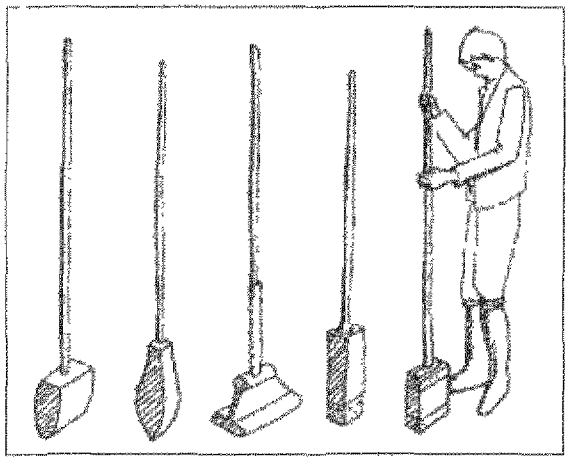
6. Rammed earth walls

6.1 General

In the rammed earth technique moist earth is poured into a formwork in layers 10 to 15 cm thick and compacted by ramming. The formwork consists of two parallel panels, separated and interconnected by spacers, see Fig. 6-1. By comparison with adobe masonry, rammed earth walls provide more stability as they are monolithic.

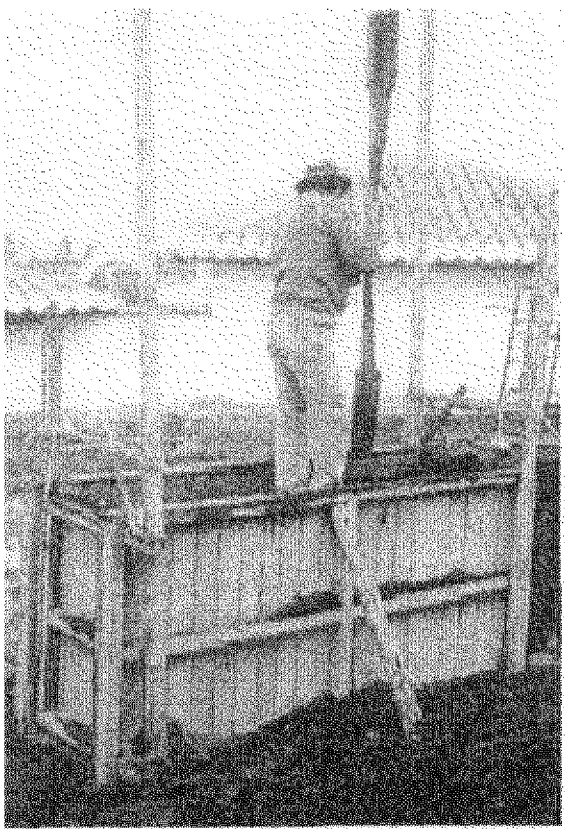


6-1 Manual tempers (Minke 2001)

Traditional techniques use formwork with big wooden spacers, which cause openings and weak parts and often show horizontal shrinkage cracks between the layers, as the fresh layer on top of the old one shows larger shrinkage.

To avoid both disadvantages a special formwork was developed at the Building Research Laboratory (FEB), University of Kassel, which is spaced only at the bottom by a very thin steel bar and on the top above the wall, see Fig. 6-4.

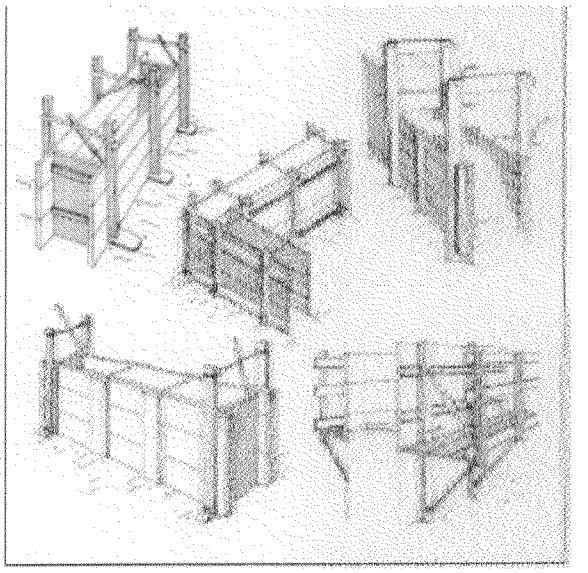
Traditional techniques use manual tampers with conical or flat heads, see Fig. 6-1. Conical tampers give a better bond between the different earth layers, but need more time. It is preferable to use a tamper with two heads, one with a round surface and the other with a square surface, see Fig. 6-2. The square tamper has to be used at the borders of the formwork. Pneumatic tampers and stronger formwork, as used nowadays for instance in Australia, can reduce the labor input by the factor of 10. (For further details see: G. Minke: Earth Construction Handbook. WIT Southampton, UK 2000)



