

## CHAPTER X

### MAINTENANCE AND REPAIRS

Tempus edax rerum.

OVID (43 B. C. to 17 A. D.), *Met.* xv. 234.

Time, the devourer of all things.

A REVIEW of the ancient inscriptions and other sources of knowledge that relate to the repairs constantly made necessary on the aqueducts of Rome inevitably brings one to the conclusion that, so far from meriting unalloyed admiration, or from being taken as models at the present day as regards their fitness to convey water and their durability of construction, they may, on the contrary, be subjected to valid engineering criticism on both accounts. Frontinus recites how Appia and Anio Vetus were out of repair when Marcia was built (145 B. C.); how Agrippa (34 B. C.) built Julia, *and in the same year*<sup>1</sup> restored Appia, Anio Vetus, and Marcia. This must mean, however, that these aqueducts were out of repair merely, and not destroyed, or else they could not have been restored to use in one year, — a year, moreover, in which a new aqueduct was under construction. Nevertheless, only twenty-nine years later, as we read on the St. Laurentian gate, “Augustus, son of the Divine Caesar, sovereign Pontiff, in the twelfth year of his consulate, the nineteenth year of his office as tribune, fourteen times proclaimed emperor, repaired all the water channels” (*rivos aquarum omnium refecit*).<sup>2</sup> This was 5 B. C. But other inscriptions tell of repairs on Virgo A. D. 31, again in 43, and in 44; on Claudia and Anio Novus in 52; Claudia again in 71, after nine years of disuse, or after running only ten years; Marcia in 79; Claudia and Anio Novus again in 80, after running nine years, and Claudia again in 84; then Marcia again in 103, being about the time of Frontinus’ death. It is very evident that these works suffered

<sup>1</sup> *De Aquis*, 9.

<sup>2</sup> Also on the “Monumentum Ancyranum” (Middleton, i. 386).

severely from the action of the elements, and, it may be argued, had not originally been properly designed or constructed.

The fault was with their design.

In the first place, it is all wrong to construct of masonry any continuous, simple channel above-ground, and expect it long to hold water. The mere expansion and contraction of the stone-work, beaten upon by the great heat of the sun in summer, as Frontinus tells us, and exposed to frost in the winter, will speedily crack such masonry channels, or their thin concrete lining. A crack once formed, the water will soon make it larger, for to no work is the proverb of "a stitch in time saves nine" more applicable than to works conveying or storing water.

And yet is the knowledge and full appreciation of this one of the most recent acquisitions of modern engineering, dating, as it were, but from yesterday. When the Sudbury conduit was built for Boston, Mass., about 1874, the masonry aqueducts on the line were constructed in a manner probably superior to any aqueducts that had anywhere preceded them, as regards this very point of providing for the expansion and contraction of the masonry channel by heat and cold, and of allowing it to thus change its length without affecting the main structure. This was done by making clear lines of demarcation between the bridge proper or carrying member, and the water channel. Nevertheless, twenty years' service showed unmistakably that masonry alone could never succeed in the unequal contest, and would always become leaky in the course of but a few years, when exposed to a northern climate. It may be sufficient thus to build in Southern France or in the tropics, or in Southern California; it is not sufficient where the range of temperature is 120 degrees of Fahrenheit outside, forty or forty-five degrees in the water itself.

So much being settled, the method of construction followed by the same engineers in 1898, in building the Nashua aqueduct, becomes interesting. It becomes doubly interesting to a student of Frontinus, when he observes that they made their original and permanent structure in the way that Frontinus describes in Chapter 124 as a method of making quick repairs. They lined the channel with sheet lead, for its whole length, building with brick for stability, both inside

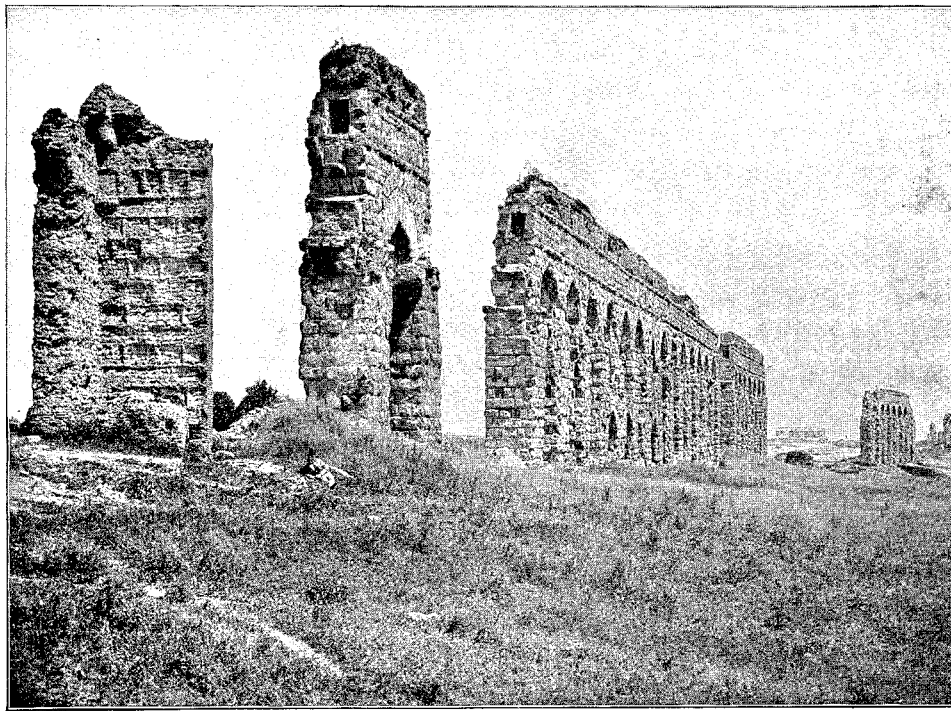
and outside of the sheet lead, but depending on the elastic metal to keep the channel water-tight.

