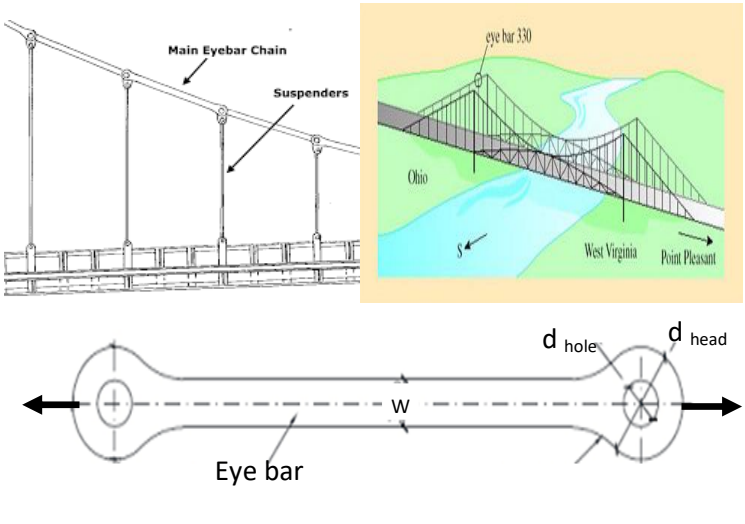
EYE BARS MEMBER (D-6 P.P30 &P.P-254)

In structural engineering and construction, an eye bar is a straight bar, usually of metal, with a hole ("eye") at each end for fixing to other components. Eye bars are used in structures such as bridges, in settings in which only tension, and never compression, is applied. Also referred to as "pin - and eye bar construction" in instances where pins are being used



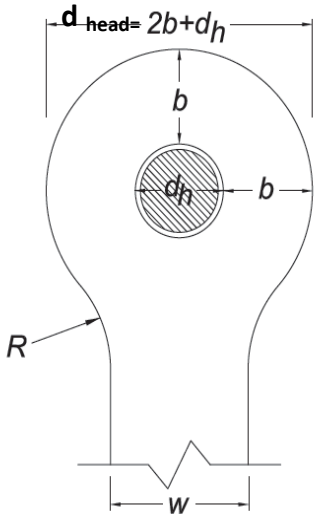
Dimension requirements according to AISC limitations

Eye bars shall be of uniform thickness, without reinforcement at the pin holes, and have circular heads with the periphery concentric with the pin hole. The radius of transition between the circular head and the eye bar body shall not be less than the head diameter. The pin diameter shall not be less than seven-eighths times the eye bar body width, and the pin hole diameter shall not be more than 1/32 in. (1 mm) greater than the pin diameter. For steels having Fy greater than 70 ksi , the hole diameter shall not exceed five times the plate thickness, and the width of the eye bar body shall be reduced accordingly. A thickness of less than 1/2 in. is permissible only if external nuts are provided to tighten pin plates and filler plates into snug contact. The width from the hole edge to the plate edge perpendicular to the direction of applied load shall be greater than two-thirds and, for the purpose of calculation, not more than three-fourths times the eye bar body width.

EYEBARS

Dimensional Requirements

1- Thickness shall be uniform
2- $t \geq 1/2$ in.
3- $w \leq 8t$
4- $d_{pin} \geq 7/8w$
5- $d_{hole} \leq d_{pin} + 1/32$ in. if fy > 70 then $d_{hole} \leq 5t$
6- $R \geq d_{head} = d_{hole} + 2b$
7- $2/3w \leq b \leq 3/4w$ (Upper limit is for calculation purposes only)



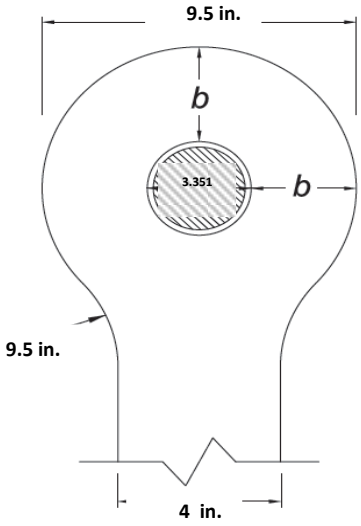
Example

Check the dimension of eye bar according to AISC limitations (requirements) if:
W= 4 in., t= ½ in.,d_{head} =9.5 in,R=9.5 in.,d_{pin} =3.5 in., d $_{hole}$=3.351 in. use A36 steel material.