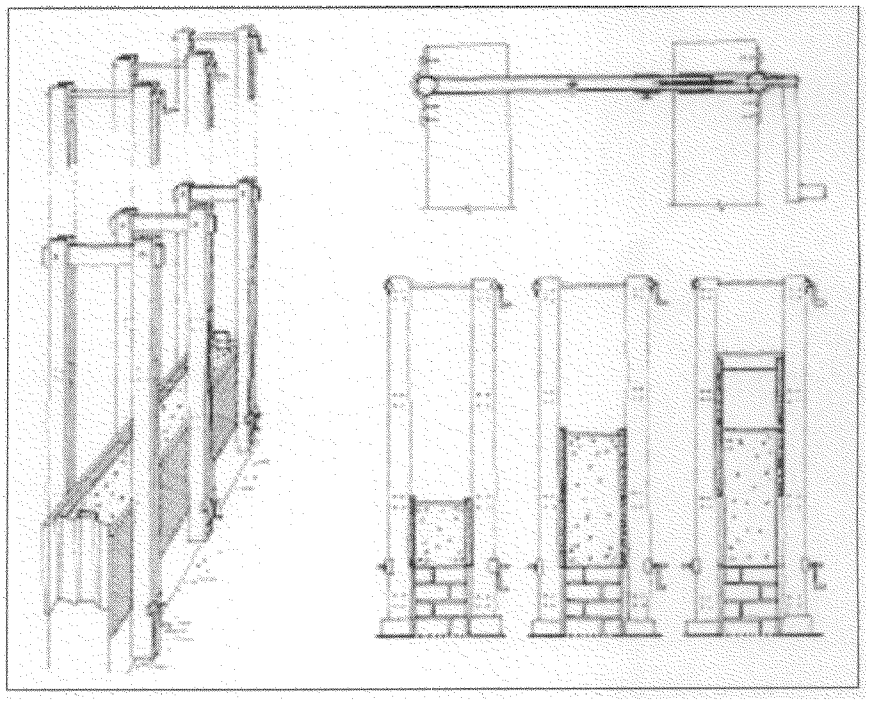
6-2 Temper with two «heads», used in Ecuador (Minke 2001)

6.2 Stabilization through mass

Rammed earth walls 60 to 100 cm thick, which are not too high, can withstand horizontal seismic shocks without additional old age withstood all earthquakes, whereas newly constructed houses next to them collapsed, even when they were built with bricks and a concrete ring beam. As thick rammed earth walls are too labor-intensive and no longer affordable nowadays, new structural solutions have to be used, as set out in the following chapters



