



**"Studiu tehnic privind eficiența economică a utilizării învelitorilor de tip Bramac prin analiza influențelor structurale generate de tipul de învelitoare asupra sistemului structural al unei clădiri cu regim de înălțime P+M"**

Beneficiar:

**S.C. BMI ROMANIA SISTEME DE INVELITORI S.R.L.**

-2024-

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# STUDIU TEHNIC

## 1. PREZENTARE STUDIU TEHNIC

Prezentul studiu tehnic a fost întocmit la solicitarea beneficiarului BMI ROMANIA SISTEME DE INVELITORI S.R.L. în scopul determinării eficienței economice în cazul utilizării învelitorilor de tip „Bramac”. Astfel, în cadrul studiului se vor analiza influențele generate de tipul învelitorii asupra sistemului structural al unei clădiri, respectiv cuantificarea acestora sub formă de consumuri de material.

La solicitarea beneficiarului s-a ales aleatoriu un partiu de arhitectură pentru o clădire de tip vilă cu regim de înălțime P+M și structură în cadre de beton armat cu funcțiunea de locuință unifamilială. Amplasamentul pentru care se efectuează analiza structurală a modelor de calcul a fost propus de beneficiar într-o zonă cu hazard seismic moderat care acoperă o bună parte din teritoriul României, iar pentru stabilirea parametrilor de calcul ai acțiunii seismice s-a ales un amplasament localizat în orașul Brașov.

Modelarea acțiunii seismice s-a făcut în acord cu prevederile normativului de proiectare seismică a clădirilor în vigoare P100-1/2013. Codul de Proiectare Seismică P100-1/2013 utilizează un IMR de 225 ani (Siguranța Vieții), corespunzătoare unei probabilități de depășire de 20% în următorii 50 de ani. Harta de zonare seismică și valorile rezultate ale accelerației terenului pentru proiectare sunt prevăzute la un IMR de 225 ani. Întrucât tendința codurilor de proiectare la nivel global este de majorare a intervalului mediu de recurență, la solicitarea beneficiarului s-a considerat o cerință de performanță superioară care să aibă în vedere viitoarele modificări ale codurilor de proiectare. Astfel, pentru determinarea valorilor de proiectare ale forțelor seismice a fost considerat un IMR de 475 de ani, iar accelerația terenului de proiectare pentru acest IMR a fost determinată prin scalare conform prevederilor din normativul pentru evaluarea seismică a construcțiilor existente în vigoare P100-3/2019 unde sunt indicați factori de scalare pentru cerințe de performanță superioare.

Analiza structurală a fost efectuată în programe de calcul cu element finit, respectiv ETABS21, iar structurile s-au modelat independent pentru fiecare caz analizat. Cele două modele prezintă structuri de rezistență, compartimentări și alcătuirii similare, diferența între modele constând în tipul de învelitoare utilizat la nivelul acoperișului. În primul model s-a utilizat învelitoare de tip „Țigla română”, iar în cel de al doilea model s-a utilizat învelitoare din „Țigla metalică”.

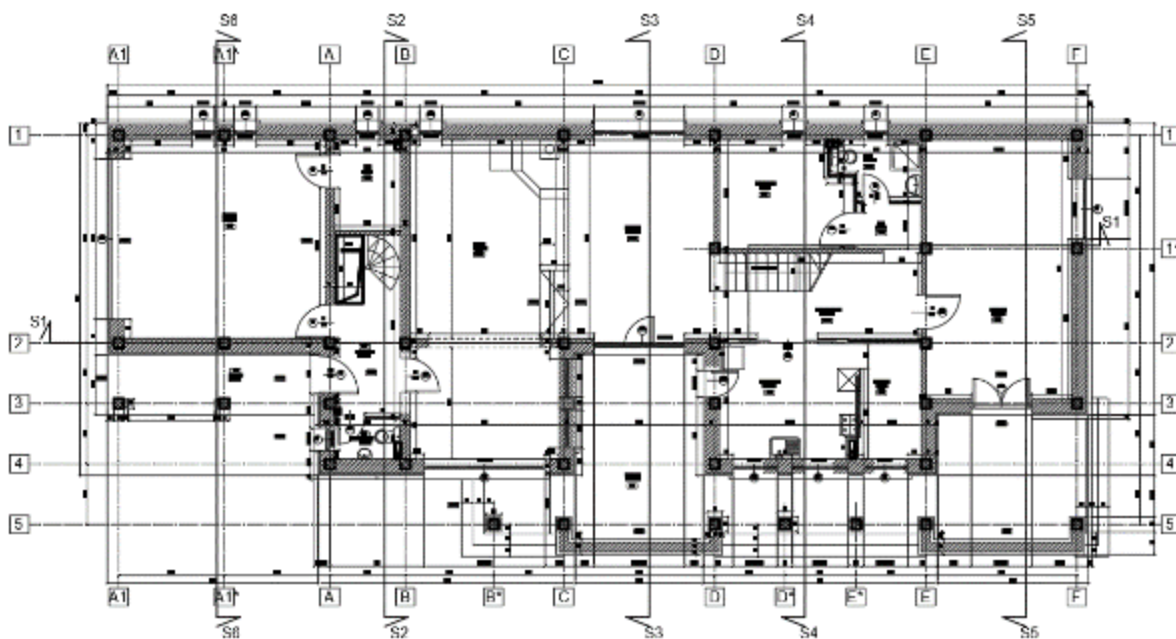
Învelitoarea de tip „Țigla română” utilizată în analiza structurală este realizată din nisip, ciment, apă și pigmenți anorganici, având o greutate de 4.45 kg/buc.

Pentru un  $m^2$  de acoperiș sunt necesare cca. 10 bucăți de țiglă, astfel rezultă o greutate topită de cca.  $45 \text{ kg/m}^2$  de acoperiș.

Învelitoarea de tip „Țiglă metalică” utilizată în modele de calcul este realizată din oțel galvanizat la cald, având o greutate specifică redusă de  $4.45 \text{ kg/m}^2$  de acoperiș.

În cadrul studiului tehnic s-a realizat o analiză comparativă a celor două modele considerate pentru fiecare etapă a calculului structural. S-au evaluat rezultate din analiza modală, deplasări relative de nivel, eforturi de proiectare, dimensionare elemente de beton armat (grinzi, stâlpi, plăci) și elemente constitutive șarpantă. Diferențele rezultate s-au evidențiat atât din punct de vedere al eforturilor de proiectare, cât și în consumurile aferente de materiale pentru cele două cazuri dimensionate.

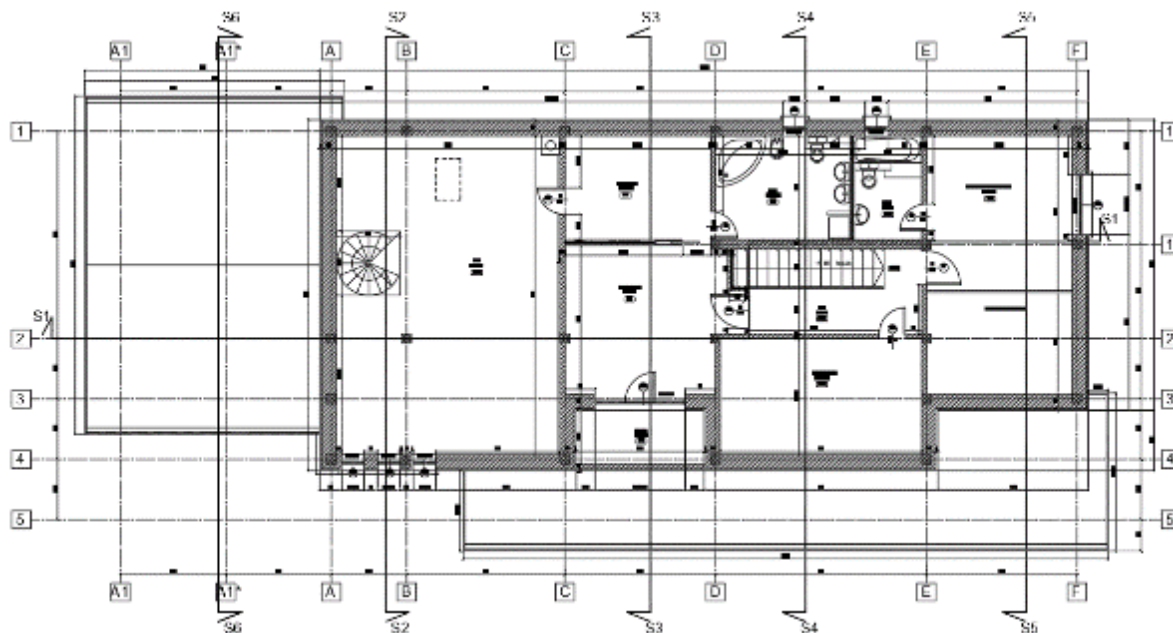
Construcția propusă este o clădire de tip vilă unifamilială cu o suprafață construită la sol de cca. 268 mp. În elevație, clădirea are o înălțime supratrană maximă de cca. 7.50 m. Suprastructura se încadrează în plan într-un dreptunghi cu laturile de 10.70m x 25.90 m.



