Screwed joints

STEP lecture C8
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Objective

To describe the load carrying behaviour and the load-carrying capacity of screws.

Prerequisite

C3 Joints with dowel-type fasteners - Theory

Summary

The lecture describes the load-carrying behaviour of screwed joints and presents the design rules given in EC5.

Introduction

Wood screws are especially suitable for steel-to-timber and panel-to-timber joints, but they also can be used for timber-to-timber joints. Such screwed joints are mainly designed as single shear joints.

Screws with a diameter greater than 5 *mm* should be turned into pre-drilled holes to prevent splitting of the wood. The holes should be pre-drilled over the length of the unthreaded shank with the diameter of the smooth shank and over the threaded portion with a diameter of about 70 per cent of the shank diameter. Screws should be inserted by turning and not by driving with a hammer, otherwise the load carrying capacity, mainly the withdrawal capacity, will decrease significantly.

Requirements referring to design and material of the screws will be fixed in a European product standard. In the design equations d should be taken as the diameter of the screw measured on the smooth shank. The diameter d of coach screws varies from 8 to 20 *mm*, the diameter of countersunk head or round head screws varies from 4 to 8 *mm*. The root diameter of the screw in the threaded portion d_1 is about 70 per cent of the diameter measured on the smooth shank. The depth of the thread h_1 varies from 0,125 d to 0,14 d, the threadpitch h_2 from 0,4 d to 0,5 d. The length of the threaded portion is about 60 per cent of the total length of the shank.

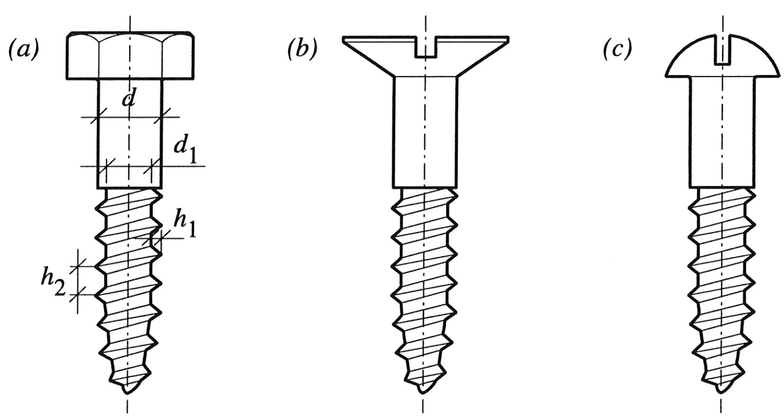

Figure 1 Typical wood screws: (a) coach screw (b) countersunk head (c) round head.

At present the relevant national product standards do not specify any values regarding fastener properties with respect to the load carrying capacity. It is assumed that the design rules for screwed joints in EC5 are applicable for screws according with the British Standard BS 1210 "Wood screws" and the German Standards DIN 96 "Halbrund-Holzschrauben mit Schlitz", DIN 97 "Senk-Holzschrauben mit Schlitz" and DIN 571 "Sechskant-Holzschrauben".

Load carrying behaviour

Laterally loaded screws have nominally a smaller load-carrying capacity than nails or round steel bolts with, because the yield moment in the threaded portion is smaller than the yield moment of the smooth shank.

For small diameters the angle between the force and the grain direction has no significant influence on the load-carrying capacity. For larger diameters there is an increasing influence on the embedding strength of the members. Therefore, joints with screws having a diameter less than 8 *mm* can be designed principally as nailed joints, whereas for diameters greater than or equal to 8 *mm* the decreasing embedding strength for increasing angle between force and grain must be taken into account. It should also be taken into consideration, that screws taper to the point, so that there is almost no contact in the region of the point.

For applying the rules in EC5 it is assumed that:

- the screws are turned into pre-drilled holes and
- the length of the smooth shank is at least equal to the thickness of the member under the screw head

Laterally loaded screws

For screws with a diameter less than 8 *mm* the rules for nails apply, for screws with a diameter equal to or greater than 8 *mm* the rules for bolts apply. In designing spacings and end/edge distances the diameter of the smooth shank is decisive. The penetration of the screw should be at least 4*d*.

