Chapter 6

PURE SHEARING

6.1 GENERALS

The shearing is called **pure** when in a cross section of a bar the single distinct stress is the **shear force T** (all other stresses N = M_i = M_t = 0). In construction elements this case is rarely met and eventually only in characteristic cross sections.

That's why we can't talk about pure shearing into an element, but only a cross section subjected to pure shearing. Generally, shearing acts simultaneously with bending and/or torsion. However, pure shearing may be met at short cantilevers loaded with big concentrate forces, (Fig.6.1) or in the connection pieces (fasteners), as: rivets, screws, bolts, nails, etc.

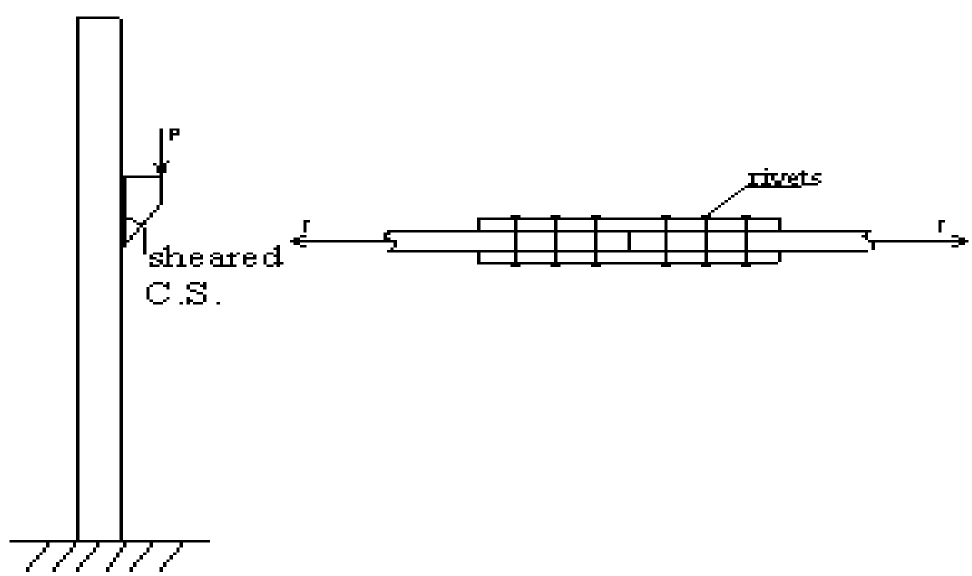


Fig.6.1

6.2 GEOMETRICAL AND STATIC ASPECT

The experimental realization of a model illustrating only the presence of the shear force is very complicated to do. However, only for testing, it is used a steel piece having an S shape, loaded by two concentrates forces acting in the piece ends (Fig.6.2).

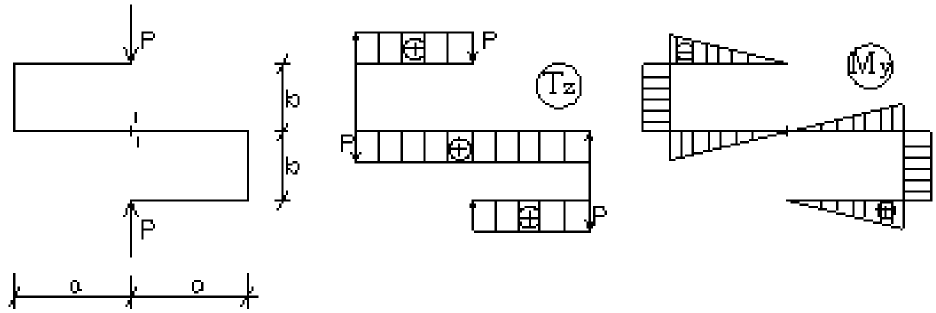


Fig.6.2

Section 1-1 is subjected only to pure shearing. The steel model is sheared into equal rectangles in the vicinity of section 1-1. We may see that after deformation these rectangles present only modification of the initial right angles, so specific sliding γ (Fig.6.3).