Solution

Steel	fy	fu
A36	36	58

EYEBARS



Check the dimensional Requirements

1- Thickness shall be uniform
Thickness is uniform OK

2- t ≥ 1/2 in .
½ = ½ OK

3- w ≤ 8t
4 ≤ 8 x ½
4 = 4 OK

4- $d_{pin} \geq 7/8w$
3.5 ≥ 7/8 x 4
3.5 = 3.5 OK

5- $d_{hole} \leq d_{pin}$ + 1/32 in. (fy= 36 < 70)
$d_{hole} \leq d_{pin}$ + 1/32 in
3.531 ≤ 3.5 +1/32
3.531 = 3.531 OK

6- R ≥ d $_{head}$ =d_{hole} + 2b
9.5 = 9.5 Ok

7- 2/3w ≤ b ≤ 3/4w

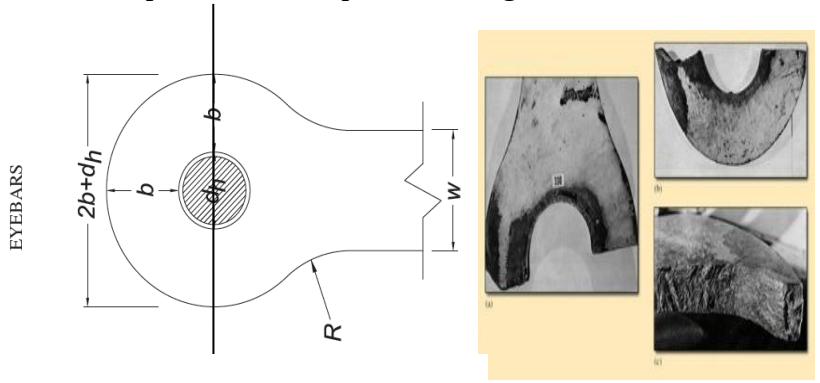
$$b=\frac{(d\ head\ -dhole)}{2} = \frac{9.5-3.531}{2} = 2.984\ in$$

2/3 w ≤ b ≤ 3/4w
2/3x4 ≤ 2.984 ≤ 3/4x4
2.66 ≤ 2.984 ≤ 3 OK

The dimension of eye bar is adequate according to AISC limitations

2- Tensile Strength of eye bar

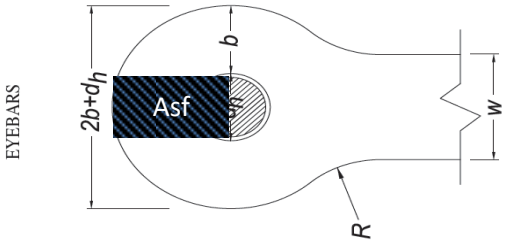
The design of eye bar is governed by the geometry and physical dimensions of the member as well as limit states for strength. The governing strength design limit state is the lowest value of the following: tensile rupture, shear rupture bearing on the member, and yielding as follows:



