Structures for transmission systems

STEP lecture E24
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Objective

To introduce and to describe the structural use of timber and glulam in transmission masts.

Summary

The lecture gives a general background to transmission systems constructed in timber and covers structural forms, preservative treatment, actions, and the different functions of masts and foundations.

Introduction

Electric power and signals from telegraphs and telephones have normally been transmitted and distributed by means of overhead transmission lines. The most common supporting structures have been round poles treated with different preservatives such as creosote. During the last decades glued laminated cross sections have been used even for high voltage lines.

The reasons for choosing a timber construction for this purpose can be many. A high voltage line hardly fits in to the surrounding countryside, especially if the line passes through areas of natural beauty. If the masts are made of a natural material such as timber many people might find them more acceptable. In addition to timber being a natural material, it also allows the designer great latitude in the configuration of the structure. The possibilities of getting an acceptable design are quite good.

Timber constructions are also easy to transport, for example by helicopter. Hollow cross sections of glued laminated timber will in addition weigh only about 60-70% of a solid pole with the same load carrying capacity.

Finally, the high electrical resistance of timber with low moisture content offers significant advantages when compared with metal structures.

Structural forms

Round poles

Round poles of pine have been the most common form for use as transmission lines. They are made of large trees, have often a length of 20 metres or more and a top diameter from 150 *mm* to 250 *mm*. The available length of the poles has been limited by three main factors. The length of the trees, the length of the preservative treating cylinders and the length that can be transported (truck or train).

Glued laminated masts

Glued laminated masts can be produced with different cross-sections which can be solid or hollow. Figure 1 gives examples of some types of glued laminated cross-sections. Glued laminated cross-sections have the advantage compared with solid round poles that the necessary dimensions and lengths can easily be achieved without the need for extremely large trees.

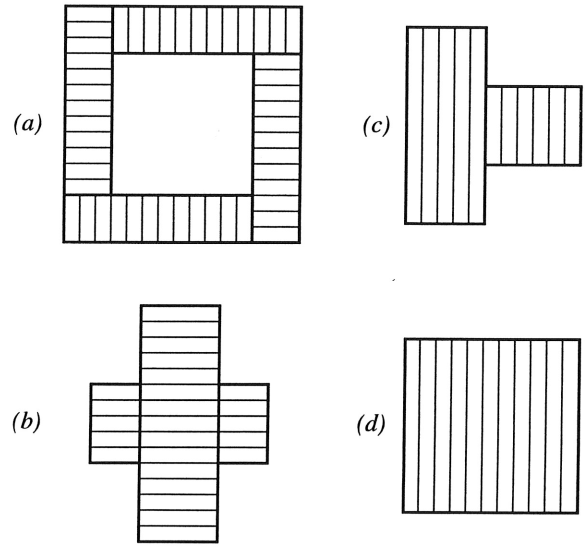


Figure 1 Examples of different glued laminated cross sections.

Preservative treatment

Round poles
Poles are treated with either creosote or water-borne preservatives. As for pressure treatment of other wood products the moisture content in the poles must be lower than the fibre saturation point before treatment. Because of health and environmental risks the water-borne preservatives have to be fixed in the poles before handling. There are restrictions on the use of wood treated with creosote and some water-borne preservatives in some countries.

Glued laminated masts
Glued laminated timber can be treated in two different ways, and both methods involve certain problems.

One method is to treat the laminations before gluing. This method is limited to water-borne preservatives since creosote treated timber cannot be glued. To achieve a good glueline it is necessary to plane the laminations. In this way the outer parts with the best protected areas are removed, often exposing untreated heartwood. In addition glued beams are often planed to give exact dimensions and smooth surfaces, whereby the resistance against micro organisms is weakened further.

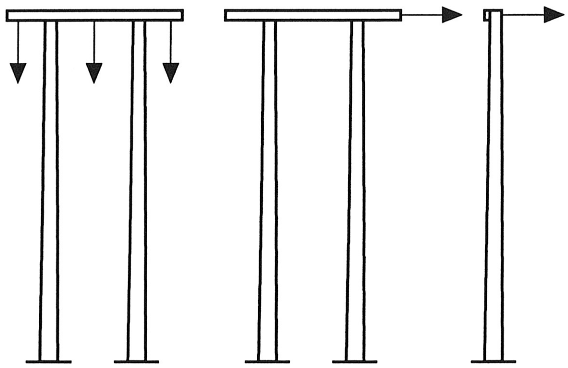
The other method is pressure treatment of the glued product. This method has a limitation caused by the size of the actual treating cylinder. The penetration of the preservative can be reduced because the laminations in practice will have heartwood zones out to the edge of the cross-section. Because of the drastic swelling during treatment and corresponding shrinkage during the following drying and thereby risk of cracking, water based preservatives are avoided. Creosote, however, is ideal in this connection as the heat from the oil tends to post-cure the gluelines, giving better strength and water resistance to the gluelines.