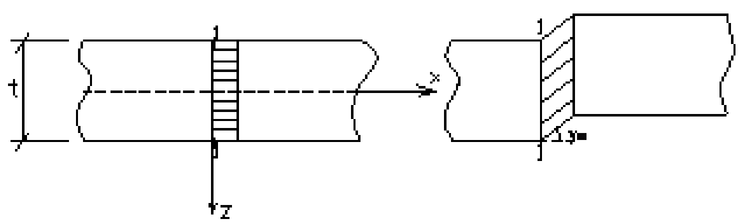


Fig.6.3

If the thickness t is very small, as in the case of the thin-walled members, the sliding γ are considered to have a constant distribution on t:

γ_{xz} = const./cross section and $\varepsilon_x = 0$

From static point of view:

$V_z^{st} = P$

6.3 PHYSICAL ASPECT

In elastic domain, writing Hooke's law for shearing: $\tau_{xz} = G \cdot \gamma_{xz} = const.$

So, the shear stress will have a constant distribution on cross section. Writing the shear force from interior:

$$V_z^{res} = \int_A \tau_{xz} dA = \tau_{xz} \cdot A$$

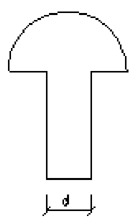
But: $V_z^{st} = V_z^{res} \Rightarrow P = \tau_{xz} \cdot A = V_z$

$$\Rightarrow \quad \boxed{\tau_{xz} = \frac{V_z}{A}}$$

6.4 RIVETED CONNECTIONS

In a riveted joining the element which realizes the connection is the **rivet**.

The **rivet** is a cylindrical rod provided with a semicircular head, made from a mild steel of an inferior quality with respect to the steel from the joined elements. For example, the element is made from steel OL37 (S235) and the rivet is made from OL34.



The rivet has a standard diameter:

d = 12,16, 20, 22, 24, 27 mm

The connected elements are previously drilled, the hole diameter being made with 1mm greater than the rivet diameter: $d_h = d + 1$mm. After the rivet is stroked, the rod of the rivet will completely fill the hole. The rod of the rivet is longer than the thickness of the block which is joined, the material which is in excess becoming the other head of the rivet, after striking. The rivet is heated (temperature of $750^0 - 1000^0$C) and it is introduced in the hole from pieces.

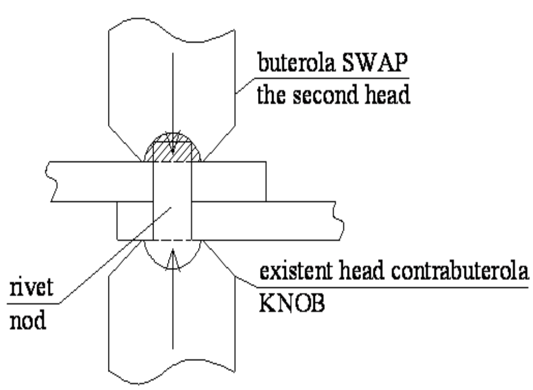


Fig.6.3

Over the existent head of the rivet, a device called ***knob*** (contrabuterola in Romanian) is applied, and on the free end a similar piece is disposed, called ***swap*** (buterola in Romanian). These 2 devices compose the ***riveting set*** (Fig.6.3). This second piece is stroked with a hammer (pneumatic or manual) and the free end forms the second head. After cooling, the rivet rod is contracted and the ends of the rivet strongly press the joined elements.

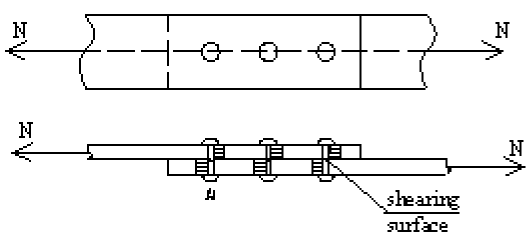
The riveted connection **failure** can be produced in 2 extreme cases:

- for rivets with small diameter, **the rivet shearing**; the shearing is produced in the contact surface of the joined elements.

