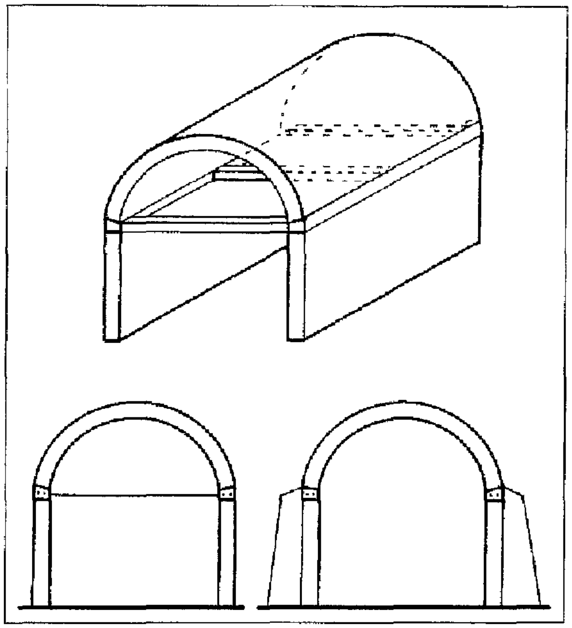
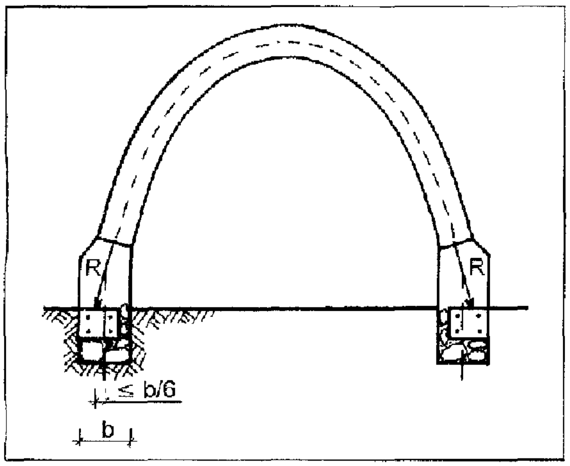
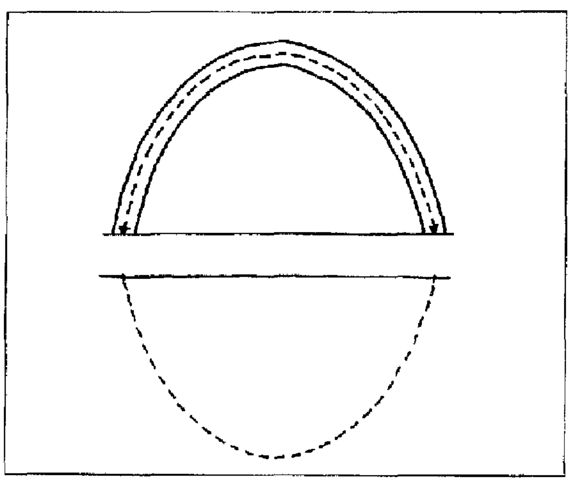


15-1 Ring beams stabilized by tensors or buttresses



15-2 Permitted eccentricity



15-3 Inverted catenary as ideal section for vaults (Minke 2000)

15. Vaults

In an earthquake vaults are less stable than domes, as described in chapter 14. It is advisable to have a square plan. If a rectangular plan is desired, buttresses or tensile elements connecting the beams are required, see Fig. 15-1. To create more stability, a vault should start directly above a low plinth instead of above a wall, see Fig. 15-2.
The vertical section of a vault should have the shape of an inverted catenary if it only has to transfer its own load. Then it only transfers forces in compression, see Fig. 15-3.

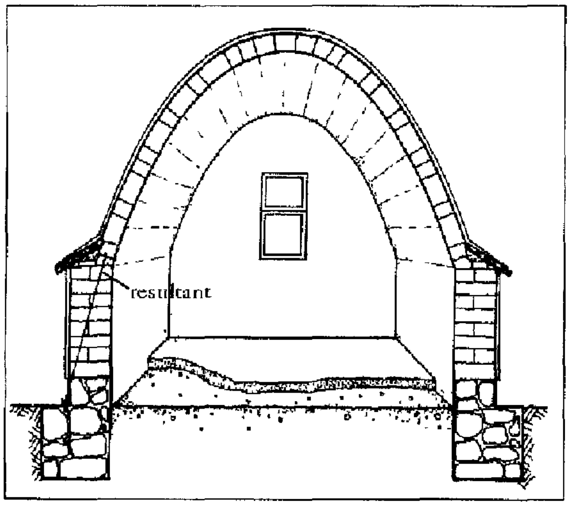
An important rule for the design of plinth and foundation is that the resultant force at the bottom of the vault should go through the inner third of the surface of the foundation. This means that the eccentricity should be less than 1/6, see Fig. 15-2. The foundation must have a reinforced concrete beam, which can also withstand the additional horizontal forces created by an earthquake.
Fig. 15-4 shows a section of a building which was built in an earthquake-prone area in Bolivia. Its plinth has structurally dangerous proportions, as the resultant force from the vault creates a bending moment in the plinth and does not stay within the inner third of the wall, as necessary.

