OBSERVATIONS AND TRIALS ON TWO METHODS OF CONNECTING POLE TIMBERS TO FORM STRUCTURE FRAMES

by M Herbert

SUMMARY

In many developing countries pole timbers provide an inexpensive source of structural timber and are widely used for traditional buildings. Sources include mangrove swamps and thinnings from eucalyptus or softwood plantations. However, in many situations craft methods, for constructing joints (such as the use of sisal rope or strips of bark), do not permit the full strength of the poles to be utilised. Improved low cost connections could lead to stronger structures and more economical use of materials. Additionally better resistance to imposed forces such as those caused by hurricanes and earthquakes and the ability to support heavier more durable indigenous roof coverings could stem from such improvements.

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The paper reports on trials, conducted in Kenya and Sudan to examine the merits of nailed flitch plate joints for the construction of portal frames and roof trusses and halved pole construction for roof strusses. Aspects of design and manufacture are discussed and the paper concludes that the new connection methods could usefully be applied to short span portals as might be used in houses and also to the longer span structures of other buildings in rural areas.

This work has been funded by the Overseas Development Administration as part of the United Kingdom programme of technical cooperation with developing countries and is aimed at improved ways of using indigenous materials.

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INTRODUCTION

Improved techniques should aim at producing inexpensive, simple and easily understood connections which require only simple tools and moderate skills. Such connections should be able to cope with variations in pole diameter, be applicable to a wide variety of frame forms, use materials which are readily available and ideally allow members to be connected in the same plane.

Two methods aimed at achieving these objectives have been investigated by the Building Research Establishment in collaboration with the Kenyan Housing Research and Development Unit and the Sudanese Forest Research Institute.

POLE TIMBERS

Circular sections of timber are not ideal to resist bending. However they are well suited to framed structures where they are mainly subjected to direct tension and compression. The strength of pole timber is less affected by the presence of spiral grain and knots than sawn timber due to continuity of the grain. Because they contain a high proportion of sap wood, small diameter poles are generally more susceptible to decay and insect attack than sawn structural timbers which contain a higher percentage of heart wood. However, as sap wood is often more permeable than heart wood, preservative treatment can be easier to achieve.

The cut ends of poles are particularly susceptible to damage from shrinkage due to drying. The splitting shown in Plate 1 is typical of the defects due to this cause and can weaken connections near the ends of poles. This must be considered when connections are made and the defective ends cut off before use.

THE CONNECTIONS DEVELOPED

Research has been carried out to investigate two methods of connecting the round pole timbers; the use of the nailed flitch plates and the use of halved poles. (Reference 1) Both are primarily intended for connecting poles to form structural frames for buildings but there may be other applications.

The nailed flitch plate connection (NFP) Figure 1 consists of mild steel sheets inserted into longitudinal saw cuts in the timber poles and connected to them by nails driven through the timber and the steel at right angles to the plate. Trials have shown that round wire steel nails down to 10 swg (3.25 mm) can be driven through mild steel sheets up to 1 mm thickness without pre-drilling. Thicker sheets require drilling or the use of hard steel nails.

The halved pole method uses the flat faces formed by cutting the poles along their centre line to provide mating surfaces which can be joined by conventional nailing, bolting or timber connectors. The method is illustrated in Plates 2 and 4.

FEASIBILITY TRIALS

Following preliminary work at BRE, fabrication and exposure trials were carried out in Nairobi and Khartoum using locally grown pine and eucalyptus poles. 6 m (20') span trial roof trusses and 3.7 m (12') portal frames were made from freshly cut poles using locally made wire nails. See Plates 3 and 4. All these poles were found to be easy to saw and nail when green, but eucalyptus was difficult to nail when dry (15% moisture content below) and would require pre drilling if dry poles were used.

The specimens were exposed in Nairobi and Khartoum to examine the effect of exposure and long term loading. Loads were applied at mid points to represent the estimated safe working load of the structure. After one year - as would be expected, the moisture content in the timber had decreased considerably down to 3% in Khartoum and 12-15% in Nairobi. The joints had opened slightly but there was little splitting either at the ends of the poles or at the nail fixings. All nails appeared to be holding well, and in the eucalyptus specimens were impossible to withdraw. The cut faces had become slightly curved, presumably due to drying shrinkage, see Plate 5. This observation coupled with the absence of splitting at the cut ends suggests that the longitudinal slitting or halving of small diameter poles relieves the stressed due to shrinkage and prevents random splitting which would affect the integrity of the connection. Sustained loading, equivalent to the estimated safe working load, had been supported without any apparent stress and there was no change in the initial deflections.

ULTIMATE LOADS TESTS

Loading tests to failure were caried out at HRDU Nairobi on two NFP trusses and one halved pole to determine their behaviour under load, mode of failure and the order of ultimate load. All these trusses tested were made from Kenyan grown Pinus Radiata poles with diameters varying from 4-6 inches. This was the weakest of all the timbers used and therefore likely to give the lowest strengths. The trusses and method of loading are shown in Figures 1, 3 and 4. Under test trusses were restrained laterally at their node points.

NFP Trusses

The total loads at failure were similar for both type 1 (king post) and 2 ('W') - 8000 kg and 7000 kg respectively. As the trusses approached ultimate load slight buckling occurred in the plates connecting the members in compression, accompanied by tightening of the meeting ends of the compression members. In both trusses, ultimate failure occurred in the steel plates, see Figures 8 and 9. Failure was gradual and signs of stretching distortion and bearing failure in the steel plates were clearly apparent before ultimate collapse occurred. While this mode of failure has much to commend it, especially in earthquake areas, the test results suggest that fewer nails could have been used and the length of plate required to accommodate them then reduced at some connections. A small series of short pull-out tests were therefore conducted to determine the number of nails required to resist the ultimate load which could be taken by the plates. Typical test specimens are shown in Plate 6. The results indicate that 10 number 10 gauge wire nails are sufficient for a 100 mm (4 inch wide) 1 mm (20 gauge) sheet and 15 nails for a 150 mm (6 inch) wide plate, and suggest that the enclosed length of the plate could have been reduced by some 100 mm (4"). While such economies are worthwhile seeking because of the relatively high cost of the steel, these must be balanced against the skills and degree of supervision available for construction of the truss, also the possibility of combined stresses occurring at connections due to rotation must also be considered.

The halved pole trusses

As would be expected, from a frame composed of asymmetrical members which are not in the same plain, there was a tendency for the top compression member to buckle sideways as the loads increased. However, ultimate failure occurred at one of the supports, the most highly stressed connection, due to bearing failure of the timber and bending and pulling out of the nails. The mode of failure suggests that this could be improved by providing stronger connections; for example bolts with toothed plates at the most highly stressed joints.

PORTAL FRAMES

No tests to destruction have been carried out on portal frames. However, short and long term loading tests were carried out in Nairobi on the design shown in Figure 5, which was made from 4 inch diameter eucalyptus globulus poles. The tests indicate that the maximum point loads (applied at each of the quarter points of the span) which the frame could sustain without creep, were 120 kg. In many circumstances this is sufficient to support a corrugated steel roof when the frames are spaced suitable centres, and confirms observations made on a similar structure constructed at BRE. Plate number 7.

A valuable property of the nail flitch plate connection when used to resist bending forces, as in portal frames, is its ability to sustain loads after gross distortion. This characteristic of energy absorption suggests that it could be applied with advantage to structures in earthquake and hurricane areas. This property is illustrated in Figure 6, which shows the load deflection curves derived from bending tests on 1.2 m (4') long 100 mm (4 inch) diameter NFP connected beams.