- for thin pieces in the block that is joined, a **crushing pressure of the hole walls** is produced and eventually the elements splitting.

a) The rivet shearing

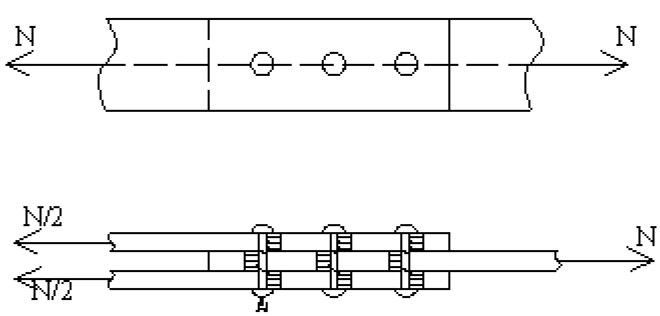
Let's assume a riveted joining of 2 pieces is subjected to tension.



For each rivet, the failure is produced through the shearing surface (the contact surface) of area:

$$A_f = \frac{\pi d^2}{4}$$

But this joining isn't recommended because this is an unsymmetrical joining. If the joining has 3 pieces, the shearing of each rivet is produced in 2 surfaces of area:



$$A_f = 2\frac{\pi d^2}{4}$$

Generally, if one rivet presses a block of *n+1* pieces, the shearing surface is:

$A_f = n_f \frac{\pi d^2}{4}$ $\quad$ n_f: the number of shearing surfaces

Knowing the design strength in shearing of a riveted connection R_f^n and the rivet diameter *d*, the **capable stress of one rivet subjected to shearing** is:

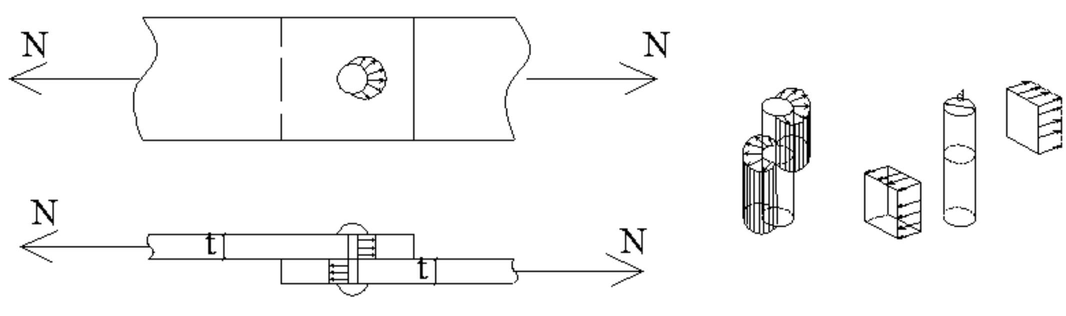
$$N_f = A_f \cdot R_f^n = n_f \cdot \frac{\pi d^2}{4} \cdot 0.8R$$

With: n_f: the number of shearing surfaces

$R_f^n \cong 0.8R \cong 1700 \frac{daN}{cm^2}$ for mild steel OL37(S235)

b) The crushing (the local pressure) on hole

The distribution of local pressure on the hole walls is irregular (b) but in design it can be admitted a uniform distribution (c) on a diametric section.



a $\quad$ b $\quad$ c

The area at local pressure, for 2 joined pieces having the same thickness *t*, is:

$$A_p = d \cdot t$$

If there are joined many pieces of different thickness t_i, the area is:

$$A_p = d \cdot (\boldsymbol{\Sigma} t_i)_{min}$$

where: $(\boldsymbol{\Sigma} t_i)_{min}$ is the minimum thickness of the pieces that are subjected (displaced) in one sense (direction)

With this, **the capable stress of one rivet to local pressure is:**

$$N_p = A_p \cdot R_p^{\ n} = d \cdot (\boldsymbol{\Sigma} t_i)_{min} \cdot 2R$$

$R_p^{\ n} = 2R = 4200 \frac{daN}{cm^2}$ for mild steel OL37 (S235)