The facades of vaults should be stabilized like the gables described in chapter 11. However, the best solution is to build them light and flexible with "wattle and daub", mats covered with earth plaster, or with timber planks.

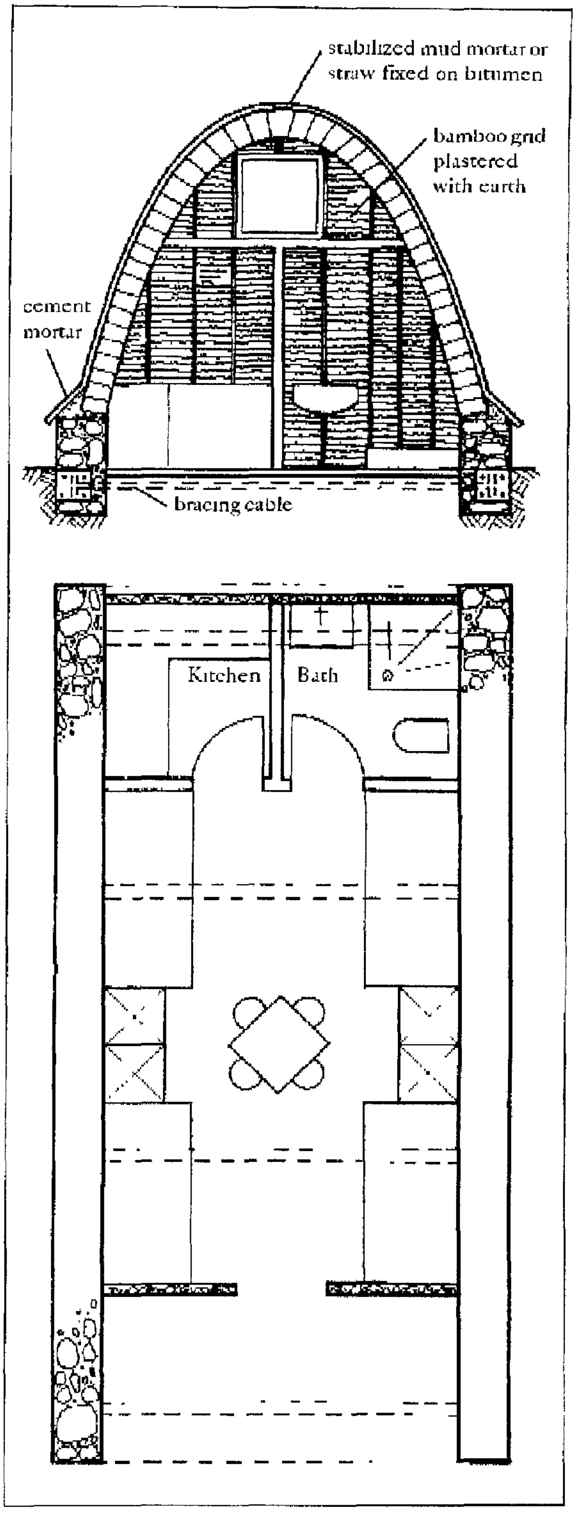
Fig. 15-5 shows a design of the author for an earthquake-resistant low-cost-housing project in the region of Gujarat, India.

A proposal for stabilizing adobe vaults by bamboo arches also guaranteeing a certain ductility was realized within a test structure built in 2001 at the University of Kassel, see Figs. 15-6 to 15-9. This was built with special U-shaped adobes which rest on an arch, built of three layers of split bamboo. The bamboo sections were kept in water for 3 days in order to be able to bend them. Then they were bent over sticks, which were pushed into the ground in a catenary line, see Fig. 15-7. In order to keep the arch in form, the three bamboo sections were wrapped together with galvanized steel wire every 50 cm. The arch was put into a vertical position and fixed to steel bars which stick out of the plinth. This connection must be able to take tensile forces within an earthquake. Above the adobe vault a membrane of PVC-coated polyester fabric is fixed and tightened to the plinth. This has two functions: firstly it gives shelter against rain and wind, and secondly it pretensions the arch and therefore increases its stability against movements created by the earthquake.