1- Tension on the net effective area

θ = 0.75 (LRFD)
Ω= 2.00 (ASD)
$Pn = 2tb\,Fu$
b= (d_{head}- dh_{ole})/2

2- Shear on the effective area (Figure b

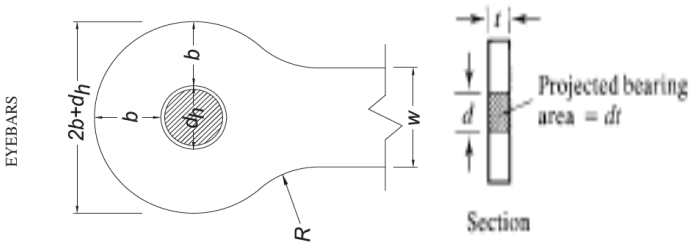


θ = 0.75
Ω = 2.00
$Pn = 0.6FuAsf$

Where:

A_{sf} =2t (b +d_{pin}/2) (in^2)
d_{pin}= pin diameter (in.)
t= thickness of connected part

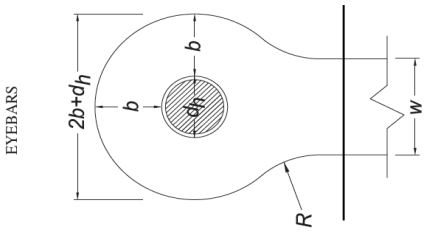
3. Bearing strength. This requirement is given in Chapter J (Connections, Joints, and fasteners) Section J7:



θ= 0.75 (LRFD)
Ω = 2.0 (ASD)
$Pn = 1.8FyApb$ (AISC Equation J7-1)

$A_{pb=}$ projected bearing area (d_{pin}t)
d_{pin}= pin diameter
t= thickness of connected part

4. Tension on the gross section



θ = 0.90 (LRFD)
Ω= 1.67 (ASD)
$Pn = Ag\,Fy$

Where
Ag = gross area in^2 = W x t
Fy= yielding strength (ksi)
The available tensile strength of eye bars shall be determined in accordance with Section D2, with Ag taken as the cross-sectional area of the body. For calculation purposes, the width of the body of the eye bars shall not exceed eight times its thickness.

The strength of an eye bar meeting the dimensional requirements of AISC specification Section D6 is governed by tensile yielding of the body.

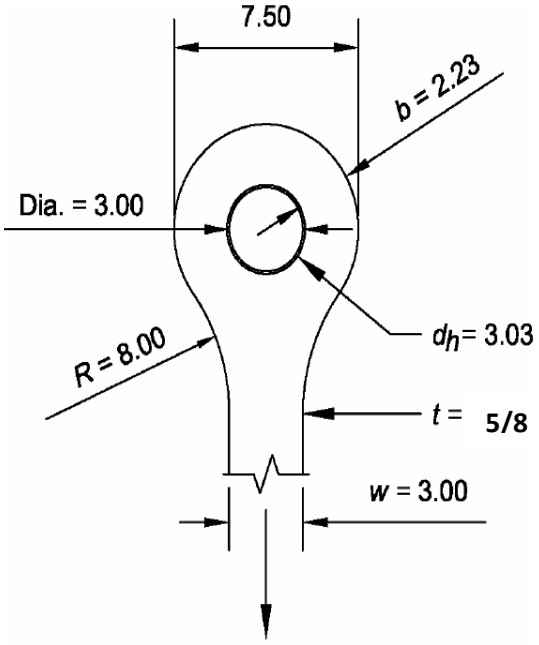
Example

A 5/8 in. thick eye bar member, ASTM A36, carries a dead load of 25 kips and a live load of 15 kips in tension. The pin diameter is 3 in. Verify the strength by both LRFD and ASD methods.