DESIGN CONSIDERATIONS

The tests gave results similar to those predicted by calculation and suggest that conventional structural design procedures are appropriate for both the halved pole and the NFP connections. However, because of the variable nature of the skills and materials available in developing countries, it is advisable to confirm the validity of designs by tests. These can be of an unsophisticated nature as illustrated in Plate 8.

Of the three materials used, timber, nails and steel sheet, the latter is likely to have the most consistent performance. It is therefore reasonable to use a lower factor of safety for this material than for the others, which are less consistent, a practice which accords with the desirability of gradual failure under ultimate load provided by the ability of the steel to yield.

For both types of connection, the nail spacings recommended in British Standard Code of Practice 112 (the structural use of timber in building) were found to be appropriate for all the timbers used, although due to irregularities in the poles, it was not always possible to conform strictly to regular nail patterns and allowance should be made for this in design. 1 mm sheet and wire nails were used for the components tested as these materials are frequently available in developing countries. However, if stronger connections are required the use of thicker plates fixed with either driven hard steel nails or mild steel nails or pins through pre drilled holes should be considered. Alternatively the number of 1 mm thick sheets can be increased.

Because most poles are tapered the areas available for plating and/or nailing vary. This can be used to advantage by positioning the larger ends at connections subject to the greatest forces such as at the supports.

As with all framed structures, sufficient bracing must be included in the overall design to ensure stability and prevent buckling of the members.

SOME LIMITATIONS AND PROBLEMS

Pole timbers are not always straight, their surfrace can be irregular and diameters vary. Frames made from poles are therefore best suited to claddings which can accommodate these variations such as tiles, renderings, and profiled metal sheets. Irregularities, both in the surface of the members and between members nominally in the same plane, can make the attachment of rigid or brittle sheet materials such as asbestos cement difficult, although the problems can be overcome to a limited extent, by trimming and packing.

Many of these inherent problems can be mitigated by using the straightest poles to support claddings, straining bowed members into line before fixing and setting out frames to overall or critical dimensions rather than centrelines.

The positioning of saw cuts for single NFP's can, with experience, be judged by eye. However, when two or more plates are used it is advisable to employ a guide or jig to ensure that the spacing of the cuts will be the same as in the other member to be joined. A simple method is illustrated in Plate 9.

It is a characteristic of round poles, particularly of eucalyptus poles, that when they are cut along their length the halved sections will warp away from the cut face. This creates few problems if the connections are made within a few hours of cutting. However, if longer delays are unavoidable halved poles should be stacked, and if necessary weighted, to prevent distortion and saw cuts for flitch plates restrained by temporarily nailing or clamping.

CONCLUDING DISCUSSION

Timber poles are an indiginous low cost structure material available in many developing countries. However traditional jointing methods lack durability and do not utilise the strength of the poles efficiently. More economic and stronger structures could stem from the introduction of durable and efficient method of connection provided they are simple, inexpensive and use locally available materials.

The investigation reported in this paper suggests two inexpensive simple methods of connecting round pole timbers to form strong structural frames and that these methods are appropriate for many developing countries. Of the two, the simplest is the halved pole. Its strength is adequate for many circumstances and the timber content is low, although pit or power sawing facilities are required for cutting the poles. However the NFP method provides high strength, a slow mode of failure and ease of construction with simple tools. But against this must be set the slightly higher cost and possible difficulties of obtaining steel sheet.

For supporting low pitched short span sheeted roofs, simple purlin construction may often provide the cheapest and simplest solution. For long spans and more steeply pitched roofs, trusses can often provide a cheaper option.

While the investigations reported here were confined to a limited range of structural forms the same methods of connection could be applied to a variety of structural frames, possibly including small bridge girders.

ACKNOWLEDGEMENTS

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The Overseas Development Administration of the Uk Foreign and Commonwealth Office and was undertaken in collaboration with The Housing Research and Development Unit in Nairobi and the Forest Research Intitute in Khartoum. The cooperation of these organisations is gratefully acknowledged.

REFERENCE

1. Structural connection for indigenous pole timbers by M R M Herbert. Proceedings of the International Conference Economical Housing in Developing Countries, Paris 25-27 Jan 83 p 149-153.