6.3 Formwork for rammed earth (Minke 2000)

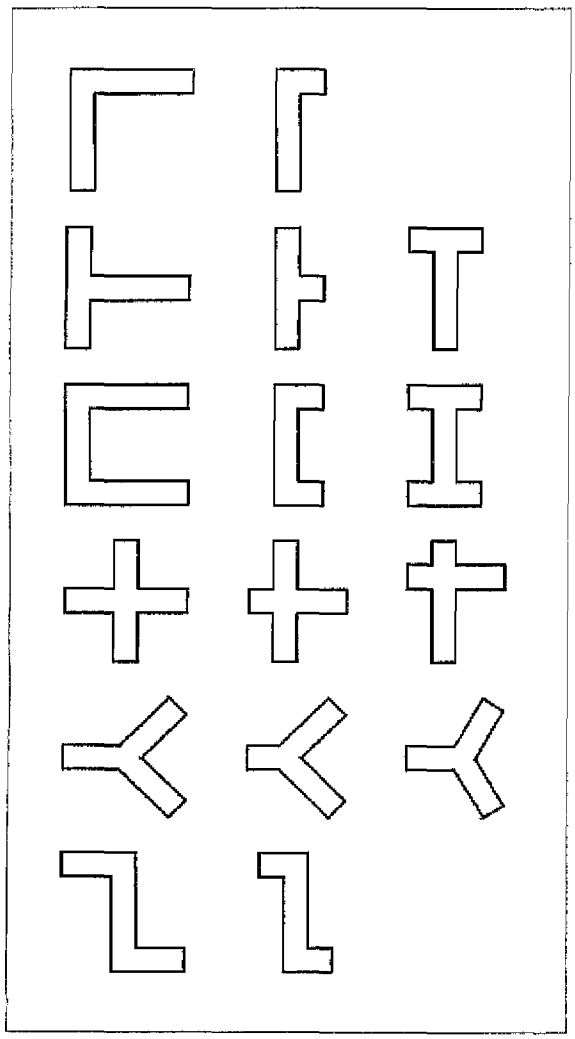


6-4 Climbing formwork (Minke 2000)

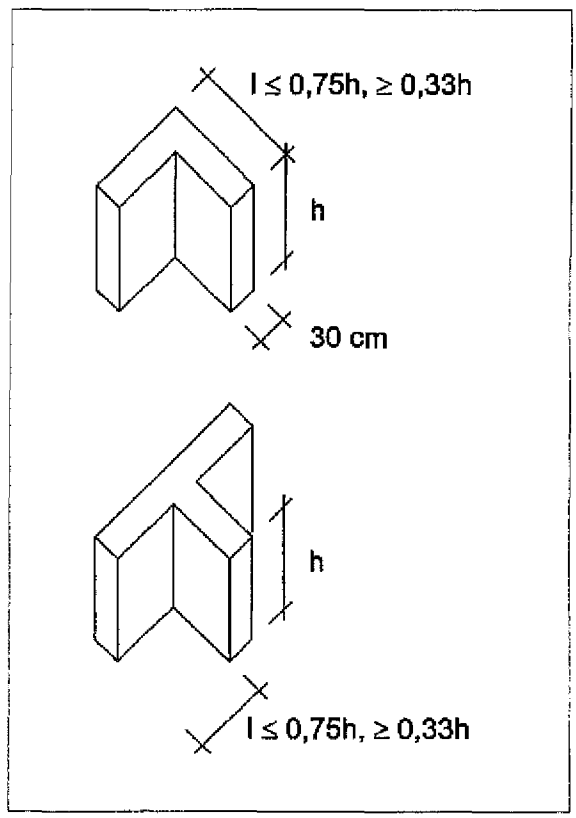
6.3 Stabilization through shape of elements

A simple solution for stabilizing rammed earth walls of lesser thickness is to use elements in the shape of L, T, U, X, Y or Z (Fig. 6-5). Due to their angles they show better stability against lateral forces. If the wall is 30 cm thick, the free ends of the elements should not be longer than 3/4 and not shorter than 1/3 of their height, see Fig. 6-6. This minimal length is necessary to transfer the loads diagonally to the plinth or foundation. If the free ends are longer than 3/4 of its height, they should be stabilized by another angle. If the angle is well fixed on the bottom to the plinth and on the top to a ring beam, it can be larger or higher. Nevertheless, the height should not be more than 8 times the width, see Fig. 6-7.

The forces perpendicular to the wall are transferred into the angle which is parallel to the direction of the force. This means it is transferred versus a moment which creates stress concentration at the inner corner of the angle.



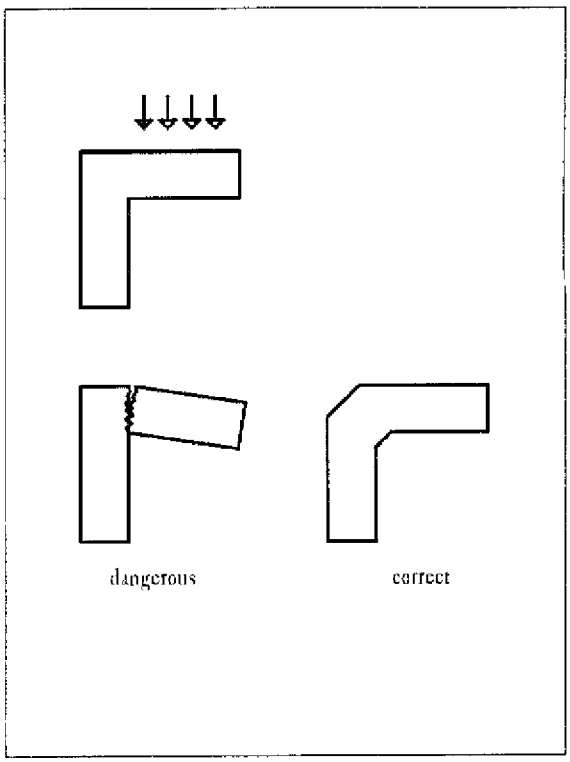
6-5 Wall elements stabilized by their shape



