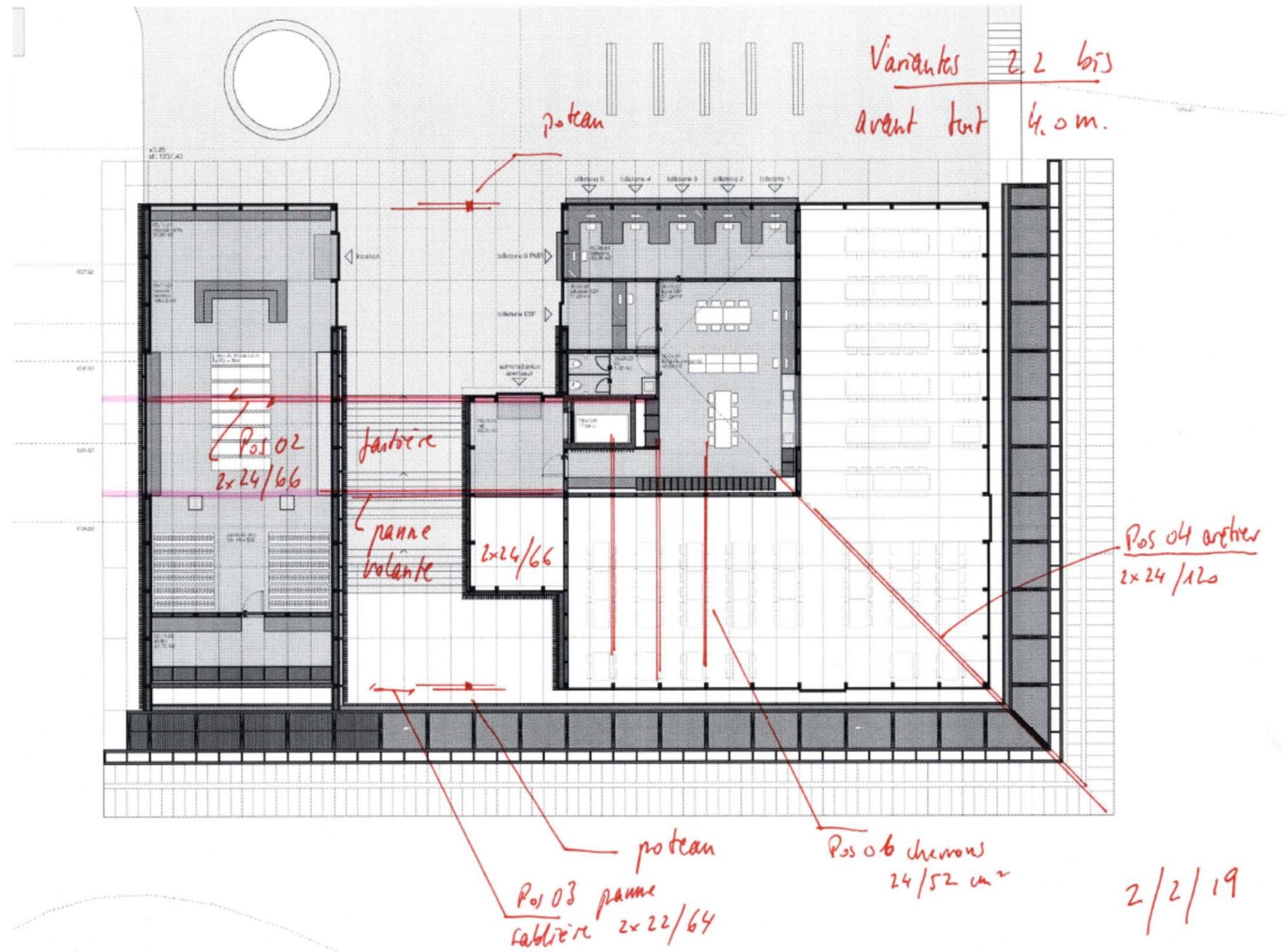


# Systèmes de poutres et porte à faux

Natterer Johannes

Ing. dipl. EPFL

EPFL - SGC

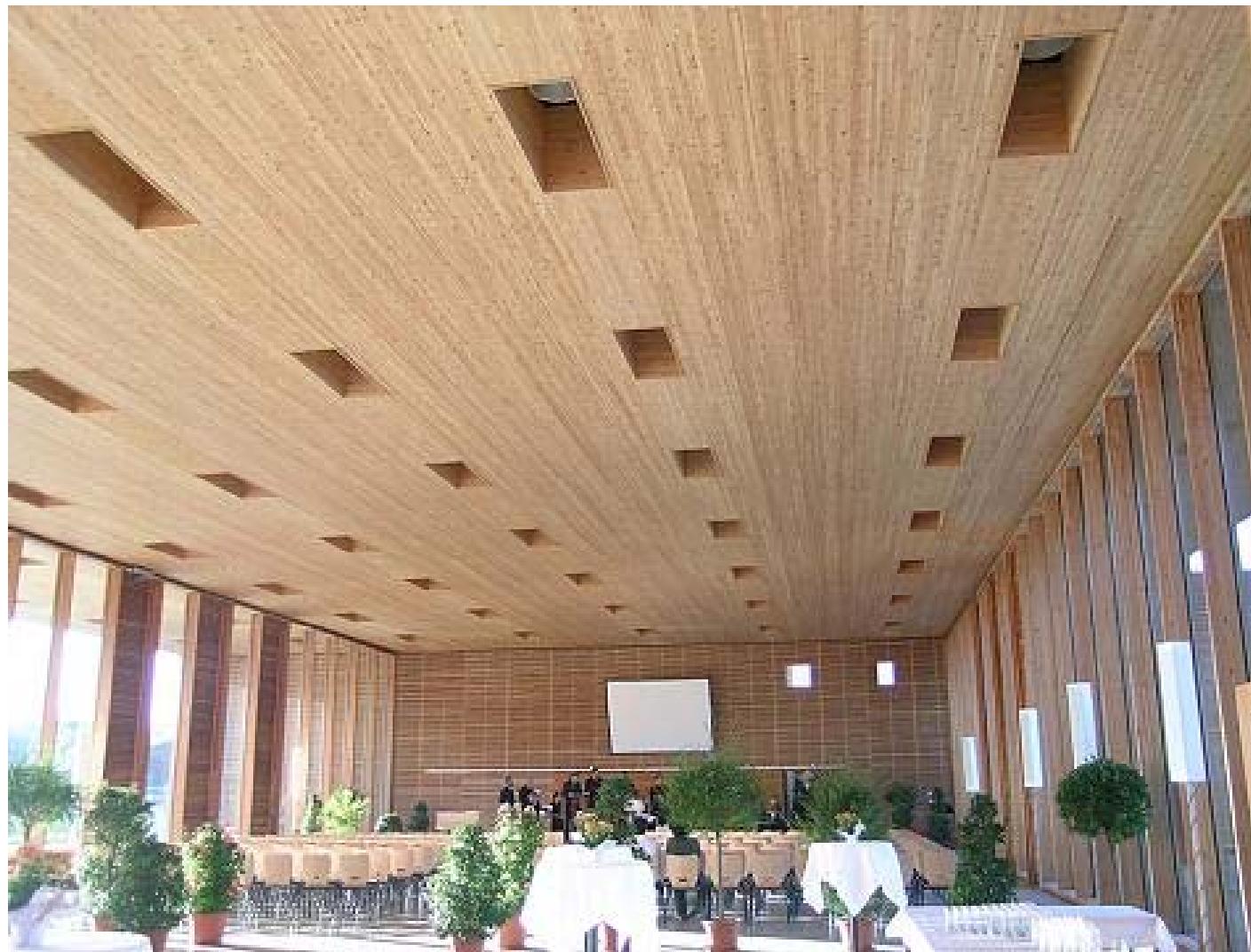


**Comparatif des coûts**

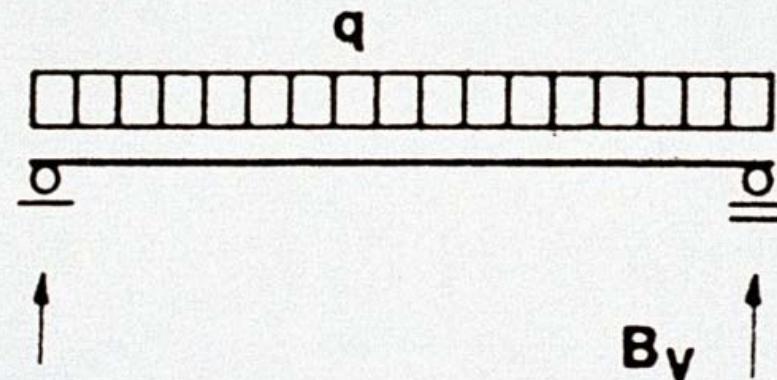
		non structure	structure	total					
Variantes		Prix SNP +/- 20% CHF	Prix SP +/- 20% CHF	Prix total +/- 20% CHF	Av. toit 5,5m	Av. toit 4,0m	entraxe chevrons Pos.06 = 2,0m	entraxe chevrons Pos.06 = 0,6m	Appui supplémentaire sablière Pos.03
Caisson		340 172	622 009	962 181	x				
chevron	1.1	354 442	432 657	787 099	x		x		
	1.2	354 442	423 326	777 768	x		x		x
	2.1	337 690	359 157	696 847		x	x		
	2.2	337 690	338 882	676 572		x	x		x
	2.2.bis	337 690	315 671	653 361		x	x		x
	3.1	354 442	616 937	971 379	x			x	
	3.2	354 442	597 929	952 371	x			x	x
	4.1	354 442	465 675	820 117		x		x	
	4.2	354 442	447 704	802 146		x		x	x

# Konrad Merz, kley und partner





## Poutres sur deux appuis, ouvrages porteurs



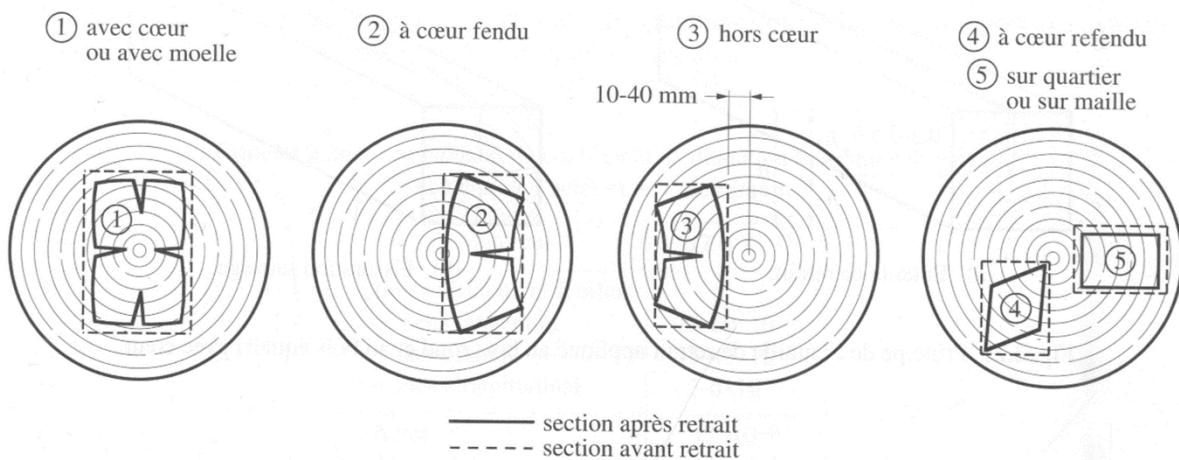
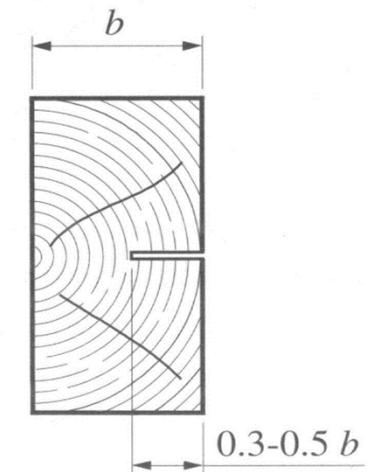
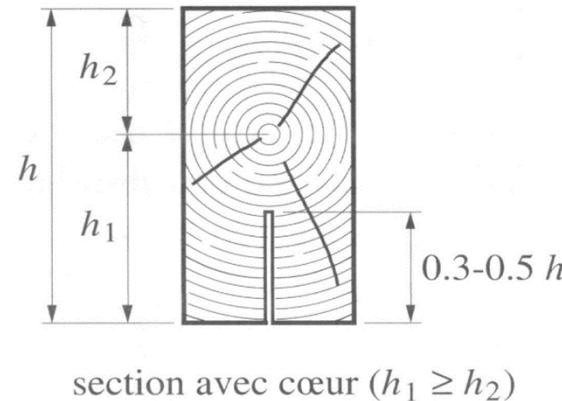
charges:

charges uniformément réparties,  
verticales

# Bois massif

# Poutre en bois massif

## ■ Limite de section



Voir table de construction en bois

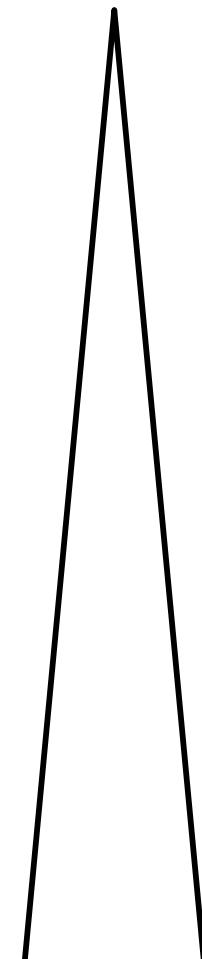
Fig. 2.24 Déformations et fissurations des sections pour les principaux modes de débit.

# L'origine du bois

## ■ Le tronc d'arbre

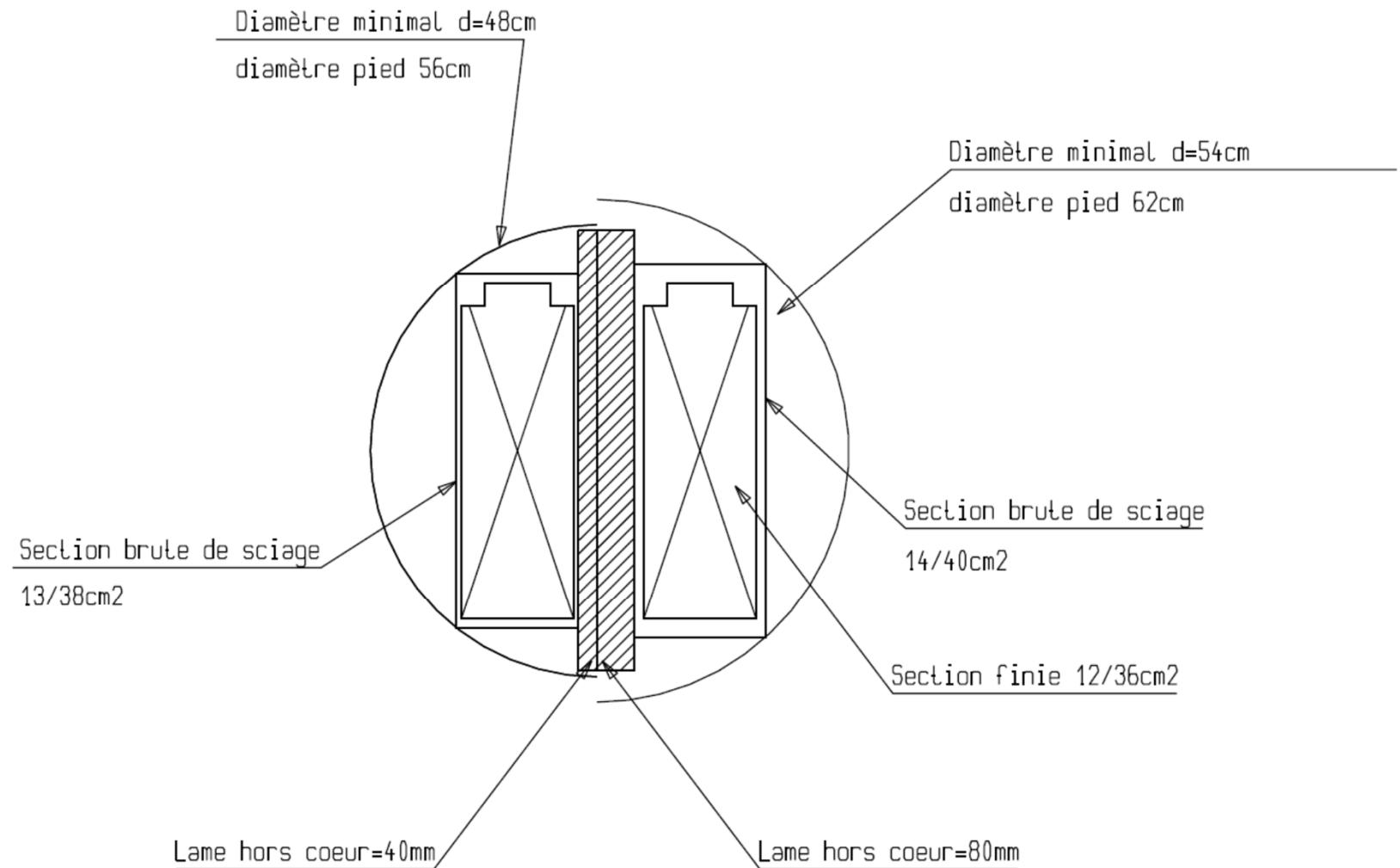


Conicité de 1cm/mètre



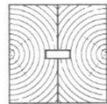
# Poutre en bois massif

## ■ Projet de Ursy

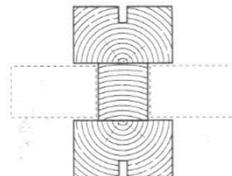


# Section composée

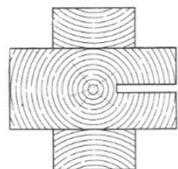
- Pour augmenter la surface – inertie -> résistance



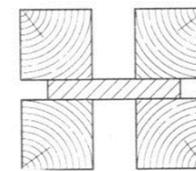
à partir de madriers à cœur refendu,  
avec gorge de décharge à l'intérieur



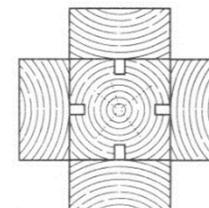
profil en I à partir de madriers



section en croix à partir de trois madriers

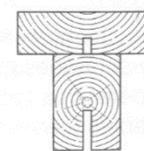
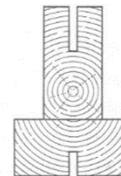


section rectangulaire composée d'un  
bastaing et de quatre madriers



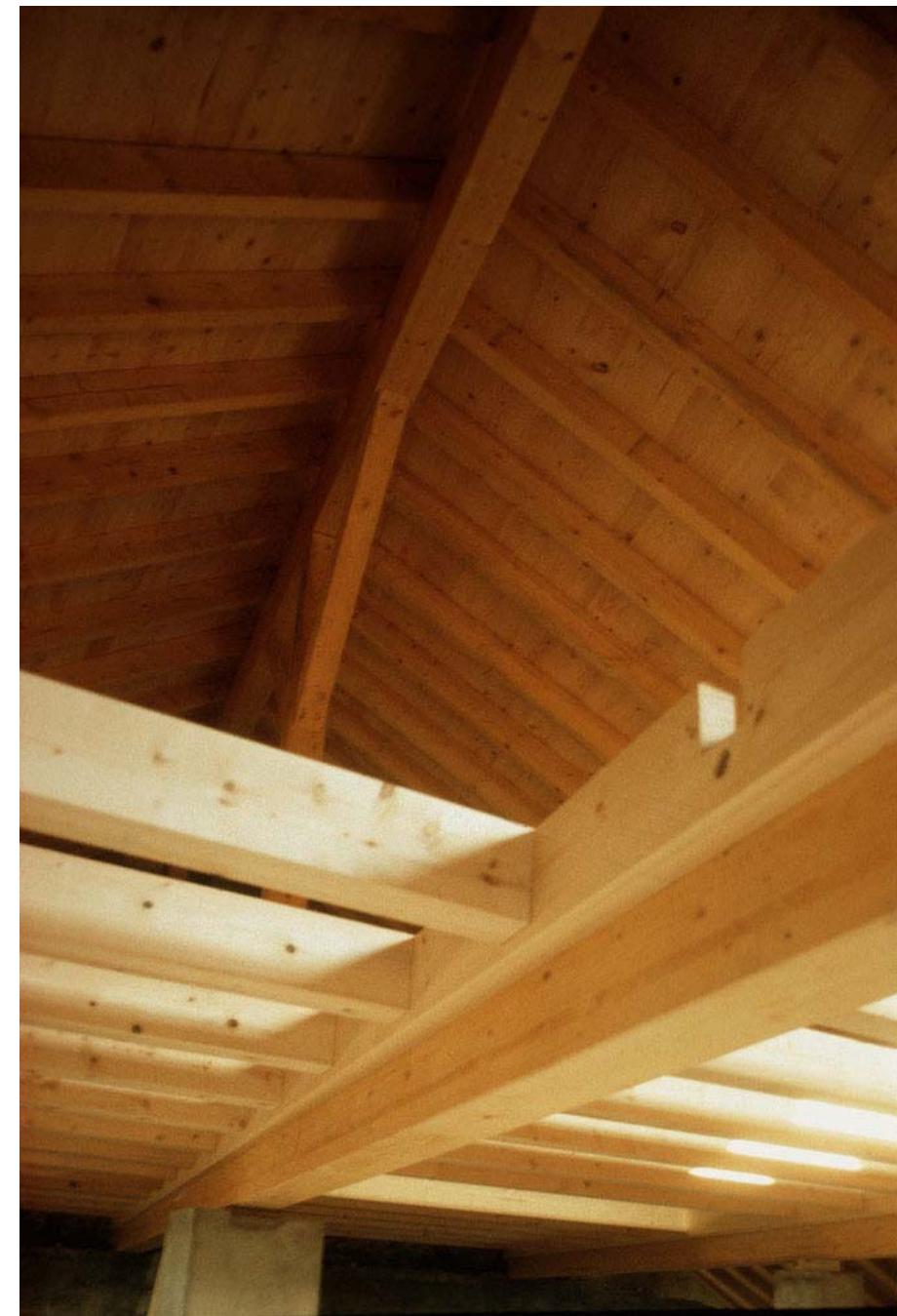
section en croix avec madrier et quatre  
bastaings