### PLAN PARTER

Cota  $\pm 0,00 \text{ m}$  a clădirii este cu cca. 66 cm mai sus față de cota terenului natural din amplasament. Cota terenului amenajat (CTA) este la  $-0.56 \text{ m}$  raportate la cota  $\pm 0.00$  (a finisajului de la parter din zona central-estică). Zona vestică a clădirii de află la cota  $-0.36 \text{ m}$  raportată la cota  $\pm 0.00$ .

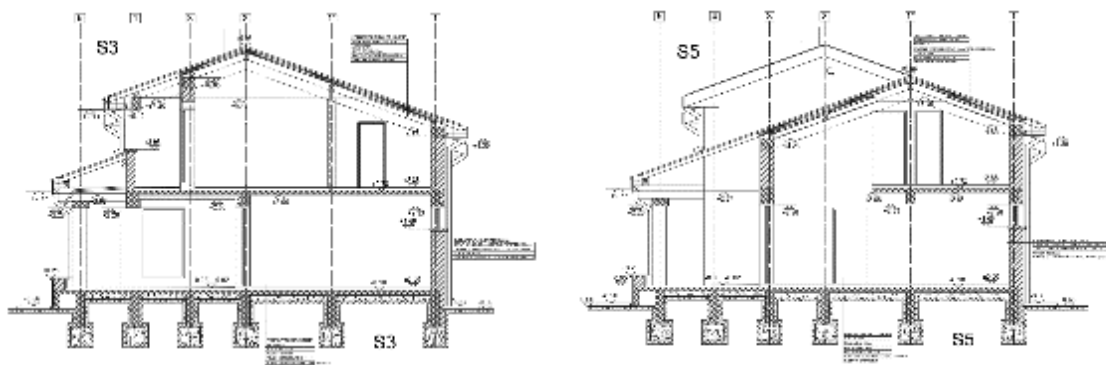
Înălțimile de nivel sunt: parterul este de 2.88 m în zona central estică, respectiv 3.24 m în zona vestică, iar mansarda are înălțime variabilă.



### PLAN MANSARDĂ

Cota  $\pm 0,00$  m a clădirii este cu cca. 66 cm mai sus față de cota terenului natural din amplasament. Cota terenului amenajat (CTA) este la  $-0.56$  m raportate la cota  $\pm 0.00$  (a finisajului de la parter din zona central-estică). Zona vestică a clădirii de află la cota  $-0.36$  m raportată la cota  $\pm 0.00$ .

Înălțimile de nivel sunt: parterul este de 2.88 m în zona central estică, respectiv 3.24 m în zona vestică, iar mansarda are înălțime variabilă.



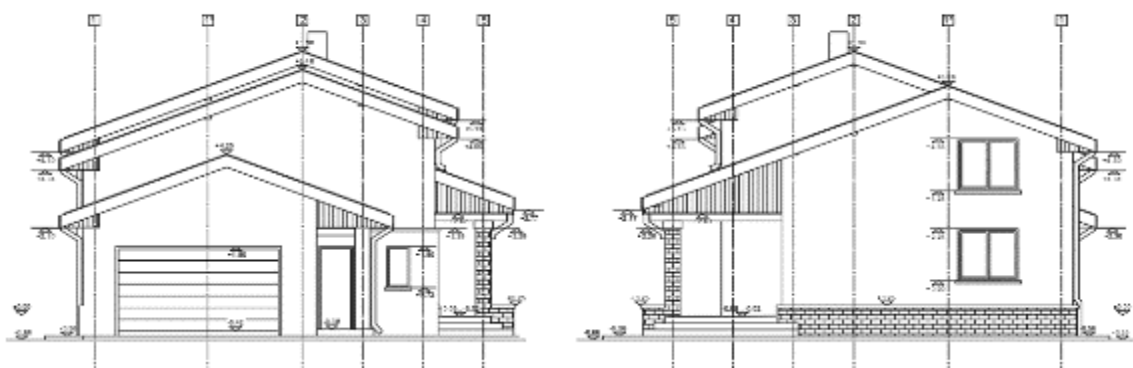
### SECȚIUNI TRANSVERSALE

Din punct de vedere al modului de organizare al spațiului interior, la parter, se regăsește garajul dispus în zona vestică, un portic cu două travee, zona de living, un grup sanitar și spațiul tehnic. Zona centrală și estică se dezvoltă la cota  $\pm 0.00$  și cuprinde zona de dining, bucătărie și dormitoare, precum și zona de terase realizate sub forma unui portic ce este dispus în fațada sudică. Accesul spre mansardă se face printr-o scara într-o rampă. Mansarda clădirii cuprinde dormitoare, grupuri sanitare și depozitari.

Mansarda se dezvoltă la cote variabile pe înălțime, iar acoperișul este realizat în fiecare zonă cu învelitoare în două ape, având un unghi de cca. 20° (panta de cca. 40%).



**FAȚADĂ PRINCIPALĂ**



**FAȚADE LATERALE**

Pentru realizarea prezentului studiu tehnic s-au avut în vedere standardele și normativele în vigoare.



**MODEL 3D: VEDERE SUD-VEST**

## 2. PREZENTAREA SISTEMULUI CONSTRUCTIV

### 2.1. SUPRASTRUCTURA

Partiul de arhitectură propus de beneficiar în prezentul studiu se caracterizează prin deschideri între pereți de cca. 5,00 m, iar pereții interiori de compartimentare au preponderent grosimi reduse de 12,5 cm și sunt realizați din gips-carton.

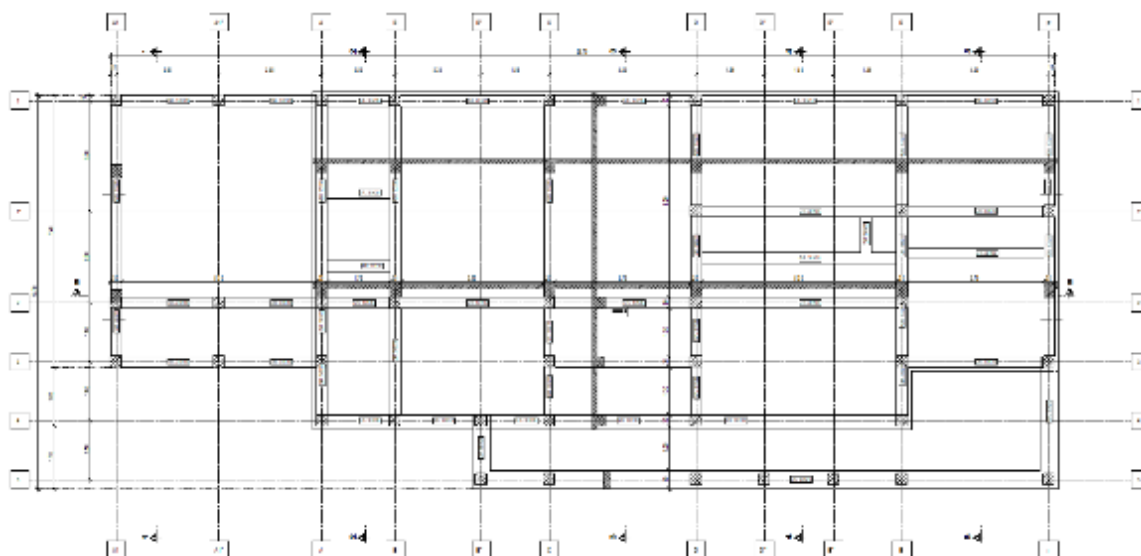
Pentru iluminarea naturală a spațiilor interioare, tema de proiectare propune spații vitrate generoase. În consecință, pentru a satisface cerințele arhitectural-funcționale și volumele propuse prin tema de proiectare a fost necesară implementarea unui sistem structural de tip cadre din beton armat dispuse pe cele două direcții principale.

