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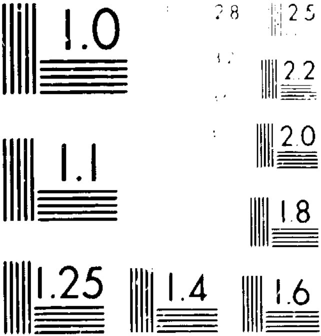
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GLUED LAMINATED WOOD*

by

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1. Historical background:

Heavily influenced by Philibert de L'Orme, many 16th Century architects employed nailed planks to form the rounded shapes required for building large arches or domes. This technique involved the use of planks joined vertically: the curve was obtained by planing and moulding the edge of the planks according to a pre-established model. Thus, the wood was mainly subjected to axial strain; but in view of the necessarily minimal thicknesses of the planks, and since it was impossible to guarantee the strength of the overall assembly, bending was a common occurrence, representing a considerable danger to the stability of the structure.

In 1832, Emy adopted the principle of forming curved sections, regardless of the size of the trees available by overlapping curved strips, aligned by brackets and bolts featuring large-diameter washers. This technique - employed on a number of occasions - failed to gain widespread popularity, due to the poor knowledge at the time about the rational use of timber, its mechanical strength properties, and its behaviour in relation to bolts.

In 1906, Hetzer decided to try and assemble planks by glueing them together with casein glue. During the next three decades, breakthroughs in the field of synthetic adhesives led to the discovery of a method capable of achieving results which would have seemed inconceivable at the start of the century. Initially reinforced with nails and bolts, glueing is today employed successfully without reinforcements, thanks to synthetic resins of outstanding effectiveness.

2. General:

The term "glued-laminated wood" (called "glulam" by way of abbreviation), is used to describe a compact material consisting of thin layers of sawn timber, featuring parallel grain, held together by special adhesives.

This modern utilization of wood features countless technical and economic advantages:

Size-wise:

Compared to traditional solid beam dimensions, by joining together an adequate number of layers, it is possible to achieve widths and lengths that are far greater than those dictated by the diameter and height of the available trees.

Shape-wise:

Shapes need not be restricted to straight ones alone; specific milling and curving operations easily produce curved shapes that could otherwise never be produced from a tree trunk.

With regards to wood defects:

In beams sawn from whole tree trunks, it is impossible to eliminate the knots in the wood; hence due attention must be paid to the negative effects these knots may have on the beam's mechanical strength characteristics. Instead, laminates are assembled in such a way that the knots are staggered, thus drastically reducing their negative influence within a given section. Hence, it is possible to select each lamina separately, and position those with knots near the longitudinal axis or near supports, i.e. where bending stress is less marked.

With regards to moisture content:

Even after months of treatment, solid beams still contain some degree of moisture; moreover, as the drying process continues, shrinkage leads inevitably to splits or cracks at the perimeter of the beam. Laminates, instead, can be dried to uniform perfection, below the threshold at which wood is subject to fungal attack: these will be thus in the very best condition to guarantee maximum dimensional stability and overall duration.

From the architectural and aesthetic viewpoint:

The various shapes, curved or whatever, that can be achieved by using glued laminates, may well solve any of the static or aesthetic problems existing with massive wooden structures: spans of even 100 meters can be built using glued laminates; moreover, they are ideal in the field of modular construction, especially in developing countries.

Economically speaking:

With respect to massive wooden structures that require standard sizes (at least in the manufacturing of beams), not always immediately available in a forest, glulam beams feature the important bonus of being made out of sawn timber supplied by any sawmill. The sawn timber can furthermore come in any length, even short, so that even low-quality scrap sections can be used. All these factors, that are already of considerable importance per se, are likewise valuable within the general framework of timber as a raw material, requiring the rational utilization of the whole output.

In a course devoted to the assessment of woodworking machinery, it would not be appropirate to describe the methods for calculating the properties of structures made of glued laminates; we will thus simply stress the fact that glulam structures are virtually as strong as structures made of solid wood.

