CALCULATION MODE FOR ALUSH18 ®

Shear aluminium sheet for Alufoot® system

INTRODUCTION

ALUSH18® plate, being part of Alufoot® system, is used in order to connect the CLT wall to the Alufoot® aluminium beam. SH18 geometry has been optimized in order to withstand the traction forces. We suggest to apply them as *shear plates*.

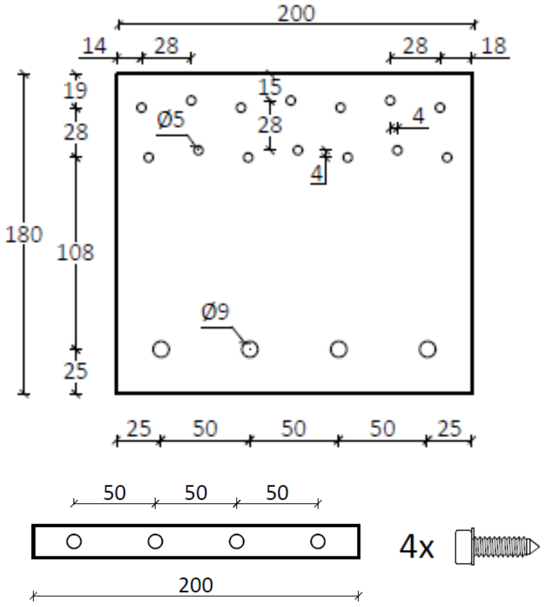
Below you can find the report of the strength verification of the sheet, following Eurocode 9, using the limit state design, that lead to the definition of the design strength field compared to the ultimate limit state

Strength verification is led with the only attention to the failure modes on the metal side (*metal side verification*). Strength verifications of the sheet fastening to the timber wall (*timber side verification*) are left to the designer, being subject of many design variables, such as class, wooden type, service class, period of the load, type of fasteners.

SET OF RULES

Eurocode 9 - EN 1999-1-1 (EC9 below)
Eurocode 3 - EN 1993-1-8 (EC3 below)

GEOMETRY AND MATERIALS



The system is composed of:

- ALUSH18 plate, aluminium EN AW-5754, 180X200X5 mm
- EN AW-6082 aluminium guide, L=200 mm, with 4 threaded holes, for M8 bolts;
- 4 self –threading M8 bolts, steel class 8.8, hot galvanizing

The holes (9 mm diameters) for the insertion of the M8 bolts are designed in order to respect the minimum distances as prescribed in EC9 (§8.5.1).

Pic. 1: Geometry of SH18 plate

MATERIAL STRENGTH

According EC9, for EN AW-5754 it is correct to use the characteristic strength values below:

- Yelding: $f_o = 80\ \mathrm{MPa}$
- Failure: $f_u = 190\ \mathrm{MPa}$

According to EC3, for steel class 8.8 bolts the characteristic strength values below are assumeable:

- Yelding*:* $f_{yb} = 640\ \mathrm{MPa}$
- Failure: $f_{ub} = 800\ \mathrm{MPa}$

The Eurocodes provides the safety factors below:

- Aluminium ductile failure (EN 1999-1-1 §6.1.3) $\gamma_{M1} = 1.10$
- Aluminium brittle failure (EN 1999-1-1 §6.1.3) $\gamma_{M2} = 1.25$
- Bolts (EN 1993-1-8 §2.2) $\gamma_{M2} = 1.25$

SECTION CLASSIFICATION

The section classification of the plate is calculated according to §6.1.4 of EC9.

For SH18 we have:

- $\beta = 0{,}4\, b/t = 0{,}4 \cdot 200/5 = 16$
- $\varepsilon = \sqrt{(250/80)} = 1.77$
- $\beta/\varepsilon = 9.05$

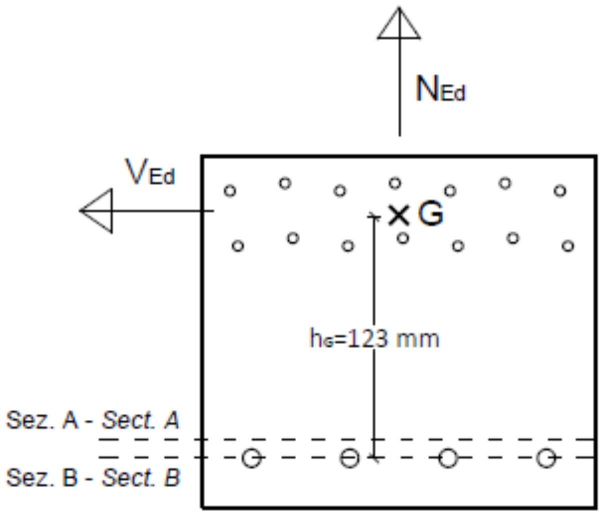
According to table 6.2 of EC9 the section classi s 1. For that class the ultimate strength of the section can be calculated with reference to the ultimate limit state of plastic failure.