Este important de precizat de faptul că un sistem structural de tip pereți portanți de zidărie confinată nu poate fi adaptat partiului de arhitectură propus din cauza grosimilor de pereți interiori, volumelor mari de goluri etc.

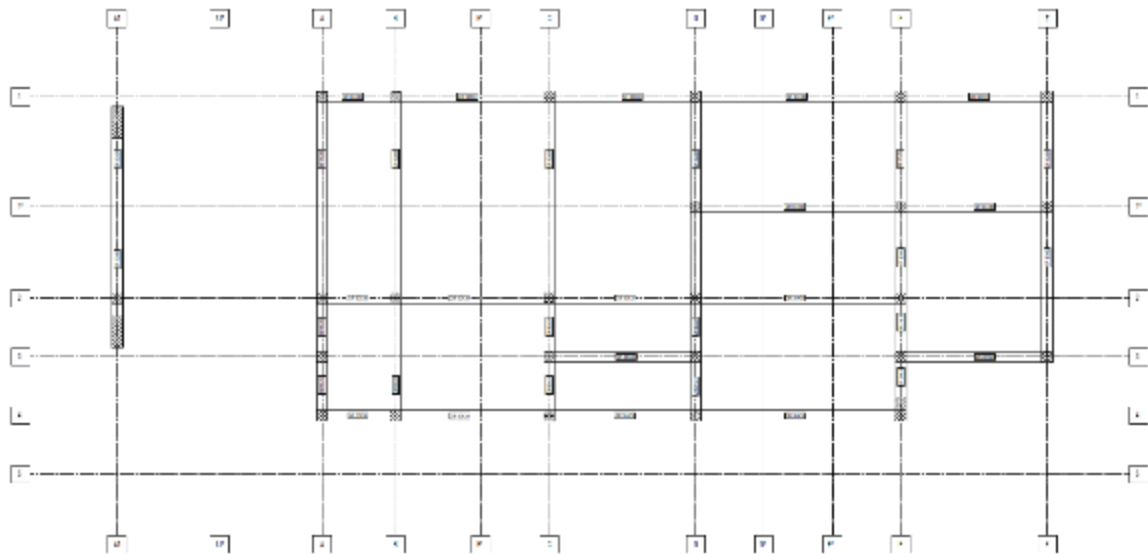
În urma predimensionărilor de rezistență și rigiditate au rezultat următoarele secțiuni ale elementelor structurale: stâlpii au dimensiuni de **30x30 cm**, iar grinzile cadrelor au secțiunea de **30x35 cm** fiind rigidizate în plan orizontal cu plăci de beton armat cu grosimea de 13 cm. Grinzile dispuse pentru bordajul golurilor din placă, cât și centurile de la nivelul mansardei vor avea dimensiuni de **30x30 cm**.

Planșeul de beton armat asigură pe de o parte efectul de șaiabă orizontală care distribuie forțele orizontale din seism la toate elementele structurii și pe de altă parte izolația fonică necesară între niveluri.

Peste zona de garaj și peste cele două portice din fațada sudică nu s-au prevăzut plăci din beton armat din considerente estetice de arhitectură.



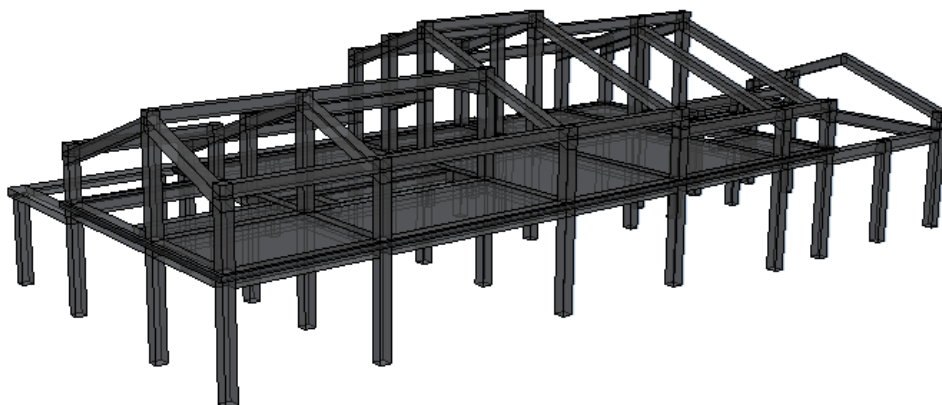
**PLAN COFRAJ PESTE PARTER**



**PLAN COFRAJ MANSARDĂ**



**MODEL STRUCTURAL 3D: VEDERE SUD-VEST**



**MODEL STRUCTURAL 3D: VEDERE NORD-EST**



## 2.2. ELEMENTE NESTRUCTURALE

Pereții din zidărie au rol de închidere perimetrală și sunt realizați din elemente ceramice GVP în grosime de 38 cm. S-a ales această soluție de anvelopă întrucât studiul are în vedere acoperirea unui areal cât mai mare de construcții dispuse atât în zone cu climat mai rece, cât și cu climat mai cald. Totodată, normele care au intrat în vigoare privind eficiența energetică și emisiile de carbon actuale NZEB prevăd soluții de izolare termică superioară, față de cele utilizate în mod curent până în prezent pe teritoriul României. Grosimea superioară a zidărie conduce și la un spor de greutate în ceea ce privește încărcările provenite din închideri, astfel analiza structurală fiind efectuată pe un model cât mai relevant de implementat în viitoarea perioadă. La nivelul parterului, compartimentările interioare sunt parțial din zidărie de cărămidă de 25 cm grosime (GVP) și preponderent din pereți de gips-carton montați pe structură ușoară din profile de aluminiu. La nivelul mansardei, compartimentările interioare propuse sunt din pereți ușori din gips-carton, cu excepția peretelui adiacent scării.

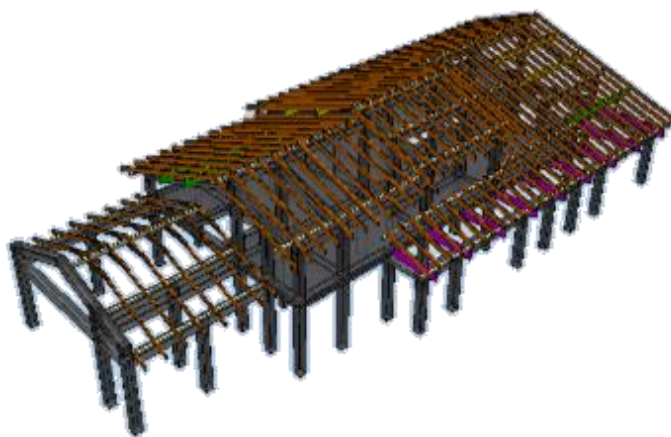
## 2.3. SISTEMUL DE ACOPERIȘ

Șarpanta este realizată din elemente de lemn ecarisat și prezintă conform temei de proiectare propuse studiului tehnic două ape. Aceasta este realizată la cote diferite pe înălțime, unghiul realizat de șarpantă fiind de 20° (panta de cca. 40%).