Experience has, in fact, shown that if construction procedures are carried out in strict compliance with relevant specifications and regulations, working stresses can be increased by even ten percent: nevertheless, many experts advise the adoption of specific reduction coefficients, if the height of the section exceeds 30 cm, and the profile is not straight, i.e. when the curving of the sheets has introduced stresses. In this case, due attention must be paid to the relationship between sheet thickness and bending radius: the reduction coefficients drop from 0.93 if the thickness/radius ratio is 0.05 percent, to 0.85 if the ratio is one percent, and to 0.77 if the figure is 1.5 percent.

3. Manufacturing specifications:

Choice of timber:

Timber affected by fungi or other pests and parasites must be rejected. In this connection, it must be noted that in dried timber, the presence of large grub holes or smaller darkish tunnels (dug by ambrosia beetles) is of little consequence, since none of the insects are still alive at this stage. On the contrary, if there are small tunnels filled with powder the same colour as the wood (signalling the presence of powder post beetles), then the insects may still be alive, and thus the timber is seriously threatened.

Among the other defects that are serious enough to warrant rejecting sawn timber are the following:

- lamina deformations due, for instance, to the presence of reaction wood (abnormal wood in trees that are not straight or perfectly rectilinear);
- cup shakes;
- pitch pockets or gum pockets;
- cross grain;
- decayed knots.

Though the glued laminate structures made in Europe and North America are almost exclusively fashioned out of conifers, it is also possible to utilize hardwoods: many tropical or subtropical countries widely and successfully employ this type of timber (eg. Eucalyptus, Limba, Ilombe, Meranti, etc.). Other timbers, such as Iroko, are also utilized for building straight or curved members in the hull of certain types of watercraft.

Lamina conditioning and preparation:

One condition that is absolutely essential in guaranteeing the success of a glulam structure is the even distribution of moisture, which must be correctly related to the ambient air. The following limits have been advised:

- indoors 12 % (± 3 %)
- outdoors 15 % (± 3 %)

With regard to lamina dimensions, the experts have not yet agreed on a definite specification. However, we suggest a thickness of 25 mm and width of 20 cm.

The laminas must always be joined via multifinger joints: for laminas to be employed in areas of the structure featuring lower bending stresses, joints may also be effected directly between the two square ends, or via a plain scarf but if the minifinger jointing equipment is located on a production line, it is best to chose the same system for all laminas.

Planing and gaging:

Laminas must feature perfectly smooth surfaces, as well as a constantly even, carefully gauged thickness.

Glueing:

Only after the previous requisites have been fulfilled will it be possible to glue the laminas together using the adhesive best suited to the type of structure involved, and in particular also to the degree of humidity of the location it is to be erected in.

Lamina edges must be positioned accurately, and ends must be staggered with respect to the laminas themselves, and also to any knots present.

Finishing:

Even if glueing operations are performed with the utmost care, there will virtually always be bulges on the surface of the wood. Thus, surfaces must be planed by means of machines specifically designed to handle this task. Subsequently, antiseptic products may be applied to protect the laminate from biological alterations (fungi, insects), and from fire: it is in any case worth mentioning that glulam, even without fire-proofing treatment, behaves extremely well in the presence of fire.

