

CALCULATION MODE FOR ALUHD56®

Traction aluminium plate for Alufoot® system

INTRODUCTION

ALUHD56® plate, being part of Alufoot® system, is used in order to connect the CLT wall to the Alufoot® aluminium beam. HD56 geometry has been optimized in order to withstand the traction forces. We suggest to apply them as *hold-down* at the beginning/end of the wall.

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

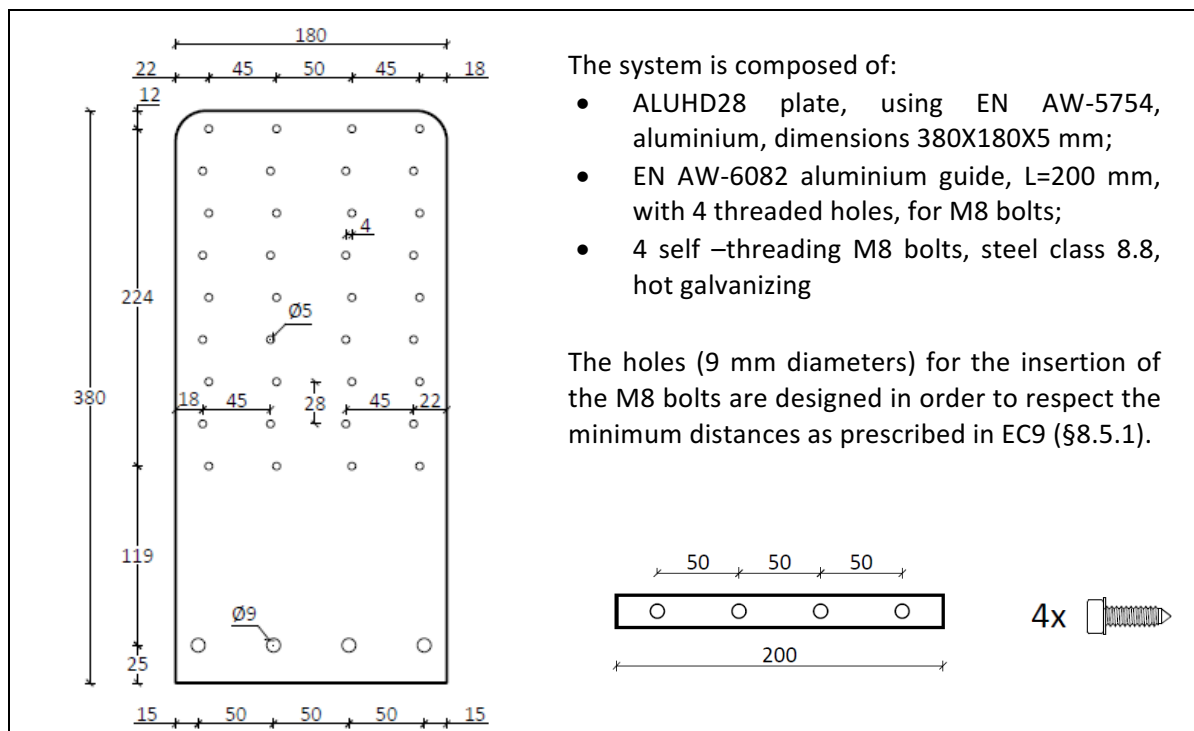
Strength verification is led with the only attention to the failure modes on the metal side (*metal side verification*). Strength verifications of the plate fastening to the timber wall (*timber side verification*) are left to the designer, being subject of many design variables, such as class, wooden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



Pic. 1: Geometry of HD56 plate

MATERIAL STRENGTH

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

- Yielding: $f_o=80$ MPa
- Failure: $f_u=190$ MPa

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

- Yielding: $f_{yb}=640$ MPa
- Failure: $f_{ub}=800$ 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 HD56 we have:

- $\beta = 0.4 b/t = 0.4 \cdot 180/5 = 14.4$
- $\varepsilon = \sqrt{(250/80)} = 1.77$
- $\beta/\varepsilon = 3.62$