Cota maximă a șarpantei este în zona centrală a clădirii, având cota superioară la +6.98m față de cota ±0.00. Adiacent zonei centrale, în vestul acesteia șarpanta are cota superioară la +6.45 m, iar în zona estică +6.06 m. Zona garajului dispus în extremitatea vestică prezintă coama la cota cea mai redusă, respectiv la cota +4.25m.

În primul model analizat învelitoarea este realizată din „Țiglă română” și are o greutate de cca. 45 kg/m<sup>2</sup> (0.5K N/m<sup>2</sup>).

În cel de al doilea model analizat învelitoarea este realizată din „Țiglă metalică” și are o greutate de cca. 4.45 kg/m<sup>2</sup> (0.05KN/m<sup>2</sup>).



**MODEL 3D CU ALCĂTUIREA ȘARPANTEI**

### 3. BREVIAR DE CALCUL

#### 3.1. ÎNCĂRCĂRI ȘI ACȚIUNI ASUPRA STRUCTURII

Pentru calculul eforturilor structurale și dimensionarea elementelor de beton armat: plăci, grinzi și stâlpi, s-a avut în vedere evaluarea încărcărilor gravitaționale și a celor cvasipermanente: greutatea proprie a elementelor structurale, zidăria de compartimentare, pereții despărțitori, pardoseală și încărcarea utilă pentru scări și planșee. Totodată, în conformitate cu amplasamentul propus s-au luat în considerare încărcările provenite din zăpadă și vânt, precum și acțiunea seismică. Valoarea încărcărilor și modul de combinare au avut în vedere prevederile normativelor enumerate mai jos:

- P100-1/2013 - Cod de proiectare seismică: Partea I - Prevederi de proiectare pentru clădiri;
- P100-3/2019 - Cod de proiectare seismică: Partea a III-a - Prevederi pentru evaluarea seismică a clădirilor existente;
- SR EN 1990:2004 - Bazele proiectării structurilor;
- SR EN 1990:2004/NA:2006 - Bazele proiectării structurilor - Anexa Națională
- SR EN 1991-1-1:2004 - Acțiuni generale - greutate specifice, greutate proprii, încărcări utile pentru clădiri;
- SR EN 1991-1-1:2004/NA:2006 - Acțiuni generale - greutate specifice, greutate proprii, încărcări utile pentru clădiri - Anexa Națională;
- SR EN 1991-1-3:2005 - Acțiuni generale - încărcări date de zăpadă;
- SR EN 1991-1-3:2005/NA:2006 - Acțiuni generale - încărcări date de zăpadă – Anexa Națională;
- SR EN 1991-1-4:2006 - Acțiuni generale - Acțiuni ale vântului;
- SR EN 1991-1-4:2006/NB:2007 - Acțiuni generale - Acțiuni ale vântului – Anexa Națională;
- SR EN 1996-1-1:2006 - Reguli generale pentru construcții de zidărie armată și nearmată;
- SR EN 1996-1-1:2006/NB:2008 - Reguli generale pentru construcții de zidărie armată și nearmată - Anexa Națională;
- SR EN 1992-1-1:2006 - Proiectarea structurilor de beton - reguli generale și reguli pentru clădiri;
- SR EN 1992-1-1:2006/NB:2008 - Proiectarea structurilor de beton – reguli generale și reguli pentru clădiri - Anexa Națională;
- SR EN 1998-1:2006 - Proiectarea structurilor pentru rezistență la cutremure - reguli generale, acțiuni seismice și reguli pentru clădiri;

- SR EN 1998-1:2006/NA:2008 - Proiectarea structurilor pentru rezistență la cutremure - reguli generale, acțiuni seismice și reguli pentru clădiri – Anexa Națională;
- CR0-2012 - Cod de proiectare. Bazele proiectării construcțiilor;
- CR 1-1-3-2012 - "Cod de proiectare. Evaluarea acțiunii zăpezii asupra construcțiilor"
- CR 1-1-4-2012 - Cod de proiectare. Evaluarea acțiunii vântului asupra construcțiilor",
- CR6-2006 - Cod de proiectare pentru structuri din zidărie;
- NP 112-04 - Normativ pentru proiectarea structurilor de fundare directă;

### 3.1.1. ÎNCĂRCĂRI PERMANENTE

Greutatea proprie a elementelor structurale din beton armat și a elementelor de șarpantă se determină în mod automat în cadrul programului de calcul.

Față de greutatele proprii a elementelor s-au mai dispus următoarele încărcări permanente:

- **Model 1: Învelitoare din „Țiglă romană”**

Pereți de închidere din zidărie GVP	$b_{\text{zid}} \cdot h_{\text{zid}} \cdot \gamma_{\text{GVP}}$ kN/ml
Pereți de compartimentare din zidărie GVP	$b_{\text{zid}} \cdot h_{\text{zid}} \cdot \gamma_{\text{GVP}}$ kN/ml
Pardoseală și straturi planșeu peste parter	2.50 kN/m <sup>2</sup>
Greutate proprie învelitoare „Țiglă romana”	0.50 kN/m <sup>2</sup>

- **Model 2: Învelitoare din „Țiglă metalică”**

Pereți de închidere din zidărie GVP	$b_{\text{zid}} \cdot h_{\text{zid}} \cdot \gamma_{\text{GVP}}$ kN/ml
Pereți de compartimentare din zidărie GVP	$b_{\text{zid}} \cdot h_{\text{zid}} \cdot \gamma_{\text{GVP}}$ kN/ml
Greutate elemente șarpantă	
Pardoseală și straturi planșeu peste parter	2.50 kN/m <sup>2</sup>
Greutate proprie învelitoare „Țiglă metalică”	0.05 kN/m <sup>2</sup>

### 3.1.2. ACȚIUNI VARIABLE

Încărcări distribuite uniform pe suprafață ( $q_k$ ):

Spații standard de locuit, Clădire Categoria A	2.0 kN/m <sup>2</sup>
Scări	2.5 kN/m <sup>2</sup>
Balcoane	2.5 kN/m <sup>2</sup>
Pereți despărțitori – Gips-Carton	Pereți cu greutate <2,0 kN/m <sup>2</sup> : 0.80 kN/m <sup>2</sup>

### 3.1.3. ÎNCĂRCAREA DATĂ DE ZĂPADĂ

Conf. CR 1-1-3:2012 (4.1)

$S = \gamma_{IS} \mu_i C_e C_t S_k$ , unde

$\gamma_{IS}$  – este factorul de importanță-expunere pentru acțiunea zăpezii

$\gamma_{IS} = 1$

$\mu_i$  – coeficientul de formă al încărcării din zăpadă pe acoperiș

$\mu_i = 0.8$

$S_k$  – valoarea caracteristică a încărcării din zăpadă pe sol [KN/m<sup>2</sup>]

$S_k = 2,00$  KN/m<sup>2</sup> pentru amplasament Brașov

$C_e$  – coeficientul de expunere al construcției în amplasament

$C_e = 1.00$

$C_t$  – coeficientul termic

$C_t = 1.00$

Astfel, încărcarea din zăpadă la nivelul acoperișului este:

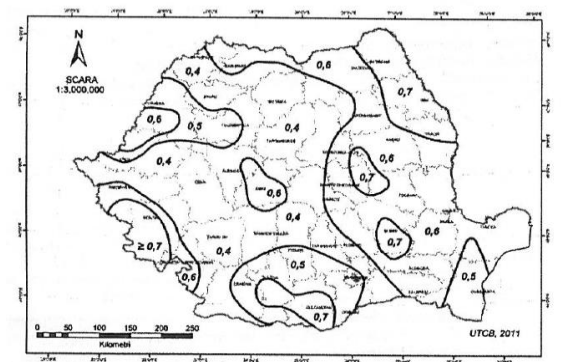
$$S = \gamma_{IS} \mu_i C_e C_t S_k = 1.60 \text{ KN/m}^2$$



Figura 3.1 Zonarea valorilor caracteristice ale încărcării din zăpadă pe sol  $s_k$ , [KN/m<sup>2</sup>], pentru abțitulini  $A \leq 1000$  m<sup>2</sup>. Nota: Pentru abțitulini  $A > 1000$  m<sup>2</sup> se determină cu relațiile (3.1) și (3.2).