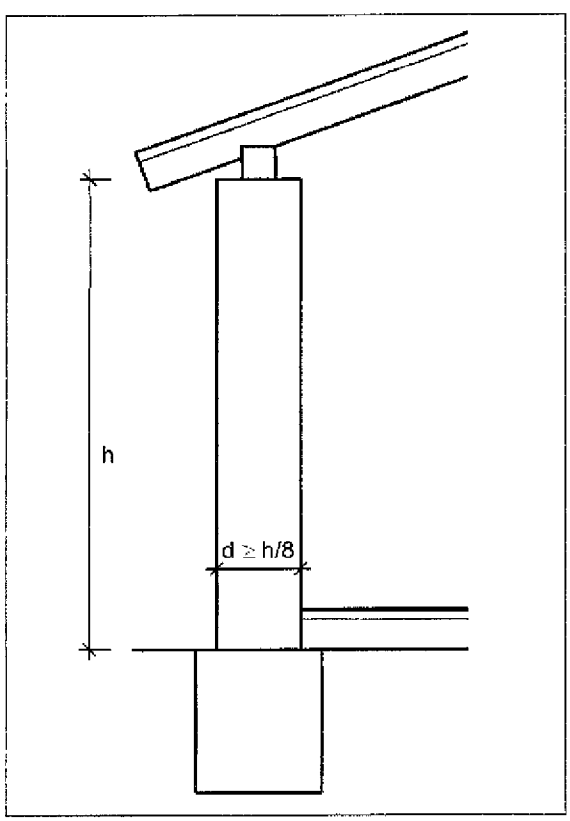
6-6 Recommended proportions

Therefore it is advisable to enlarge the section at this corner, shown in Figs. 6-8 and 6-9. Fig. 6-12 shows different proposals for plans utilizing angular elements.

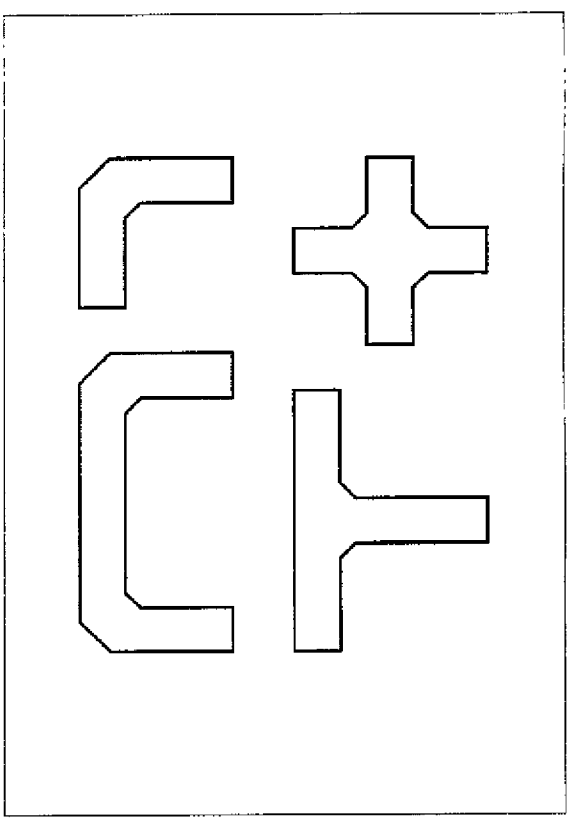
To improve lateral stability the joint of two elements should be formed with tongue and groove, see Fig. 6-10. However, in order to obtain a more flexible structure, elements with shorter length and no tongue and groove joint should be used (Fig. 6-11), if the elements are well linked to a ring beam above and to a plinth below. This kind of solution is used in the project described in chapter 6.4