In practice, after choosing the rivet diameter *d* function the thickness of the joined pieces, the required number of rivets for a joining, to transmit the axial stress is:

$$n = \frac{N}{Nmin}$$

where: *n*: the number of rivets

N: the design axial stress which must be transmitted through connection

$N_{min} = \min (N_f, N_p)$

6.5 APPLICATIONS

6.5.1 A steel cantilever is made of two parts (the first made from two plates 14×200 and the second made from three plates 8×250) connected with rivets Φ13 disposed on two rows (Fig.6.4). If the load parameter is n_F = 1,0 and the design strength of steel is R = 2100 daN/cm^2, determine the value of the load parameter F in order to have the strength conditions fulfilled in the entire bar. Then calculate the required number of rivets

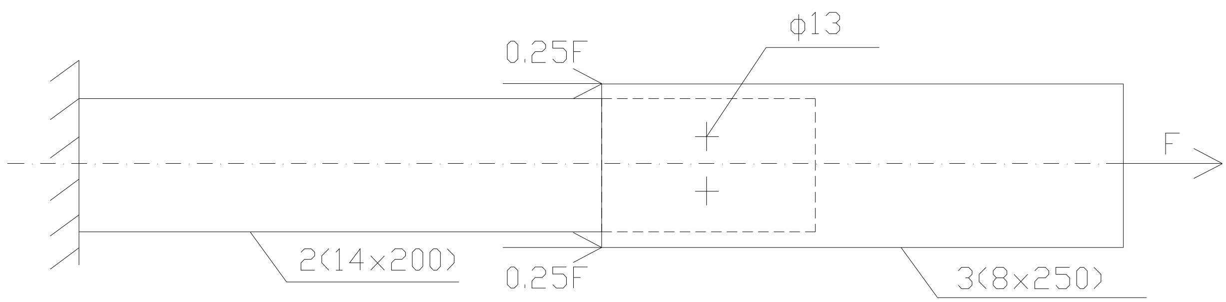


Fig.6.4

The axial force N diagram and the critical sections are presented in Fig.6.5:

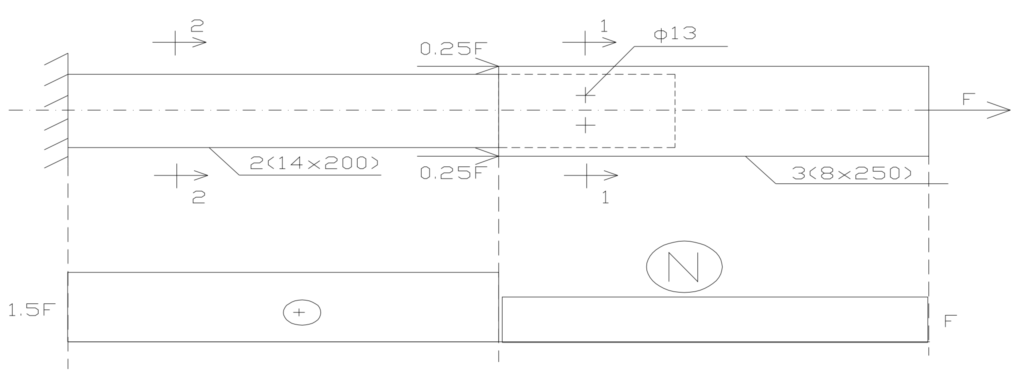


Fig.6.5

Section 1-1:

$$A_{net\ 1} = 3(25 \cdot 0{,}8 - 2 \cdot 1{,}3 \cdot 0{,}8) = 53{,}76\ cm^2$$

$$A_{net\ 2} = 2(20 \cdot 1{,}4 - 2 \cdot 1{,}3 \cdot 1{,}4) = cm^2 = A_{net\ min}$$

$$\sigma_x = \frac{N}{A_{net\ min}} \leq R \rightarrow N = F \leq R \cdot A_{net\ min} \rightarrow F \cdot 10^2 \leq 2100 \cdot 48{,}72 \rightarrow$$

$F \leq 1023{,}12$ kN

Section 1-1:

$$A \quad = 2 \cdot 20 \cdot 1{,}4 = 56\ cm^2$$

$$\sigma_x = \frac{N}{A} \leq R \rightarrow N = 1{,}5F \leq R \cdot A \quad \rightarrow 1{,}5F \cdot 10^2 \leq 2100 \cdot 56 \rightarrow$$