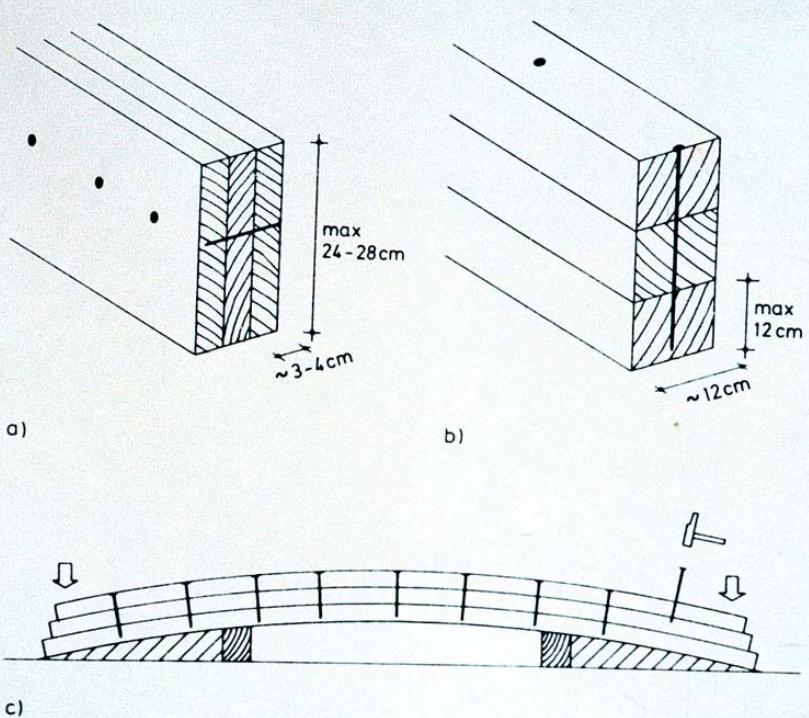
Sections composées de poutres







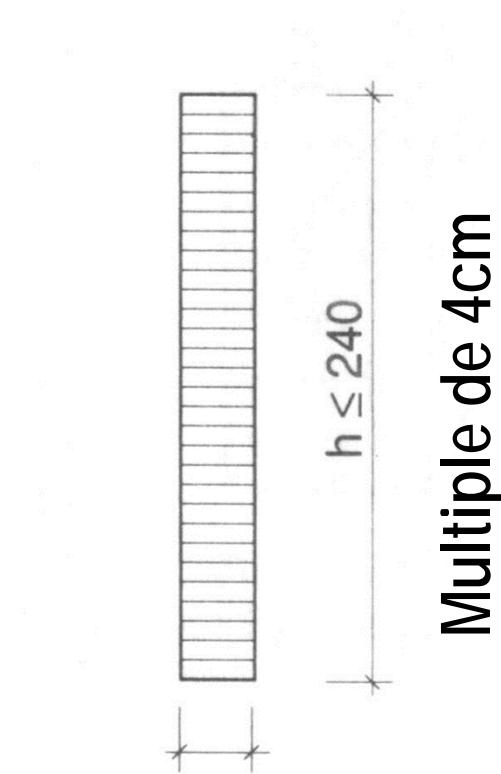






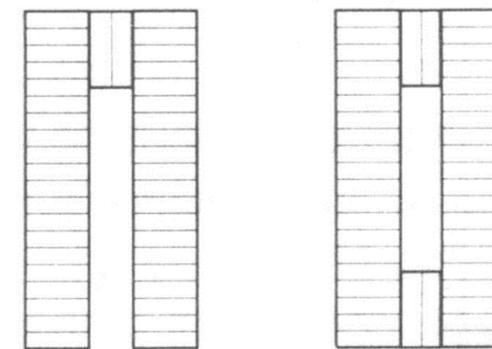
# Poutre en bois lamellé collé

# Limite de section



Multiple de 4cm

$12 < b < 24$  cm

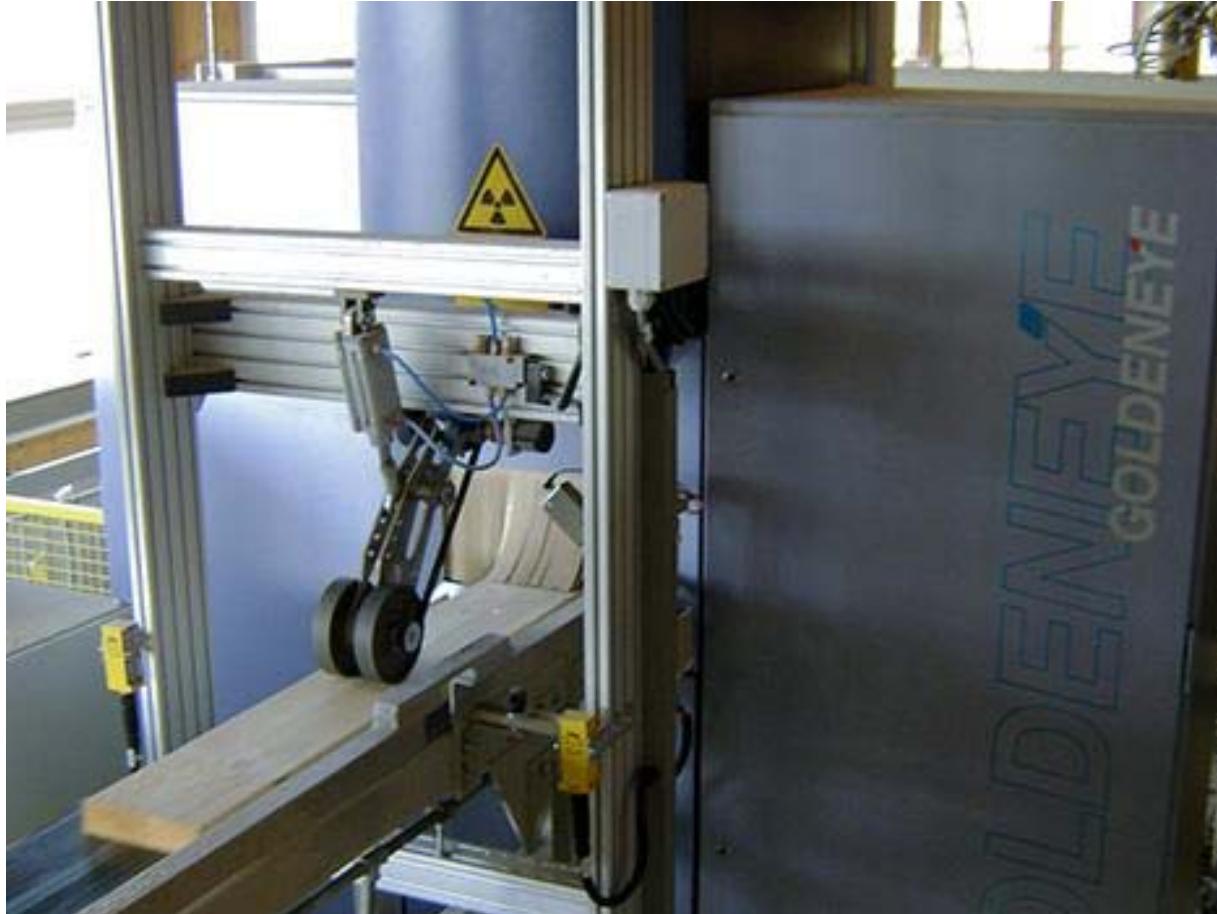


section en U retourné, section à caisson

# fabrication

- Sciage en planche
- Séchage -> 12%
- Triage
- Aboutage
- Encollage
- Serrage et séchage
- Taille et finitions

# Triage – Golden Eye



Quelques point:

Vitesse de triage : jusqu'à 450m/minutes

Mesure:    densité moyenne du bois  
                  taux d'humidité  
                  densité des noeuds

# Classe de qualité des lames

## Propriétés des lames

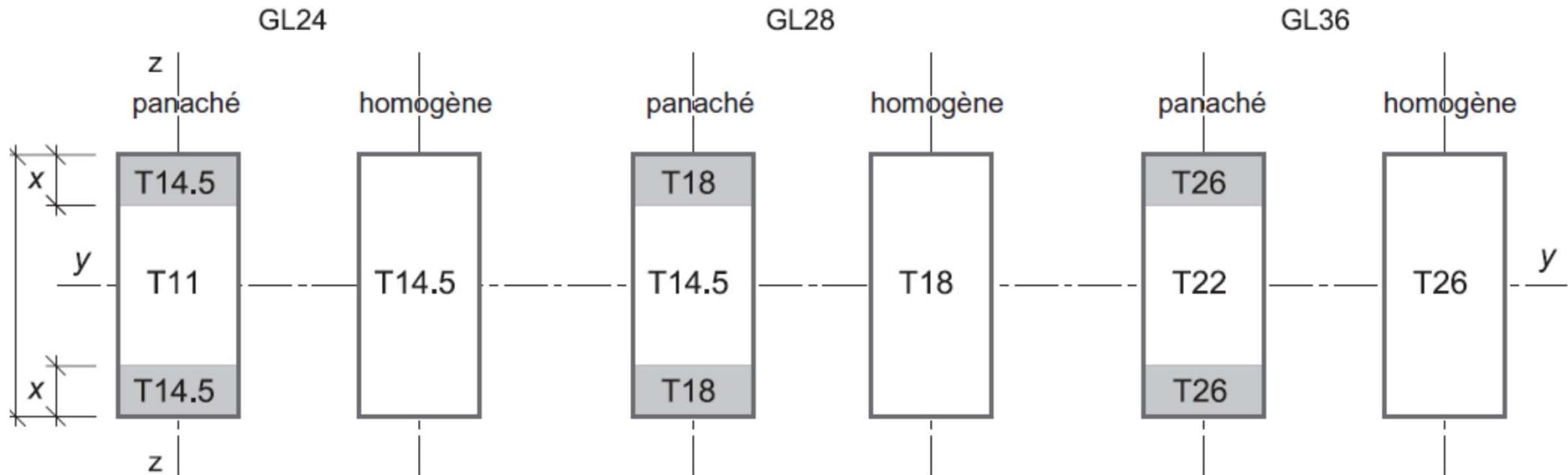
Les lames et leurs joints longitudinaux (en règle générale des aboutages dentelés) doivent correspondre aux caractéristiques du tableau 11 (EN 1194):

Tableau 11: Exigences relatives aux propriétés des lames et des aboutages

Désignation des lames	T11	T14.5	T18	T22 <sup>3)</sup>	T26 <sup>3)</sup>
Valeur caractéristique de la résistance à la traction, en N/mm <sup>2</sup> $f_{t,0,l,k}$ <sup>1)</sup>	11	14,5	18	22	26
Module E moyen en traction, en kN/mm <sup>2</sup> $E_{t,0,mean}$	9	11	12	13	14
Valeur caractéristique de la résistance à la traction des aboutages dentelés, en N/mm <sup>2</sup> $f_{t,j,k}$ <sup>2)</sup>	16	20	23	27	31
<sup>1)</sup> définie pour la section totale de la planche, pour une longueur libre de 2000 mm <sup>2)</sup> définie pour la section totale de l'aboutage, pour une longueur libre $\geq 200$ mm <sup>3)</sup> vérifier les possibilités de fabrication (nécessite un tri mécanique)					

# Composition des BLC

Figure 13: Constitution de la section de bois lamellé collé



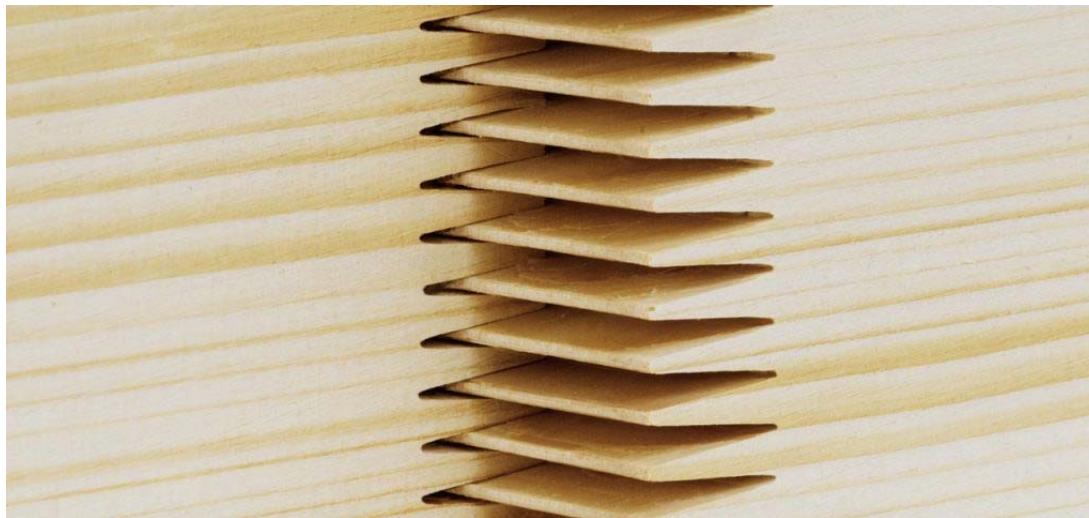
$$x \geq \frac{h}{6}, \text{ au minimum 2 lames}$$

T11: désignation des lames

T = tension (traction)

11 = valeur caractéristique de la résistance à la traction, en N/mm<sup>2</sup>.

# Aboutage



# Collage



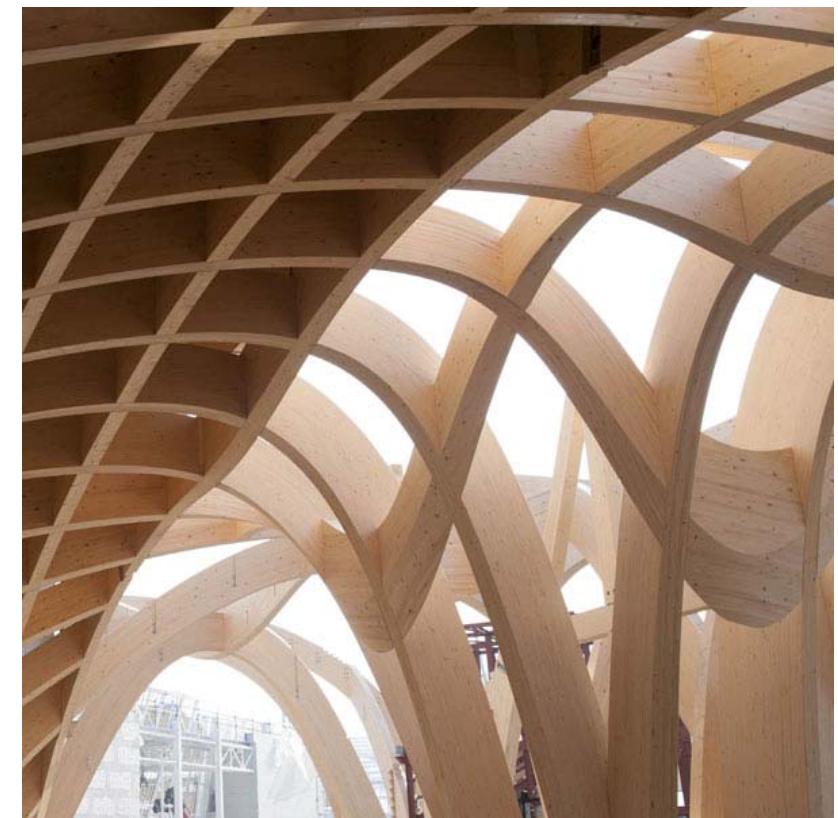
**DPF-DUCRET**



# Usinage – Assemblage

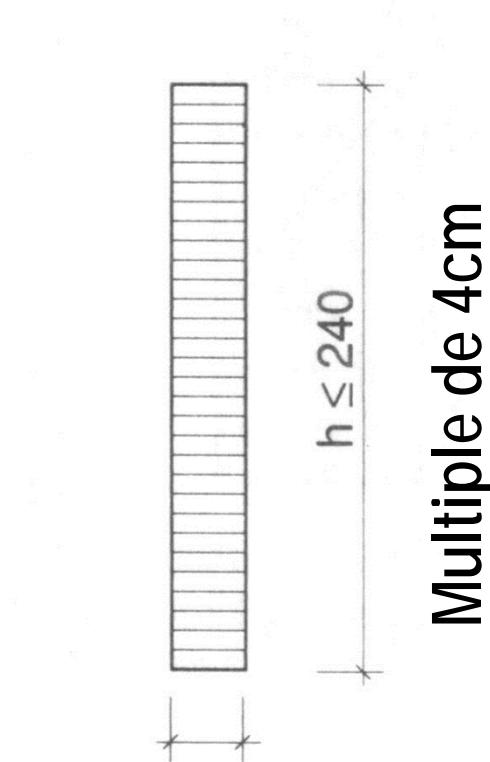


**JPF-DUCRET**



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# Limite de section



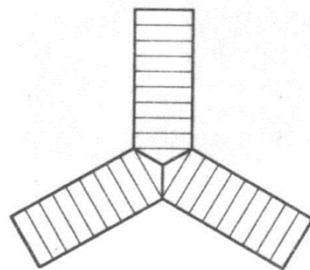
$12 \text{ cm} < b < 24 \text{ cm}$

Multiple de 4cm

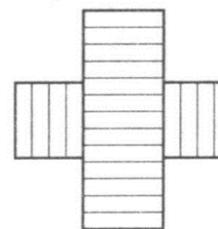
Limite de longueur

25 m - 38 m

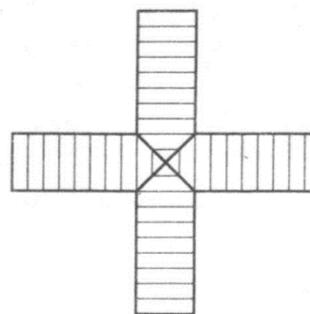
# Section composée



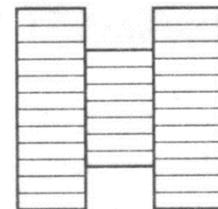
poteau triangulaire non massif



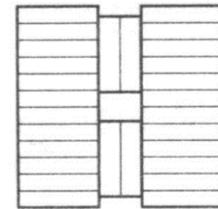
à éléments croisés

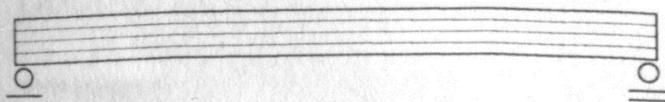


poteau en croix

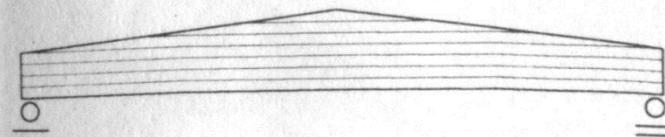


profils en I

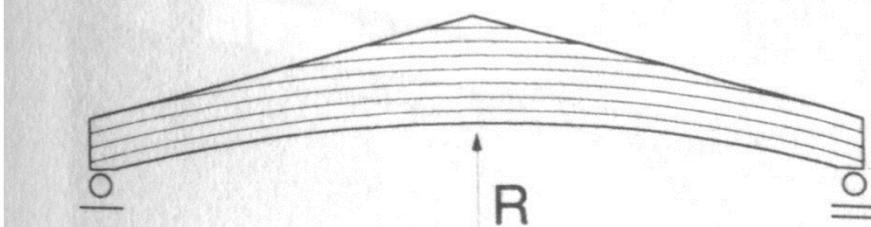




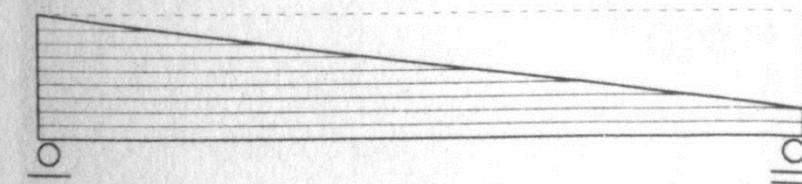
poutre lamellée-collée avec contre-flèche