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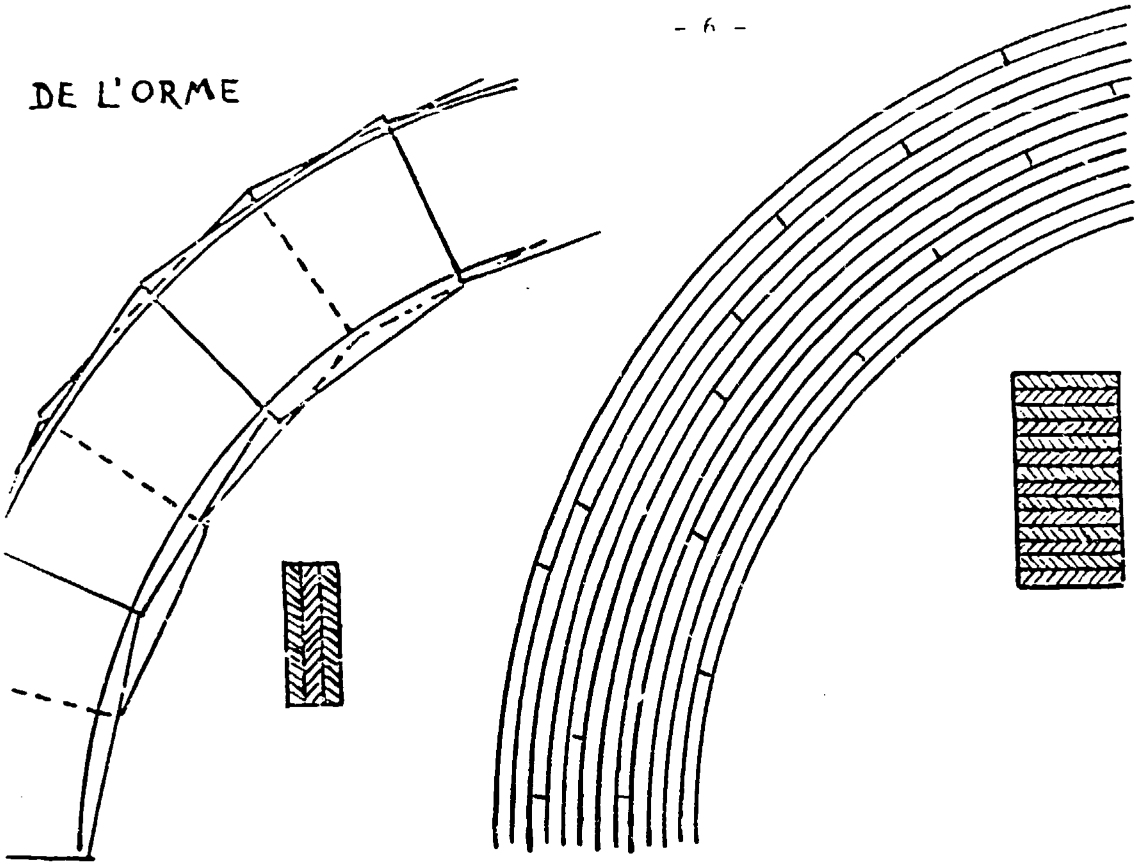

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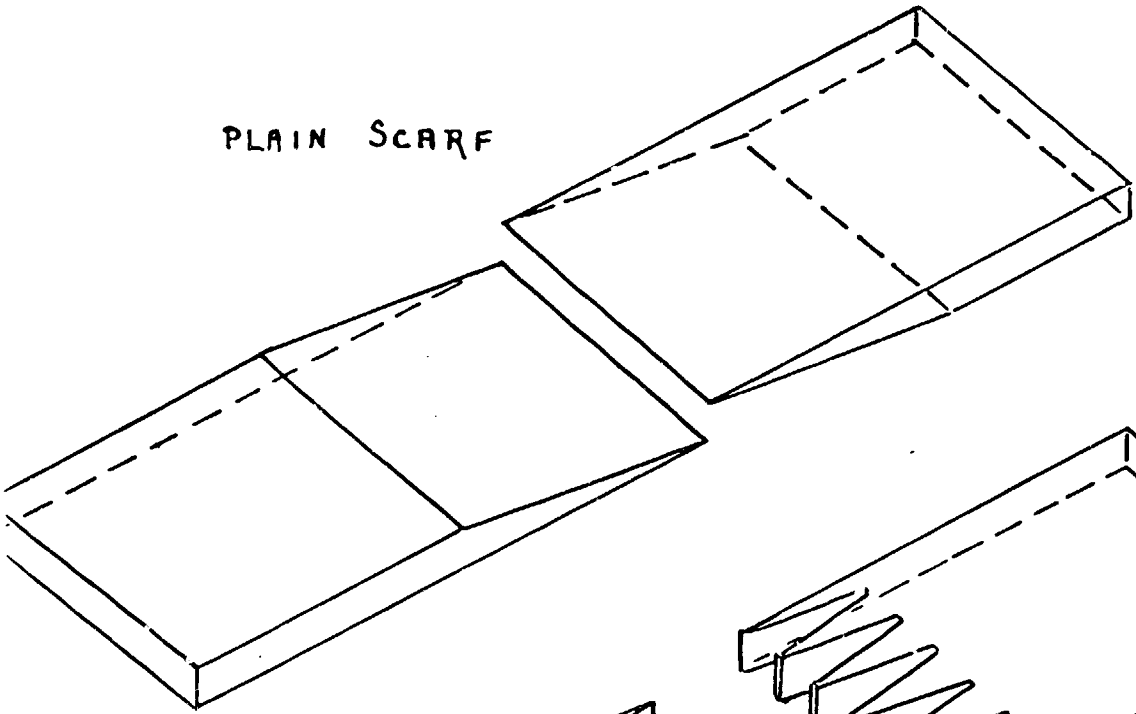