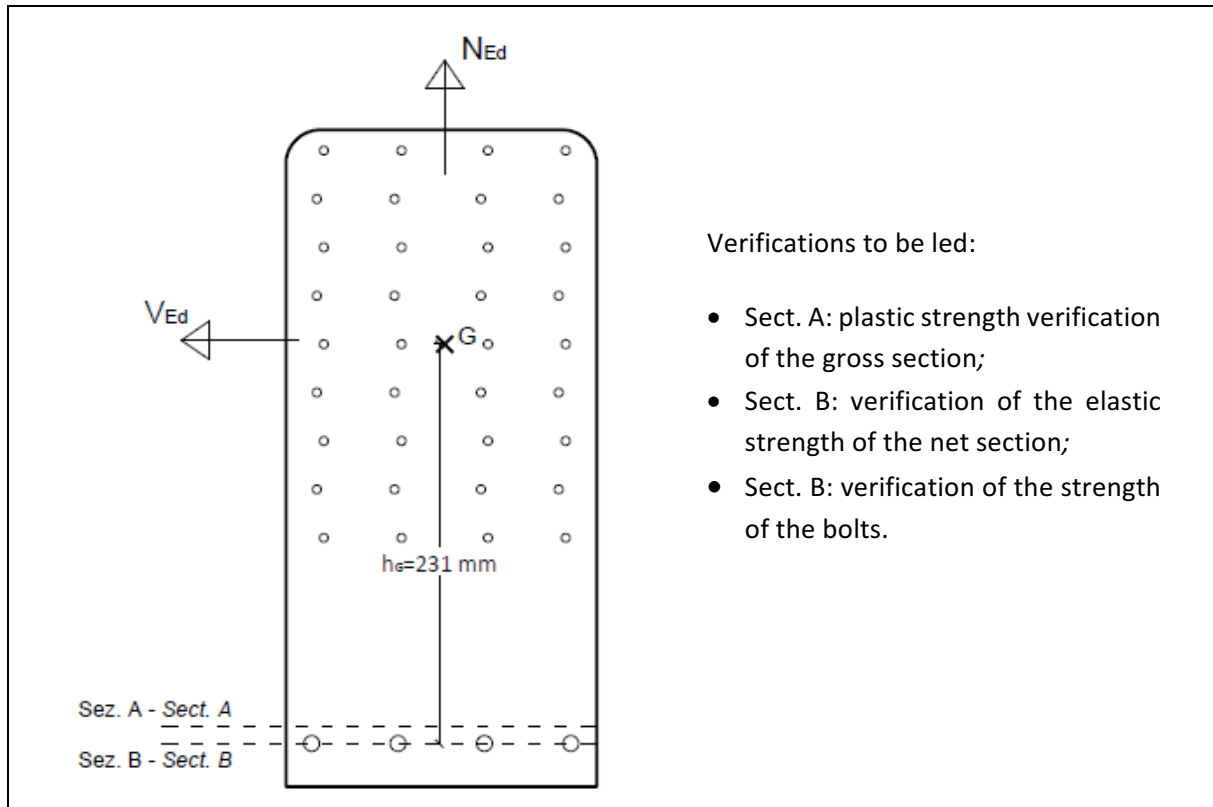
According to table 6.2 of EC9 the section class is 1. For that class the ultimate strength of the section can be calculated with reference to the ultimate limit state of plastic failure.

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).

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



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 that 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:

$$N_{o,Rd} = A_g f_o / \gamma_{M1} = 900 \cdot 80 / 1.10 = 65.45 \text{ kN}$$

- Maximum shear strength:

$$V_{o,Rd} = A_g f_o / (\sqrt{3} \gamma_{M1}) = 900 \cdot 80 / (\sqrt{3} \cdot 1.10) = 37.79 \text{ kN}$$

- Maximum moment strength:

$$M_{o,Rd} = W_{pl} f_o / \gamma_{M1} = 1/4 \cdot 5 \cdot 180^2 \cdot 80 / 1.10 = 2.95 \text{ kNm}$$

Because of the calculation hypothesis, the design moment is equal to the shear force multiplied for the distance between center of mass 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 231 mm.