poutre de toit à deux pans



poutre de toit à deux pans, incurvée

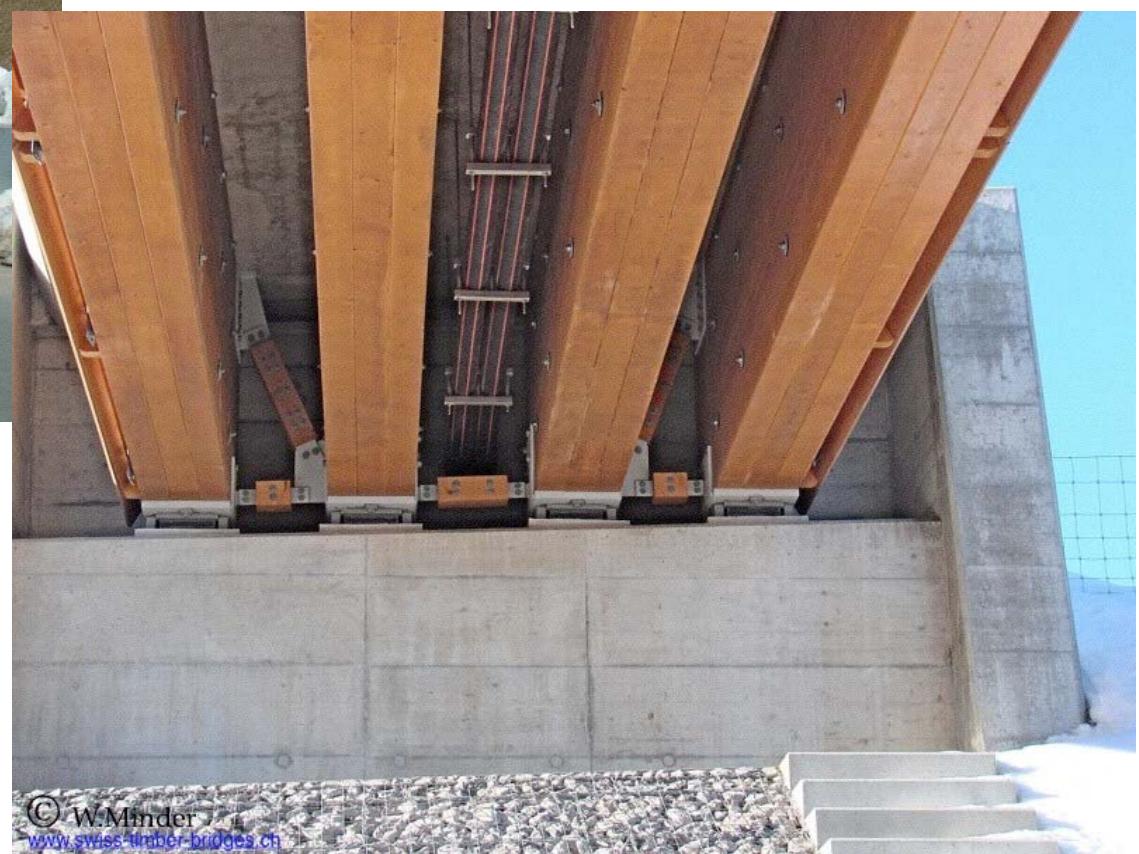


poutre rectangulaire donnant deux éléments de pan de toit



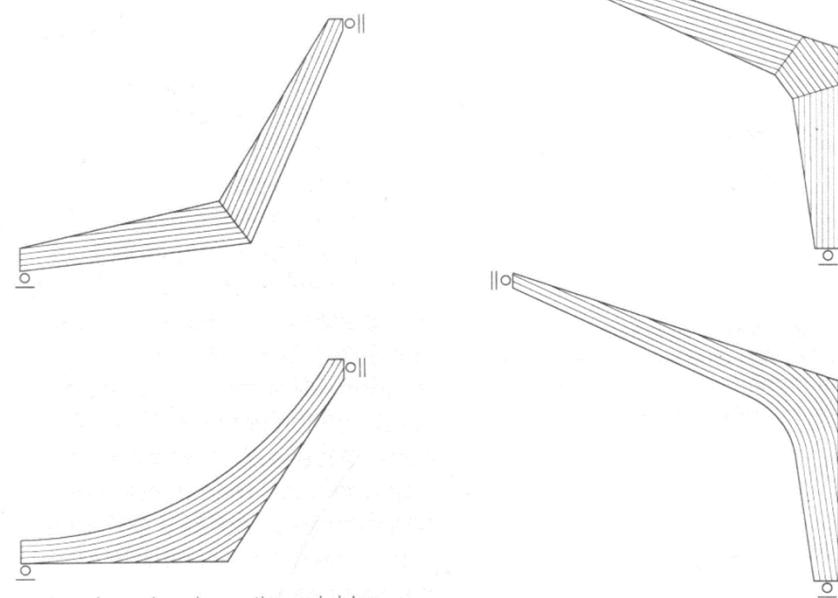




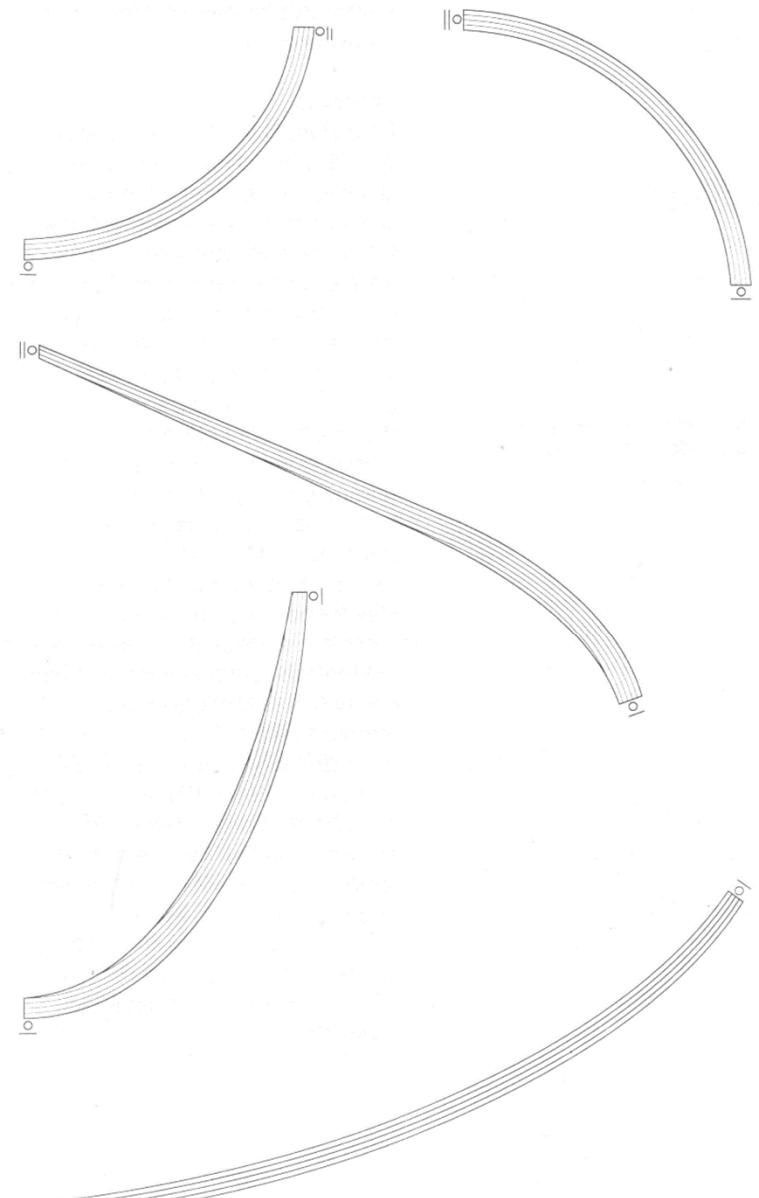




# BLC courbe



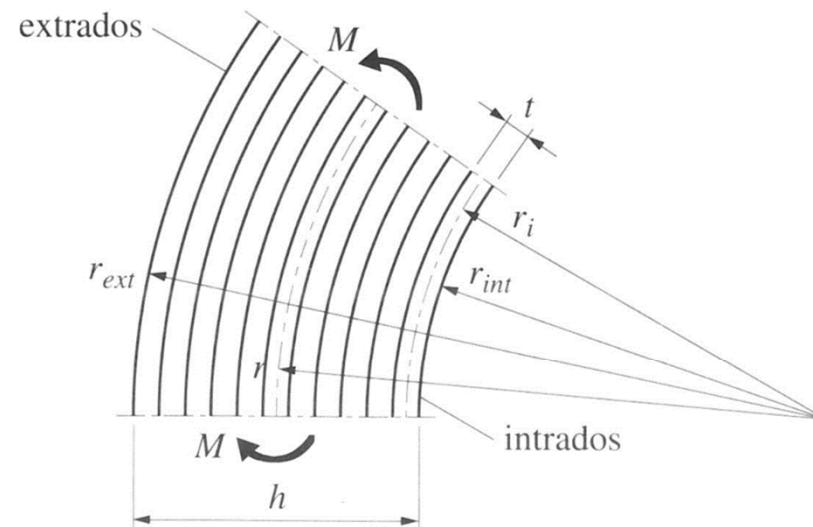
poutres à angles de portique rigides



poutres à courbure simple

# La poutre courbe

- Représentation des rayons – contrainte intérieure



**Fig. 6.41** Représentation des différents rayons de courbure à considérer.

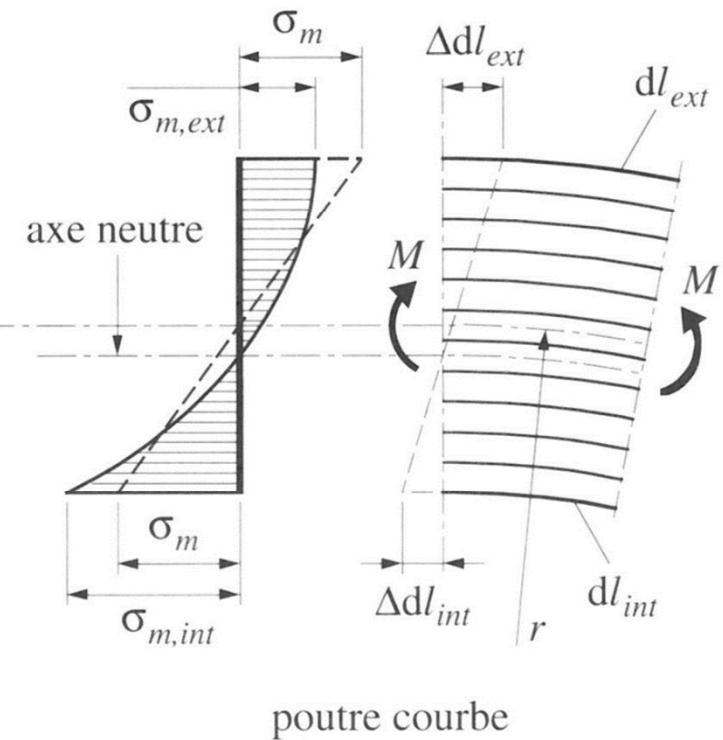
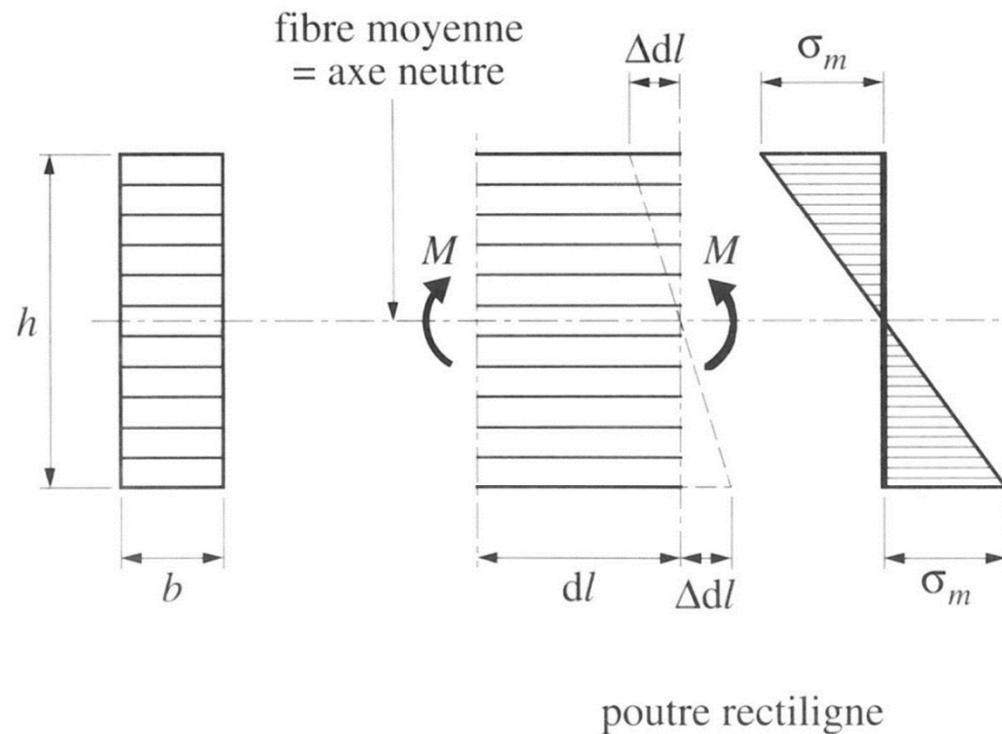
# La poutre courbe

- Contrainte intérieure

$$\sigma = \frac{1}{2} \frac{E t}{r_{int}} = \frac{1}{2} \frac{10\,000 \text{ N/mm}^2}{200} = 25 \text{ N/mm}^2$$

# La poutre courbe

## ■ Répartition de la flexion



# La poutre courbe

## ■ Facteur $k_{\parallel}$

$$\sigma_{m,d} = k_{\parallel} \frac{M_d}{W} \quad (6.41)$$

- $\sigma_{m,d}$  : valeur de calcul de la contrainte de flexion
- $k_{\parallel}$  : coefficient tenant compte de la distribution hyperbolique des contraintes de flexion pour les poutres courbes à inertie constante
- $M_d$  : valeur de calcul du moment de flexion

## ■ Selon Eurocode 5

$$k_{\parallel} = 1 + 0.35 \left( \frac{h}{r} \right) + 0.6 \left( \frac{h}{r} \right)^2$$

## ■ Selon SIA 164

$$k_{\parallel} = 1 + \frac{h}{2r}$$

# La poutre courbe

## ■ Selon SIA 265

Contraintes tangentielles (parallèles au fil):

– extrados:

$$\sigma_{ma,d} = \left| -\frac{M_{Ed}}{W} \right| \leq k_r f_{m,d}$$

– intrados:

$$\sigma_{mi,d} = \left| +\frac{M_{Ed}}{W} \left( 1 + \frac{h}{2r} \right) \right| \leq f_{m,d}$$

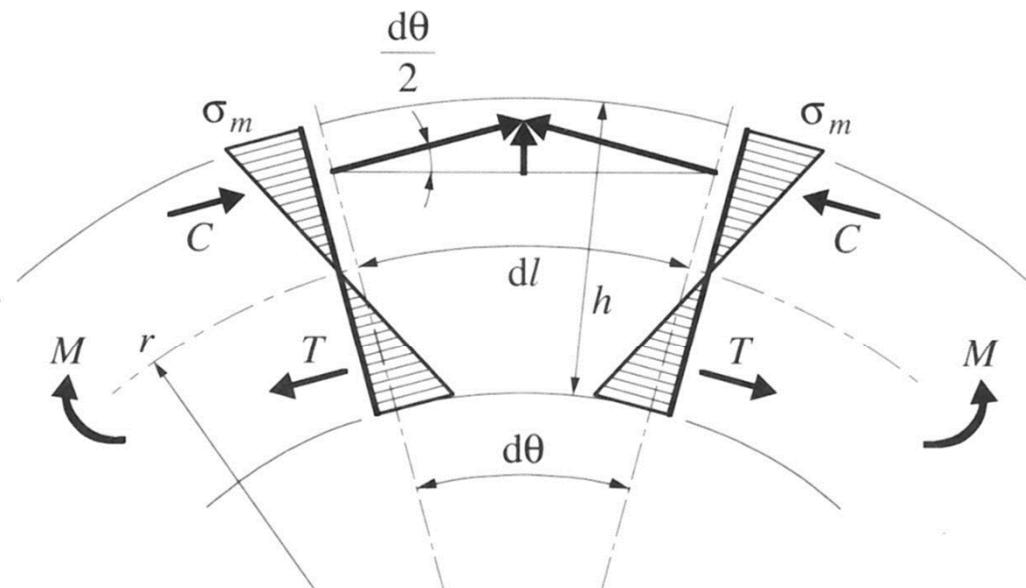
$$k_r = 1 - 40 \frac{t}{r_a}$$

$t$  épaisseur des lames

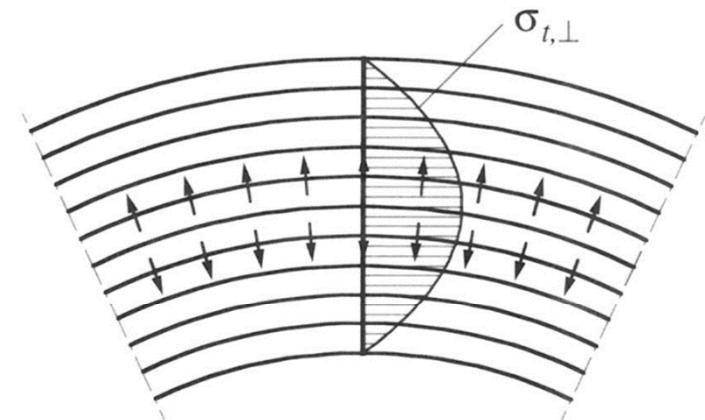
$r_a$  rayon de courbure de l'extrados.