### 3.1.4. ACȚIUNEA VÂNTULUI

Conf. CR 1-1-4:2012.



Harta zonării pentru presiunea de referință a vântului  $q_p$  (kPa), la IMR = 50 ani

*D.p.d.v. al încărcărilor din vânt, conform CR 1-1-4-2012, presiunea de referință a vântului într-un amplasament din orașul Brașov este 0.60 kPa.*

### 3.1.5. ACȚIUNEA SEISMICĂ

Proiectarea seismică a fost realizată în conformitate cu normativul P100-1/2013, iar pentru acțiunea seismică s-a avut în vedere o cerință de performanță superioară (IMR 475 ani).

Codul de Proiectare Seismică P100-1/2013 utilizează un IMR de 225 ani (Siguranța Vieții), corespunzătoare unei probabilități de depășire de 20% în următorii 50 de ani. Astfel, harta de zonare seismică și valorile rezultate ale accelerației terenului pentru proiectare sunt prevăzute la un IMR de 225 ani.

Pentru obținerea accelerațiilor de proiectare aferente cerinței de performanță IMR 475 de ani s-au utilizat prevederile codului P100-3/2018.

Valorile de vârf ale accelerației seismice orizontale corespunzătoare intervalului mediu de recurență considerat în cazul de față, respectiv 475 de ani, se determină pe baza valorilor  $a_g$  stabilite conform zonării prevăzută de P100-1/2013, pentru intervalul mediu de recurență de 225 de ani, prin multiplicare cu factorii de scalare din Tab. A.1 din P100-3/2018.

Astfel, pentru județul Brașov, pentru IMR=475 de ani, raportul între accelerația terenului de proiectare corespunzătoare unui IMR de 475 de ani și accelerația terenului de proiectare corespunzătoare unui IMR de 225 de ani este 1.35.

$$\frac{a_g^{475}}{a_g^{225}} = 1.35$$

Clasa de importanță a construcției analizate este III conform normativ P100-1-2013, iar categoria de importanță „C” conform cu HGR 766 /1997 .

Factor de importanță  $\gamma_1=1,0$

Valoarea (de vârf) a accelerației terenului pentru proiectare:



Figura 5.1. Harta de zonare a valorilor de vârf ale accelerației terenului pentru proiectare  $a_g$  în IMR = 225 ani și 20% probabilitate de depășire în 50 de ani

*Harta de zonare a valorilor de vârf ale accelerației terenului pentru proiectare cu IMR = 225 ani, corespunzătoare unei probabilități de depășire de 20% în 50 de ani*

Pentru Brașov IMR 225:

$$a_g^{225} = 0,20g$$

Pentru Brașov IMR 475:

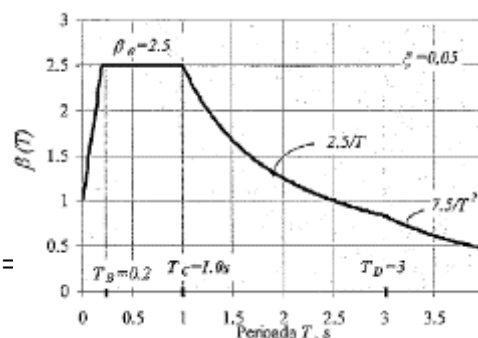
$$a_g^{475} = 0,27g$$

- **Perioade de control / de colț:**

- $T_B = 0.14s$
- $T_C = 0.7s$
- $T_D = 3.00s$



Figure 1.1. Zonarea seismică în România în termenii accelerațiilor maxime la pământ și a perioadelor de regim.



- **Factor de amplificare dinamică maxim  $\beta_0 =$**

- **Factor de comportare – q pentru structura în cadre de beton cu neregularitate în plan și elevație este 4.60.**

Forța seismică:

$$Fb = \gamma_I * Sd(T) * m * \lambda$$

Coeficientul seismic rezultă:

$$c_s = \gamma_I * a_g^{225} \frac{\beta(T)}{q} * \lambda * \frac{a_g^{475}}{a_g^{225}}$$

$$c_s = 0.147$$

## 3.2. DIMENSIONARE ȘI CALCUL

### 3.2.1. COMBINAȚII DE ÎNCĂRCĂRI

Pentru determinarea eforturilor secționale ale elementelor de beton armat efectele acțiunilor au fost combinate conform Codului de Proiectare CR0 – 2012 – Bazele Proiectării în Construcții.

(i) **În cazul de proiectare la Starea Limită Ultimă (SLU):**

- pentru încărcări gravitaționale predominante (gruparea fundamentală)

$$1.35 \sum_{j=1}^n G_{k,j} + 1.5U_k + \sum_{i=1}^n 1.05 \cdot Q_{k,i}$$

- pentru acțiunea predominantă a vântului:

$$1.35 \cdot \sum_{j=1}^n G_{kj} + 1.5 \cdot V_k + 1.05 \cdot U_k$$

- pentru acțiunea seismică (gruparea seismică):

$$\sum_{j=1}^n G_{kj} + \gamma_1 A_{Ek} + \sum_{i=1}^n 0.3 \cdot Q_{k,i}$$

**(ii) În cazul de proiectare la Starea Limită de serviciu / de exploatare (SLS):**

- Acțiunea vântului, în combinație caracteristică a efectelor acțiunilor asupra structurii:

$$\sum_{j=1}^n G_{k,j} + V_k + \sum_{i=1}^n 0.7 \cdot U_k$$

- Acțiune dinamică a vântului, în combinația frecventă a efectelor acțiunilor asupra structurii:

$$\sum_{j=1}^n G_{k,j} + 0.2 \cdot V_k + \sum_{i=1}^n 0.3 \cdot U_k$$

- Combinație cvasi-permanentă a efectelor acțiunilor gravitaționale asupra structurii (efecte de lungă durată)

$$\sum_{j=1}^n G_{k,j} + \sum_{i=1}^n 0.3 \cdot Q_{k,i}$$

- Combinație cvasi-permanentă a efectelor acțiunii seismice asupra structurii

$$\sum_{j=1}^n G_{k,j} + \gamma_1 A_{Ek} + \sum_{i=1}^n 0.3 \cdot Q_{k,i}$$

Pentru determinarea eforturilor secționale la ULS și SLS ale elementelor de lemn s-au realizat combinații de încărcări în conformitate cu prevederile CR0 – 2012, EN1995-1-1:2009 și NP 005-2022.

### 3.2.2. ANALIZA ȘI MODELAREA STRUCTURALĂ

Pentru calculul structural s-au folosit programe automate de calcul bazate pe metoda elementului finit cu care s-a putut modela suprastructura clădirii în cele două variante de învelitoare.

Se menționează că modelele de calcul au fost încastrate la baza parterului și nu s-a modelat interacțiunea teren-structura.

Conformarea de ansamblu a structurii s-a făcut astfel încât să se respecte condițiile de siguranță-stabilitate, ductilitate și rigiditate.