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

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

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

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:

$$N_{u,Rd} = 0.9A_{net}f_u/\gamma_{M2} = 0.9 \cdot 730 \cdot 190/1.25 = 99.86 \text{ kN} ;$$

- Maximum shear strength:

$$V_{u,Rd} = A_{net}f_o/\sqrt{3}\gamma_{M1} = 730 \cdot 80/\sqrt{3} \cdot 1.10 = 30.65 \text{ kN} ;$$

- Maximum moment strength:

$$M_{u,Rd} = W_{net}f_u/\gamma_{M2} = 1.9 \cdot 10^6 \cdot 190/1.25 = 3.21 \text{ kNm} .$$

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

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

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

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

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

- Burr strength

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

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

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

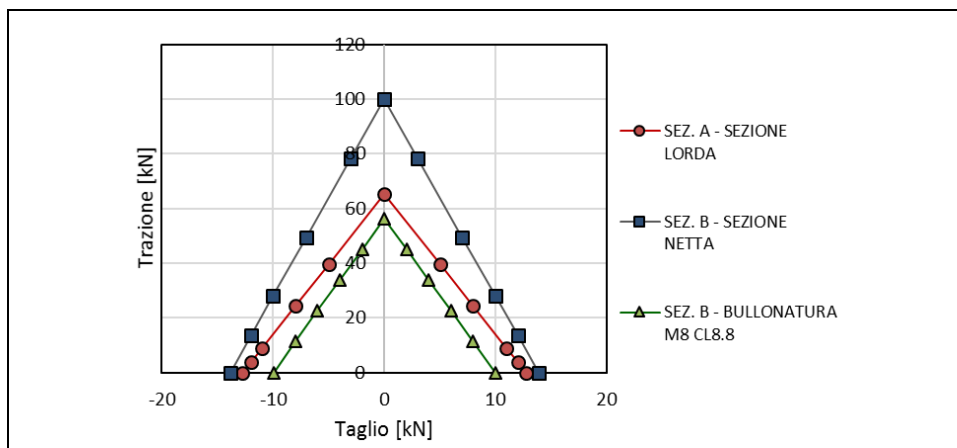
The design strength domain of the bolts, in terms of shear forces V_{Ed} and traction forces N_{Ed} , has been determined according to the following expression:

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

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

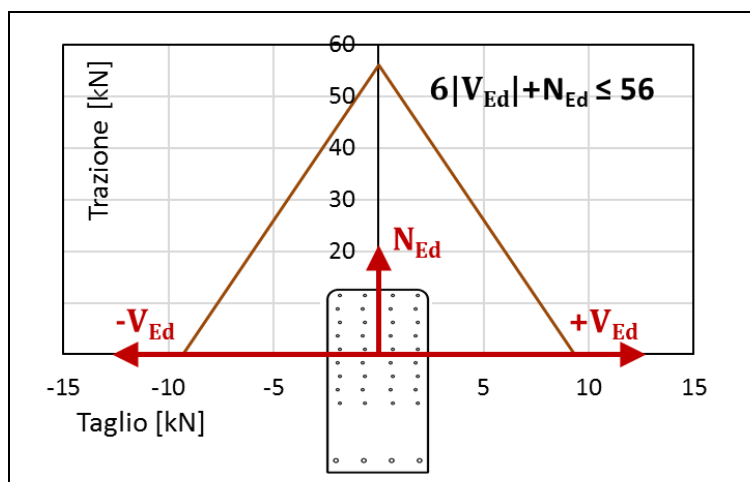


Pic.3: Results obtained by strength verifications

DESIGN STRENGTH DOMAIN OF THE PLATE

The design domain for ALUHD56 is well described by the disequations:

$$6|V_{Ed}| + N_{Ed} \leq 56$$



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