# La poutre courbe

- Autre particularité – traction perpendiculaire à la fibre



mise en évidence de la composante transversale



contrainte transversale

# La poutre courbe

## ■ Traction perpendiculaire à la fibre

$$\sigma_{t,\perp,d} = k_{\perp} \frac{M_d}{W} \quad (6.46)$$

$\sigma_{t,\perp,d}$  : valeur de calcul de la contrainte de traction perpendiculaire aux fibres

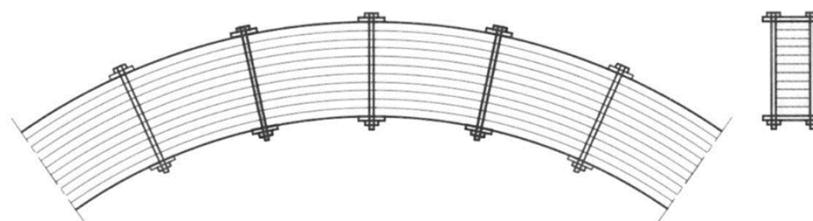
$k_{\perp}$  : coefficient lié à la géométrie de la poutre ( $k_{\perp} = h/(4 r)$  pour une poutre courbe d'inertie constante)

$M_d$  : valeur de calcul du moment de flexion

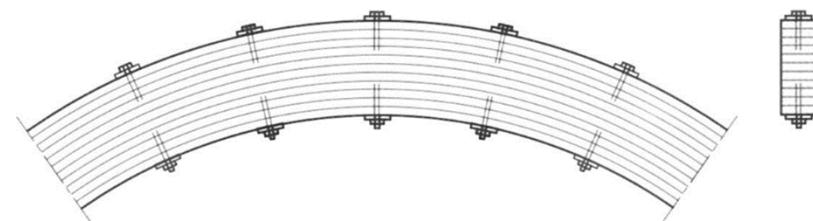
$W$  : module de flexion de la section

# La poutre courbe

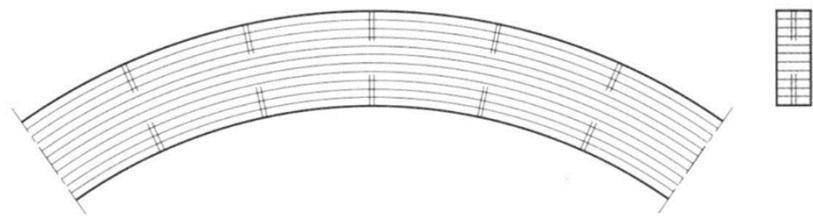
## ■ Renforcement perpendiculaire à la fibre



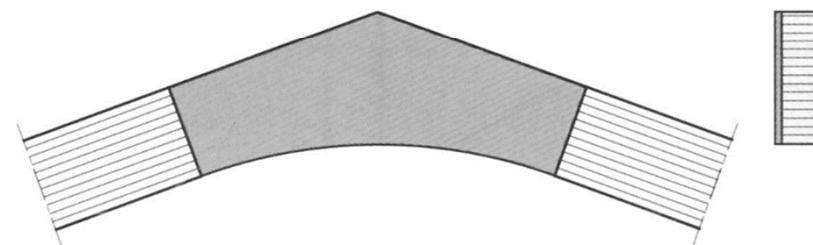
plaques et tiges filetées de chaque côté



plaques et tiges filetées à travers l'élément



tiges filetées encollées



contreplaqué de chaque côté ou fibre de verre collée

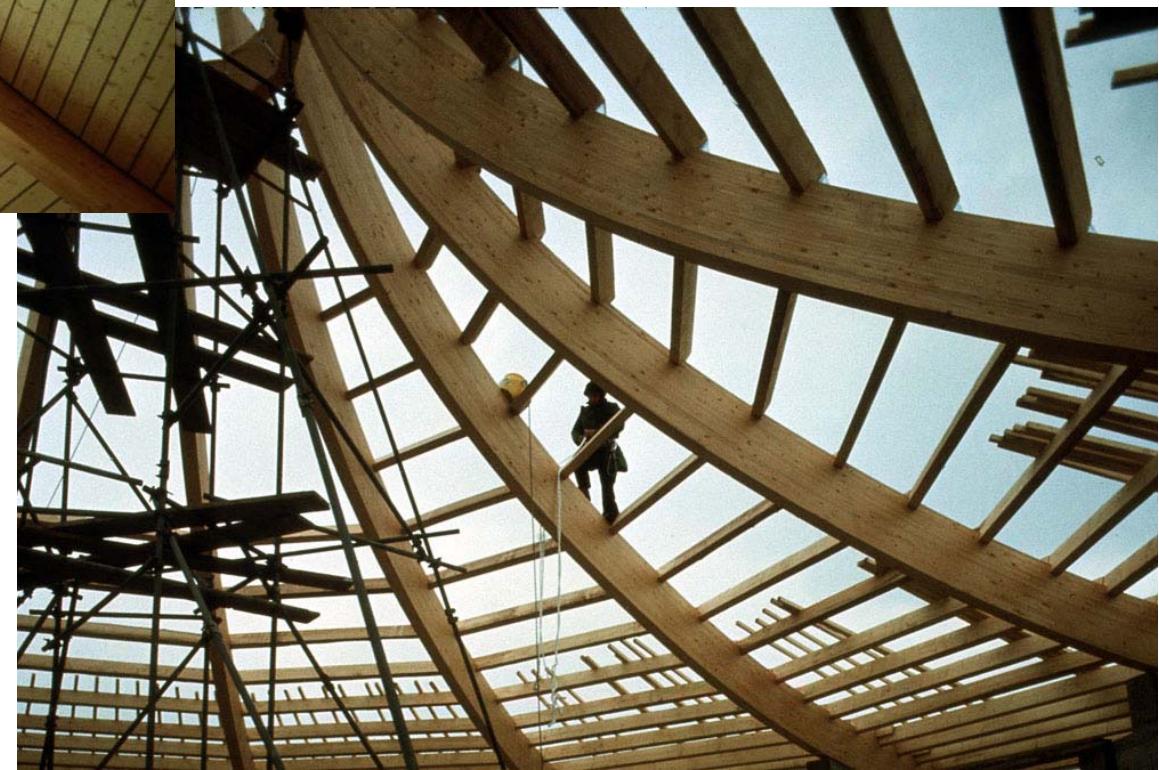
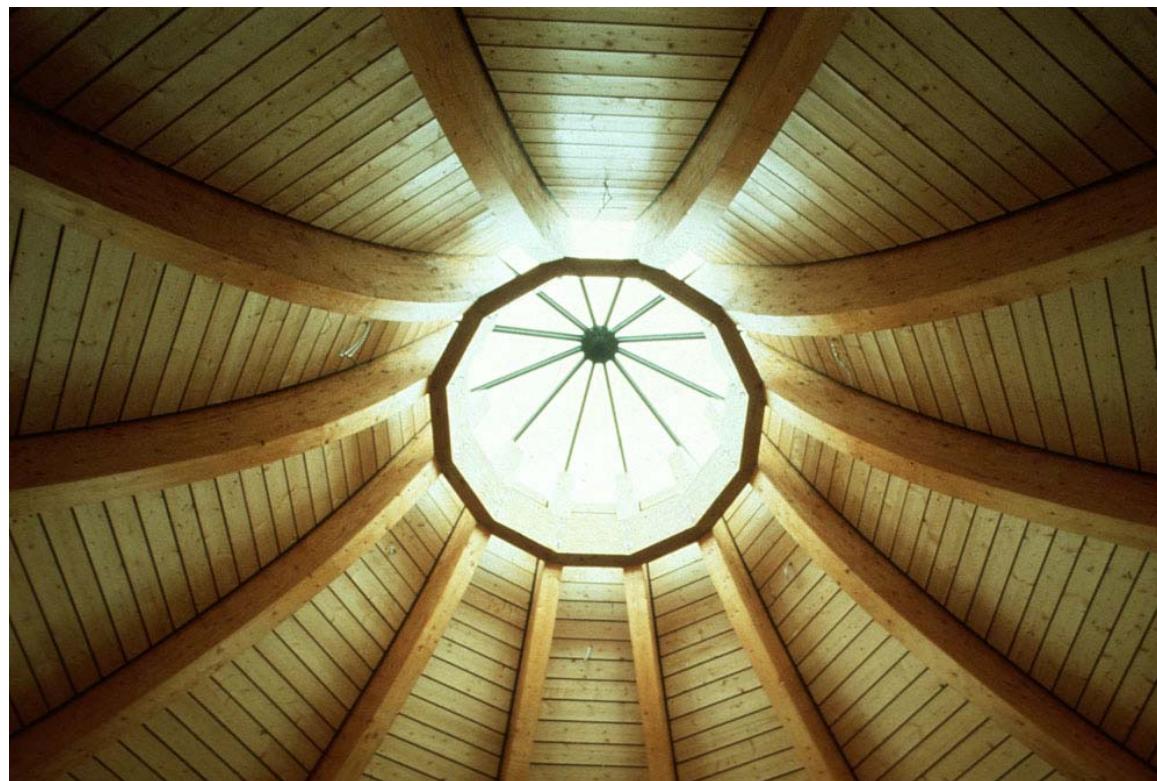
**Fig. 6.44** Systèmes de renforcements en traction perpendiculaire des arcs cintrés en bois.