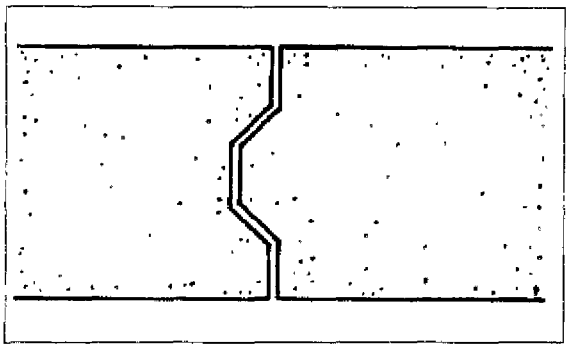
6-8 Corner solution



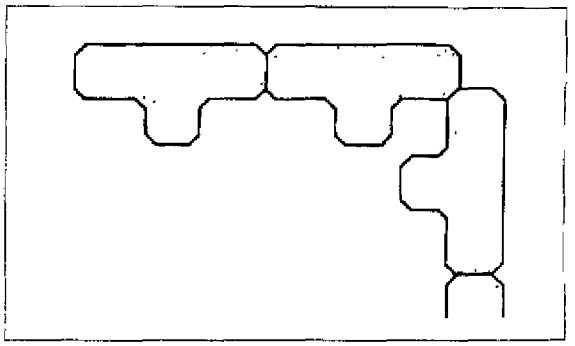
6.7 Expedient proportion of wall



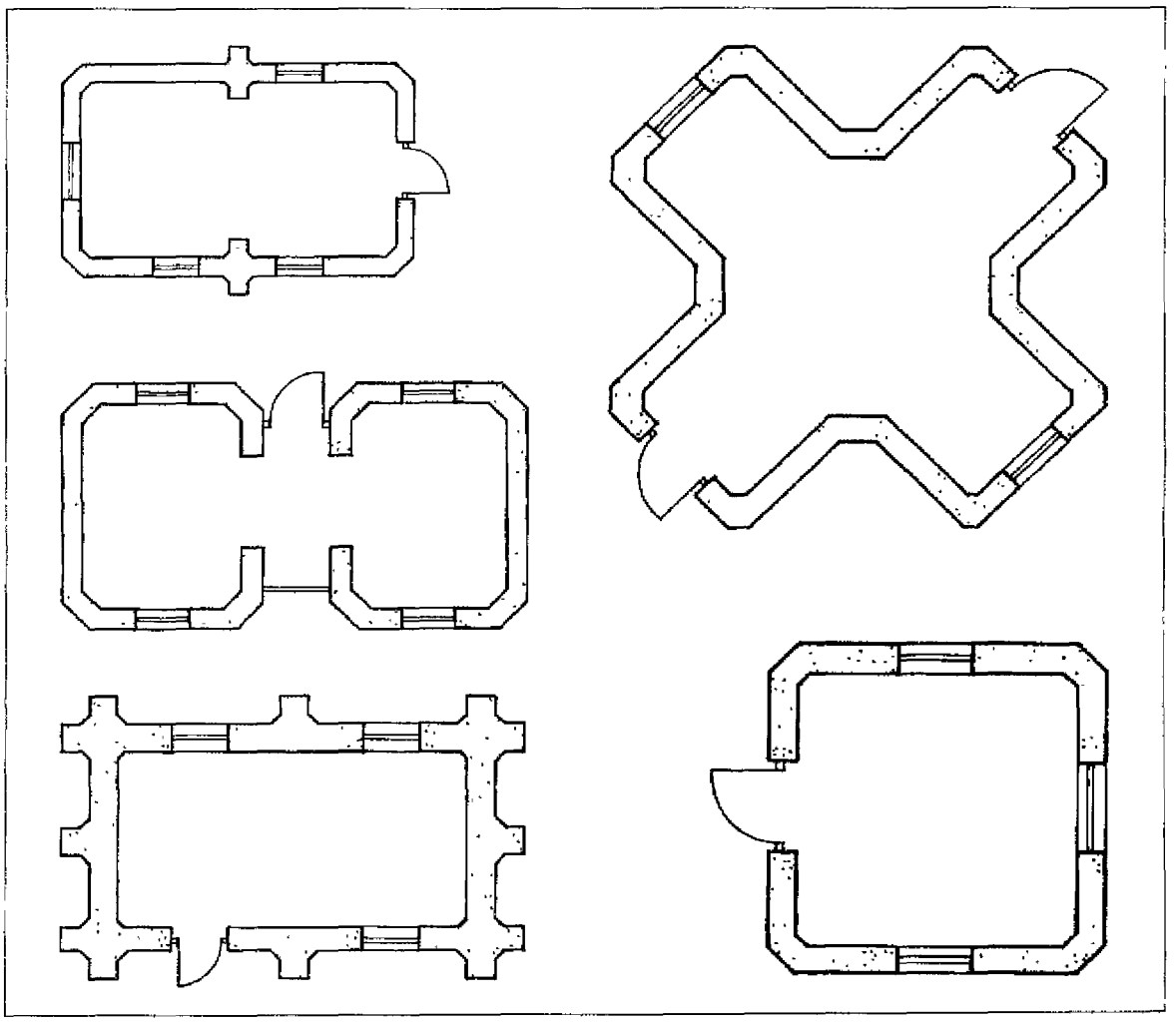
6.9 Elements with correct corner details



