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Living with earthquakes – development and usage of earthquake-resistant construction methods in European and Asian Antiquity

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Earthquakes are among the most horrible events of nature due to unexpected occurrence, for which no spiritual means are available for protection. The only way of preserving life and property is applying earthquake-resistant construction methods.
Ancient Greek architects of public buildings applied steel clamps embedded in lead casing to hold together columns and masonry walls during frequent earthquakes in the Aegean region. Elastic steel provided strength, while plastic lead casing absorbed minor shifts of blocks without fracturing rigid stone.

Romans invented concrete and built all sizes of buildings as a single, unflexible unit. Masonry surrounding and decorating concrete core of the wall did not bear load. Concrete resisted minor shaking, yielding only to forces higher than fracture limits. Roman building traditions survived the Dark Ages and 12th century Crusader castles erected in earthquake-prone Syria survive until today in reasonably good condition.

Concrete and steel clamping persisted side-by-side in the Roman Empire. Concrete was used for cheap construction as compared to building of masonry. Applying lead-encased steel increased costs, and was avoided whenever possible. Columns of the various forums in Italian Pompeii mostly lack steel fittings despite situated in well-known earthquake-prone area. Whether frequent recurrence of earthquakes in the Naples region was known to inhabitants of Pompeii might be a matter of debate. Seemingly the shock of the AD 62 earthquake was not enough to apply well-known protective engineering methods throughout the reconstruction of the city before the AD 79 volcanic catastrophe.

An independent engineering tradition developed on the island of Java (Indonesia). The mortar-less construction technique of 8-9th century Hindu masonry shrines around Yogyakarta would allow scattering of blocks during earthquakes. To prevent dilapidation an intricate mortise-and-tenon system was carved into adjacent faces of blocks. Only the outermost layer was treated this way, the core of the shrines was made of simple rectangular blocks. The system resisted both in-plane and out-of-plane shaking quite well, as proven by survival of many shrines for more than a millennium, and by fracturing of blocks instead of displacement during the 2006 Yogyakarta earthquake.

Systematic use or disuse of known earthquake-resistant techniques in any one society depends on the perception of earthquake risk and on available financial resources. Earthquake-resistant construction practice is significantly more expensive than regular construction. Perception is influenced mostly by short individual and longer social memory. If earthquake recurrence time is longer than the preservation of social memory, if damaging quakes fade into the past, societies commit the same construction mistakes again and again. Length of the memory is possibly about a generation's lifetime. Events occurring less frequently than 25-30 years can be readily forgotten, and the risk of recurrence considered as negligible, not worth the costs of safe construction practices. (Example of recurring flash floods in Hungary.) Frequent earthquakes maintain safe construction practices, like the Java masonry technique throughout at least two centuries, and like the Fachwerk tradition on Modern Aegean Samos throughout 500 years of political and technological development. (OTKA K67583)