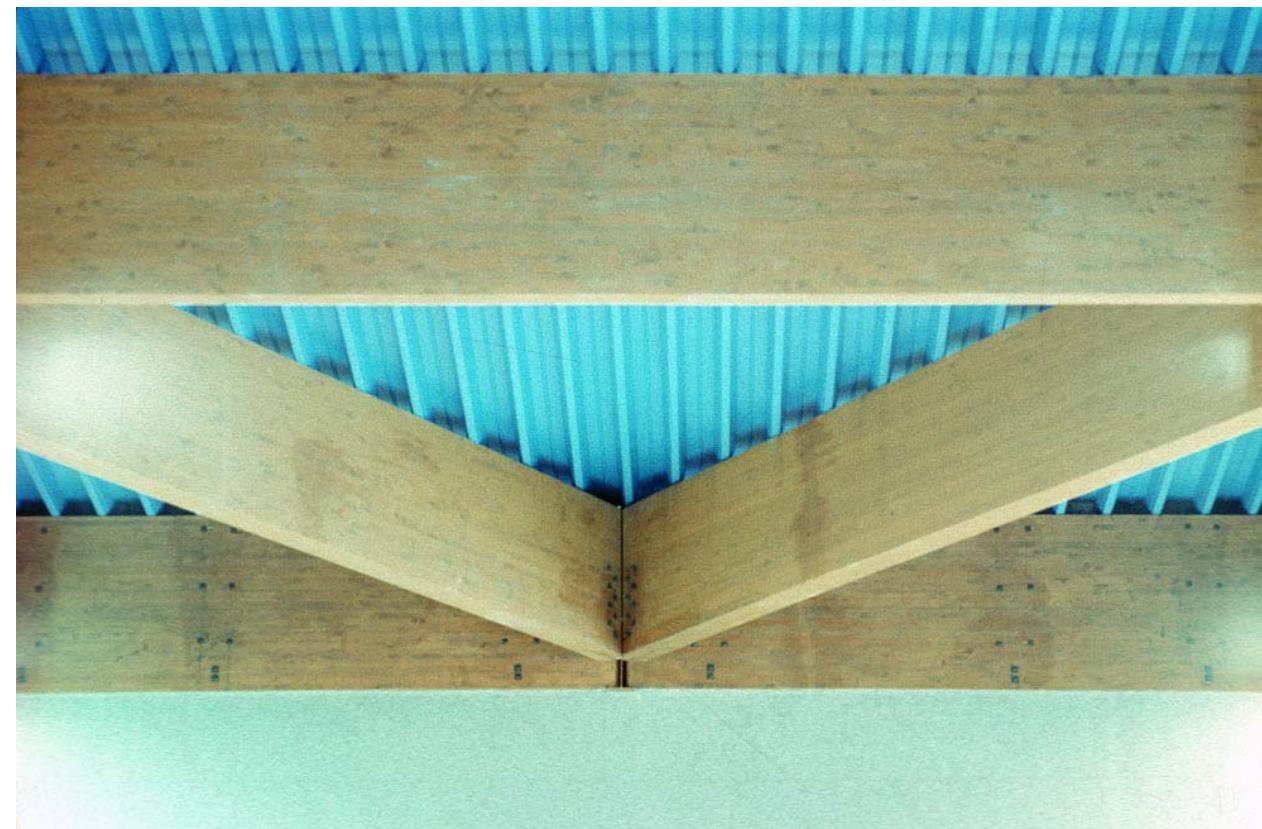








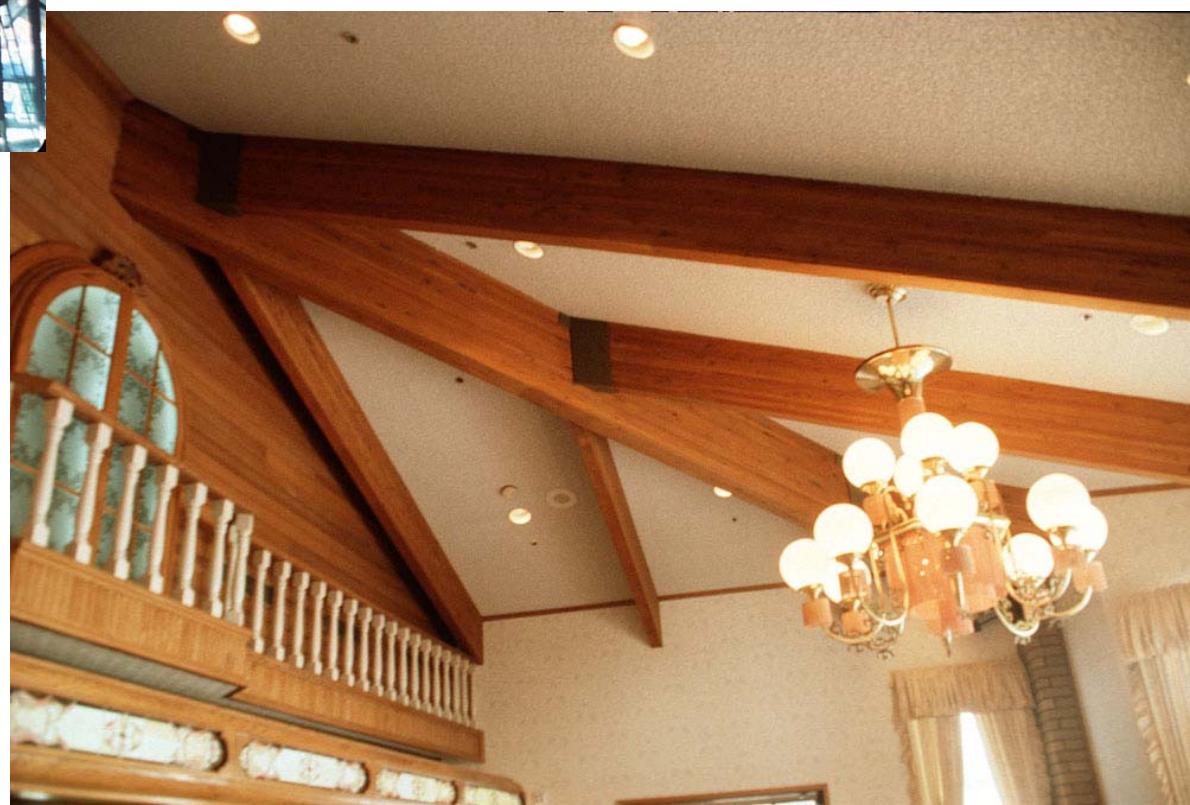


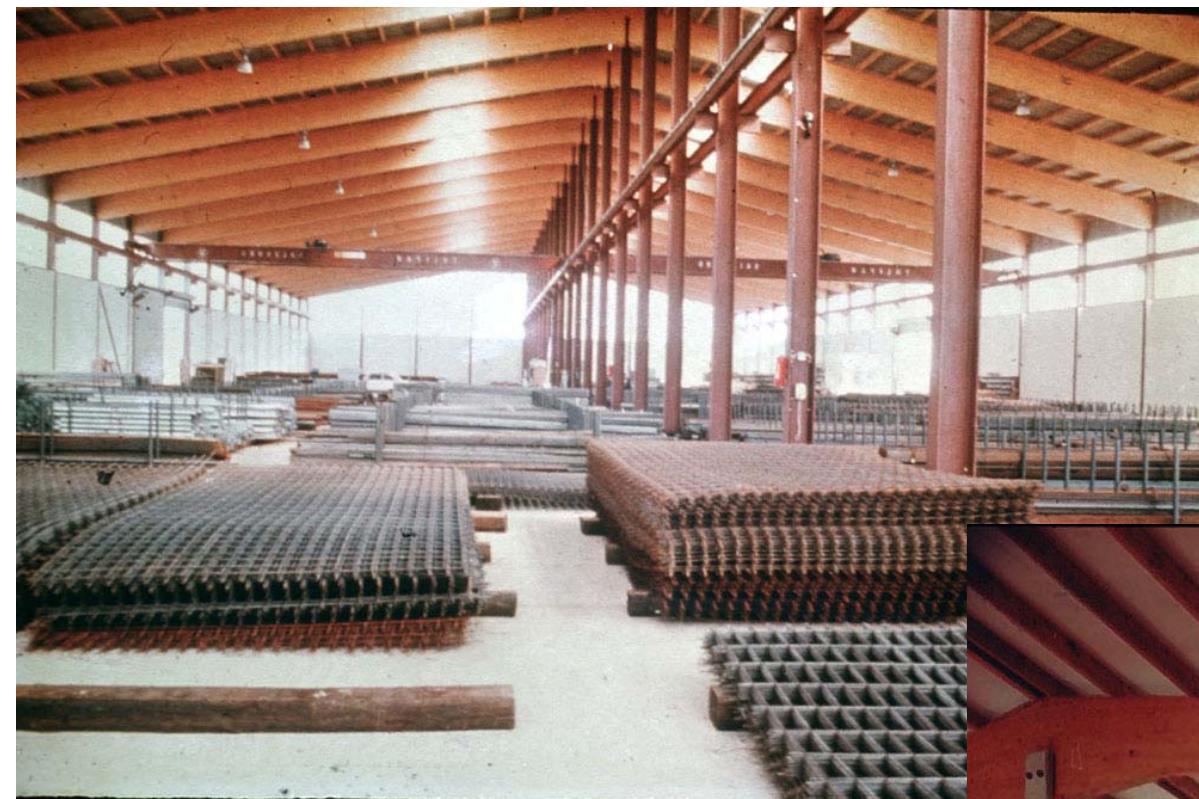




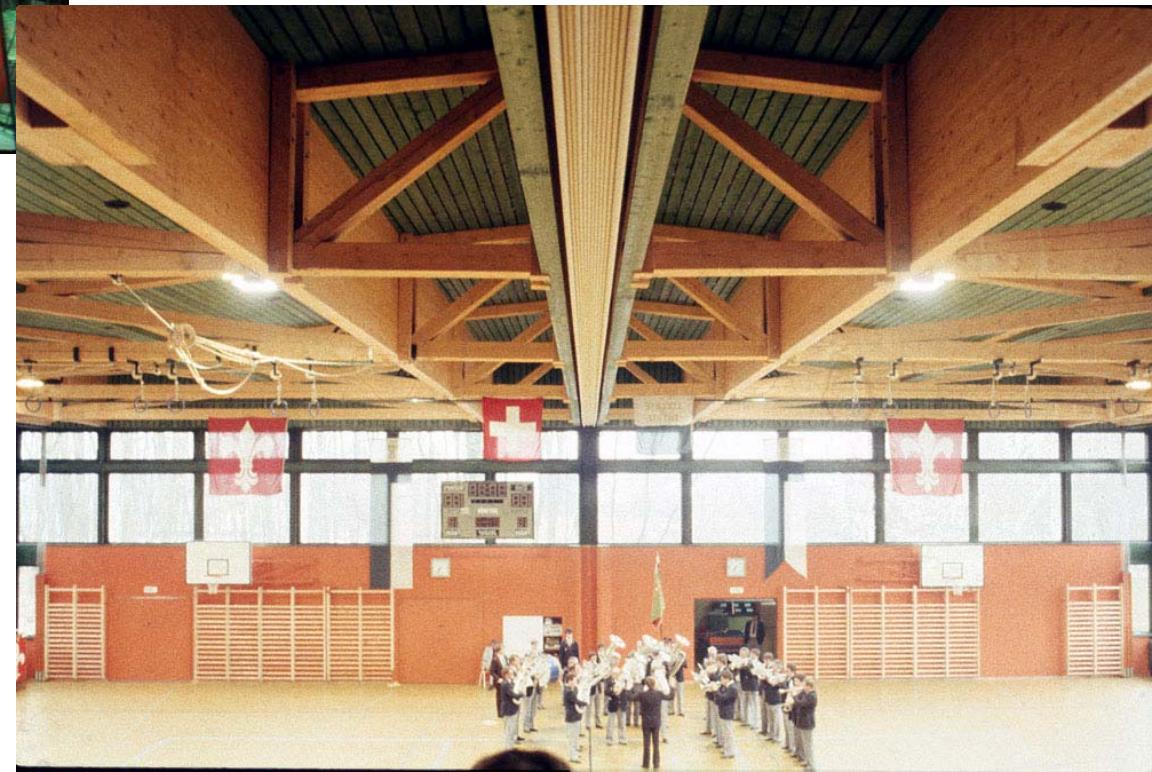








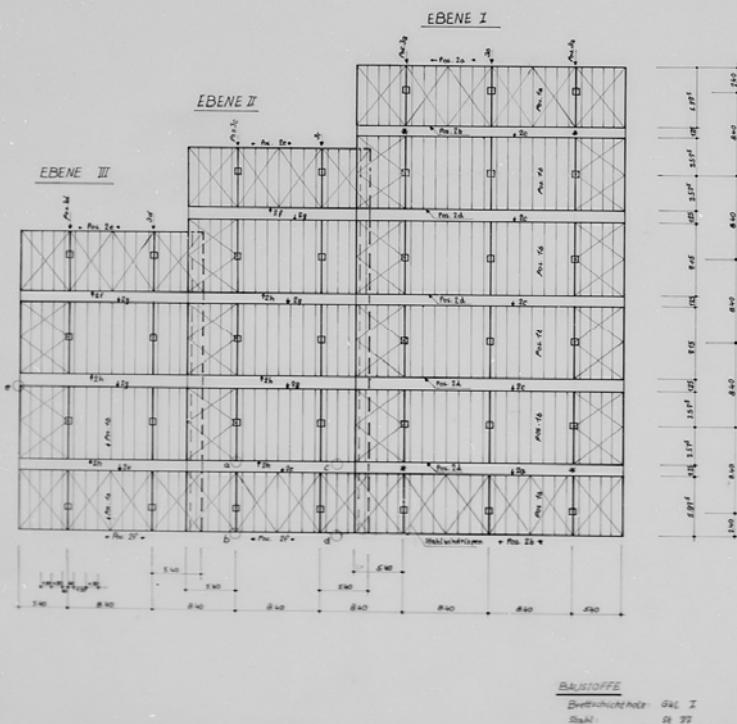




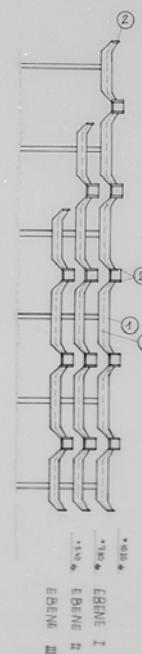


## GRUNDRISS

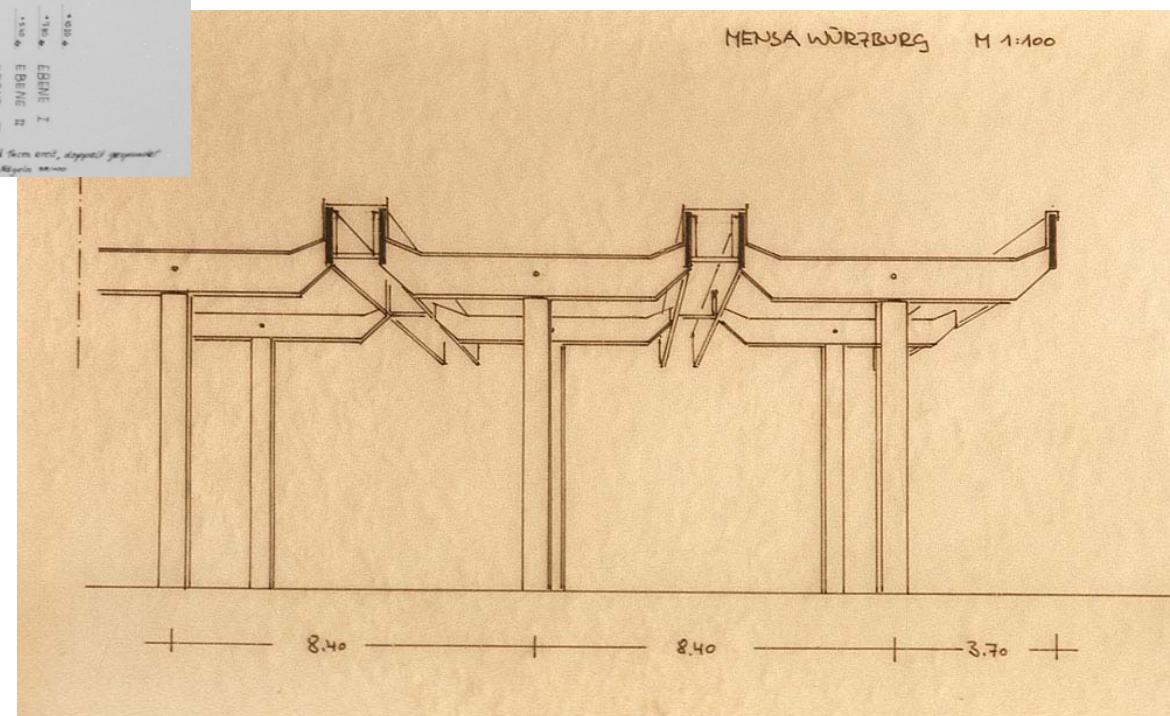
M 1:200



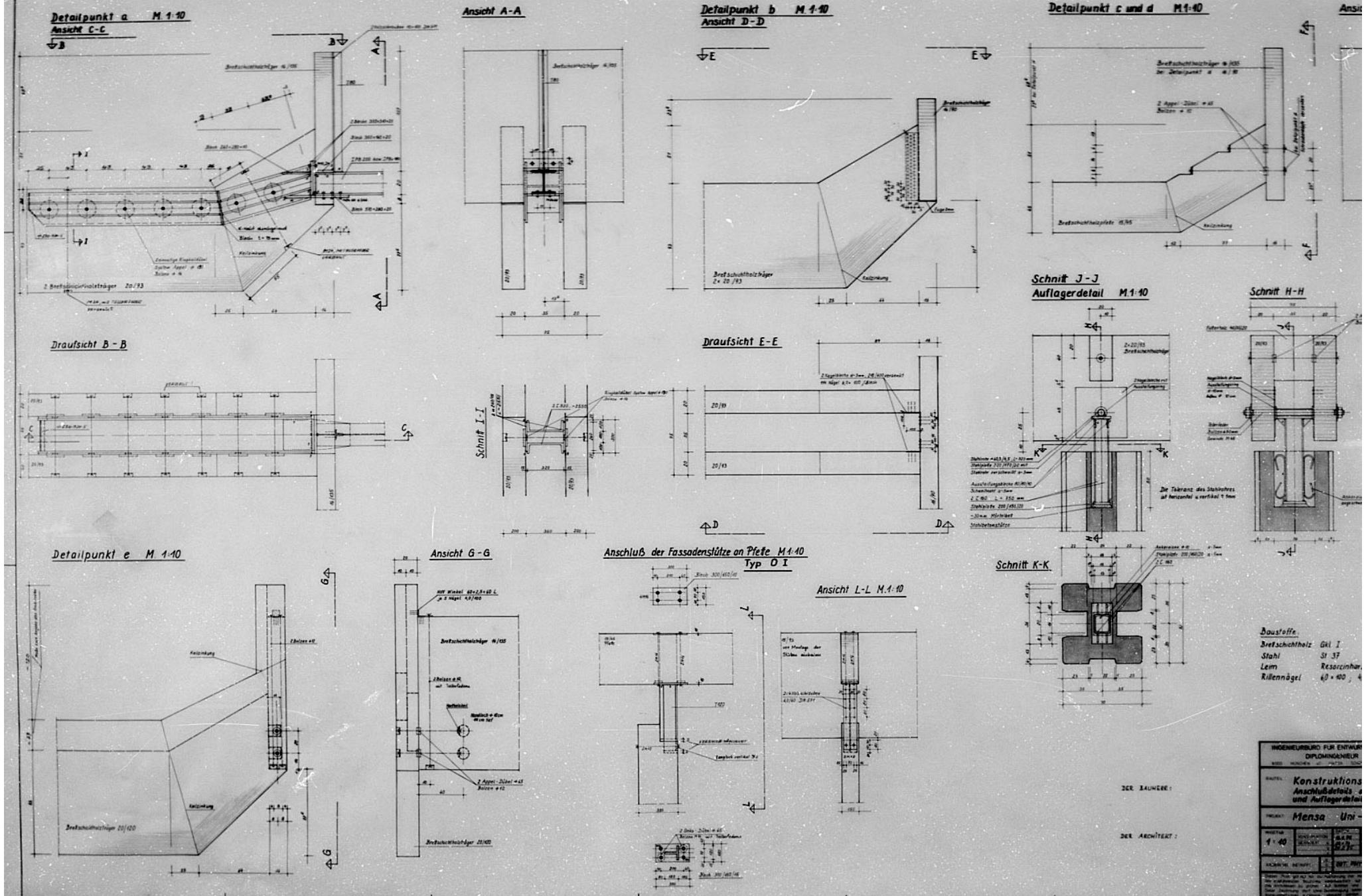
## ANSICHT A



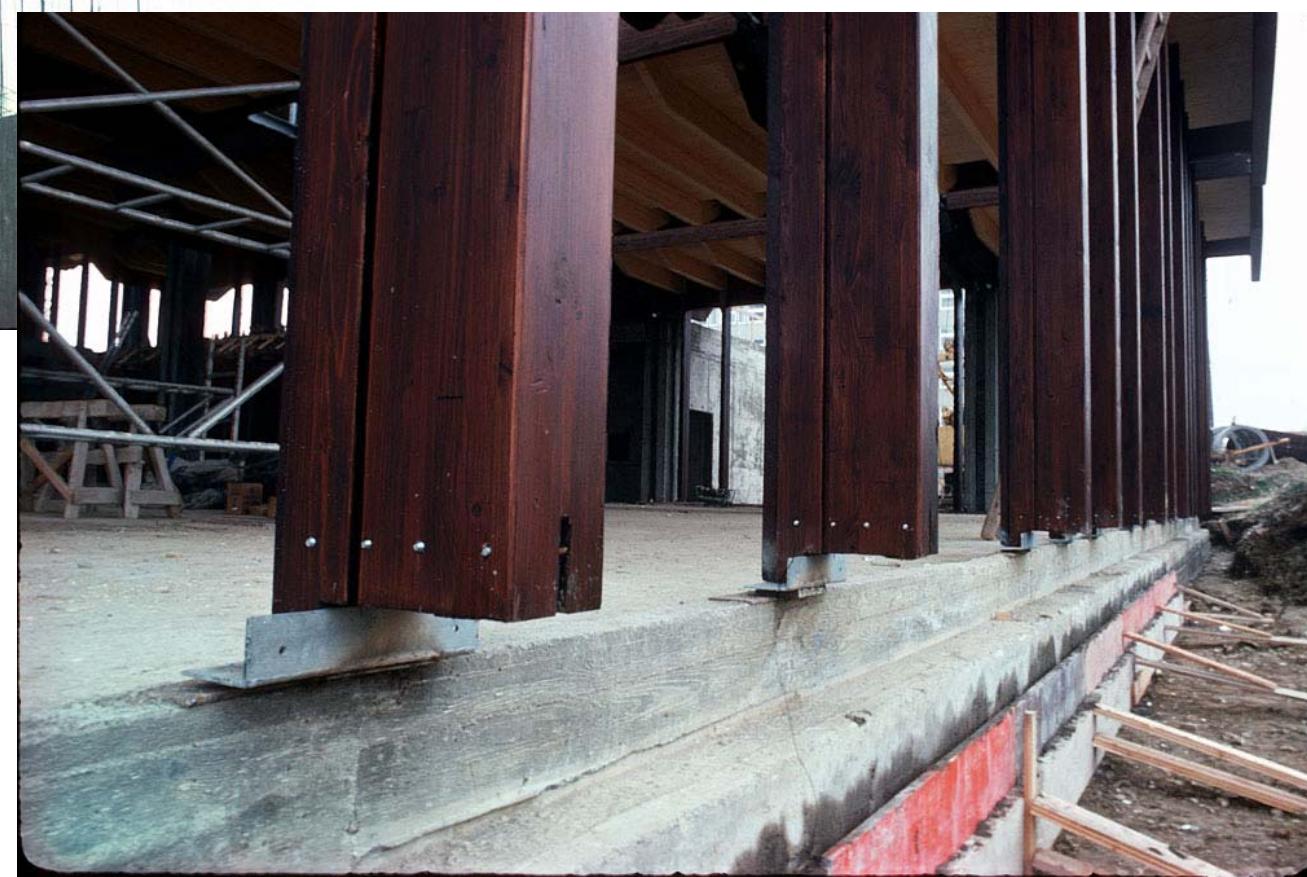
MENSA WÜRZBURG M 1:100

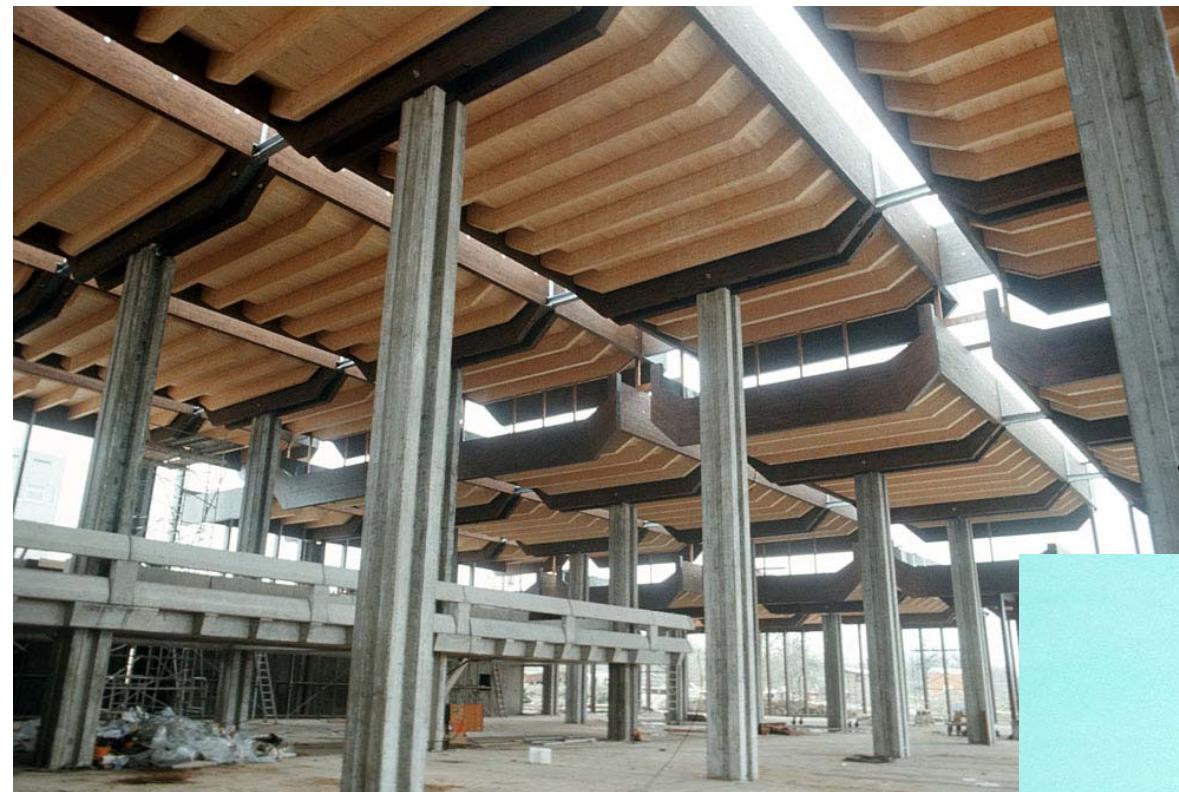


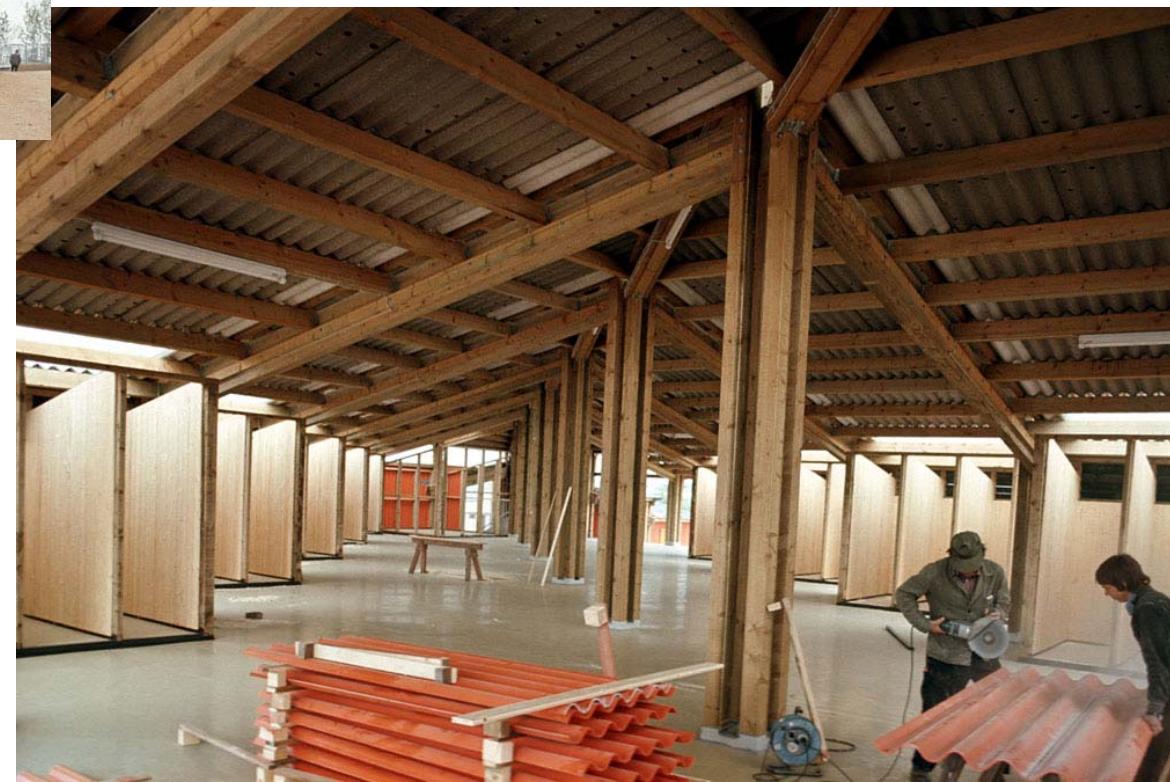