Proiectarea seismică a construcției a urmărit să realizeze:

- o conformare generală favorabilă, aceasta implicând alegerea unei forme favorabile în plan (rectangulară), cât și pe verticală, dispunerea și conformarea corectă a elementelor structurale: stâlpi, grinzi și planșee precum și a elementelor nestructurale;
- asigurarea unei rigidități suficiente la deplasări laterale în măsură să limiteze la valori admisibile atât deplasările absolute, cât și cele relative (0.005), astfel încât

să nu apară pericolul pierderii stabilității sau pentru a nu spori substanțial efectele de ordinul doi;

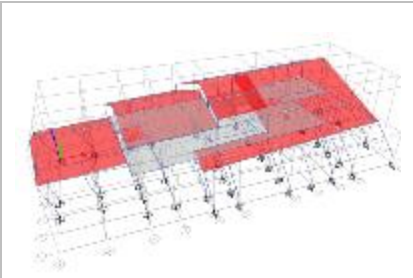
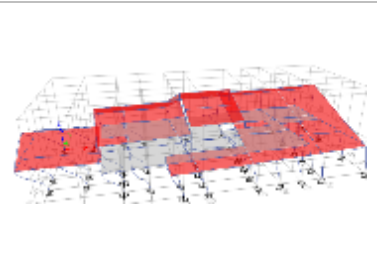
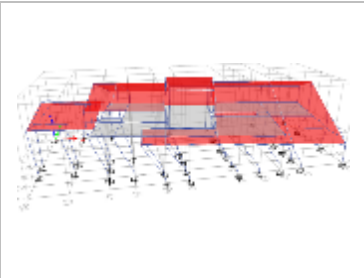
- obținerea unui mecanism structural favorabil de disipare a energiei sub acțiuni seismice de intensitate ridicată:

- dirijarea articulațiilor plastice potențiale (acele zone susceptibile a fi solificate în domeniul post-elastic) la capetele grinzilor acestea având o capacitate de deformare post-elastic substanțială - cedarea acestora nu pune în pericol stabilitatea generală a construcției;
- articulațiile plastice potențiale sunt distribuite relativ uniform pe întreaga structură și sunt caracterizate de cerințe de ductilitate reduse;
- planșeele sunt solificate în domeniul elastic;
- elementele structurale au fost alcătuite și dimensionate astfel încât să se evite ruperea casantă a acestora;

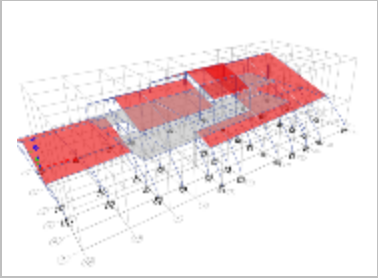
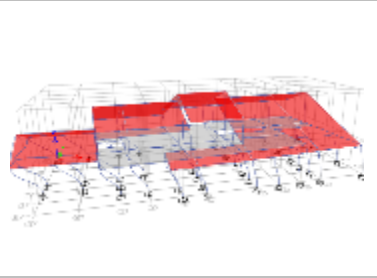
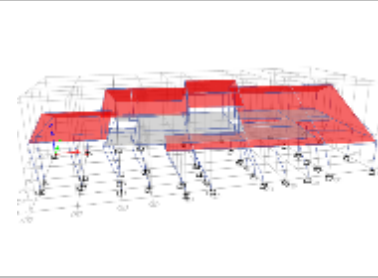
Forțele tăietoare de calcul din elementele de cadru s-au considerat cele asociate mecanismului de plastificare.

### 3.2.3. PARAMETRII PRINCIPALI ȘI REZULTATELE ANALIZEI

- **Model 1: Învelitoare din „Țiglă romană”**

		
<b>Modul 1 de vibrație</b> Perioada 0.321s Translație pe direcția OY	<b>Modul 2 de vibrație</b> Perioada 0.31s Translație pe direcția OX	<b>Modul 3 de vibrație</b> Perioada 0.261s Torsiune generala

- **Model 2: Învelitoare din „Țiglă metalică”**

		
<b>Modul 1 de vibrație</b> Perioada 0.312s Translație pe direcția OY	<b>Modul 2 de vibrație</b> Perioada 0.302s Translație pe direcția OX	<b>Modul 3 de vibrație</b> Perioada 0.254s Torsiune generala

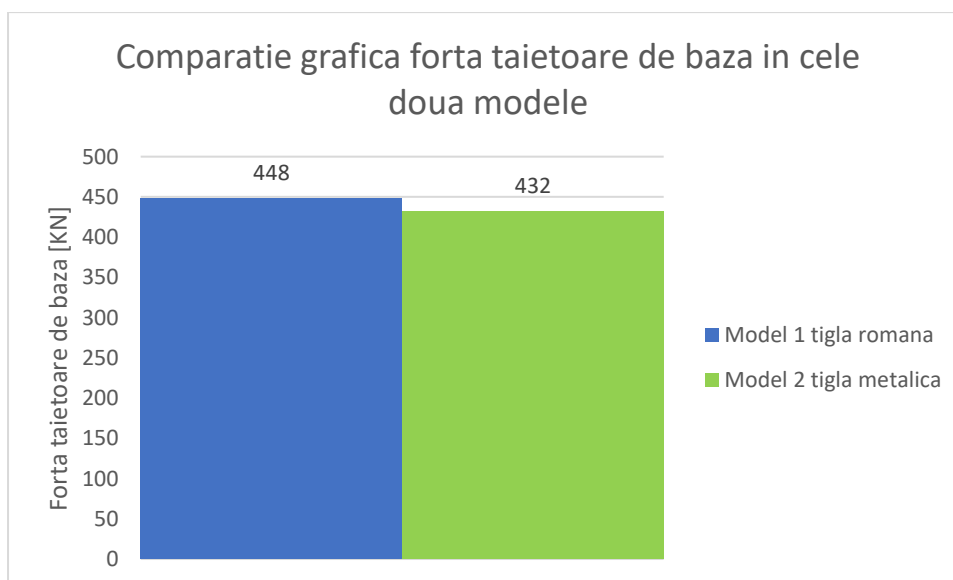
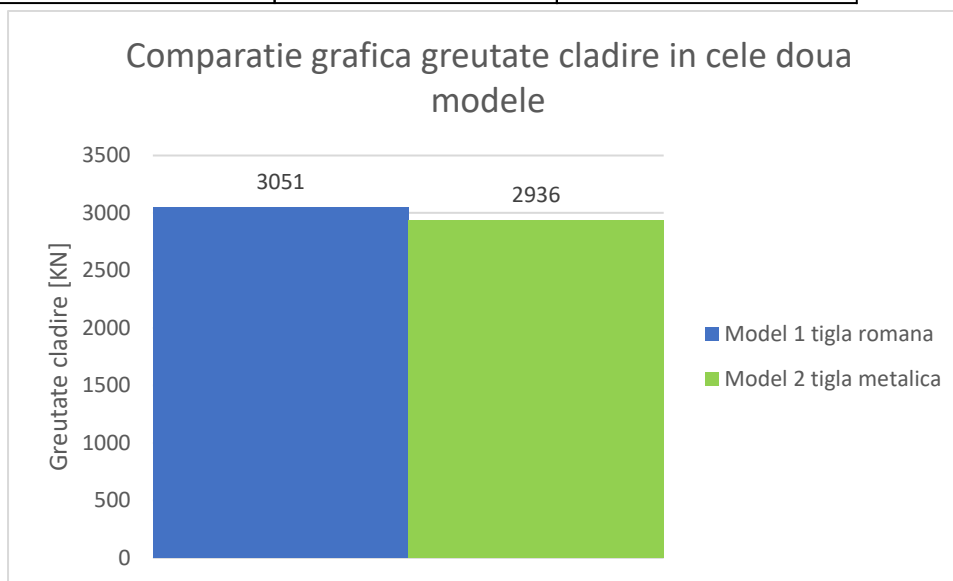
Modurile de vibrație sunt similare, respectiv translație pe direcție scurtă OY în primul mod de vibrație, translație pe direcție lungă OX în al doilea mod de vibrație



și torsiune generală în modul 3. Diferențele cu privire la perioadele de vibrație sunt ne semnificative.

Evaluarea comparativă a greutateii clădirii și a forței tăietoare de bază asociate celor două modele:

cs=0.147	Model 1 tigla romana	Model 2 tigla metalica
Greutate[KN]	3051	2936
Forța tăietoare de bază[KN]	448	432



### 3.2.4. DEPLASAREA RELATIVĂ DE NIVEL (DRIFT)

Verificarea la **starea limită de serviciu** are drept scop menținerea funcțiunii principale a clădirii în urma unor cutremure ce pot apărea de mai multe ori în viața

construcției, prin controlul degradărilor elementelor nestructurale și al componentelor instalațiilor aferente construcției.