Actions

While the design of transmission structures for telephone lines etc. is based on experience and standardised systems, the masts for high voltage power lines must be designed as a normal structural member. The design must be based on the actual actions and load combinations and also the surrounding conditions which might exert an influence on the construction.

The actions are divided into three main groups:

- vertical actions (Figure 2a),
- horizontal actions *perpendicular* to the line direction (Figure 2b),
- horizontal actions *parallel* to the line direction (Figure 2c).

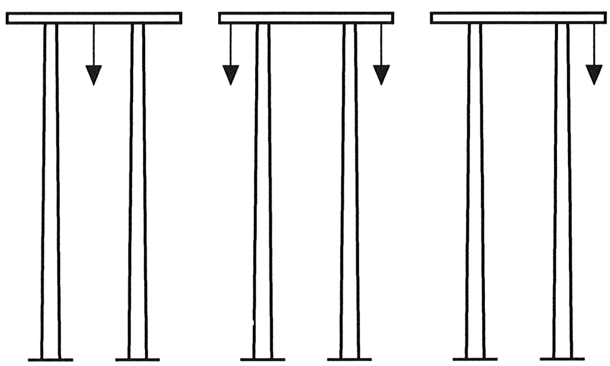


(a) *(b)* *(c)*

Figure 2 The three different types of actions on transmission masts.

Vertical actions

Vertical actions are permanent actions of the different parts of the construction and the lines. In most of Europe actions from the weight of snow and ice on the line might become the major vertical load. The fact that the vertical actions can be applied symmetrically or asymmetrically must be taken into consideration, see Figure 3a, b and c.



(a) *(b)* *(c)*

Figure 3 Vertical actions. Example of symmetrical and asymmetrical actions.

Horizontal actions perpendicular to the line direction

Horizontal actions perpendicular to the line direction are mainly caused by wind on the mast construction and the line. Especially during the winter when the line is covered with thick ice and snow, the wind actions can be huge.

Horizontal actions parallel to the line direction

Horizontal actions parallel to the line direction are caused by unbalanced tension in the line. This can occur for example when the snow and ice fall off the line in the span on one side of a mast, but not on the other side, or when the line accidentally fails on one side. As for vertical actions the horizontal actions parallel to the line direction can occur in both symmetrical and asymmetrical combinations, see Figure 4.

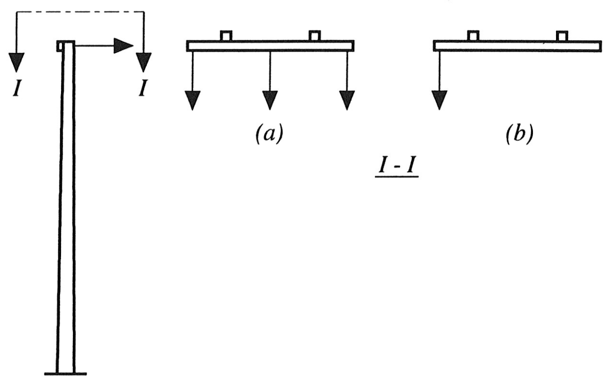


Figure 4 Horizontal actions parallel to the line direction. Example of (a) symmetrical and (b) asymmetrical load combinations.

For an asymmetrical load as given in Figure 4b it is important to allow for the torsion effect on the mast construction.

Depending on different conditions the components of the three main action types must be combined in different ways. For example if the transmission line goes down a steep hill, the action parallel to the line direction will give a bigger contribution to the resulting vertical action than if the line was crossing a flat area of land.

The function of the masts

In a transmission line the masts can be divided into standard masts and masts with special functions. The main function of the standard masts is to carry the dead loads from the cable and the mast itself and the natural loads caused by snow and wind.

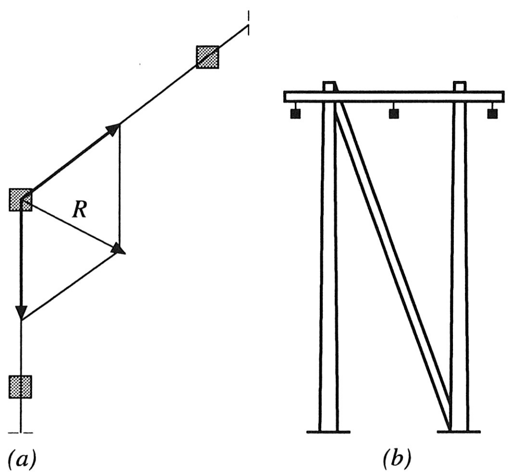


Figure 5 (a) Horizontal actions parallel to the line direction when the line changes direction. (b) An example of how mast can be designed to resist lateral actions.

