

***Opus signinum* - Roman concrete without *pulvis puteolanis* : example of the substructures of Diocletian's palace**

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ABSTRACT

Roman concrete (*opus caementicium*) is one of the most important innovations in Roman *res aedificatoria*. Made with volcanic material called by Romans *pulvis puteolanis* or *harena fossicia*, it proved to have excellent mechanical properties. This enabled major innovations in building technology and development of new structural systems. The most important architectural achievement of the long evolution of building in *opus caementicium* are large-span vaulted structures. The first large concrete dome, still preserved, is the dome of the so-called "Temple of Mercury" in Baiae, constructed in the region rich with volcanic ashes: according to Vitruvius, *harenae fossiciae* are found in the of Baiae. Large vaulted structures in Rome itself were also built with *opus caementicium*, including the dome of Pantheon in Rome, which is considered the culmination of the development of the Roman concrete dome building.

Construction of Roman concrete structures depended on its essential component: volcanic materials found only in volcanic regions, which are limited. Roman builders, knowing the advantages of Roman concrete, found a substitute for *harena fossicia*: they invented *opus signinum* ('*cocciopesto*'). Instead of volcanic material, they used broken terracotta, i.e. tiles broken up into very small pieces, to achieve characteristics similar to those of *opus caementicium*.

The most prominent example of *opus signinum* structure in Dalmatia are the vaults of the substructures of the emperor Diocletian's palace, built at the end of the third – beginning of the fourth century AD. These substructures form a raised base for the Emperor's apartments, occupying an area of ca 150 m by ca 38 m. They consist of a number of tall rooms, divided by thick bearing walls. They have been perfectly preserved, due to their excellent construction, and also due to the fact that they were filled with trash in the Early Middle Ages and therefore not accessible until the mid-20th century. The substructures form a large assembly of rooms of different shapes and sizes. Their purpose was to carry the structures of the apartments built upon them, so their walls are positioned according to the walls above them, at the structural distance of up to approx. 15 m; in the largest rooms, the span of the vaults is reduced by inserting rows of thick pillars. Walls and massive pillars bear vaults of various types: barrel vaults, groin vaults, domes, semi-domes and their combinations. Walls and pillars are built in fine ashlar, with large blocks of perfectly cut white limestone; the vaults are constructed in *opus signinum*. Intrados of the vaults is rough, with visible irregular pieces of tufa inserted in thick mortar. This is not a masonry vault, as interpreted by some scholars; this is Roman concrete, made without *pulvis puteolanis*: in fact, this is an example of *opus signinum*, precisely dated structure, constructed by skilled builders employed by the emperor himself.

The vaults of the substructures of Diocletian's palace are important for the history of construction and building technology: for their excellent state of preservation they are significant for the research of structures of the ancient Mediterranean *res aedificatoria*.

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