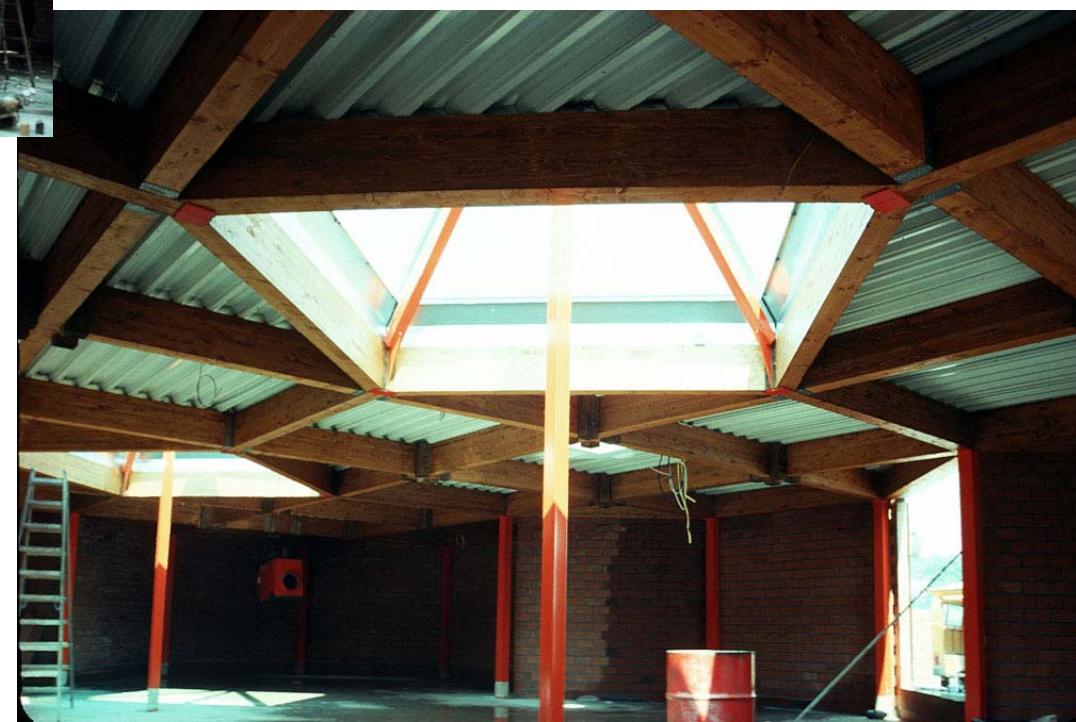


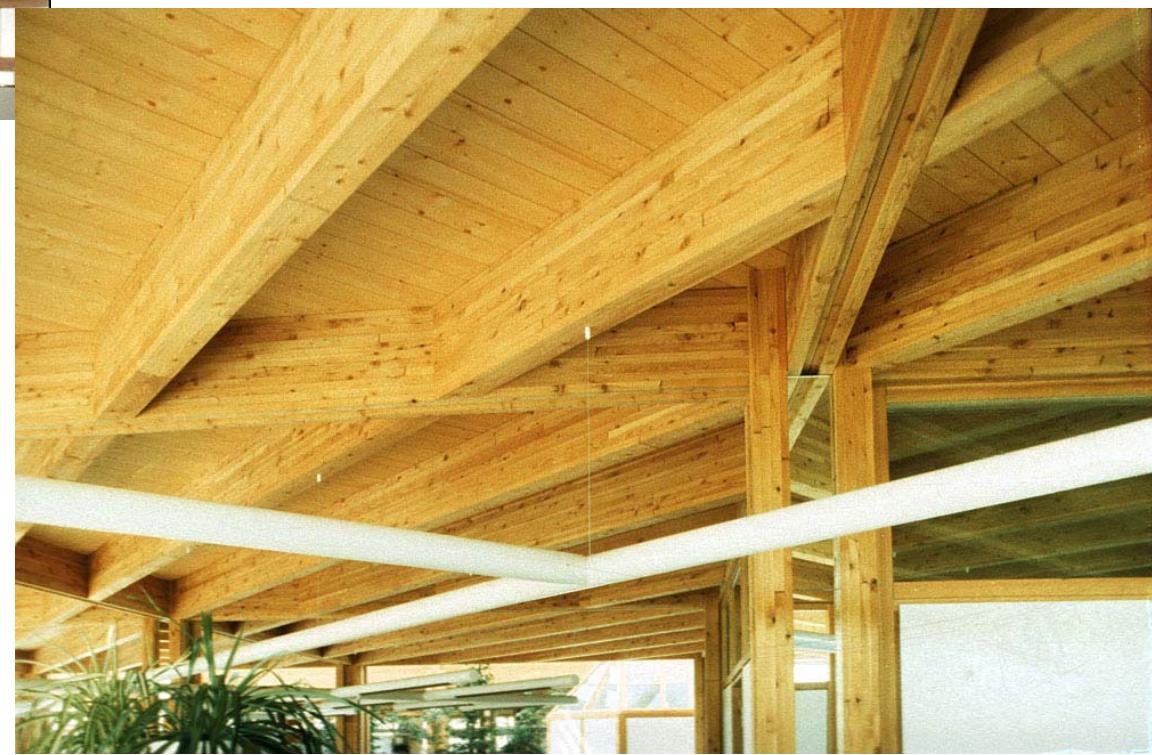


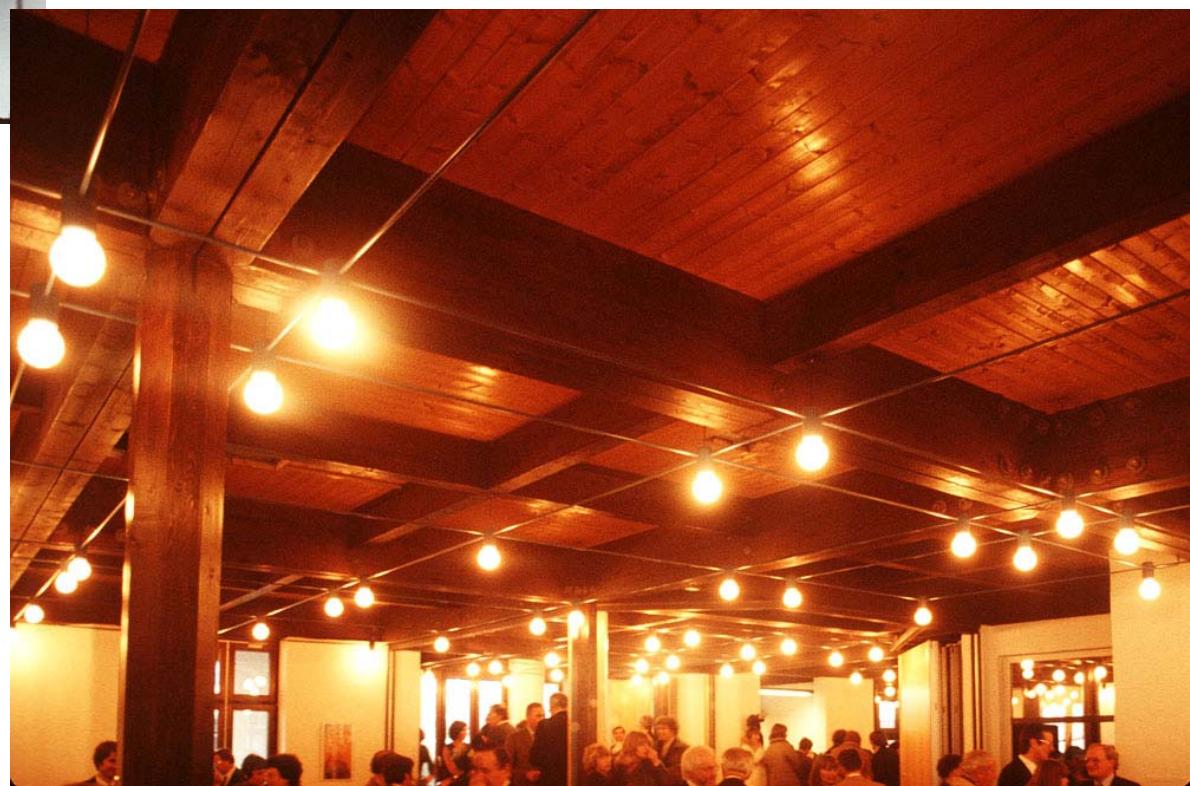




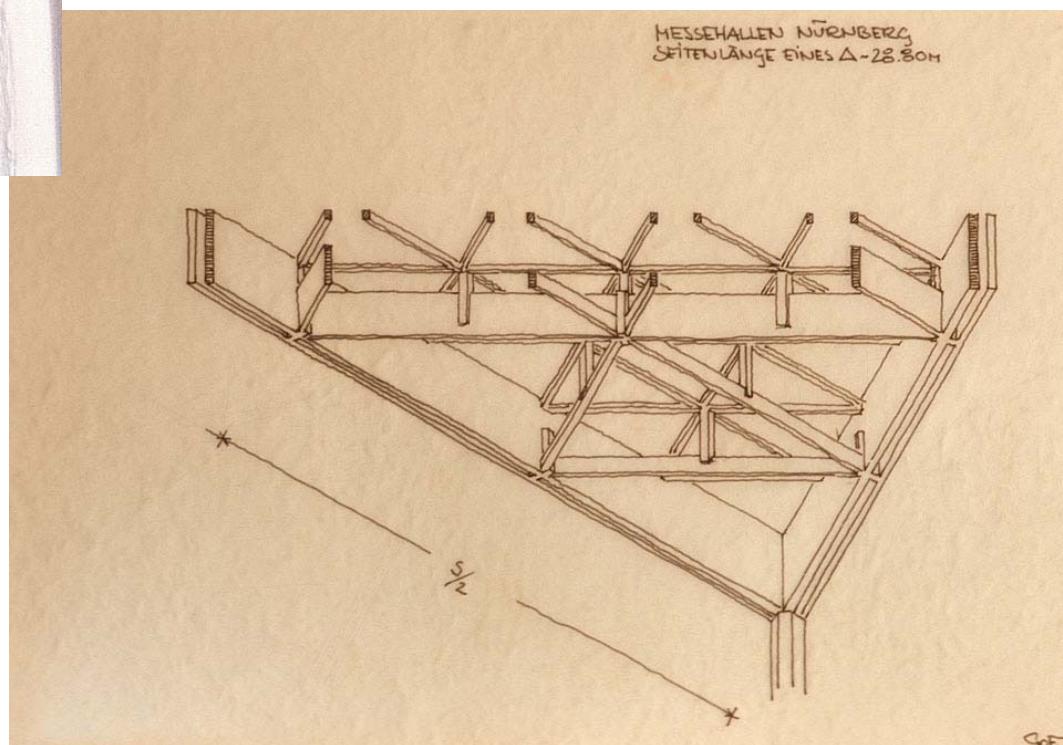
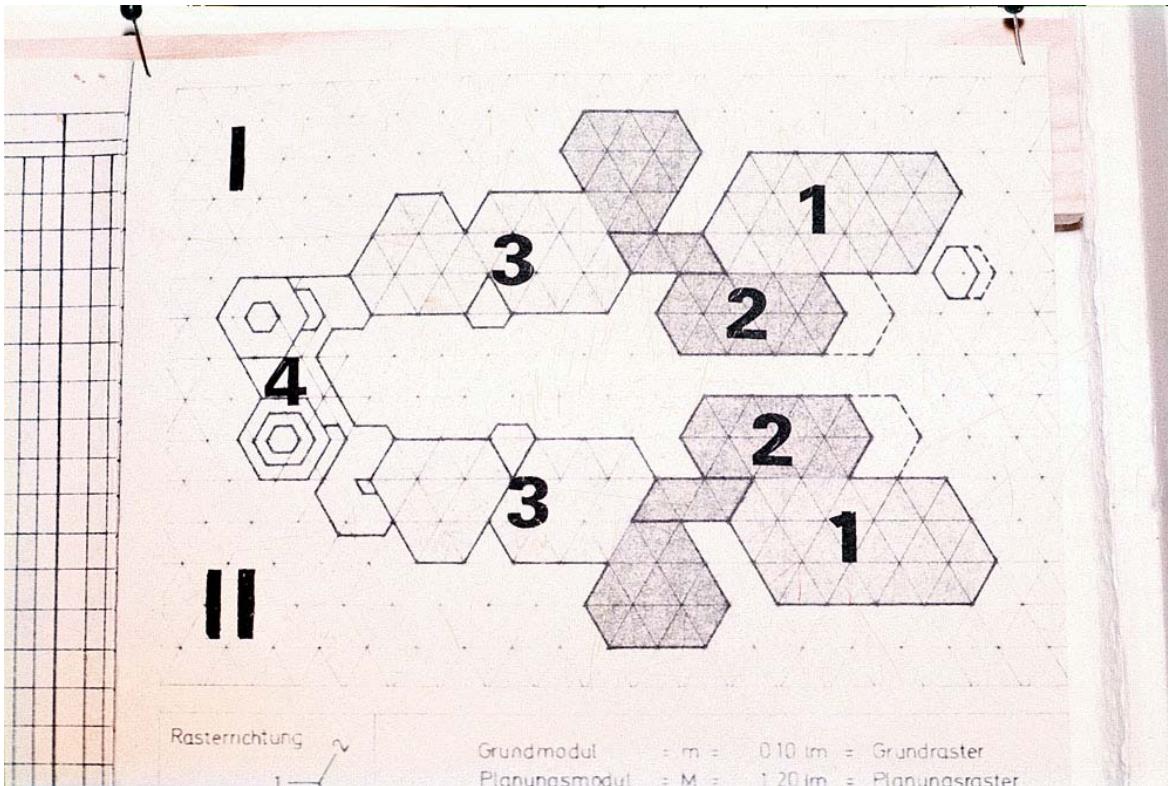


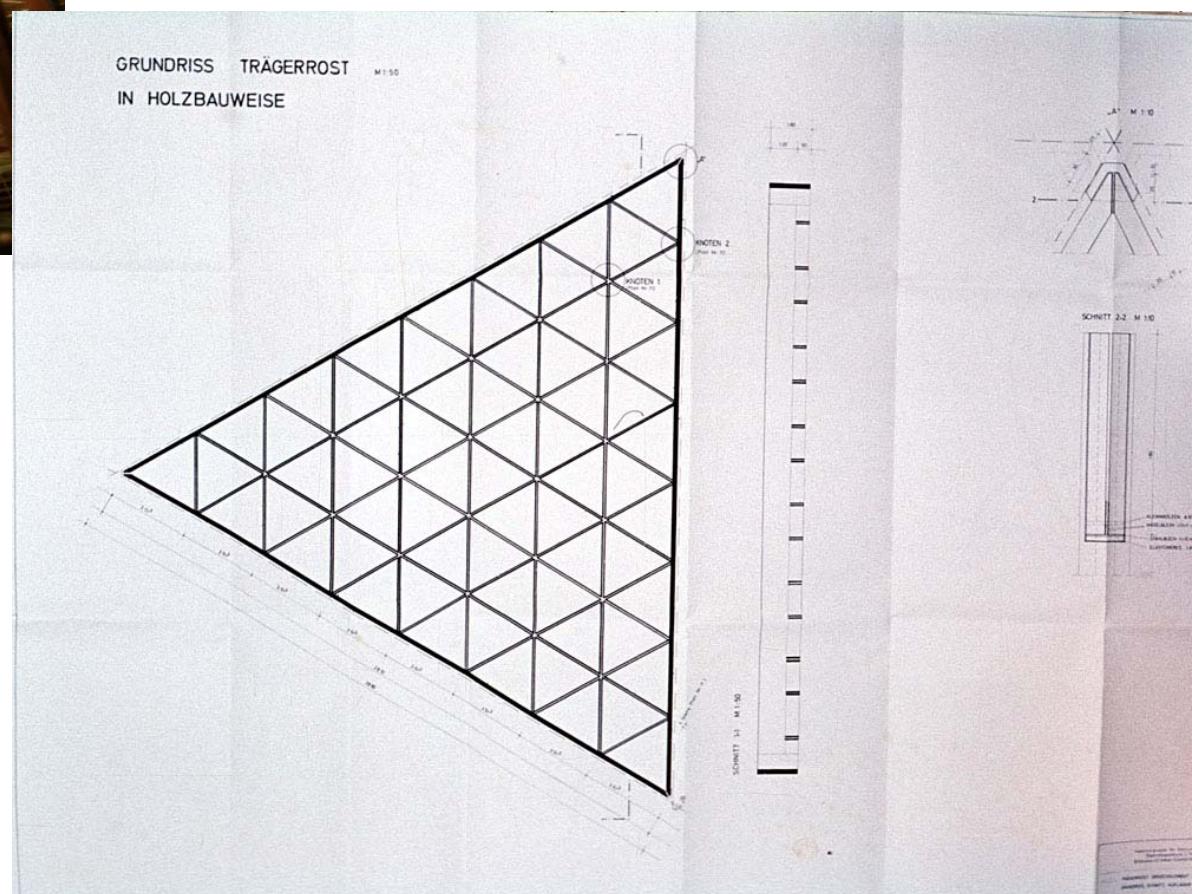


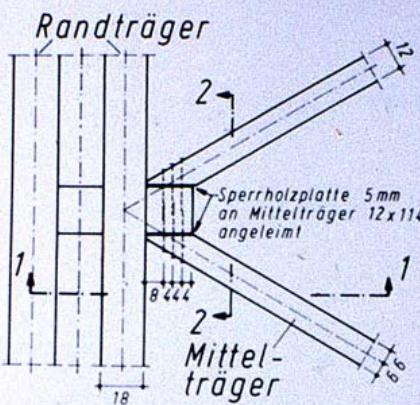






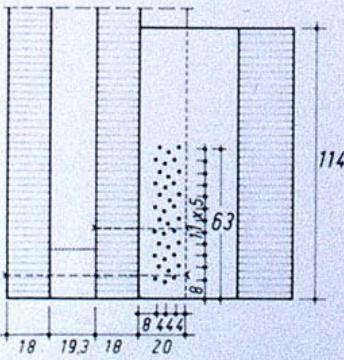






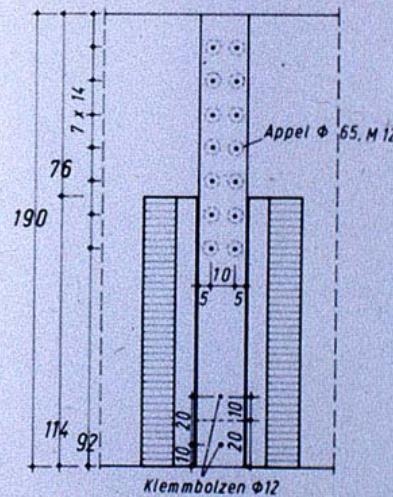
*Anschiß  
Mittelträger  
an Randträger*

*Schnitt 1-1*

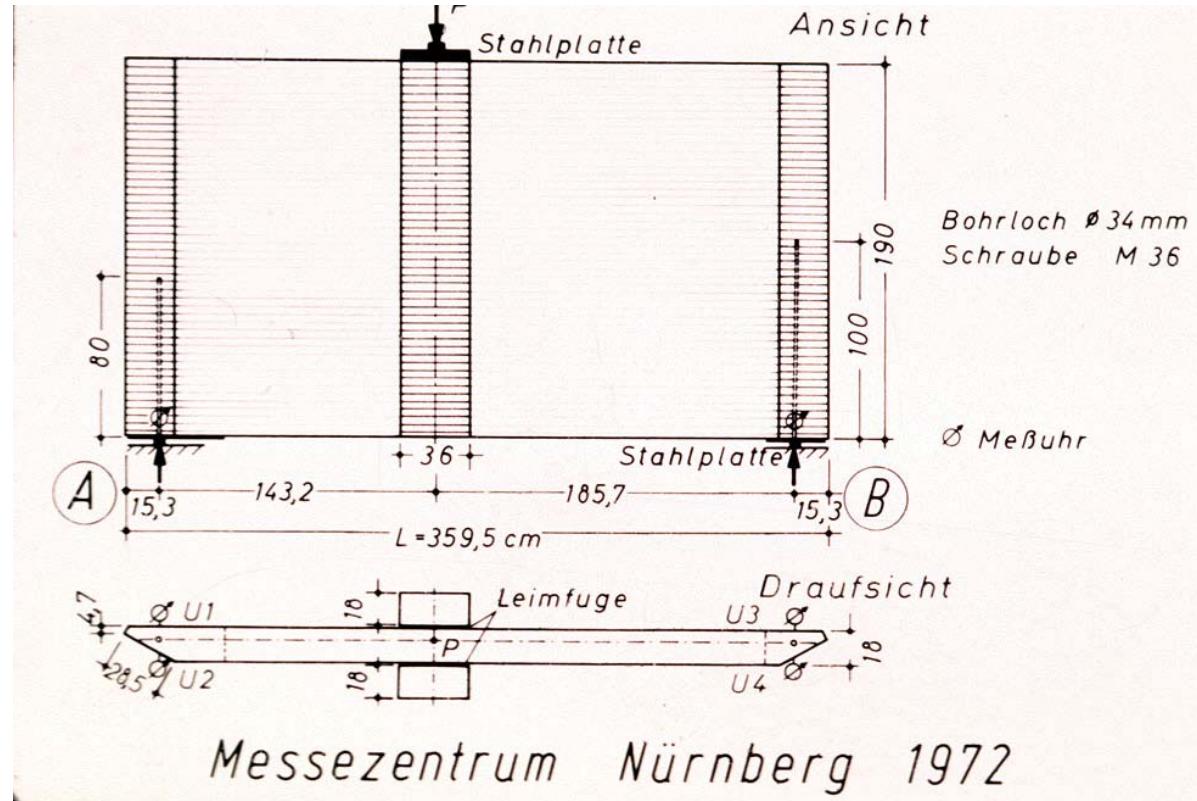


2x36 Nagel 70x210 verzinkt,  
vorgebohrt,  
Nagelbild um 25 mm versetzt!