DESIGN HYPOTHESIS

The design hypothesis is that the total design force pass through the mass center G of the nailing on the timber wall (see pic. 2). This assumption is more cautionary than the verification of the plate strength and than the fixing bolts (*metal side verifications*).

STRENGTH VERIFICATIONS

The set of strength verifications to be led is illustrated in Picture 2. The strength field of the plate, in terms of design forces N_{Ed} (traction) and V_{Ed} (shear) will be determined by the weakest strength mechanism



Verifications to be led:

- Sect. A: plastic strength verification of the gross section;
- Sect. B: verification of the elastic strength of the net section;
- Sect. B: verification of the strength of the bolts.

Pic. 2: Verifications to be led

The bolts are fixed to the aluminium profile through an aluminium sliding bar, that is put into the specific pit realized on the profile.

Experimental tests have shown tha the fixing system is over-resistant compared to the bolts, as the failure always comes for the slicing of the bolt on the contact section between plate and aluminium guide.

Section A: plastic strength of the gross section

Because of the geometry of the plate and the material behaviour, the quantities below must be defined:

- Maximum traction strength:

  $N_{o,Rd} = A_g f_o/\gamma_{M1} = 1000 \cdot {}^{80}\!/_{1.10} = 72.73\ kN$
- Maxmum shear strength:

  $V_{o,Rd} = A_g f_o/(\sqrt{3}\,\gamma_{M1}) = 1000 \cdot 80/(\sqrt{3} \cdot 1.10) = 41.99\ kN$
- Maximum moment strength:

  $M_{o,Rd} = W_{pl} f_o/\gamma_{M1} = {}^{1}\!/_{4} \cdot 5 \cdot 200^2 \cdot {}^{80}\!/_{1.10} = 3.64\ kNm$

Because of the calculation hypothesis, the design moment is equal to the shear force multiplied for the distance between center of mas of the nailing and center of mass of the bolts.

$$M_{Ed} = V_{Ed} \cdot h_G$$

where h_G is the distance between the center of mass of the nailing and the center of mass of the bolts, equal to 123 mm.

For composed forces of shear and traction, the designer must use the disequation:

$$\frac{N_{Ed}}{N_{o,Rd}} + \frac{V_{Ed} \cdot h_G}{M_{o,Rd}} \leq 1 \qquad \text{(I)}$$

where V_{Ed} is the design shear force and N_{Ed} the traction force on the plate, according to USL.

EC9 provides to lead the verification (I) using a design strength stress reduced, equal to $f_{o,V} = f_o(1-\rho) = f_o(1-(2V_{Ed}/V_{Rd}-1)^2)$ whenever is verified $V_{Ed} > 0.5V_{o,Rd}$. For $V_{Ed} > 21$ kN the strength domain of the grass section has a soft bending.

Section B: verification of the net area of the plate

Because of the geometry of the plate and the material behaviour, the quantities below must be defined:

- Maximum traction strength:
  $N_{u,Rd} = 0.9 A_{net} f_u / \gamma_{M2} = 0.9 \cdot 830 \cdot 190/1.25 = 113.54\ kN$;
- Maximum shear strength:
  $V_{u,Rd} = A_{net} f_o / \sqrt{3}\, \gamma_{M1} = 830 \cdot 80/\sqrt{3} \cdot 1.10\ = 34.85\ kN$;
- Maximum moment strength:
  $M_{u,Rd} = W_{net} f_u / \gamma_{M2} = 2.8 \cdot 10^6 \cdot 190/1.25 = 4.26\ kNm$.

Once determined the values of $N_{u,Rd}$, $V_{u,Rd}$ e $M_{u,Rd}$, the resistent field is obtained by the same considerations as the previous paragraph, by following the disequation:

$$\frac{N_{Ed}}{N_{u,Rd}} + \frac{V_{Ed} \cdot h_G}{M_{u,Rd}} < 1 \qquad \text{(II)}$$

where h_G is the distance between the center of mass of the nailing and the center of mass of the bolts.