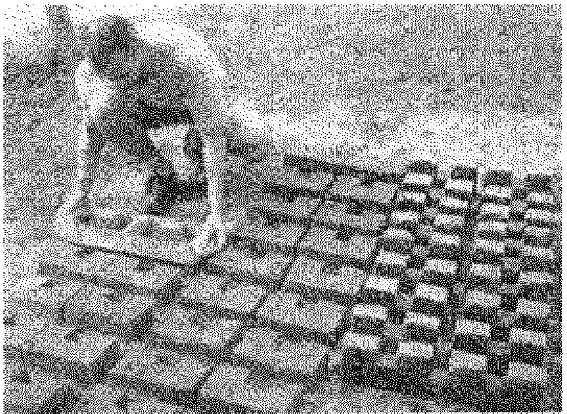
These movements may deform the vault to a certain extent, so that the adobe joints may open, but the vault will not collapse as it is held by the tensile prestressed membrane at the top and the compressive prestressed bamboo arch underneath. Thus the stability of this structure depends mainly on its ductility. However, it must be taken into account that if the pretension of the membrane is high, the optimal section of the vault is more like an ellipse.



15-4 Badly designed plinth with eccentric thrust line

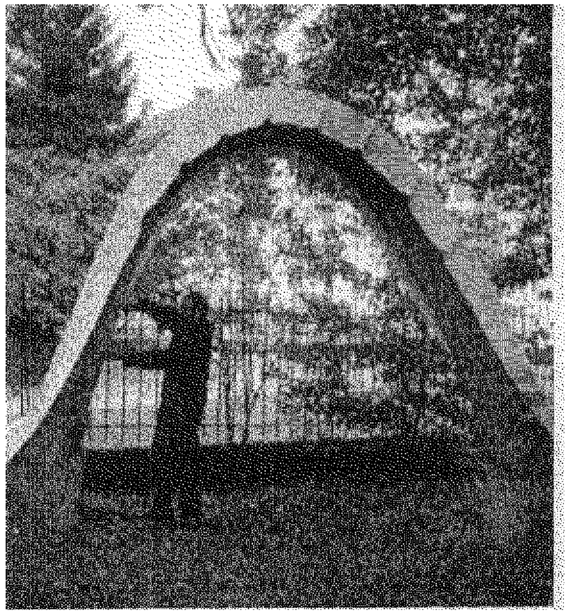


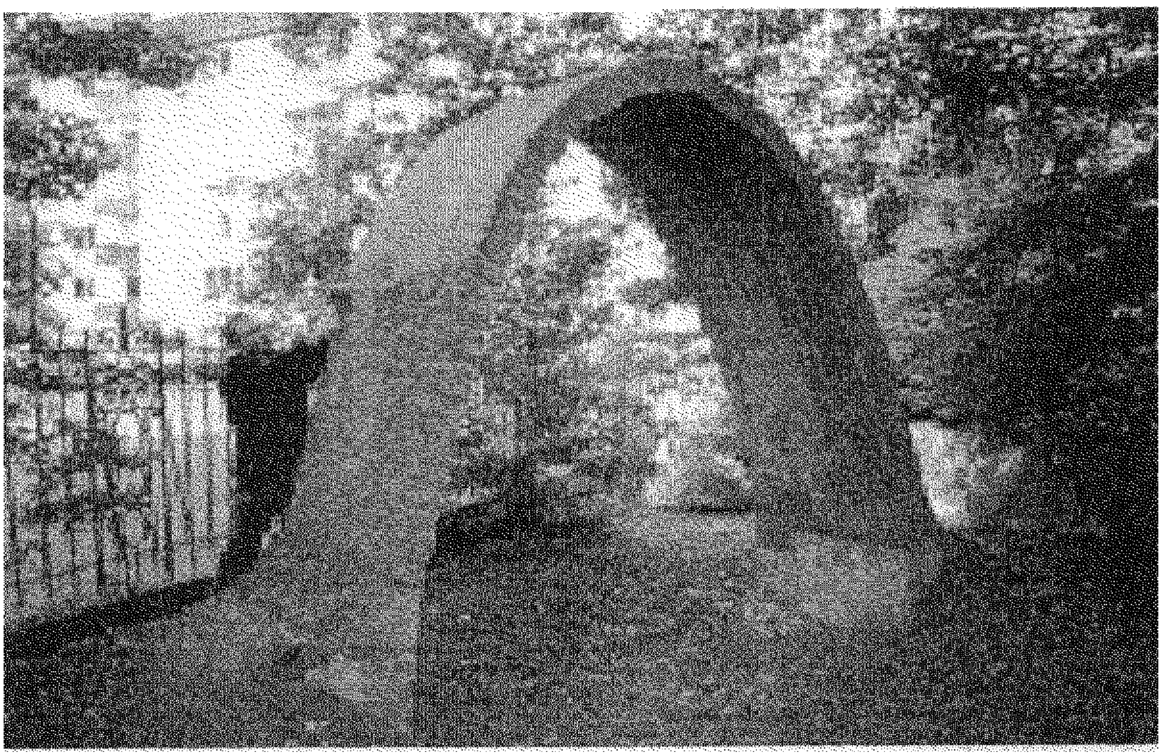
15-5 Proposal for an earthquake resistant vault structure for India



15-6 Production of special adobes

15-7 Construction of the arc with split bamboo





15-8 and 15-9 Earthquake resistant vault reinforced with bamboo
FEB, Kassel, 2001