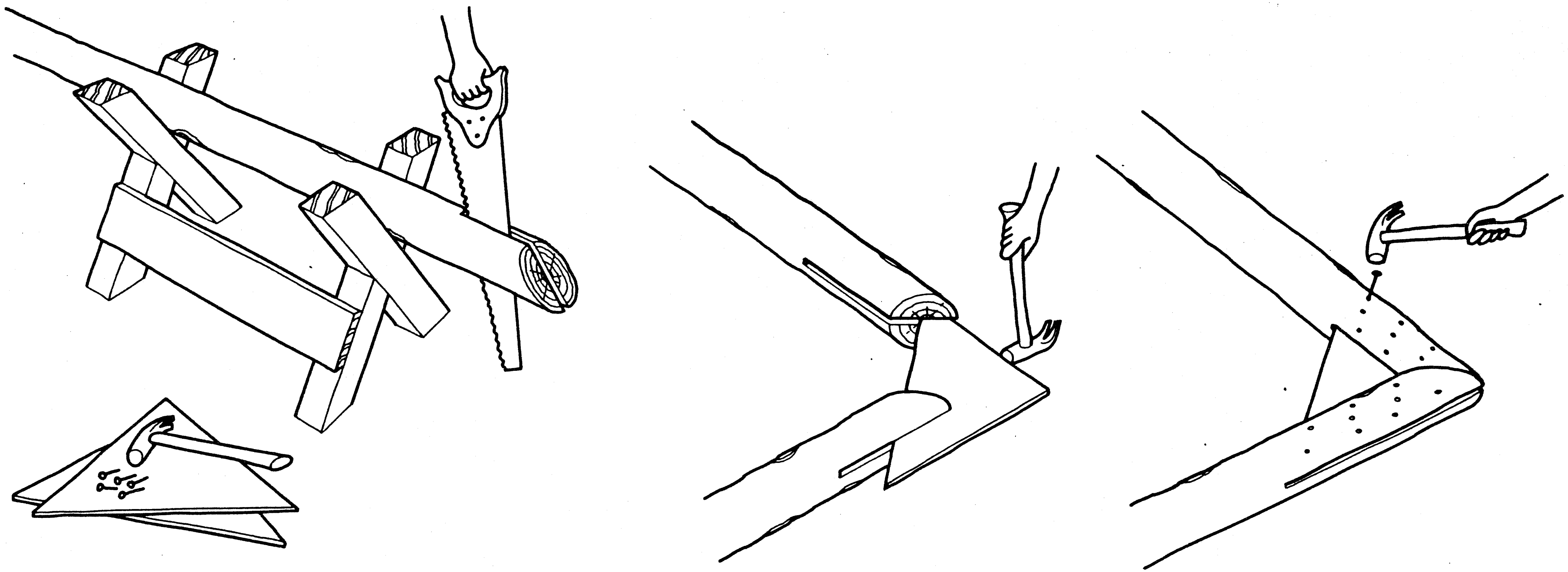

Figure 1 BRE method of connecting poles using a nailed steel flitch plate

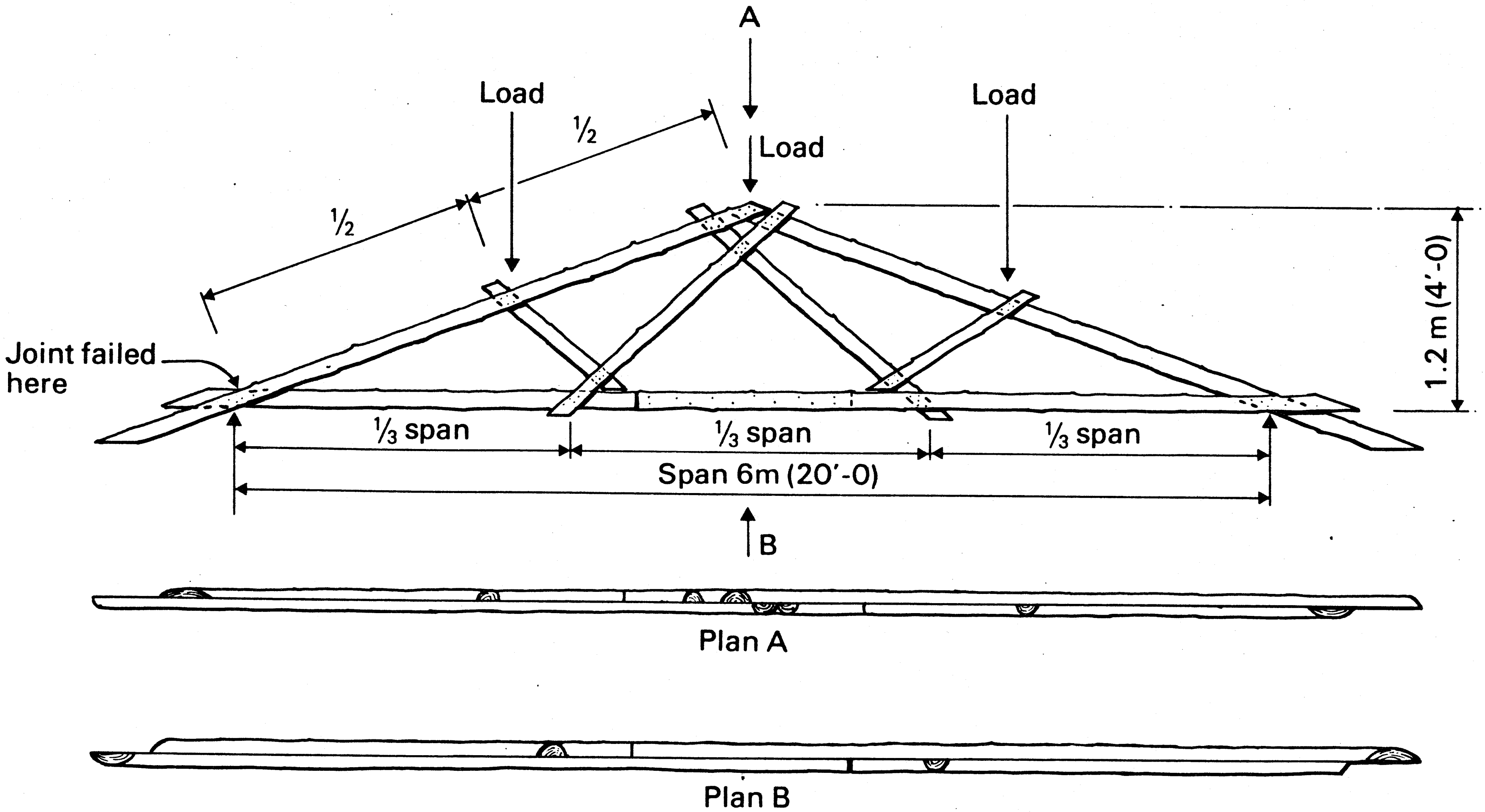

Figure 2 Halved pole truss

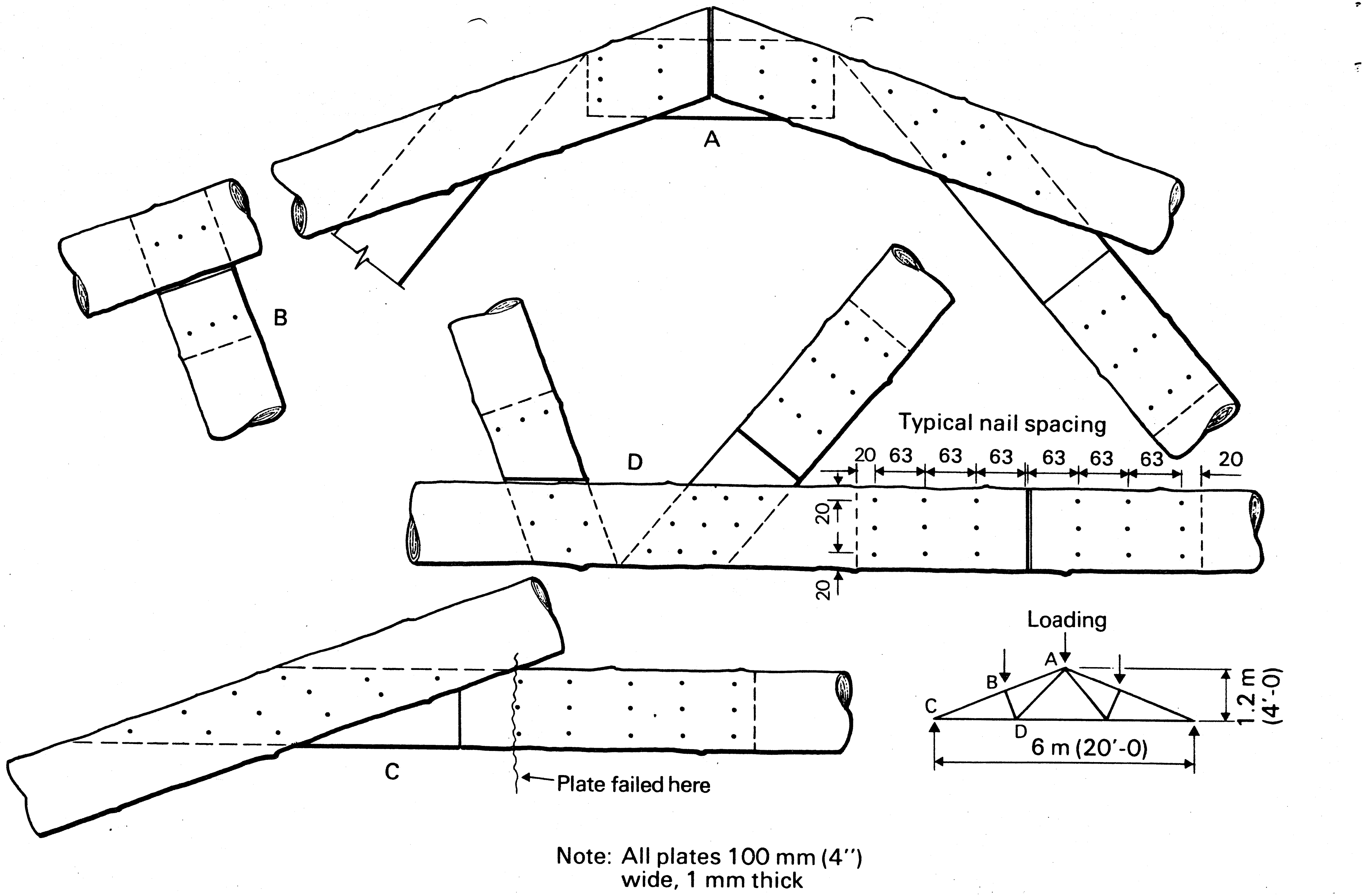

