORE ABOUT BRICKS

In the 19th and 20th centuries, the scientific method began to be applied to the traditional problems of poor tensile resistance and high water absorption associated with brick construction. Several crucial hypotheses were posited and tested: that other materials could be melded with the brick construction to solve the problems; that the aspects of structure and waterproofing of the brick construction could be treated separately to solve one or the other of the problems; that use of the engineering properties and engineering measurements and techniques in experimentation would lead to solutions to the problems.

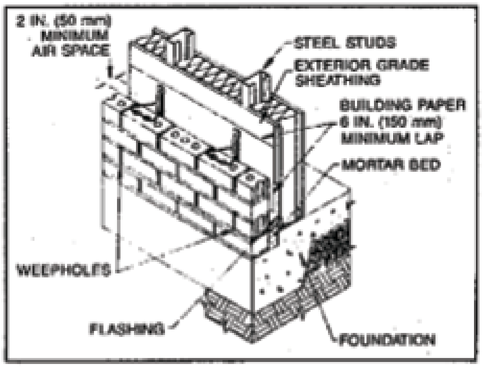
In combining other materials with brick to solve the lack of tensile strength, both steel and reinforced concrete (which contains steel) were combined with the brick to remove the tensile forces within any particular type of structure.

In the simple span of an opening, such as a door or window, rather than using the brick in an arch, steel lintels began to be used. The steel was in the shape of an angle with the brick being carried on the horizontal leg of the angle, or in longer span conditions plates in a horizontal position attached to an "H" shaped beam carried the brick. The theory was to not subject the brick to any tensile stress at all, letting the steel carry all of the tensile stress produced by the bending of the span. Within brick walls, light steel wire fabrications, some in a ladder pattern and others in a truss pattern, were developed to carry the tensile stress produced by thermal movement, slight settlement, wind loading, etc. by being laid with the mortar in the joints of the brick masonry. Testing was performed so as to develop criteria as to how much tensile stress this reinforcing would carry.

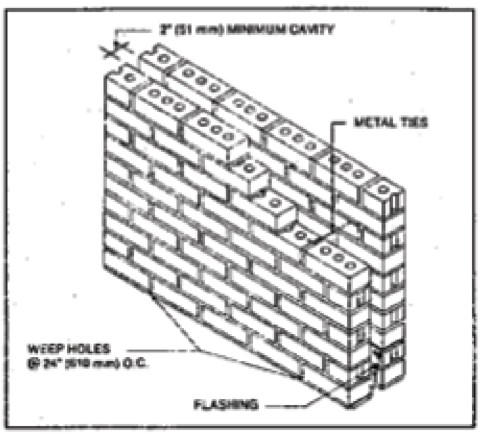
In reinforced brick masonry, the brick was treated as if it were a form within which to place reinforced concrete or a very high strength mortar. The brick provides a pleasant aesthetic visible surface, the reinforced concrete which is bonded to it by design does all of the structural work.

Walls, beams and columns, even vaults and domes have been constructed with this technique.

The properties of the brick and mortar were determined by testing that play a role in the structural problems: compressive and tensile strength, coefficient of thermal expansion, and water absorption. Testing, using these properties, was done to determine how long of a wall could one build before an expansion joint had to be designed into the wall to control and minimize cracking. Joint fillers for these expansion joints were developed to allow for the movement in one direction by compressing and expanding, yet provide strength and stability in the other direction.



Brick Veneer/Steel Stud Wall



Typical Brick Cavity Wall

Other materials were combined with the brick masonry to solve the waterproofing problems. Metal flashings were introduced at the base of walls in lieu of the traditional slate course to solve the rising damp problem. Metal flashings were also introduced within walls and other components such as chimneys to prevent water intrusion, in effect being internal roofs within the walls.

The latest methodology for solving the rising damp problem in those historic buildings that do not have a slate course or metal flashing at the base of the wall is that of chemical injection. Chemicals, of a nature compatible with the brick masonry in the silicate family, are pressure injected in holes bored in the brick wall approximately 6" on center all around the base of the wall. The porosity of the brick along with capillary action causes the brick to absorb the chemicals in an approximately 6" high layer that cures to become impermeable, thereby preventing the ground water in the brick below from rising any further.

The greatest advance though, was the separation of the brick masonry's structural function from its waterproofing function by means of the "Rainscreen Principle". See the E&A Newsletter of 3rd Quarter, 1988. Here the outer layer or wythe of brick is separated entirely from the structural purpose of carrying any imposed weight or force other than its own weight by being separated by an air space or cavity from the remainder or interior wythe(s) of the brick wall. Metal ladder or truss joint reinforcing ties the outer wythe structurally to the inner wythe and gives stability to the outer wythe. This outer wythe is allowed to absorb rain water to the point of oversaturation, so much so that the excess water leaks into the cavity. The water is allowed to drain down the interior face of the outer wythe of brick to the foundation and then through openings called weep holes to the exterior of the building. These weep holes also perform the function of equalizing the air pressure of the cavity with that of the exterior, so as to prevent "suction" of the rain water into the brick and the building. The cavity has to be completely sealed from the interior of the building to prevent the "suction" effect from drawing cavity water into the building.

The outer wythe of brick became a "veneer" when it was totally separated from any other masonry, and depended for its strength and stability upon a "back-up" wall of wood frame or metal stud construction. The waterproofing function is the same as the cavity wall described above, although the cavity is now called an air space. The brick is tied to the backup with metal wire ties or metal straps. This type of construction is commonly used in residential and light commercial construction.

PATRICIA HENSLEY

E&A of Alabama is proud to welcome Patricia as a member of our Architectural staff. She received her Bachelor of Architecture from the University of Houston, where she was on the Dean's List.

Her fifth year design thesis concentrated on healthcare facilities and subsequently she has acquired related experience on production drawings of a local hospital addition and various health laboratories.

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