Verificarea la deplasare se face pe baza expresiei (relația E.1 – anexa E, Codul P100-1/2013):

$$dr^{SLS} = v * q * dr \leq dra^{SLS}$$

unde,

$dr_{SLS}$  - deplasarea relativă de nivel sub acțiunea seismică asociată SLS;

$v$  - factor de reducere care ține seama de perioada de revenire mai mică a cutremurului. Valoarea

factorului  $v$  este: 0,5 pentru clădirile încadrate în clasa III de importanță;

$q$  - factorul de comportare specific tipului de structură;

$dr$  - deplasarea relativă a unui nivel determinată prin calcul static elastic sub încărcări seismice de proiectare;

$dra^{SLS}$  - valoarea admisibilă a deplasării relative de nivel, egală cu 0.005h.

Valorile deplasărilor se calculează folosind ipoteze de calcul a rigidității elementelor structurale conforme cu starea efectivă de fisurare a acestora, funcție de gradul de interacțiune între elementele structurale și a celor nestructurale (compartimentări și închideri).

Verificarea la **starea limita ultima** are drept scop evitarea pierderilor de viață omenești la acțiunea unui cutremur major, foarte rar, ce poate apărea în viața unei construcții, prin prevenirea prăbușirii totale a elementelor structurale. Se urmărește deopotrivă realizarea unei margini de siguranță suficiente față de stadiul cedării elementelor structurale.

Verificarea la deplasare se face pe baza expresiei:

$dr^{ULS} = c * q * dr \leq dra^{ULS}$  - deplasarea relativă de nivel sub acțiunea seismică asociată ULS

$q$  - factorul de comportare specific tipului de structură

$dr$  - definit în cadrul paragrafului F.1. În lipsa datelor care să permită o evaluare mai precisă, rigiditatea la încovoiere a elementelor structurale, utilizată pentru calculul valorii  $dr$ , se consideră egală cu jumătate din valoarea corespunzătoare secțiunilor nefisurate.

$c$  - coeficient de amplificare al deplasărilor, care ține seama ca pentru  $T < T_c$  deplasările seismice calculate în domeniul inelastic sunt mai mari decât cele corespunzătoare răspunsului seismic elastic. Valorile  $c$  se aleg conform relației de mai jos.

$dra^{ULS}$  - valoare admisibilă a deplasării relative de nivel, egală cu 2.5%.

$1 < C = 3 - 2.3 * \frac{T_1}{T_c} < \frac{\sqrt{T_c * q}}{1.7}$  – pentru structuri din beton armat și structuri compozite cu armătura rigidă

Astfel:

$q = 4.60$  – factorul de comportare al structurii pe direcția analizată;

$v = 0.5$  – factorul de reducere care ține seama de perioada de revenire mai scurtă a acțiunii seismice asociată SLS.

$c = 1.06$  – coeficientul de amplificare al deplasărilor, care ține seama că pentru  $T < T_c$  deplasările seismice calculate în domeniul inelastic sunt mai mari decât cele corespunzătoare răspunsului seismic elastic (de regula „deplasării egale”).

Au rezultat următoarele valori ale drift-urilor asociate SLS și SLU pentru cele două modele asociate celor două tipuri de învelitori:

- Seism pe direcția OX

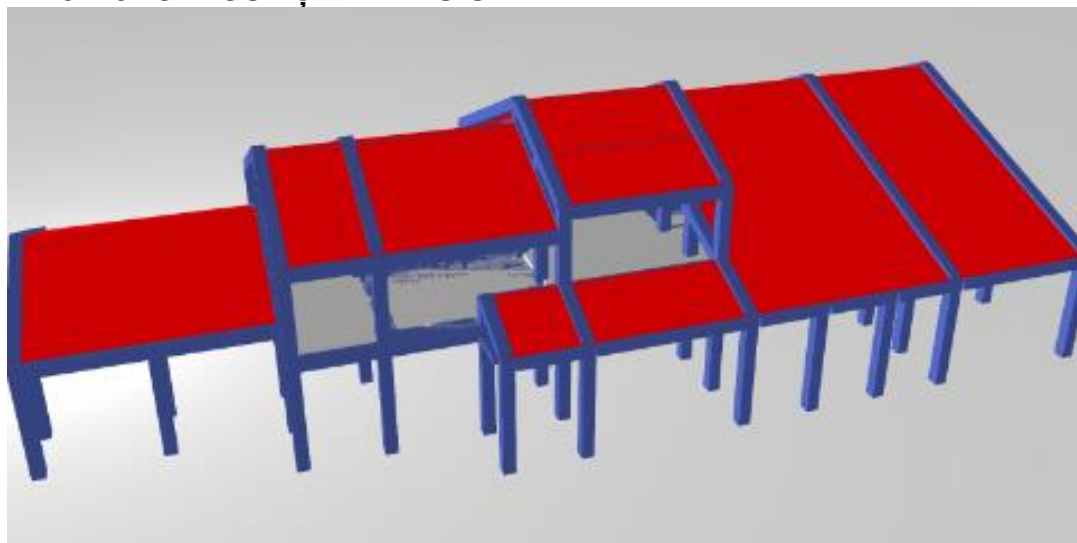
Tip învelitoare	NIVEL	DRIFT X [-]	Dr.SLS	Dr.SLU	Dra/Dr	Dra/Dr
					(SLS)	(SLU)
Model 1 (Țigla romană)	Parter	0.00132	0.00303	0.00639	1.65	3.91
Model 2(Țigla metalică)	Parter	0.00125	0.00287	0.00605	1.74	4.13

- Seism pe direcția OY

Tip învelitoare	NIVEL	DRIFT Y [-]	Dr.SLS	Dr.SLU	Dra/Dr	Dra/Dr
					(SLS)	(SLU)
Model 1 (Țigla romană)	Parter	0.00144	0.00331	0.00698	1.51	3.58
Model 2(Țigla metalică)	Parter	0.00136	0.00314	0.00662	1.59	3.77

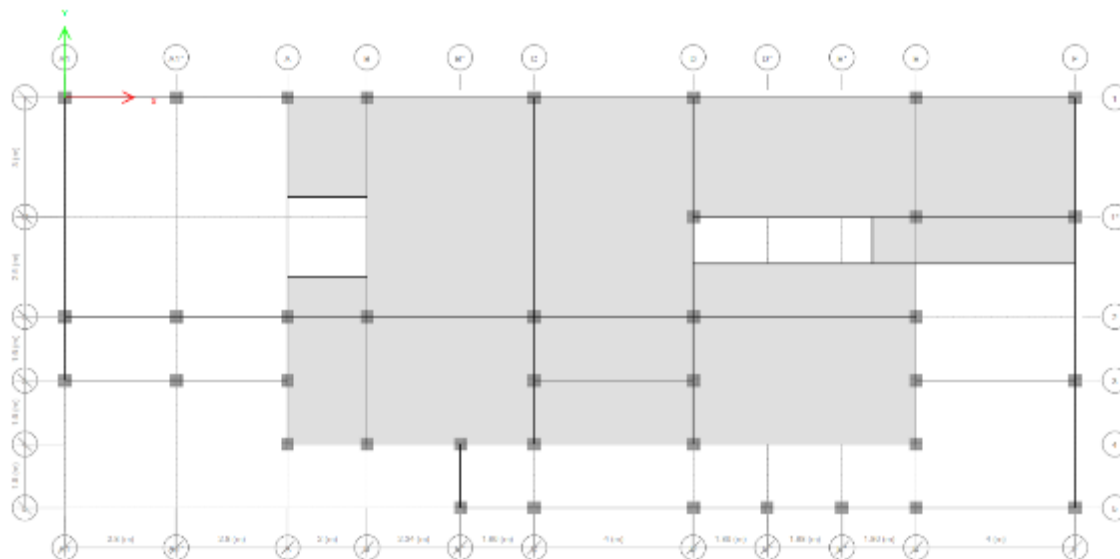
Valorile deplasărilor relative de nivel pe direcția X și cele de pe direcția Y sunt inferioare limitelor impuse de cod pentru structuri noi, atât la SLS, cât și la SLU, pentru ambele modele.