Figure 3 NFP 'W' or fink truss

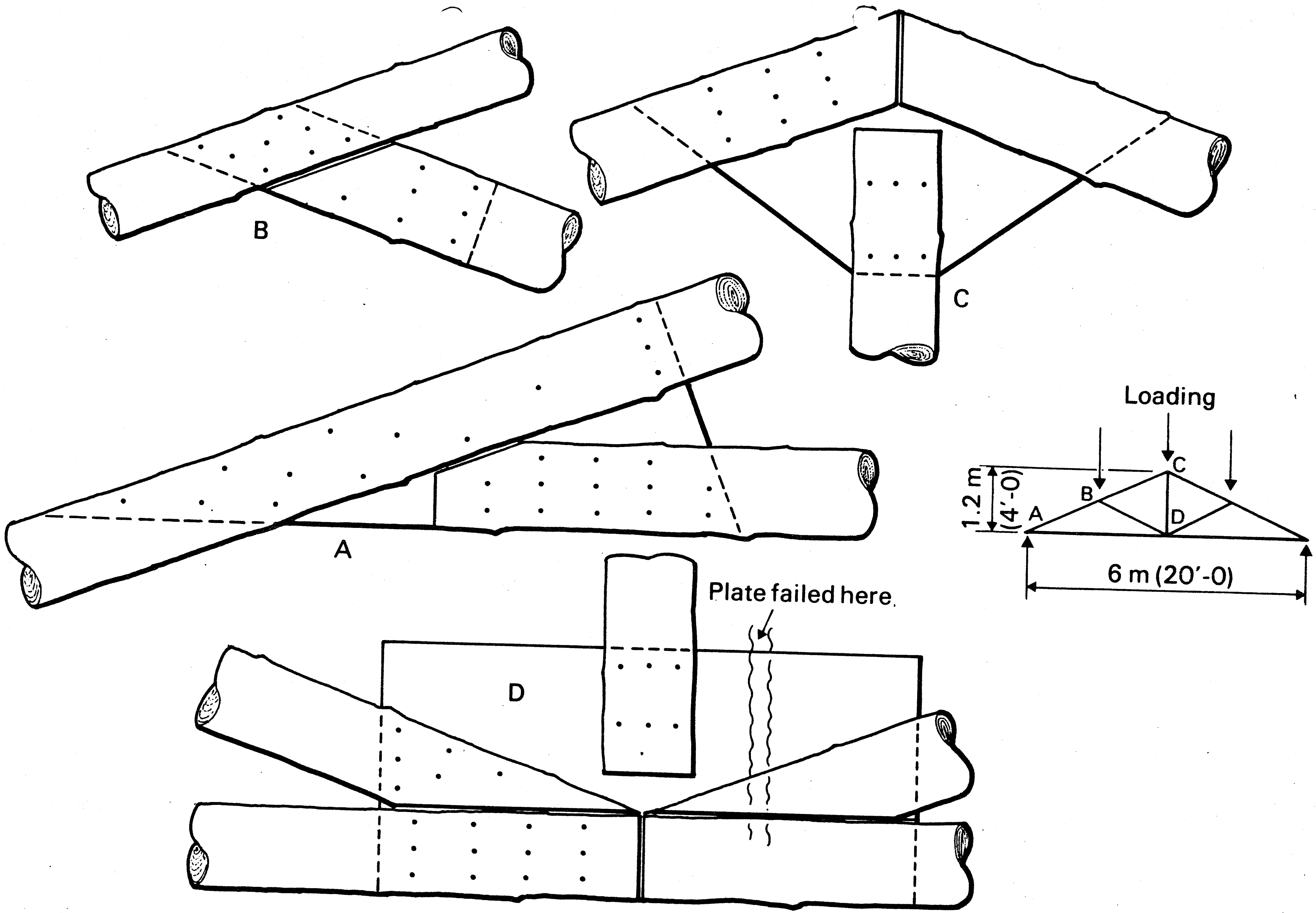

Figure 4 NFP king post truss

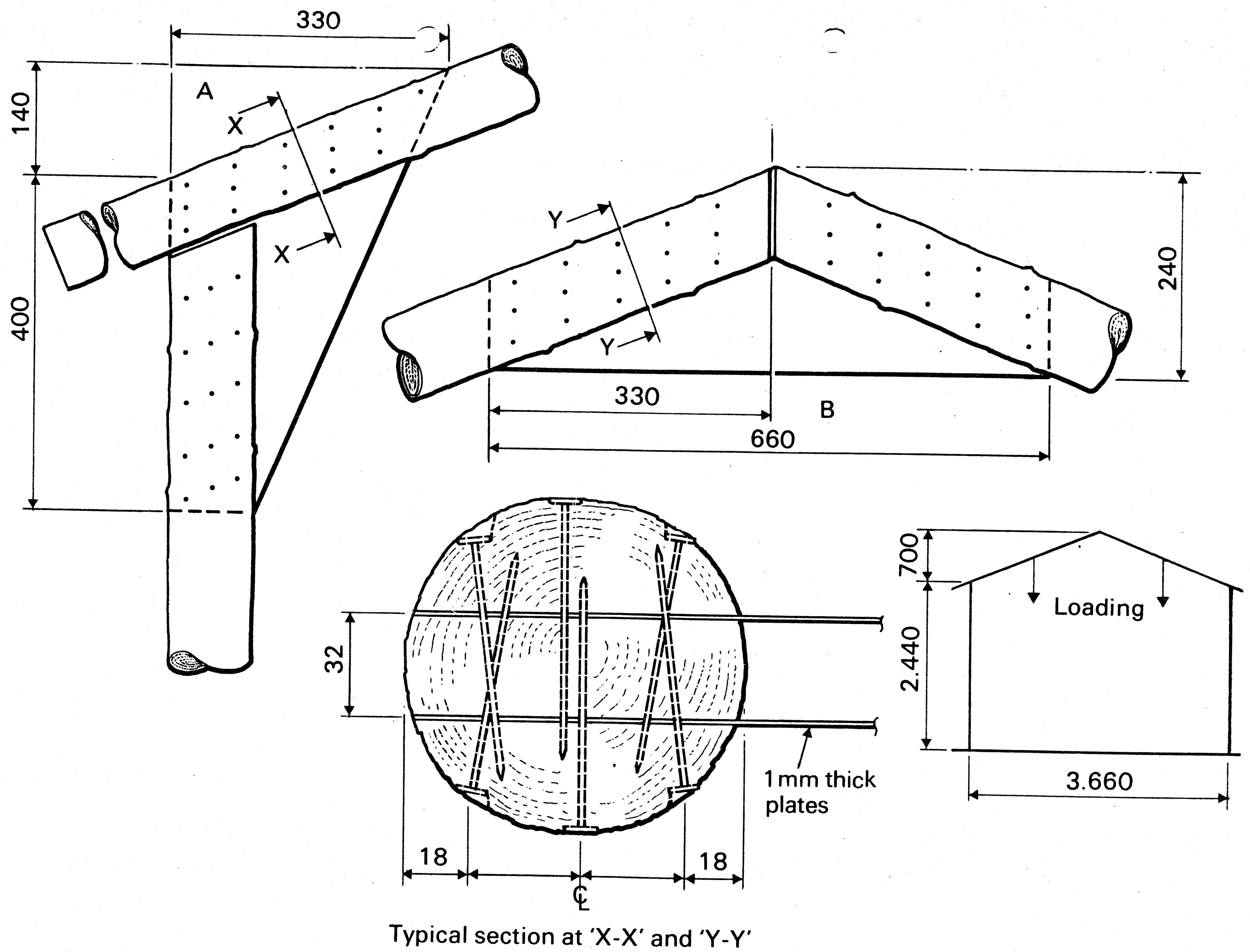

Figure 5 NFP portal frame

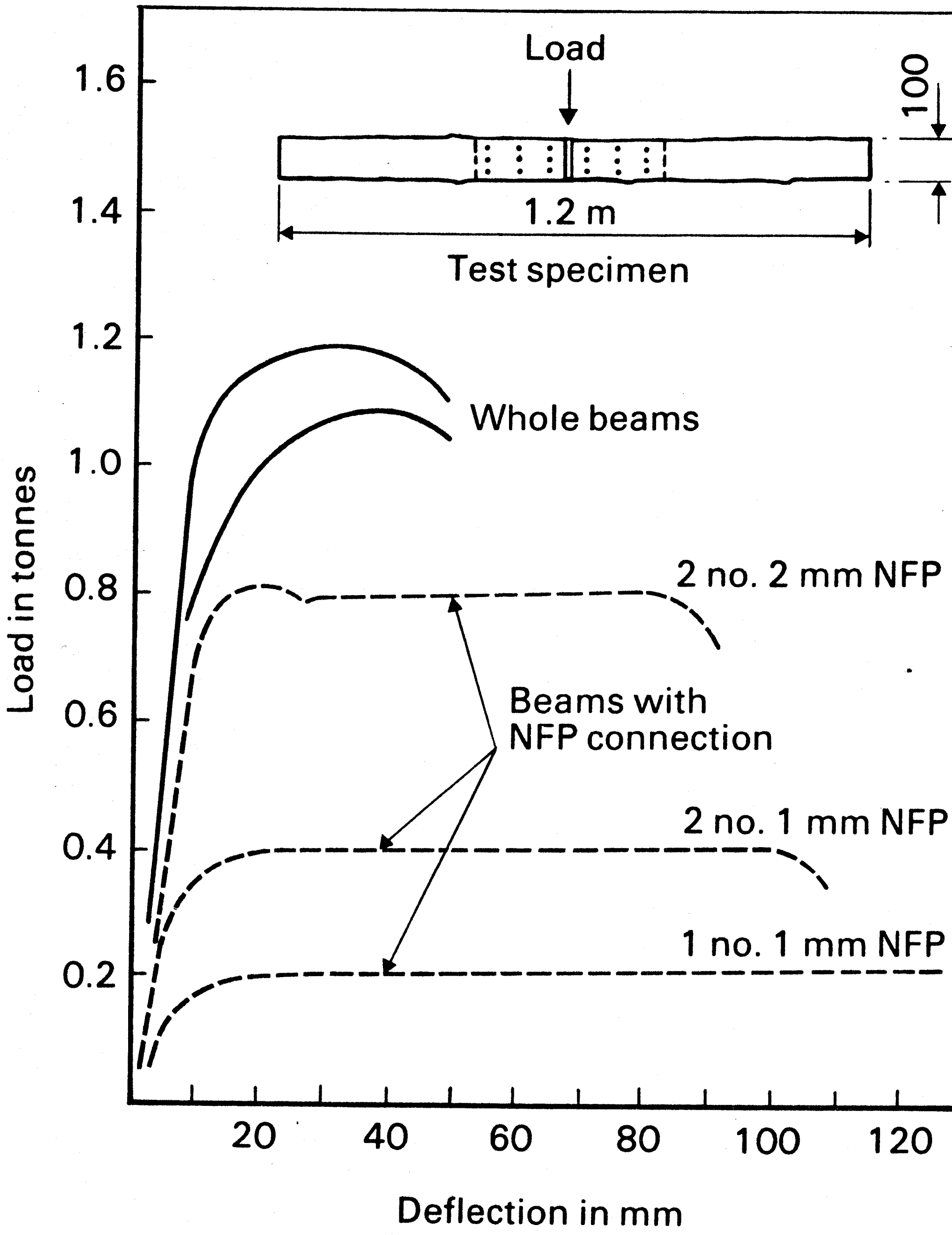