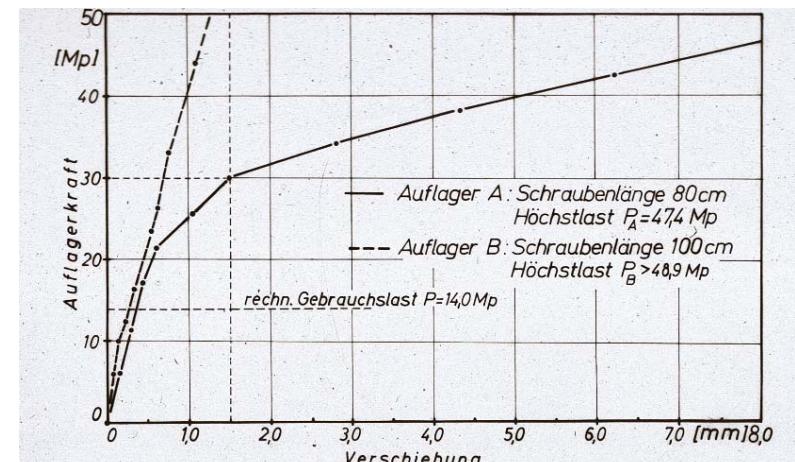
*Schnitt 2-2*



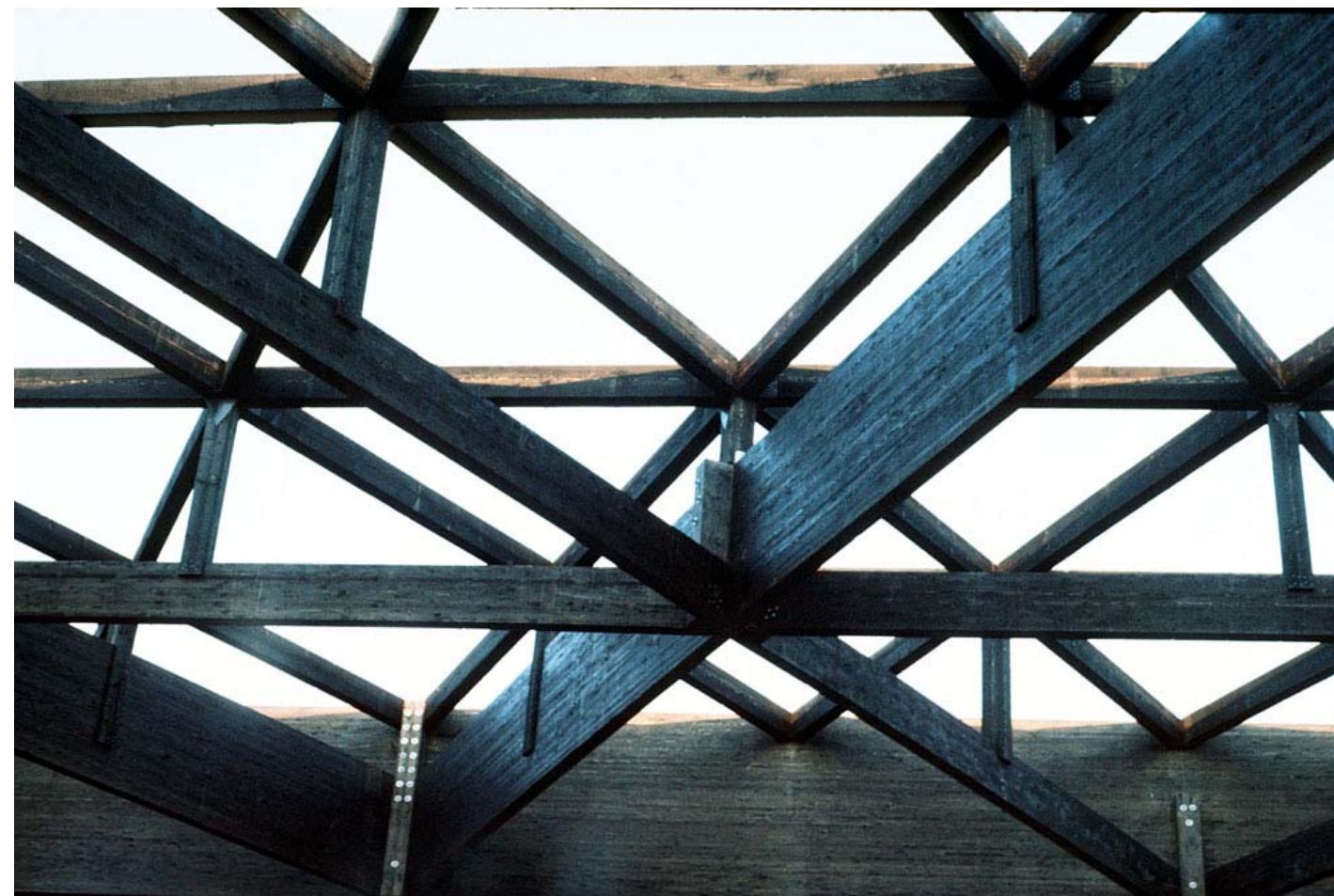
*Messezentrum Nürnberg 1972*



*Messezentrum Nürnberg 1972*

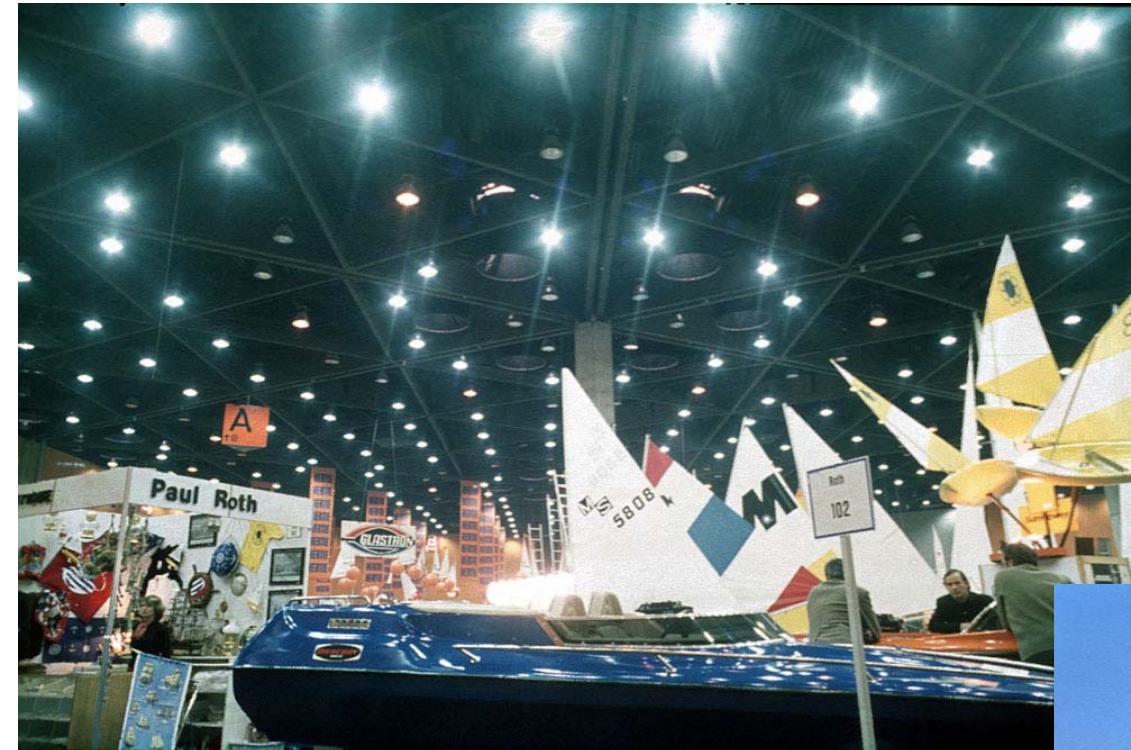


*Messezentrum Nürnberg 1972*



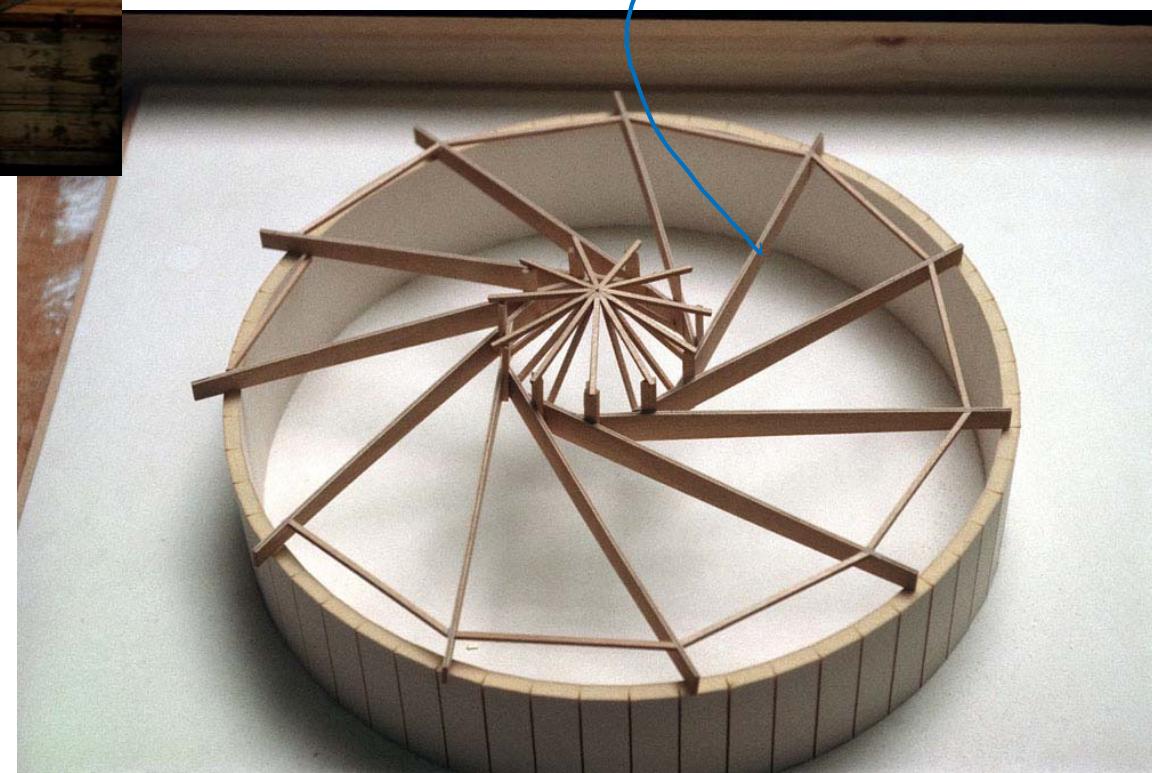
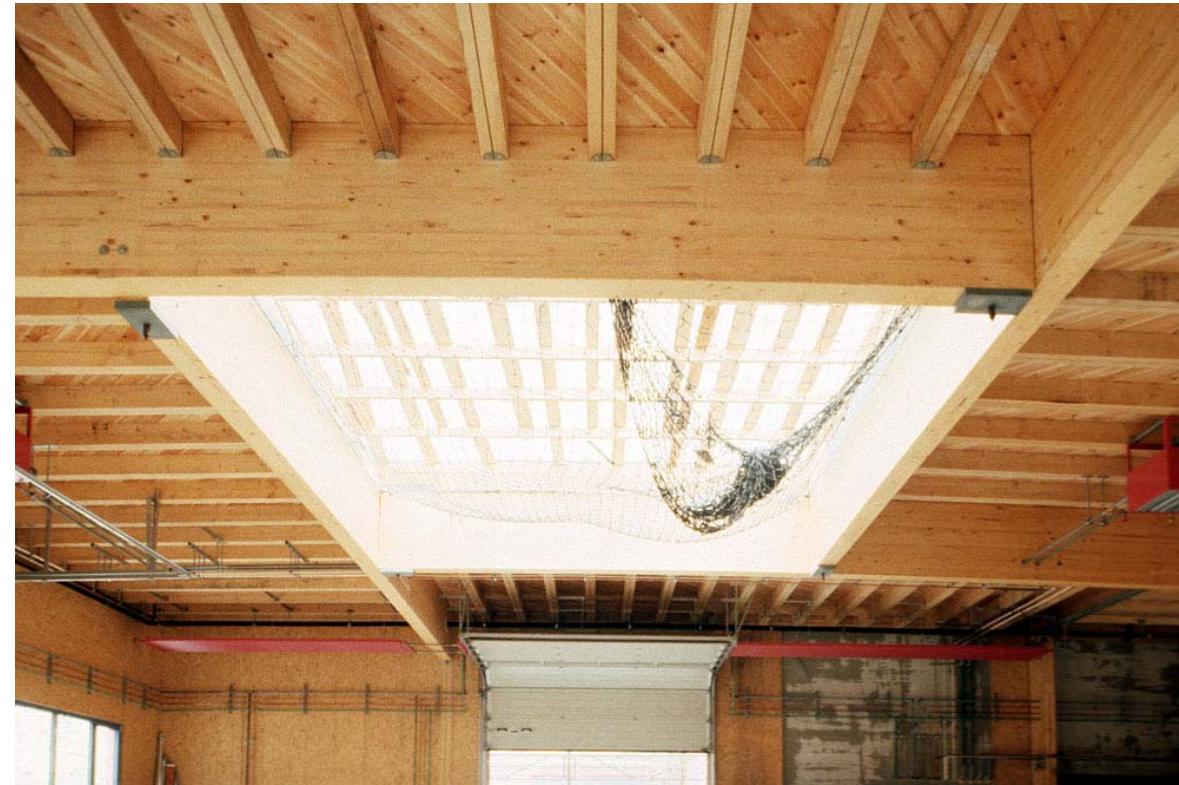