6-10 Joint with lateral stability



6-11

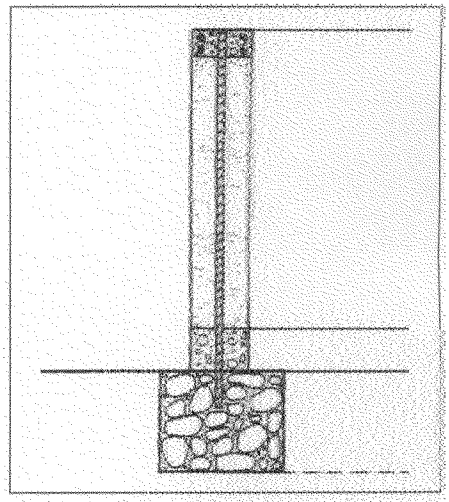


6-12 Proposals for simple plans utilizing angular elements

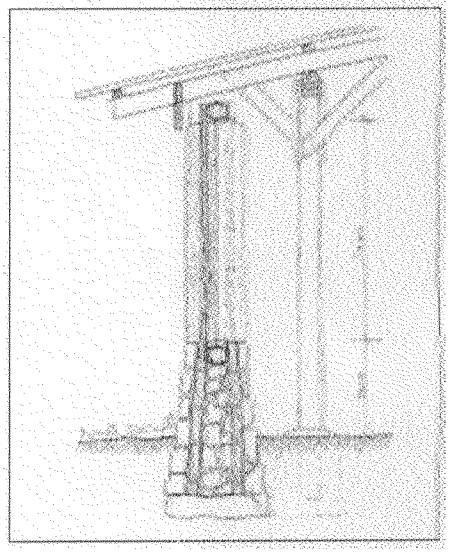
6.4 Internal reinforcement

One method of stabilizing rammed earth walls against horizontal forces is to use vertical rods of bamboo or wood inside the wall. These elements should be fixed to the foundation below and to a ring beam above, see Fig. 6-13. Horizontal reinforcement elements usually weaken the structure and lead to horizontal cracks, as shear forces cannot be transferred by the rods, since the bond between these elements and the earth is very poor. Furthermore in practice it is difficult to ram the earth well underneath these elements, due to their elastic behavior when hit.

A new system utilizing bamboo as vertical reinforcement for element-type rammed earth walls was developed in 1978 at the FEB and successfully implemented together with the University Francisco Marroquin (UFM) and Centre of Appropriate Technology (CEMAT), both from Guatemala. The low-cost housing prototype built is depicted in Figs. 6-14 to 6-19. The wall elements were rammed in a metal T-shape form, 40 cm high, 80 cm large and 14 respectively 30 cm wide, see Figs. 6-16 and 6-19. The rib plays an important role in the stabilization of the element against horizontal forces, as it acts like a buttress. The elements are reinforced by 4 vertical bamboo rods of 2 to 3 cm diameter. The bamboo rods were fixed at the bottom to the horizontal bamboo ring beam and the stretched vertical rods of the plinth, see Fig. 6-14.



6-13



6-14