Figure 6 Typical load/deflection curves from bending tests on NFP jointed poles

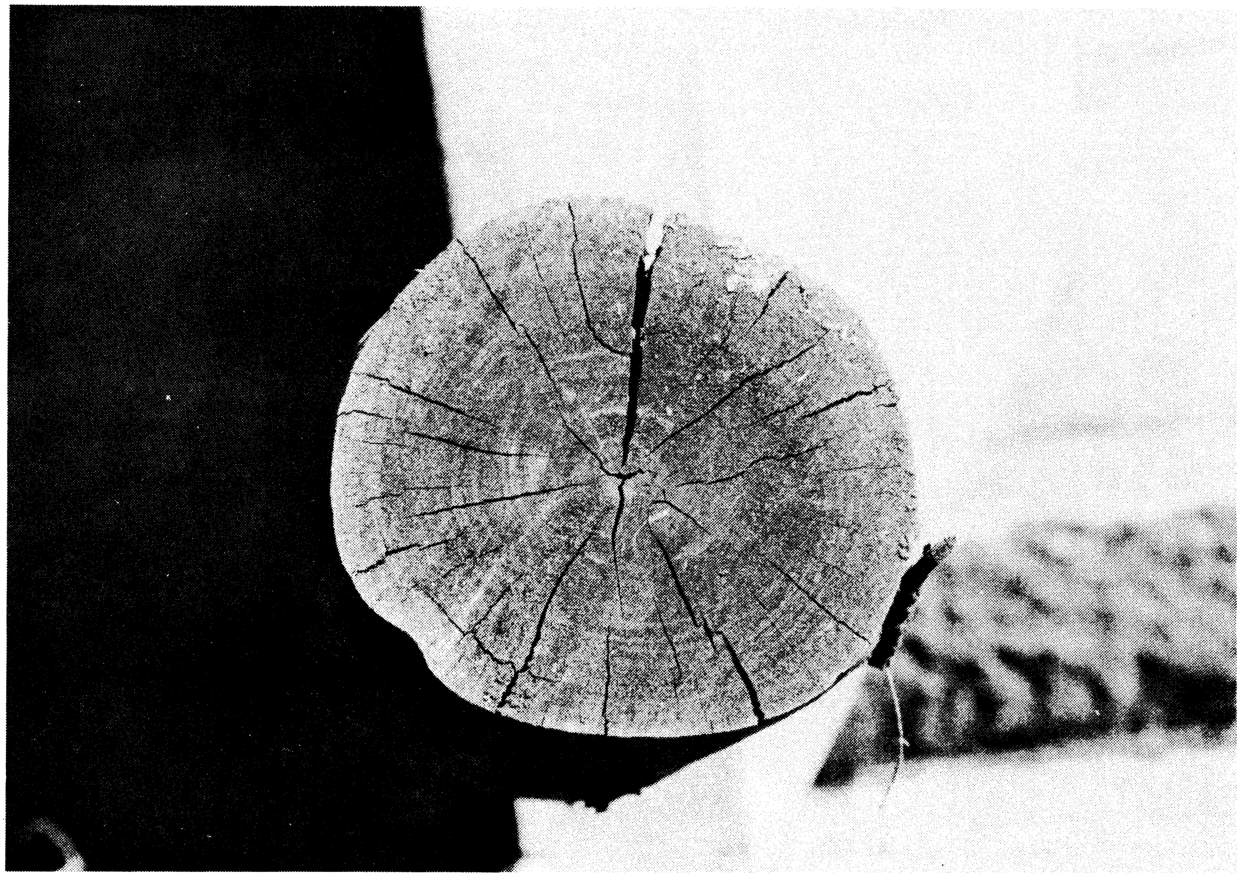

Plate 1 Cut end of a eucalyptus pole showing splitting caused by drying shrinkage.