In addition to the standard masts a line needs different types of special masts. One of the most important types of special mast is needed when the line changes direction. Since the actions in the line direction are not parallel but form an angle at this mast, the resulting action will have a different direction compared with the standard masts. While designing these mast it is important to consider the lateral actions and stability.

If a cable failure occurs in the line it will introduce an impact load effect. The result of this effect might be the same as the chain reaction made by falling domino pieces. In order to avoid too many masts failing by this domino effect, it is necessary to have specially designed masts placed in the line at frequent intervals. These special masts (see Figure 6) must be designed to accommodate the actual impact loads.

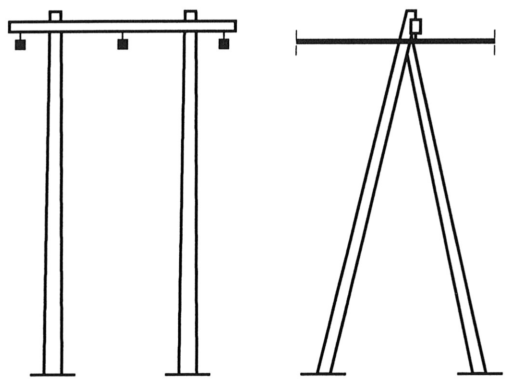


Figure 6 *Example of a mast designed to accommodate the impact actions parallel to the line.*

Foundations

The foundations for timber poles and masts depend on the ground conditions, but they are normally embedded in the ground. This method provides great savings when compared to the expensive foundations required for other types of construction. It is important to design the foundation detail having regard to shear forces, see Figure 7. The static model in the foundation must in each case be determined according to the actual foundation method.

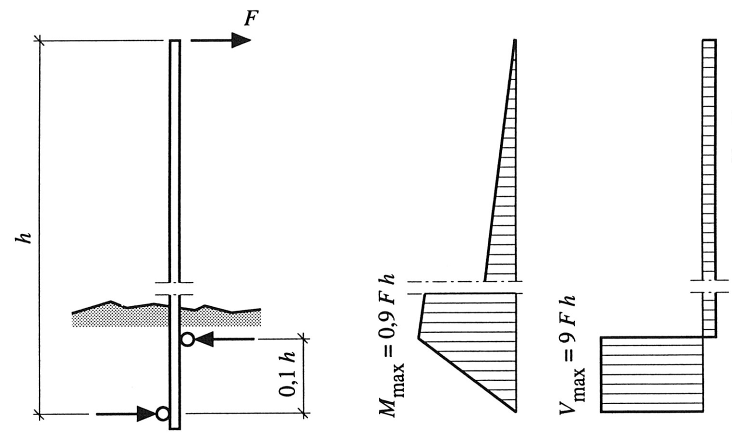


Figure 7 *Example of moment and shear forces in the foundation.*

It is also important to remember that some of the load combinations might have actions with an upward direction i.e. trying to lift the timber member from the ground.

Lateral restraint

The main part of a transmission structure is normally one or several vertical members fixed at one end, i.e. the foundation. Since many of the actions have horizontal components, lateral restraint to avoid deflections, instability etc. is needed. This can be achieved by using oblique bracing members of timber or steel, or by guys. The restraint system should also take care of the special deflection, torsion, which might be imposed on a structure by asymmetric actions.

Design process

In the design process all parts of the transmission mast must be controlled against the worst combination of actions for each specific part. Since this combination often varies from mast to mast in the same line, each structure normally needs to be designed separately.

Important stages in the design process are:

The main structure
The main structure must be controlled against bending moment, buckling, shear forces and torsion. The effects of asymmetrical actions will be different on a pole structure compared with a double mast structure with regard to torsion.

The foundation
The foundation must be controlled against bending moment and shear forces. If the structure is embedded in the ground the foundation system should also be designed with regard to decay hazard, even if the structure is treated with preservatives. If the foundation structure is performed with connector details, the effects from torsion of the main structure must be regarded. The moisture content is normally very high in this part of the structure.

Mechanical connectors
All connectors and joints must be controlled against actual load combinations. High humidity and influence from pollution (acid rain) might cause corrosion of mechanical fasteners. Untreated heartwood is often exposed in the holes for the fasteners, and this may involve decay hazard. All details round the points of line suspension must be designed with caution.

Cross bars
The cross bars must be controlled against actual load combinations. Be aware of the possibilities of forced actions caused by different deflections in the main structure, for example effects from asymmetrical loads on a double mast structure.

Bracing
The design of the bracing system is normally based on axial stresses. For members which resist compression, buckling must be considered.

Transportation and erection
Extraordinary actions caused by transportation and erection of the structure or part of it must be considered.