Engineering Structures 33 (2011) 3027–3032

Contents lists available at SciVerse ScienceDirect

Engineering Structures

journal homepage: www.elsevier.com/locate/engstruct

# Requirements for moment connections in statically indeterminate timber structures

A.J.M. Leijten

*Eindhoven University of Technology, The Netherlands*

ARTICLE INFO

*Article history:*
Available online 30 April 2011

*Keywords:*
Connection
Ductility
Engineering
Fasteners
Indeterminate
Reinforcement
Timber

ABSTRACT

In statically indeterminate structures, connections play a vital role in the moment distribution. Demonstrated here is a method to evaluate the conditions, taking full advantage of the benefits offered by the indeterminate nature of the structures, and using the well-established, graphical beam-line method. This method shows how important the immediate load take-up is, the stiffness, the moment capacity of the connection and how it all affects the structural behaviour. The examples considered here use both the traditional non-reinforced dowel-type fastener connections and also timber connections reinforced with steel plates. They show that the minimum rotation requirements to achieve an effective structure are satisfied easily in contrast to requirements on stiffness. In this respect, timber connections with local reinforcement glued at the interface of the connection area offer more prospects.



## 1. General

Statically indeterminate structures, compared to determinate structures, lead to material savings and more safety reserve. A prerequisite is the inherent property of the structural material, or the connections, to provide enough (plastic) deformation. For this reason, statically indeterminate structural designs with steel and concrete find application while taking full advantage of the benefits mentioned. In timber engineering, statically indeterminate structures are rare and, because timber is considered a brittle material, the plastic behaviour should come from the connections.

Timber connections, such as full cross-section finger joints, have a high strength and stiffness capacity but they are not ductile and are difficult to manufacture on site.

Connections with mechanical fasteners, such as bolts and dowels, can also be applied but the effectiveness depends on certain factors. For instance, when the number of fasteners increases the strength and stiffness capacity increases as well but cracks develop before attaining full capacity. This will obviously compromise ductility. To assure immediate load take-up, the fasteners should be inserted in tightly fitting holes but, to ease assembly, some clearance is necessary. This hole clearance, however, leads to slack load take-up, especially when the bending moments reverse sign.

Ductility of timber connections is, therefore, a difficult issue and not well understood at present. The development of reinforced timber connections that strongly reduce development of cracks might lead the way for indeterminate timber structures. It is for this reason a method is presented that shows, in a clear and simple way, how much ductility is required and how other properties, such as strength and stiffness, interact.

Imagine a single supported prismatic beam with moment transmitting connections at the supports, is represented by springs, and loaded by a uniform distributed vertical load (UDL) as in Fig. 1. The rotational stiffness of the springs may have a significant influence on the bending moment distribution of the beam. Springs with low stiffness can be regarded as hinges while infinite stiff springs lead to a moment distribution similar to a beam with fixed ends. The beam-line method presented provides a graphical way to analyse the moment distribution and it identifies critical locations where failure is expected. This might be failure either at mid-span or near the supports. The beam-line method could also be applied to other symmetrical load cases.

The starting point is a beam with two equal springs at either end. The rotational stiffness of these springs consists of the connection stiffness itself and the bending stiffness of other structural elements that are connected to the spring. For instance, in a portal frame, the rotational stiffness of the springs at the end of the beams is the resulting stiffness of the beam-to-column connection and the bending stiffness of the column(s) at the location of the spring as in Fig. 2.

The rotational stiffness of two symmetrical springs can be related to the flexural stiffness of the beam by Eq. (1):

$$K_s = \frac{cL}{EI} \tag{1}$$

*E-mail address:* A.J.M.Leijten@tue.nl.

0141-0296/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.engstruct.2011.03.014