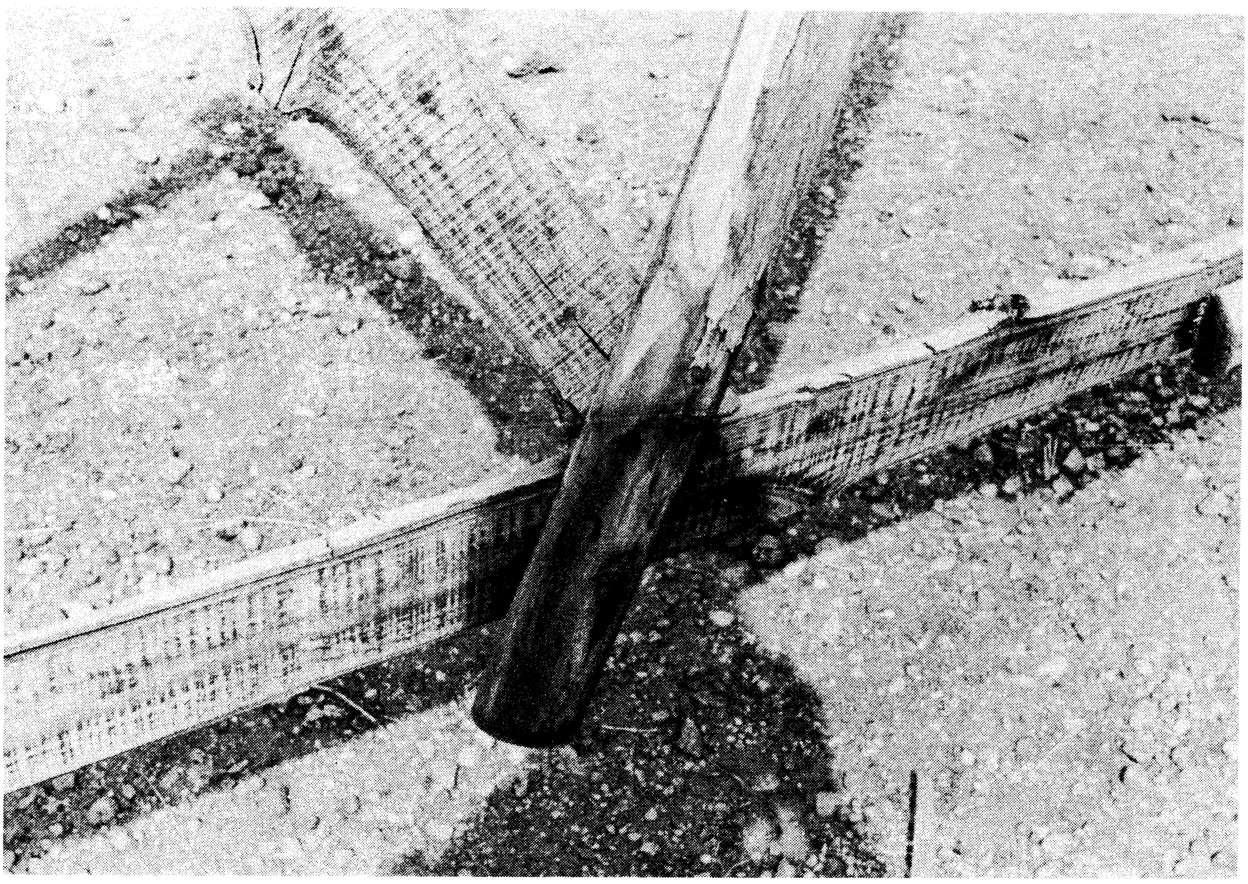

Plate 2 A halved pole connection after one years exposure. Khartoum.

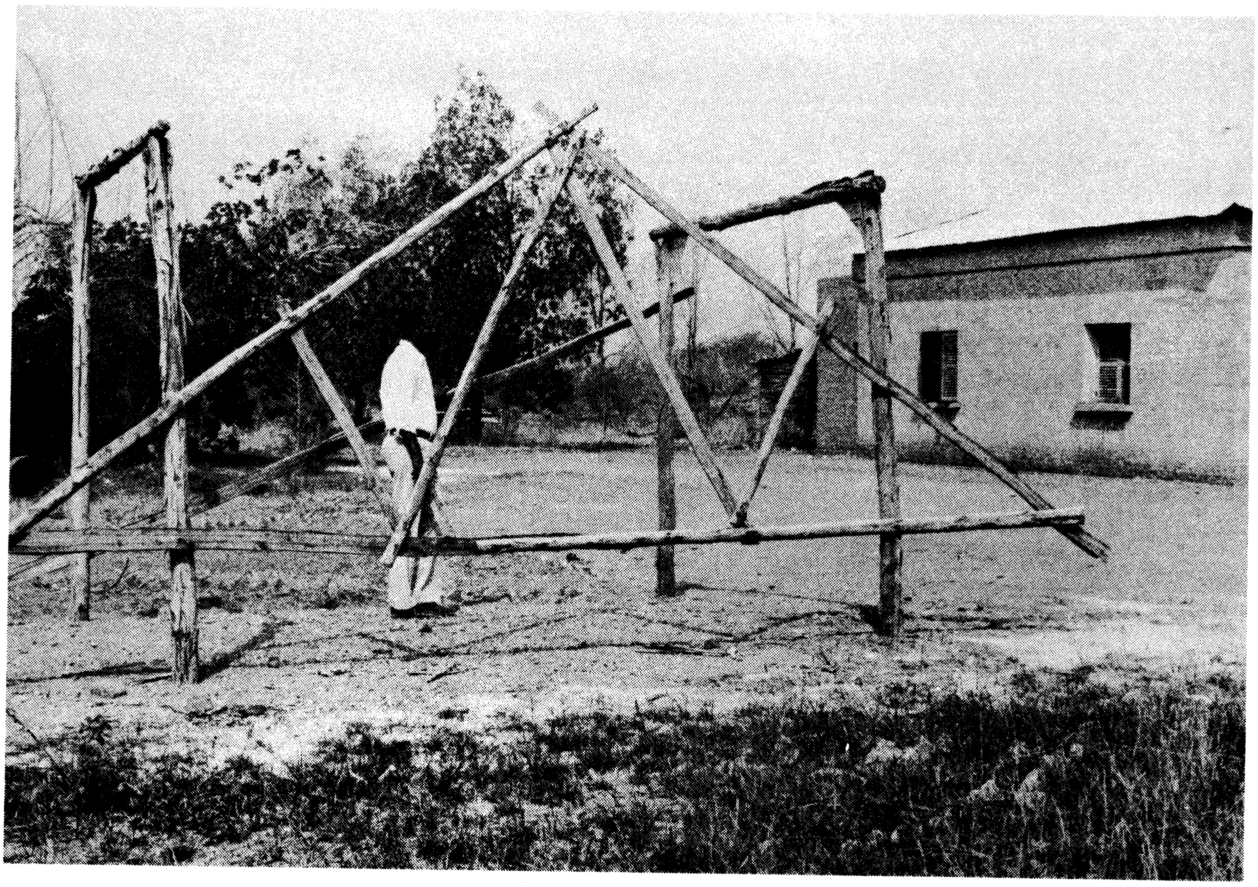

Plate 3 A halved pole truss and portal frames exposed at the Forest Research Institute Khartoum.