There is an interaction between shear and traction forces: for shear forces $V_{Ed} > 17.4\ kN,$ the verification (II) has been led with a reduced strength stress $f_{o,V}$, as done for the grass section.

Section B: strength verification of the bolts

The shear strength of the single bolt M8 cl. 8.8 ($V_{b,Rd}$) is the minimum between the burr strength of the aluminium plate and the shear strength of the bolt, given by the expressions below:

- Slicing strength of the bolt a tranciamento del bullone

$$F_{V,Rd} = \alpha_V \cdot \frac{f_{ub} A_s}{\gamma_{M2}} = 0.6 \cdot 800 \cdot \frac{36.6}{1.25} = 14.05\ kN$$

- Burr strength

$$F_{b,Rd} = k_1 \alpha_b \cdot \frac{f_u d t}{\gamma_{M2}} = 2.5 \cdot 0.926 \cdot 190 \cdot 8 \cdot \frac{5}{1.25} = 14.07\ kN$$

From the previous expressions it comes that the shear strength of the bolt is equal to:

$$V_{b,Rd} = \min\{F_{V,Rd}; F_{b,Rd}\} = 14.05\ kN.$$

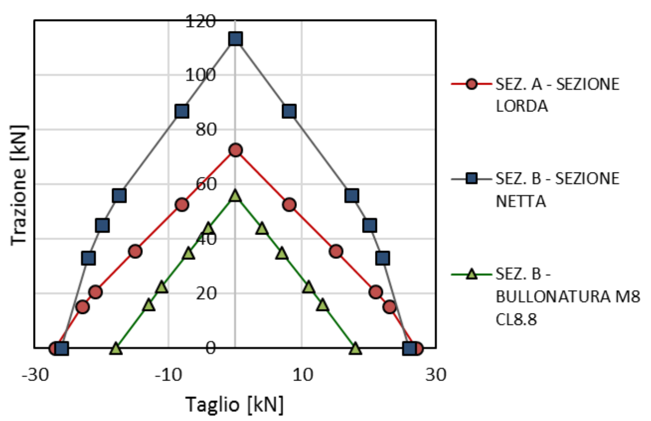
The design strength domain of the bolts, in terms of shear forces V_{Ed} and traction forces N_{Ed}, has been determined according to the following expression:

$$V_{b,Ed} = \sqrt{\left(\frac{N_{Ed}}{4} + \frac{(V_{Ed} \cdot 123 + N_{Ed} \cdot 60.3) \cdot 75}{(75^2 + 25^2)}\right)^2 + \left(\frac{V_{Ed}}{4}\right)^2} \leq V_{b,Rd}$$

which verifies that the shear force on the most forced bolt results minor than the shear strength.

REPRESENTATION OF THE STRENGTH DOMAINS

The four verifications lead to the creation of three domains, represented in Pic.3

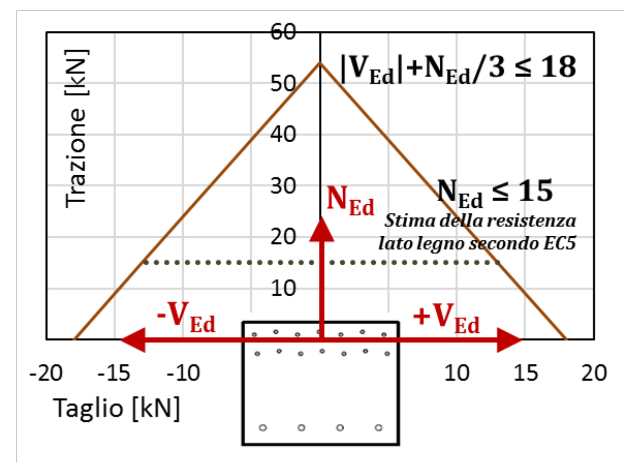


Pic.3: Results obrained by strength verifications

DESIGN STRENGTH DOMAIN OF THE PLATE

The design domain for ALUSH18 is well described by the disequations:

$$|V_{Ed}| + N_{Ed}/3 \leq 18$$



Pic. 4: Graphic representation of the design strength domain.

The forometry for the nails has been designed to optimize the shear strength of the plate. It means that the traction strength on the metal side (over than 50 kN) is not completely exploitable by the connection on the timber side, also because the inferior nail row cannot be considered when forced in the direction parallel to the timber fibers according to the minimum distances from the edge of the wall. Supposing that a nail can support a shear force of 2.15 kN, being only 7 the useful nails, the plate verification on the timber side, leads to the limit $N_{Ed} \leq 15\ kN$.