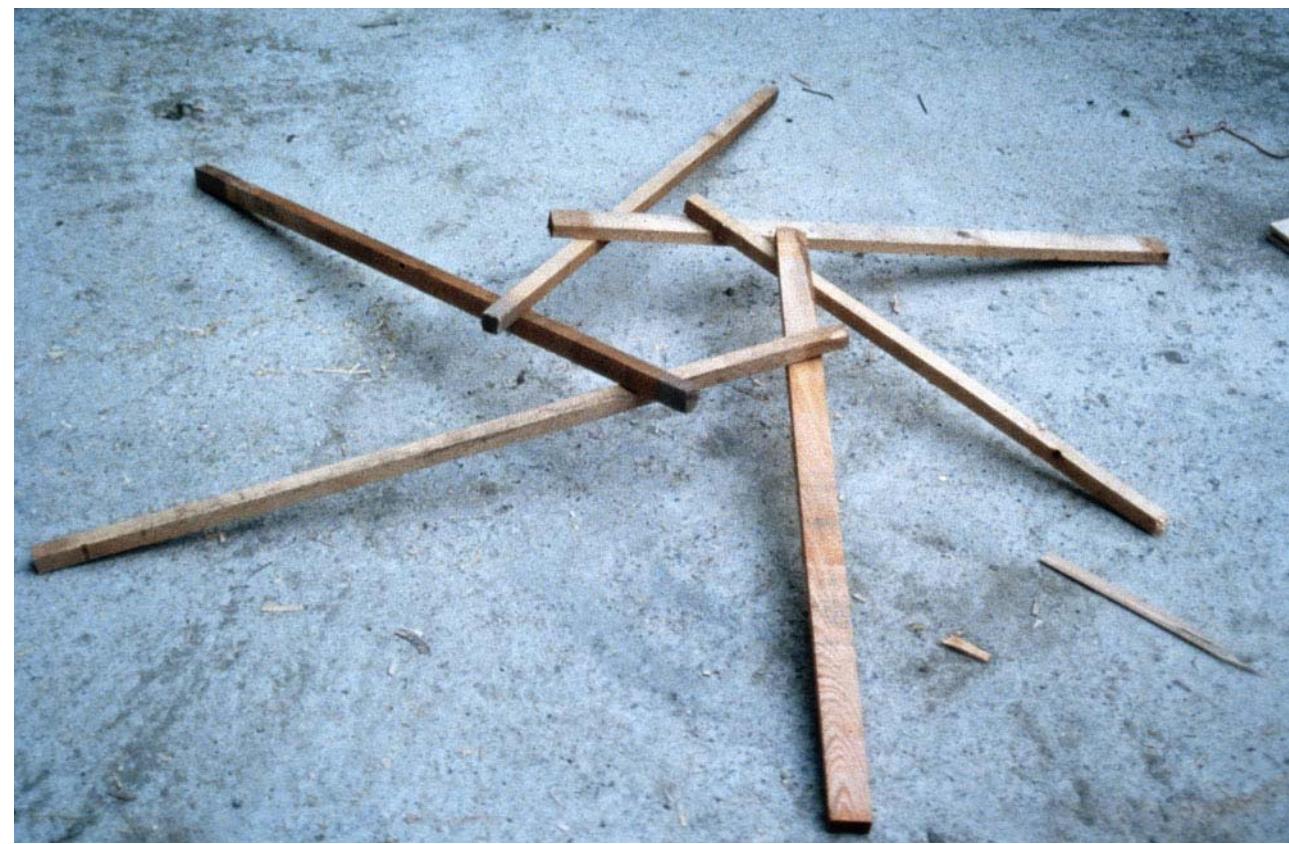






# Système de poutre réciproque

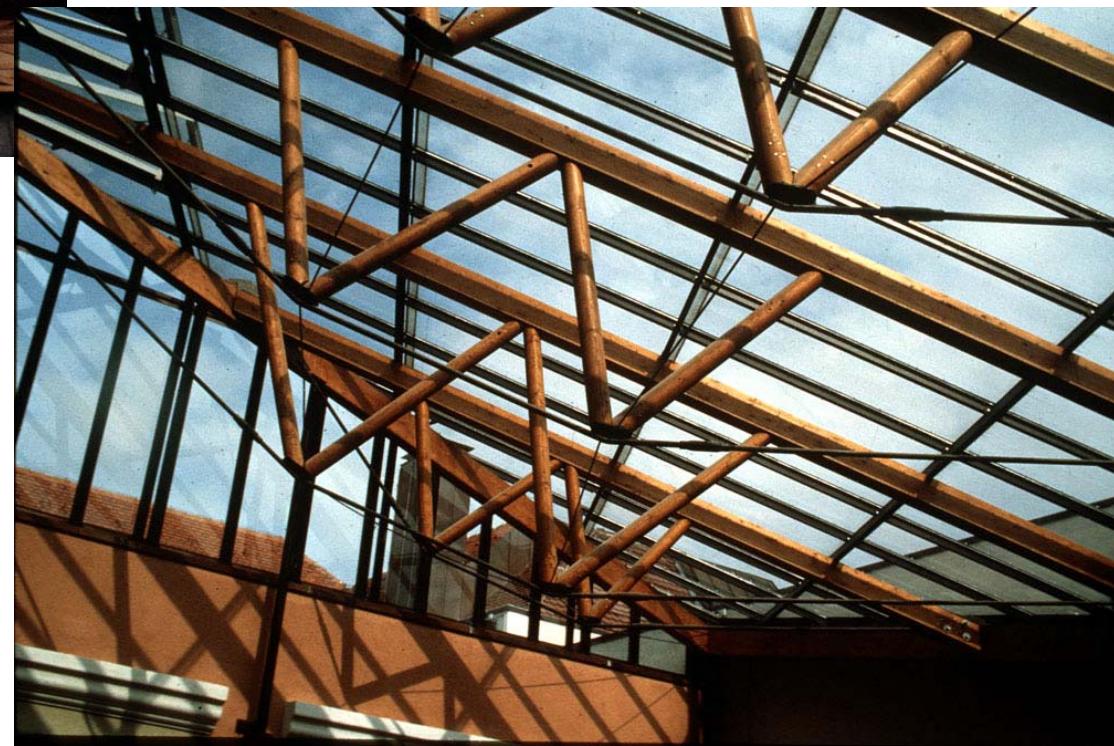




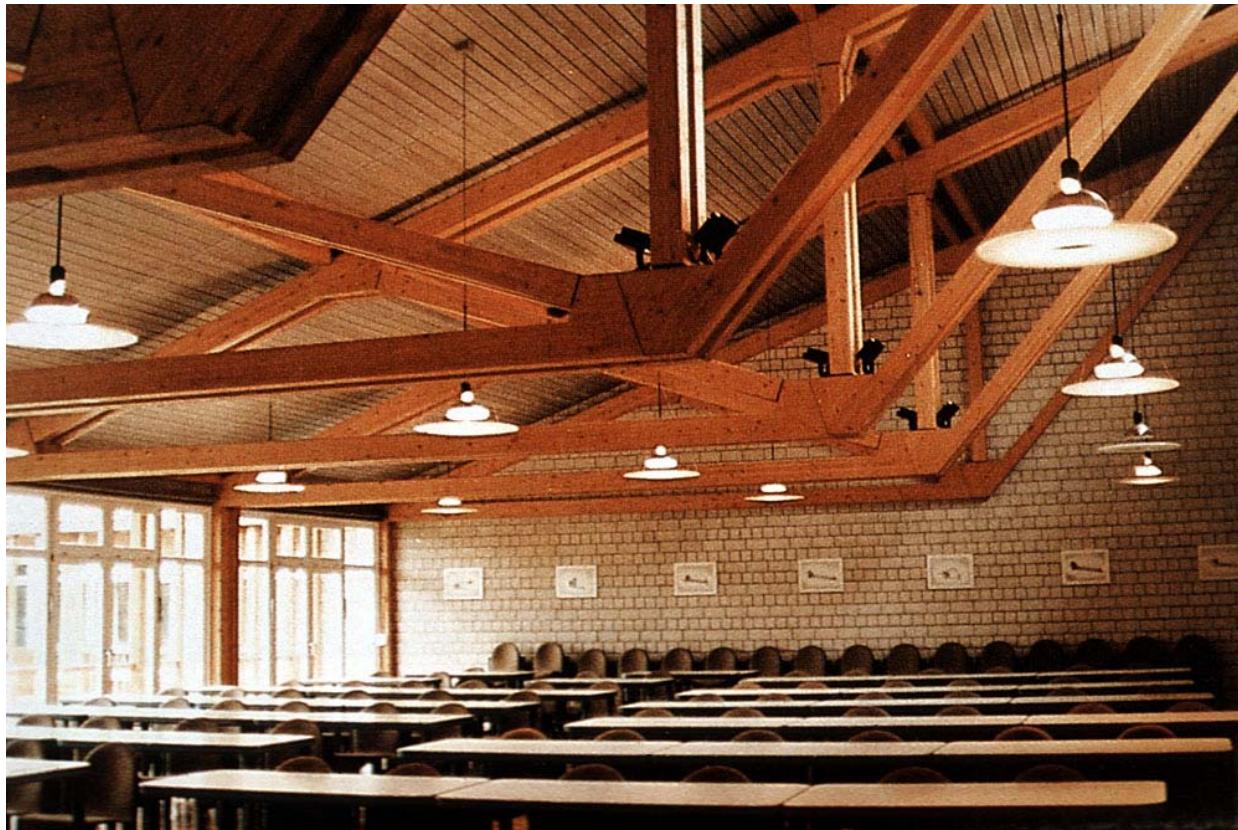




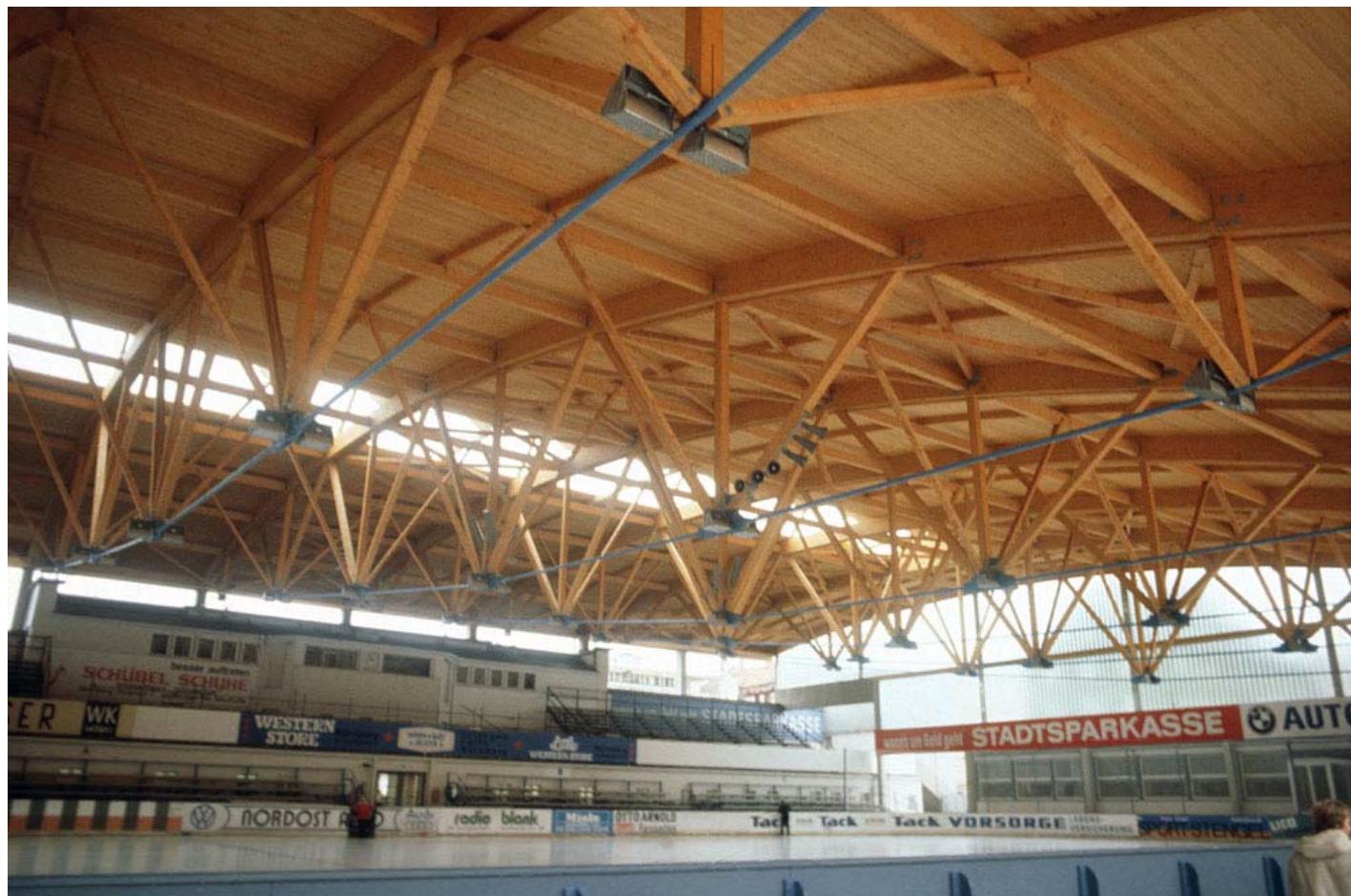
# Poutre sous-tendue



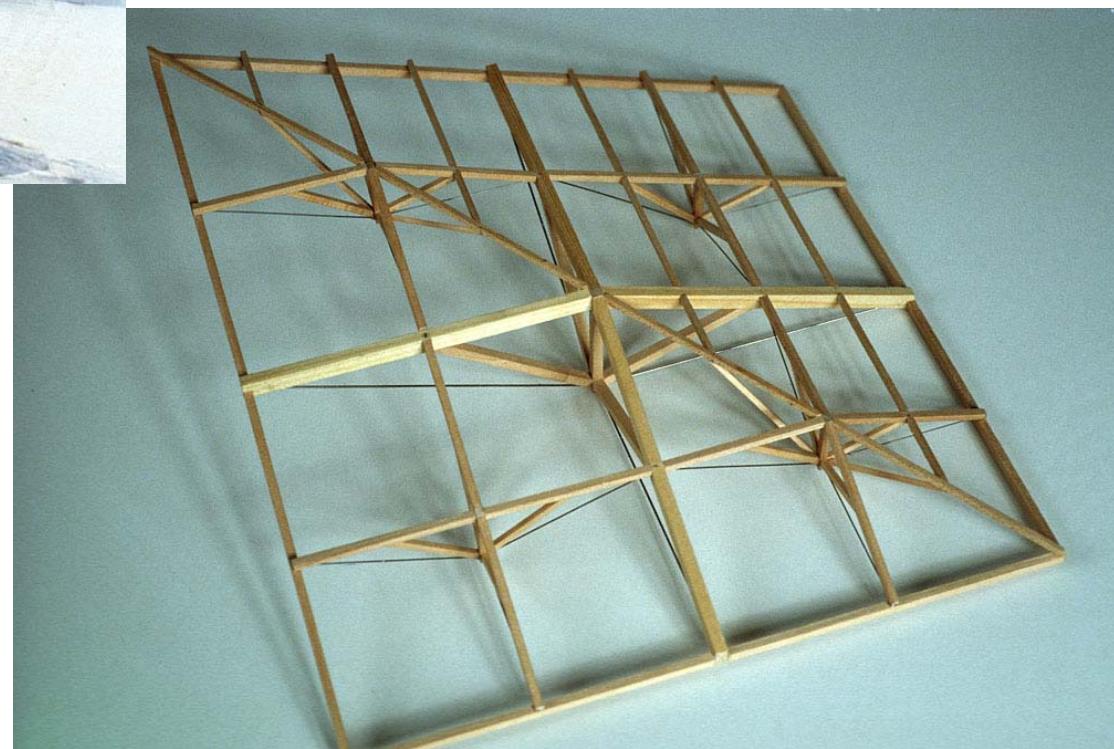










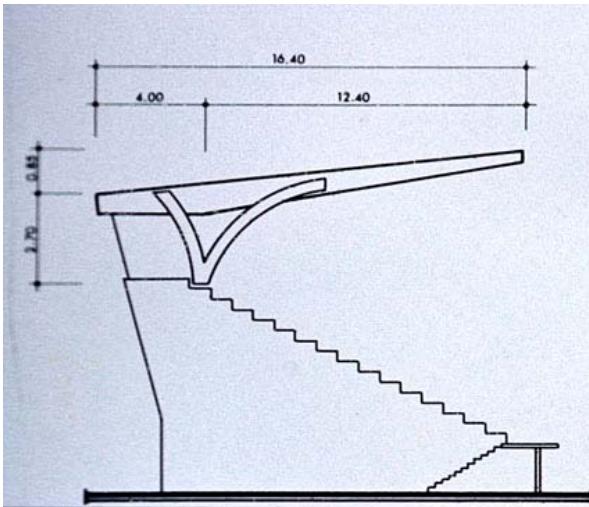


# Système à porte à faux

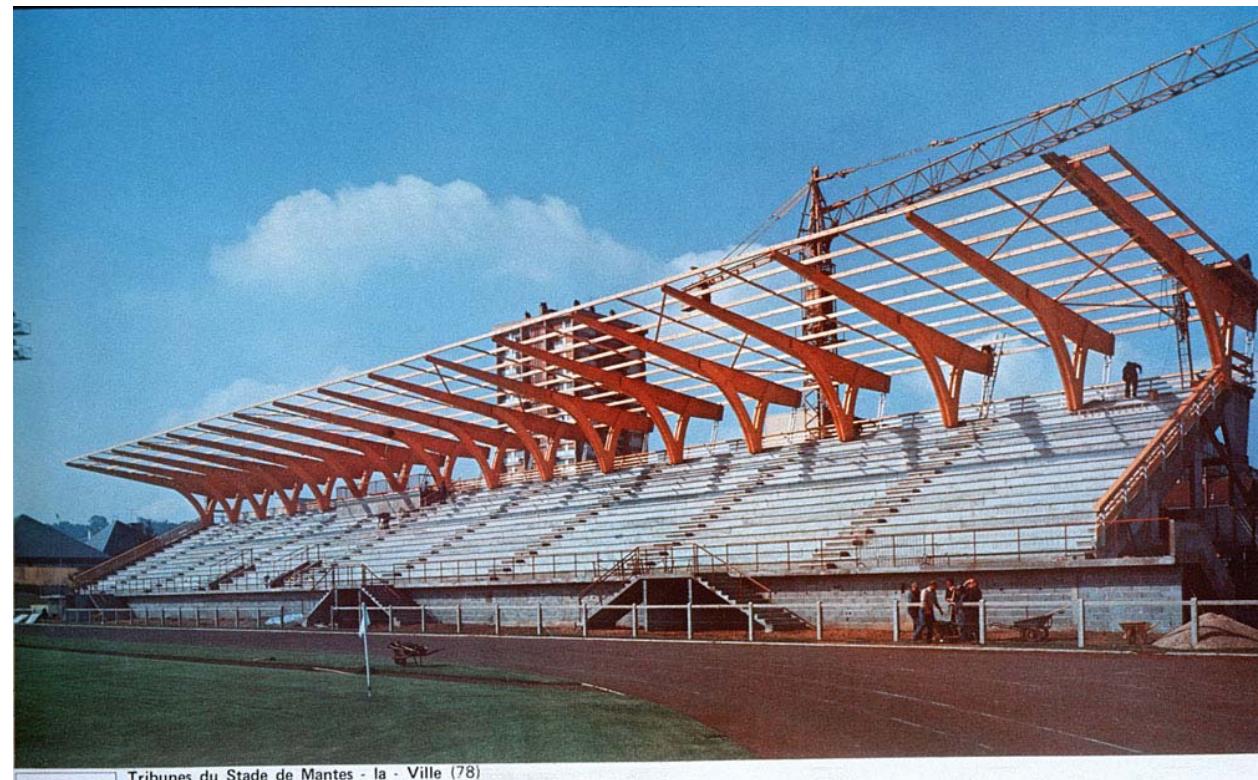








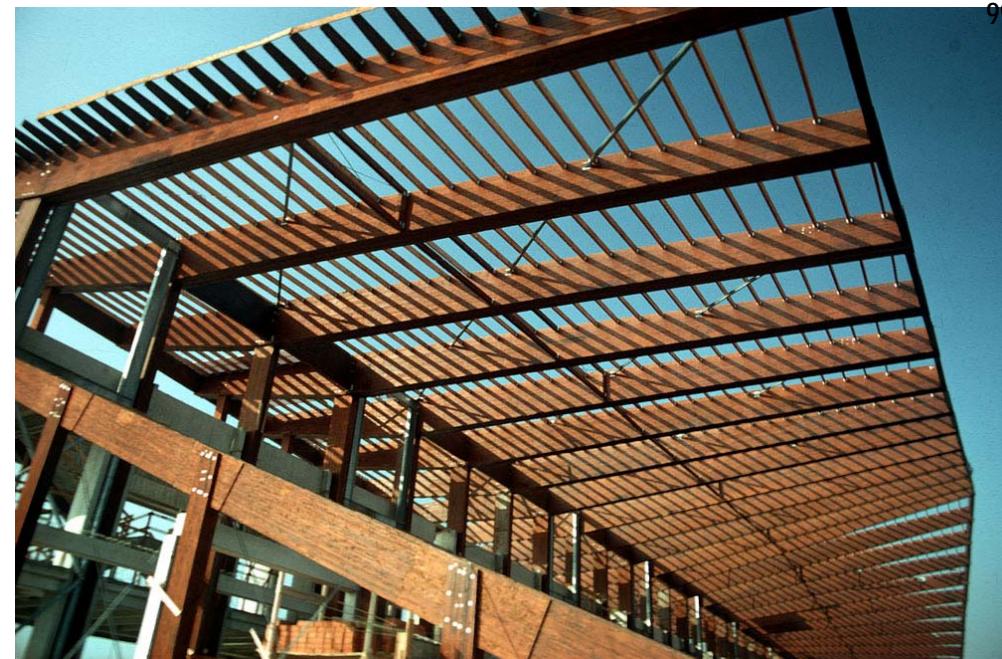
*OSSATURE : Poutres consoles avec tirants métalliques arrières*  
*Longueur totale : 86,40 m en 16 travées de 5,40 m*  
*Couverture en Balithe A.20*

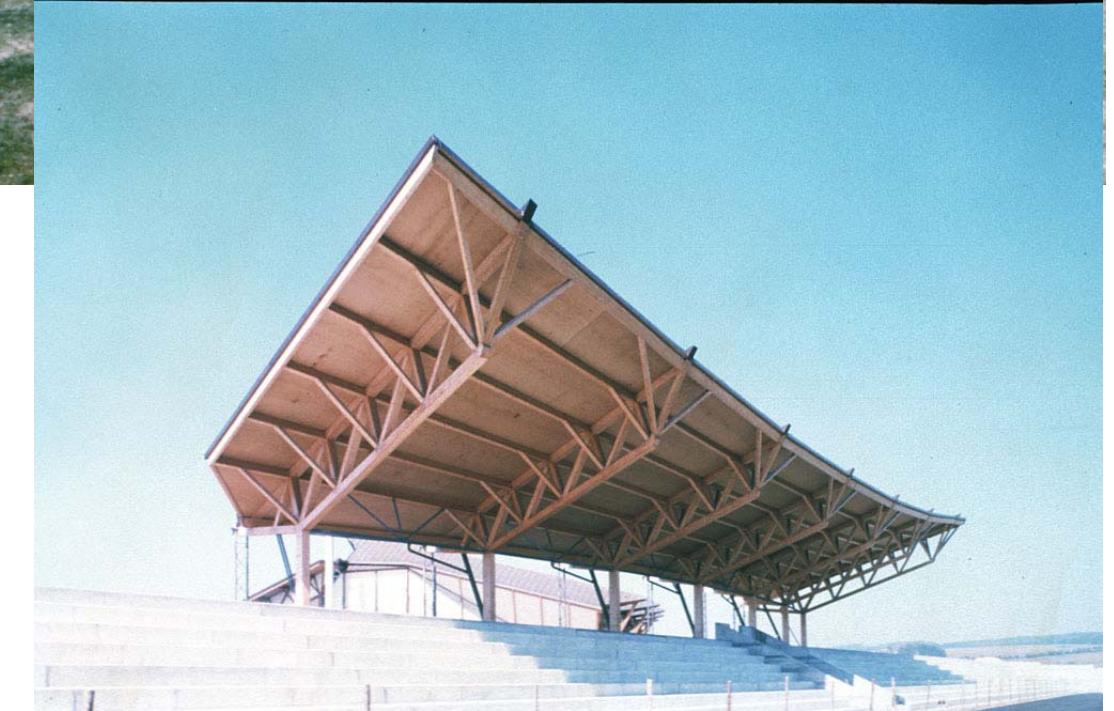


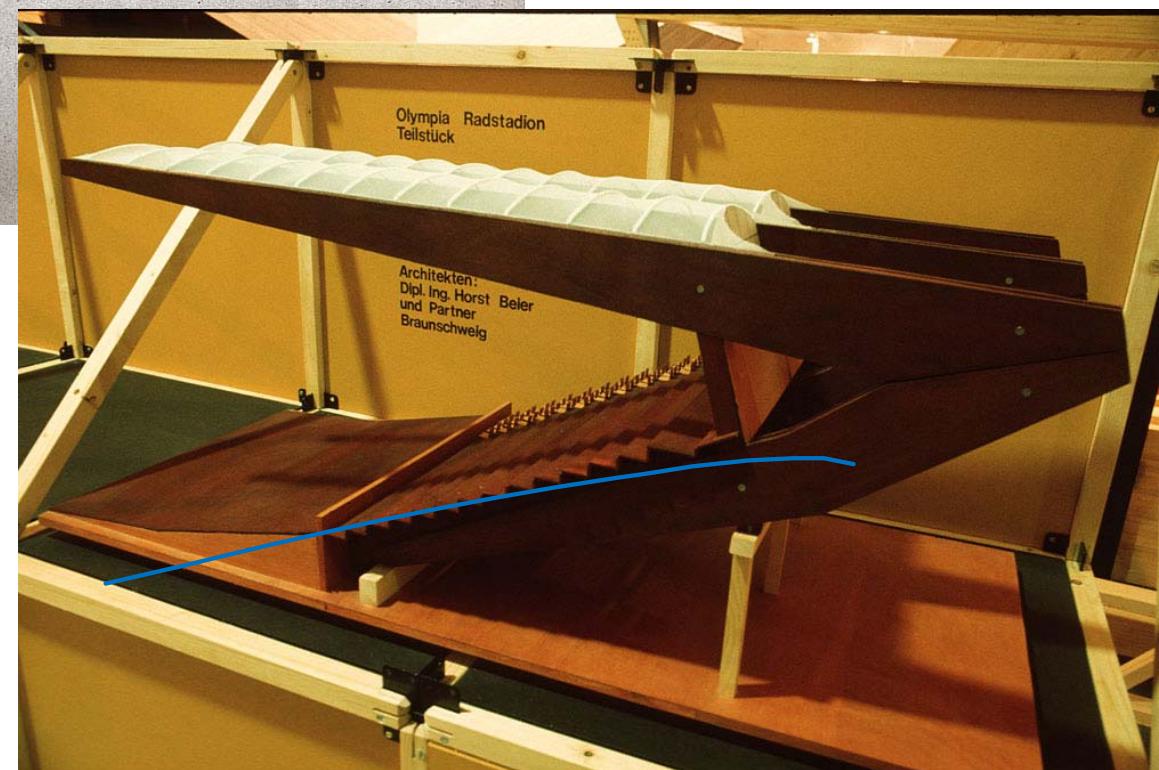
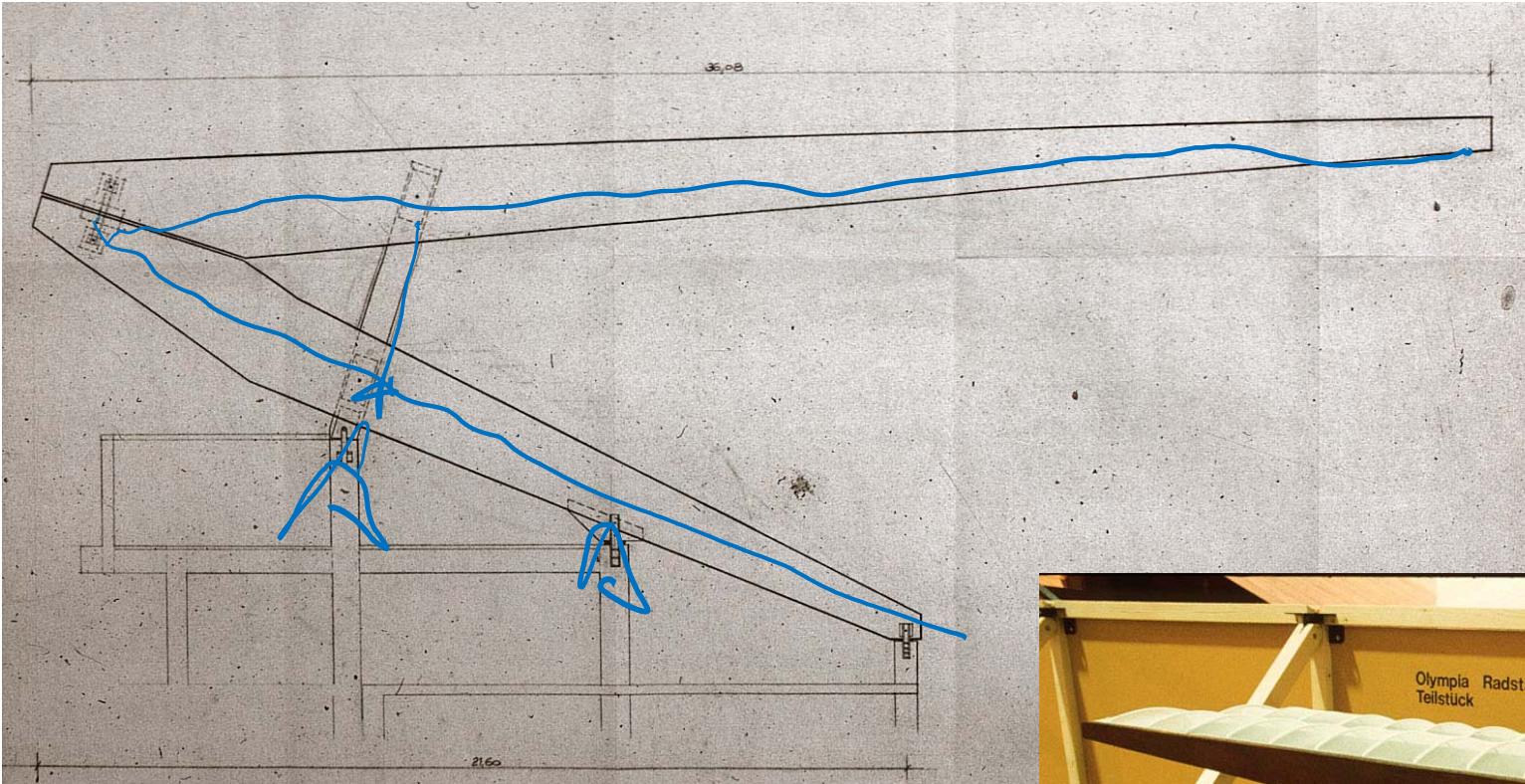
Tribunes du Stade de Mantes - la - Ville (78)

















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