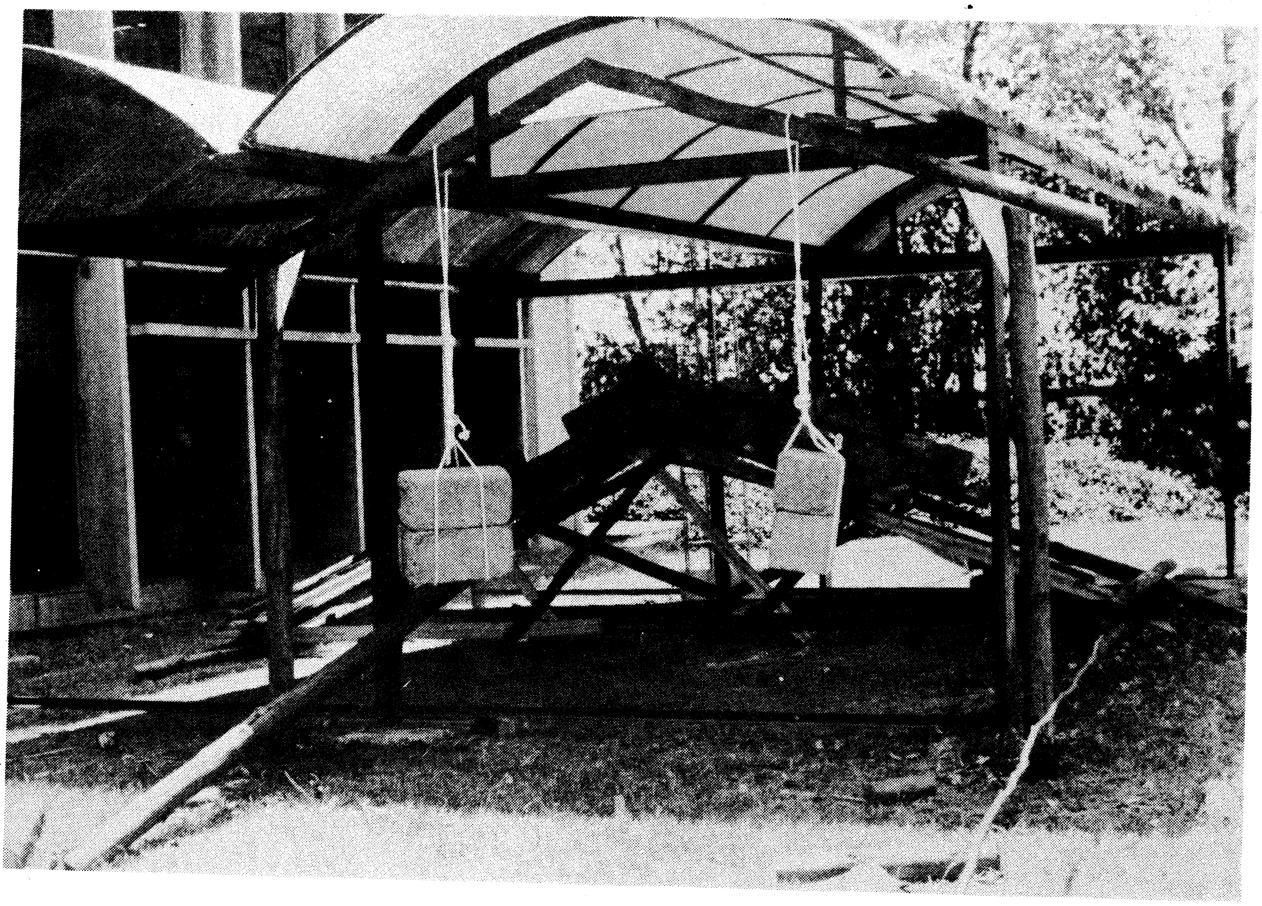

Plate 4 A portal frame and trusses under sustained loading trials at The Housing Research and Development Unit, Nairobi.

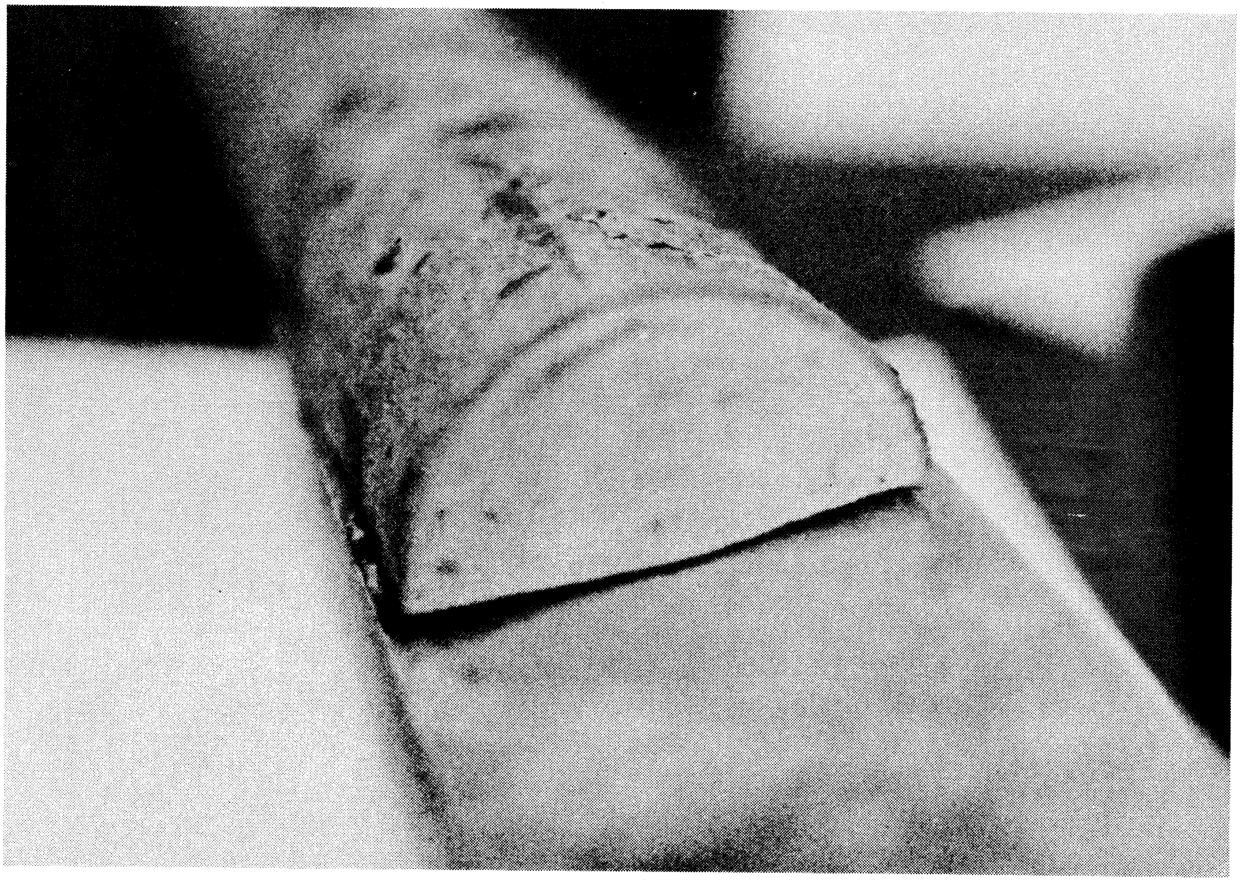

Plate 5 A N.F.P. test specimen after drying. Note curvature of cut face and absence of splitting.