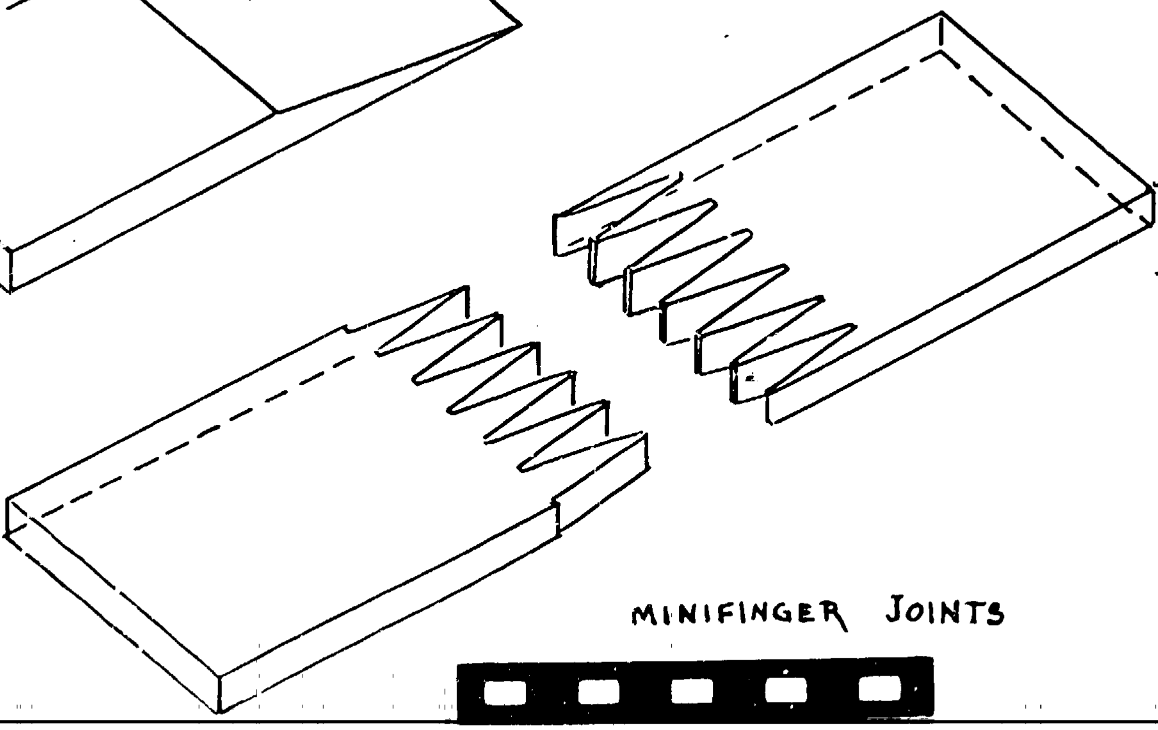

MINIFINGER JOINTS