Solution:

Steel	fy	fu
A36	36	58

Sect.	w	b	t	d_{pin}	d_{hole}	R
Eye bar	3	2.23	5/8	3	3.031	8



1- Check the dimensional Requirements

1- Thickness shall be uniform
Thickness is uniform OK

2- $t \geq 1/2$ in .
$0.625 > 0.5$ OK

3- $w \leq 8t$
$3 \leq 8 \times 0.625$
$3 < 5$ OK

4- $d_{pin} \geq 7/8w$
$3.0 \geq 7/8 \times 3$
$3.5 > 2.625$ OK

5- $d_{hole} \leq d_{pin} + 1/32$ in. (fy=36 < 70)
$d_{hole} \leq d_{pin} + 1/32$ in
$3.03 \leq 3.0 + 1/32$
$3.031 = 3.031$ OK

6- $R \geq d_{head} = d_{hole} + 2b$
$8 = 7.5$ Ok

7- $3/2\ w \leq b \leq 3/4w$

$b = \frac{(d\ head - dhole)}{2} = \frac{7.5-3.031}{2} = 2.2345\ in$

$2/3\ w \leq b \leq 3/4w$
$2/3x3 \leq 2.2345 \leq 3/4x3$
$2 \leq 2.2345 \leq 3$ OK

The dimension of eye bar is adequate according to AISC limitations

2- Check the tensile strength

Calculate the required tensile strength

LRFD	ASD
Pu = 1.2(25.0 kips) + 1.6(15.0 kips) = 54.0 kips	Pa = 25.0 kips + 15.0 kips = 40.0 kips

Calculate the available tensile yield strength at the eye bar body (at w)

Ag = 3.00 in.(0.625 in.) = 1.875 in^2.

Pn= Fy x Ag = 36 x 1.875 = 67.5 kips

LRFD	ASD
ϕ = 0.90 ϕ Pn = 0.90(67.5 kips) = 60.75 kips 60.75 kips > 54.0 kips o.k.	Ω = 1.67 Pn/Ω = (67.5 kips)/1.67 = 40.42 kips 40.42 kips > 40.0 kips o.k.

The eye bar tension member available strength is governed by the tension yield limit state.

Note: The eye bar detailing limitations ensure that the tensile yielding limit state at the eye bar body will control the strength of the eye bar itself. The pin should also be checked for shear yielding, and if the material strength is lower than that of the eye bar, bearing, as following:-

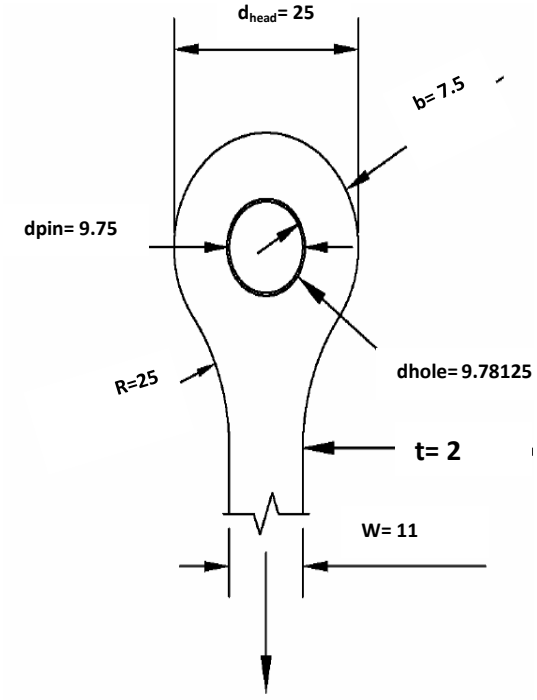
LRFD	ASD
1- Tensile yielding ϕ = 0.90 ϕ Pn = 0.90(67.5 kips) = 60.75 kips =60.75 kips > 54.0 kips ok	**1- Tensile yielding** Ω = 1.67 Pn/Ω = (67.5 kips)/1.67 = 40.42 kips =40.42 kips > 40.0 kips ok
2- Strength surface in bearing ϕ = 0.75 ϕ Pn = 0.75xA_{eff} x1.8xfy A_{eff} = d_{pin}x t =3x 5/8= 1.875 in^2 ϕ Pn = 0.75x1.875 x1.8x36 = 91.125 > 54.0 kips ok	**2- Strength surface in bearing** Ω = 2 Pn/ Ω = A_{eff} x1.8xfy/ Ω A_{eff} = d_{pin}x t =3x 5/8= 1.875 in^2 Pn/ Ω =1.875 x1.8x36/2 = 60.75 > 40.0 kips ok
3- Shear rupture on the effective net area ϕ = 0.75 ϕ Pn = 0.75x0.6xA_{eff} xfu A_{eff} = (d_{pin}/2 +b) x2t =(3/2+2.235)x2x0.625= 4.66875 in^2 ϕ Pn = 0.75x0.6x4.66875 x58 = 121.83 > 54.0 kips ok	**3- Shear rupture on the effective net area** Ω =2 Pn/ Ω = = 0.6xA_{eff} xfu/ Ω A_{eff} = (d_{pin}/2 +b) x2t =(3/2+2.235)x2x0.625= 4.66875 in^2 Pn/ Ω = = 0.6x4.66875 x58/ Ω = 81.23 > 40.0 kips ok
4- Tension rupture on the effective net area ϕ = 0.75 ϕ Pn = 0.75xA_{eff} xfu A_{eff} = 2xbxt =2x2.235 x 0.625= 2.793 in^2 ϕ Pn = 0.75x2.793 x58 = 121.528 > 54.0 kips ok	**4- Tension rupture on the effective net area** Ω =2 Pn / Ω =A_{eff} xfu A_{eff} = 2xbxt =2x2.235 x 0.625= 2.793 in^2 Pn/ Ω =2.793 x58/ 2 = 81.0 > 40.0 kips ok