One of the curious things about the ruins of the Roman aqueducts is the brick substructure, consisting of several rings of brick arches with plenty of concrete stuffing between the several rings, which may be seen under the massive dimension-stone arches of Claudia and of other aqueducts. More than that: a piece of the channel of Marcia, near where the railroad cuts through it, a short distance west of Porta Furba, is entirely encased in such a subsidiary construction, besides having such brick and concrete arches built up under the arches of the main structure.

I have never seen any proper explanation of this sort of work, the subsidiary arches being generally referred to as having been built to "help support" the aqueduct, which explanation, I venture to say, is, however, not to be thought of for a moment. So far from these brick and concrete arches helping to support the masonry arches above them, there are places on Claudia where that portion of the former which is next the ground has been knocked out from under the remainder, and has left the brick arches themselves and their brick abutments hanging by adhesion to the stone-arches above them.

The conclusion that I have come to about these described parts of structures is that they were built to stop leaks, both the brick arches, and the outside envelope of Marcia's channel above referred to. The Romans could not very well work from the inside of the water channels for two reasons: they could not spare the use of these channels during the time it would have been necessary to draw the water from them during such repairs; and the interior was subject to great diminution of cross-section as it was, by reason of incrustation from the hard water, so that they could not spare the room that such interior patching and plastering would have taken away from the useful cross-section of the channels. So they decided to work from the outside. But in so doing they tried to accomplish their purpose by what the modern plumber calls "working against the pressure," and as every one in the trade well knows, and as any one can see on the ruins of the aqueducts, they had a most uncomfortable time of it. A correct analysis of what may be seen on the ruins also explains, in my opinion,

to the fullest extent, why there are so many inscriptions that detail the repairs of the aqueducts. The truth is, that these much vaunted works, whose *ruins* stand so long, were very poorly designed to *contain water*. The amount of leakage from them, as has already been said, must have been something enormous at all times, until in a very few years, as we have seen, one or the other, or three at a time, would be



CLAUDIA, WITH ANIO NOVUS ABOVE IT.<sup>1</sup>

found to have grown so leaky that some enterprising emperor would distinguish himself by restoring them for a short period to usefulness. Sad as it may seem to be obliged to acknowledge it, the Romans apparently did not fully appreciate what an up-hill job it is to “work against the pressure.” Or else they had not ingenuity enough by skilful design of the aqueducts to disentrall themselves from the necessity of being obliged to do so, did they wish to keep the aqueducts staunch and in condition to deliver water.

<sup>1</sup> Note the brick arch under the masonry arch near the centre of the figure, suspended by adhesion from this masonry arch. Another such case was shown on p. 176.

The cupidity and thoughtless selfishness of the public contributed in no small degree, as we have seen, to the diversion of the waters of the aqueducts before they reached the city. To cap the climax, the right to take and conduct water leaking from the aqueducts, or overflowing from fountains, or otherwise wasting, was made the subject of a grant. It requires but little imagination to see how such grants were not suffered to lapse, by the grantee, for want of water wasting or leaking, if he could help it; and he, no doubt, generally could. Leaks probably grew larger, instead of being promptly repaired; and overflow and waste could be readily increased by the assistance, or only passive demeanor, of a properly persuaded water-man.

We may remember, in this connection, that description of Fabretti's of the lime deposits, from leaks that formed in places on the outside of the aqueducts, wherein he likens them to hay-stacks; and to my own observation under the arches of Claudia of a net-work of incrustations like great creepers, most of them as large in diameter as a man's arm. Leaks of this sort evidently ran both a long time and in abundant quantity. Considerations such as these readily explain to us how these frequent overhauls and repairs of the aqueducts were made necessary; and how in spite of them, as we have seen, Rome seldom, if ever, received the water of all her nine aqueducts at the same time.

To continue the history of these nine aqueducts, we find Septimius Severus repairing Marcia and extending it to his *Thermae*, in A. D. 196; and Caracalla repairing them all in 212. Claudia is running in 399, and in 402, as shown by two laws then passed with regard to it. In the year 500, Theodoric writes to Cassiodorus about Virgo, as already quoted. In 536, Procopius, coming to Rome with Belisarius, finds eleven aqueducts there, though he says he found fourteen.

In 537 Rome is besieged by the Goths and Burgundians, who destroy the aqueducts. They made a fort, or walled camp, of one portion of them; a tower, *Torre Fiscale*, thus built by them, at the intersection of several of the aqueducts, standing to this day. Nevertheless, Belisarius restored Claudia and Trajana between 537 and 549. Somewhere between 548 and 568 the aqueducts all ceased to convey water, and so remained until about 776, or over two hundred years,

when the Popes, put in power by Charlemagne, commenced to repair them.

In 776 Adrian I. restored Trajana, Marcia, Claudia, and Virgo, in the order named.

We find Claudia in use in 795, under Leo III., Adrian's successor. From 1120 to 1122, Calixtus II. used Claudia, and that is the last we hear of Claudia as a running stream of water, after its fitful existence of 1070 years.

Virgo was restored by Nicholas V. in 1447, and remained in use thirty years. Seven years after, 1484, Sixtus IV. restored Virgo. 1550 to 1555 Julius III. used its leakage waters, and in 1559 it had ceased to flow. That year Pius IV. repaired Virgo, which repairs sufficed for eleven years. Then in 1570 Pius V. restored Virgo; since when Gregory XIII., Clement XII., in 1735, and Benedictus XIV. in 1744, made changes, extensions, and improvements; and the spring "Virgo" is conveyed to Rome to-day. It now yields some sixteen million gallons per twenty-four hours.

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