The design load-carrying capacity should be taken as the smallest value found from the formulae given in STEP lecture C3. To calculate the value of the yield moment an effective diameter of $d_{ef} = 0{,}9d$ should be used, provided that the root diameter of the screw is not less than 0,7*d*. This effective diameter assumes that the thread itself also contributes to the yield moment. If the length of the smooth shank in the pointside member is not less than 4*d*, the shank diameter may be used to calculate the value of the yield moment.

For calculating the load-carrying capacity the depth of penetration t_1 or t_2 should be reduced to an effective depth of penetration, to take account of the influence of the tapering point of the screw. It is recommended that the depth of penetration be reduced by about 1,5*d*.

The following value for the characteristic yield moment should be used:

$$M_{y,k} = 0{,}8\, f_{u,k}\, \frac{d^3}{6} \qquad (1)$$

EC5: Part 1-1: 6.5.1.2e

or

$$M_{y,k} = 0{,}8\, f_{u,k}\, \frac{(0{,}9\, d)^3}{6} = 0{,}583\, f_{u,k}\, \frac{d^3}{6} \qquad (2)$$

where $f_{u,k}$ is the characteristic tensile strength of the screw material and *d* is the diameter measured on the smooth shank (nominal screw diameter).

Axially loaded screws

Screws are especially suitable for carrying withdrawal loads. To determine the design value the effective depth of penetration is assumed to be the length of the threaded portion of the screw in the member receiving the point. The influence of the point is taken into account by deducting one diameter from the effective length.

The design withdrawal capacity of screws driven at right angles to the grain should be taken as

EC5: Part 1-1: 6.7.2a

$$R_d = f_{3,d}\,(l_{ef} - d) \qquad N \tag{3}$$

The design value of the withdrawal parameter should be calculated from the characteristic withdrawal parameter taking into account the load duration class, the service class and the partial safety coefficient γ_M.

$$f_{3,d} = \frac{k_{mod}\, f_{3,k}}{\gamma_M} \qquad N/mm \tag{4}$$

EC5: Part 1-1: 6.7.2b

$$f_{3,k} = (1{,}5 + 0{,}6\,d)\,\sqrt{\rho_k} \qquad N/mm \tag{5}$$

d is the screw diameter in mm measured on the smooth shank
l_{ef} is the threaded length in mm in the member receiving the screw
ρ_k is the characteristic density in kg/m^3

If a depth of penetration of more than 10d is taken into account, the stresses should be checked against the design tensile strength of the screw material in the root area. The head pull through effect for axially loaded screws with sheet material should be checked using the equations for annular ringed shank and threaded nails. For timber to timber joints it may be necessary to use washers to avoid high pressure perpendicular to the grain.

Combined laterally and axially loaded screws

For screwed joints with a combination of axial load F_{ax} and lateral load F_{la} the following condition should be satisfied:

EC5: Part 1-1:6.3.3b

$$\left(\frac{F_{ax,d}}{R_{ax,d}}\right)^2 + \left(\frac{F_{la,d}}{R_{la,d}}\right)^2 \leq 1 \tag{6}$$

where $R_{ax,d}$ and $R_{la,d}$ are the design load-carrying capacities of the joint loaded with axial load or lateral load alone.

Design example

Screwed joint of a wind bracing. It is assumed that the spacings are in line with the relevant design rules.