$F \leq 784$ kN

The final value of the load parameter F is: $\boxed{F = 784 \text{ kN}}$

The number of rivets:

$$n = \frac{N}{Nmin}$$

$N_{min} = \min(N_f, N_p) = 8920$daN

$$N_f = n_f \cdot \frac{\pi d^2}{4} \cdot 0{,}8R = 4 \cdot \frac{\pi \cdot 1{,}3^2}{4} \cdot 0{,}8 \cdot 2100 = 8920 daN$$

$$N_p = d \cdot (\Sigma t_i)_{min} \cdot 2R = 1{,}3 \cdot 2{,}4 \cdot 2 \cdot 2100 = 13104 \text{daN}$$

$$n = \frac{784 \cdot 10^2}{8920} = 8{,}78 \ \rightarrow n = 10\ nituri$$

6.5.2 A steel cantilever is made of two parts (the first made from a laminated profile IPN360 and the second made from a plate 13×500) continuity connected, using 2 splice-plate 6×300 and rivets Φ21 disposed on two rows (Fig.6.6). If the load parameter is $n_F = 1{,}0$ and the design strength of steel is R = 2200 daN/cm^2, determine the value of the load parameter F in order to have the riveted connection made with a total number of 4 rivets. Then verify the bar.

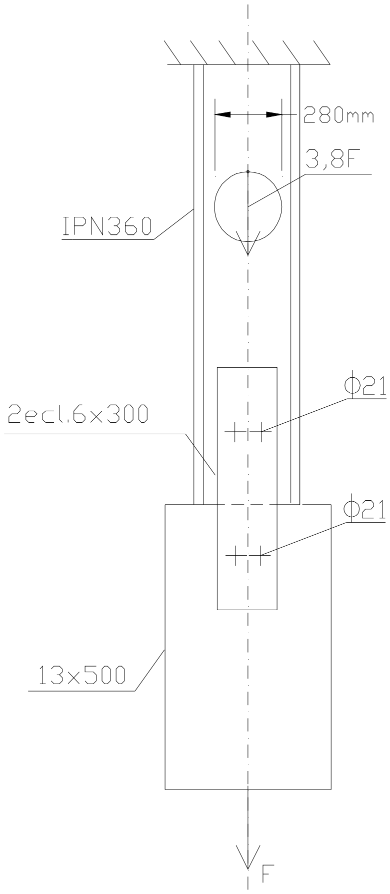


Fig.6.6

The number of rivets on one side of the connection is:

$$n = \frac{N}{Nmin} = 2$$

$N_{min} = \min(N_f, N_p) = 11088daN$

$N_f = 2\cdot \frac{\pi\cdot 2{,}1^2}{4}\cdot 0{,}8\cdot 2200 = 12192 daN$

$N_p = 2{,}1\cdot 1{,}2\cdot 2\cdot 2200 = 11088daN$

$$2 = \frac{F\cdot 10^2}{11088} \rightarrow \boxed{F = 221{,}76kN}$$

Verification of bar:

a) in the connected sections from IPN profile, respectively the plate 13×500, where N = F:

$A_{net\ IPN} = 97{,}1 - 2\cdot 2{,}1\cdot 1{,}3 = 91{,}64\ cm^2$

$A_{net\ splice\ plates} = 2(30\cdot 0{,}6 - 2\cdot 2{,}1\cdot 0{,}6)$
$= 30{,}96cm^2 = A_{net\ min}$

$A_{net\ pl.} = 1{,}3\cdot 50 - 2\cdot 2{,}1\cdot 1{,}3 = 59{,}54\ cm^2$

$$\sigma_x = \frac{22176}{30{,}96} = 716 daN/cm^2 < R$$

b) in the section where the circular hole weakens the IPN profile and N = F:

$A_{net} = 97{,}1 - 28\cdot 1{,}3 = 60{,}7cm^2$

$$\sigma_x = \frac{22176}{60{,}7} = 365 daN/cm^2 < R$$

c) in the section of maximum axial force, where N = 4,8F:

$$\sigma_x = \frac{4{,}8\cdot 22176}{97{,}1} = 1096 daN/cm^2 < R$$