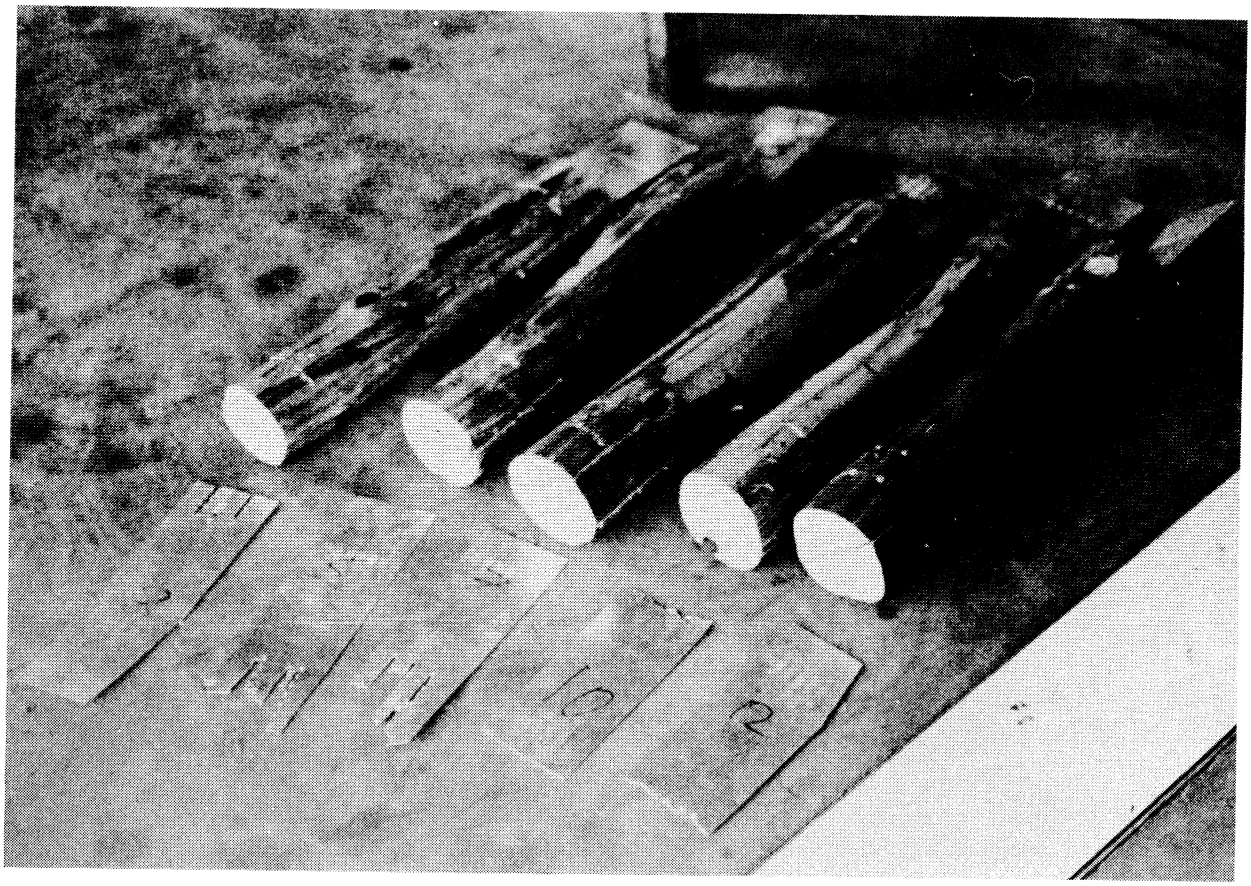

Plate 6 Specimens used in tension tests.

Plate 7 Portal frame structure at BRE.

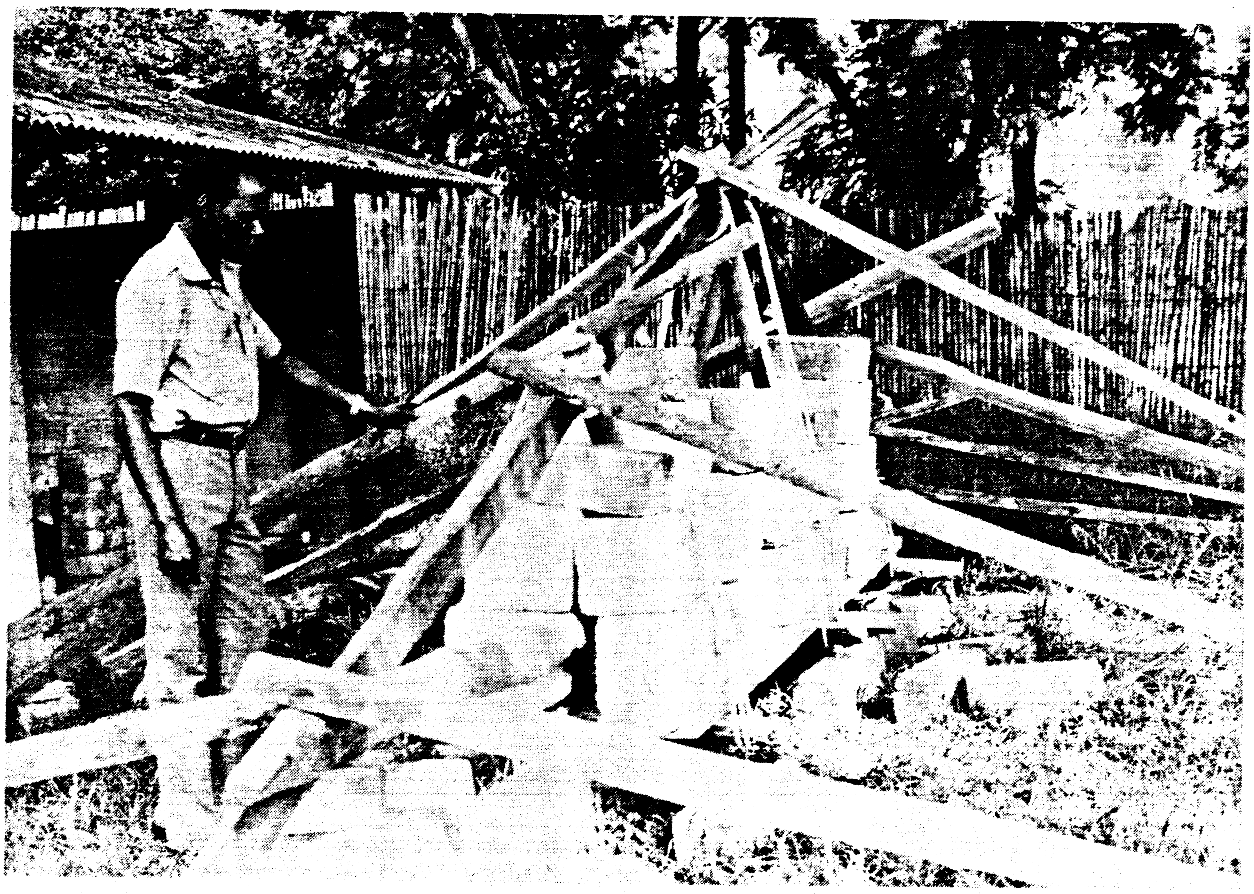

Plate 8 Loading tests on a truss at Nairobi.

Plate 9 Use of a guide for making parallel saw cuts