Design of eye bar

Design of eye bar to carry a tensile dead load (400 kip) and live load (250 kip) use A572G50 steel material and ASD method

Solution:

Steel	fy	fu
A572G50	50	65



$Pa=P_{dl}+P_{ll}$

$= 400+250= 650$ kip

$Ag = PaxΩ/fy$ $=1.67x650/50= 21.71 = 22$ in^2

Ag= W x t **assume t according to Table (2-4)**

Assume t= 2 in.

W=22/2 = 11 in.

W≤ 8t

11< 8x2 =16 ok

$d_{pin}\geq 7/8$ W

$d_{pin}\geq 7/8$ x11 =9.625

Use dpin= 9 ¾ in

$d_{hole} \leq d_{pin} + 1/32$

$d_{hole} \leq 9.75+1/32=9.78125$ in

2/3W≤b ≤ 3/4W

2/3x11≤b ≤ 3/4x11

7.33 ≤b ≤ 8.25

Use b=7.5 in

$d_{head}= 2xb+ d_{hole}$

$=2x7.5 + 9.78125= 24.78 =25$ in

$R=d_{head} = 25$ in

Check the eye bar according to the AISC limitation

Since the dimeson of eye bar was design a according to AISC limitation then the eye bar tension member available strength is governed by the tension yield limit state.

Tensile yielding

Ω = 1.67

$Pn/Ω = (Agfy)/1.67 = 11x2x50/1.67 = 658.68$ > 650 kips OK

Use eye bar (t x W x d_{head} x d_{hole})

Use eye bar (2x11x25x9.78125)

Homework

The eye bar detailing limitations ensure that the tensile yielding limit state at the eye bar body will control the strength of the eye bar itself. The pin should also be checked for shear yielding, and if the material strength is lower than that of the eye bar, bearing.

Homework

1- Check the adequacy of eye bar (2x11x25x9.78125) to carry dead load (150 kip) and live load (75 kip) acting at the end of member (BD) at pint (D) as shown in the Fig. below, use d_{pin}= 9 ¾ in , R=25 in,A572G50 steel material and LRFD method

2- If dead load (130 kip) and live load (50 kip) acting at the end of member (BD) at pint (D) Check the adequacy of the pin connection at point (A or C) if the pin connection dimension (w= 30 in, t=2 in., a =10 in. ,c =15 in., d_{pin}=9¾ in.), use A36 steel material