F_d = 22 kN (short-term), Service class 2, k_{mod} = 0,9, ρ_k= 350 kg/m^3
4 screws ϕ 12 x 120, f_u= 400 N/mm^2 (producer's specification)
d > 8 mm; the rules for bolts apply

Lateral load:

$t = 6\ mm$ (thin steel plate)

$$t_1 = l - t - 1{,}5\,d = 120 - 6 - 1{,}5 \cdot 12 = 96\ mm$$
$$0{,}4\,l - t = 0{,}4 \cdot 120 - 6 = 42\ mm \leq 4\,d = 48\ mm$$

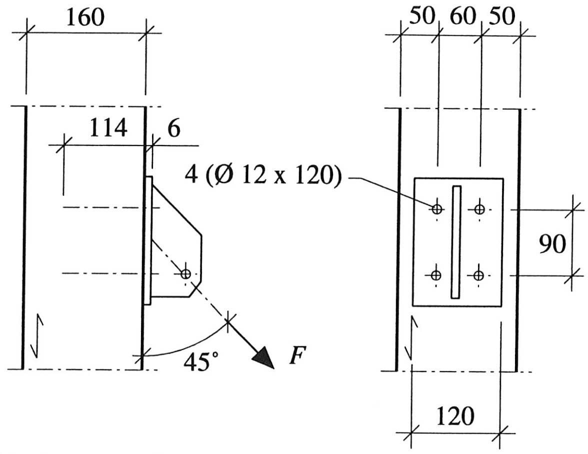

Figure 2 Design example.

The yield moment should be calculated with an effective diameter d_{ef}

$$d_{ef} = 0{,}9\ d = 10{,}8\ mm$$

EC5: Part 1-1: 6.5.1.2e

$$M_{y,d} = 0{,}8\ f_{u,k}\ \frac{d_{ef}^3}{6}\ \frac{1}{\gamma_M} = 0{,}8 \cdot 400\ \frac{10{,}8^3}{6} \cdot \frac{1}{1{,}1} = 61100\ Nmm$$

EC5: Part 1-1: 6.5.1.2b

$$f_{h,d} = 0{,}082\ (1 - 0{,}01\ d)\frac{\rho_k\ k_{mod}}{\gamma_M} = 0{,}082\ (1 - 0{,}12)\frac{350 \cdot 0{,}9}{1{,}3} = 17{,}5\ N/mm^2$$

EC5: Part 1-1: 6.2.2a

EC5: Part 1-1: 6.2.2b

$$R_d = \min \begin{cases} (\sqrt{2}-1)\ f_{h,d}\ t_1\ d = 0{,}41 \cdot 17{,}5 \cdot 96 \cdot 12 \cdot 10^{-3} = 8{,}26\ kN \\ 1{,}1\ \sqrt{2\ M_{y,d}\ f_{h,d}\ d} = 1{,}1\ \sqrt{2 \cdot 61100 \cdot 17{,}5 \cdot 12} \cdot 10^{-3} = \mathbf{5{,}57\ kN} \end{cases}$$

Axial load:

$$l_{ef} = 0{,}6 \cdot 120 = 72\ mm < 10\ d = 120\ mm$$

No need to check against tensile strength of screw material

EC5: Part 1-1: 6.7.2b

$$f_{3,d} = (1{,}5 + 0{,}6\ d)\ \sqrt{\rho_k}\ \frac{k_{mod}}{\gamma_M} = (1{,}5 + 0{,}6 \cdot 12)\ \sqrt{350} \cdot \frac{0{,}9}{1{,}3} = 113\ N/mm$$

EC5: Part 1-1: 6.7.2a

$$R_{ax,d} = f_{3,d}\ (l_{ef} - d) = 113 \cdot (72 - 12) \cdot 10^{-3} = \mathbf{6{,}76\ kN}$$

Interaction:

EC5: Part 1-1: 6.3.3b

$$\left(\frac{0{,}707 \cdot 22}{4 \cdot 5{,}57}\right)^2 + \left(\frac{0{,}707 \cdot 22}{4 \cdot 6{,}76}\right)^2 = 0{,}49 + 0{,}33 = 0{,}82 \leq 1$$

Concluding summary

- Screws are remarkably suitable for withdrawal loads.
- Screws with a diameter > 5 *mm* shall always be turned into pre-drilled holes.
- The length of the smooth shank should be greater or equal to the thickness of the member under the screw head.
- Under lateral loading for screws with a diameter less than 8 *mm* the rules for nails apply, for screws with a larger diameter the rules for bolts apply.