### 3.2.5. CALCUL ȘI DIMENSIONARE ELEMENTE

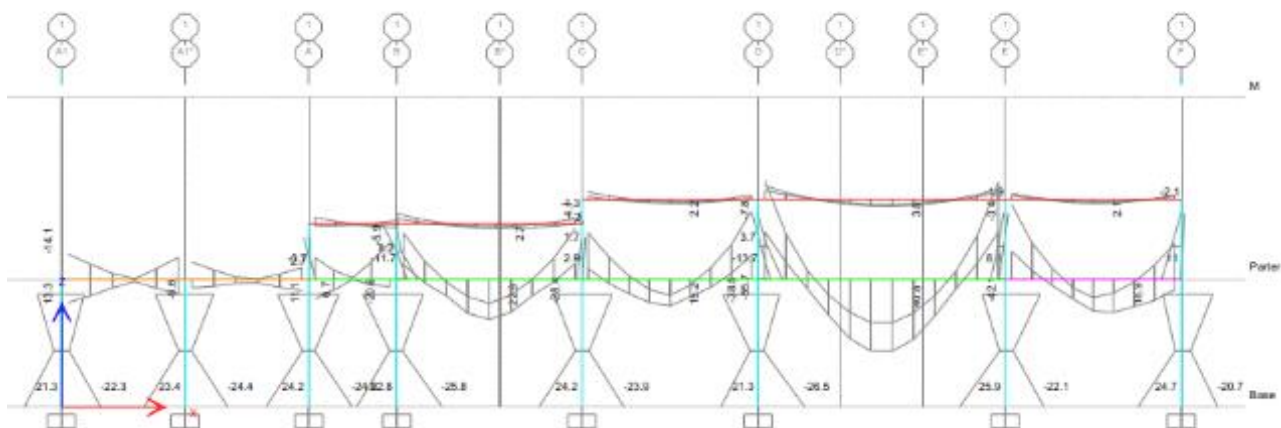
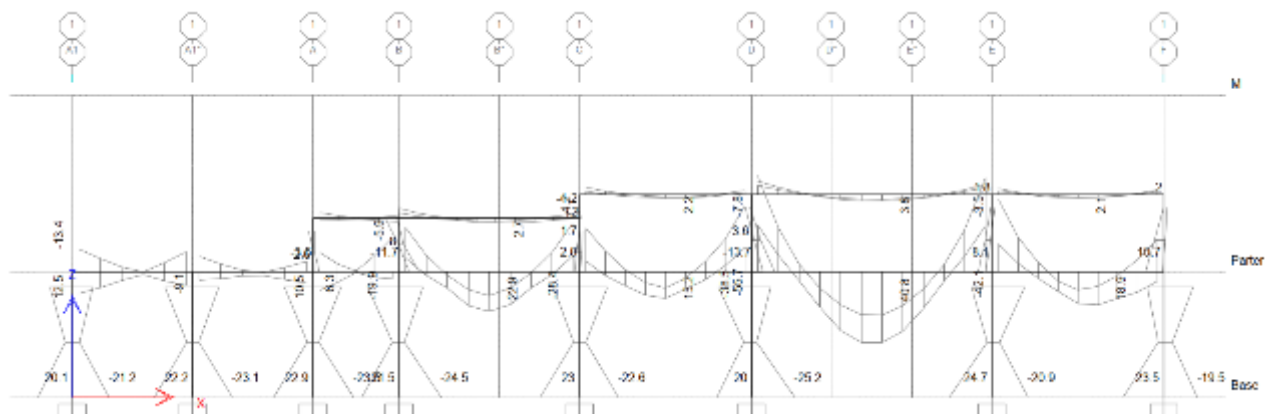


Model 3D program de calcul ETABS

Poziționarea elementelor structurale de beton armat de la parter din programul de calcul:



În continuare se prezintă evaluarea comparativă a eforturilor în elementele structurale din beton armat (grinzi, stâlpi, plăci) între cele două modele de calcul, respectiv Model 1 (Țiglă romană) și Model 2 (Țiglă metalică).

**EVALUAREA COMPARATIVĂ A MOMENTELOR ÎNCOVOIETOARE ÎN CADRU  
LONGITUDINAL AX 1**Diagrama de momente – **Model 1 – Învelitoare Țigă romană**Diagrama de momente – **Model 2 – Învelitoare Țigă metalică**

Se observă că în cele două modele diferențele de momente încovoietoare din elementele de cadru sunt ne semnificative.

## EVALUAREA COMPARATIVĂ A FORȚELOR TĂIETOARE ÎN CADRU LONGITUDINAL AX 1

Diagrama de forțe tăietoare – Model 1 – Învelitoare Țiglă romană

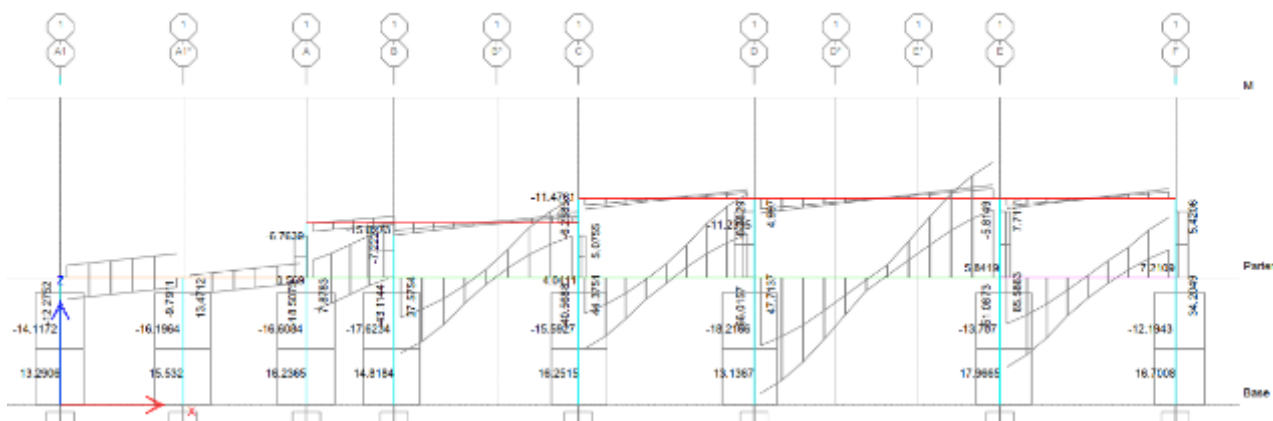
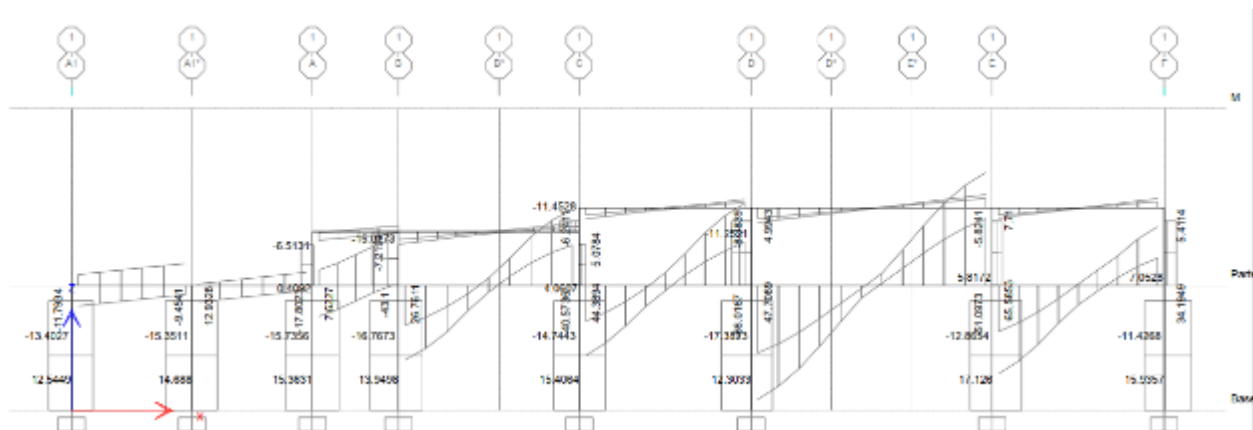
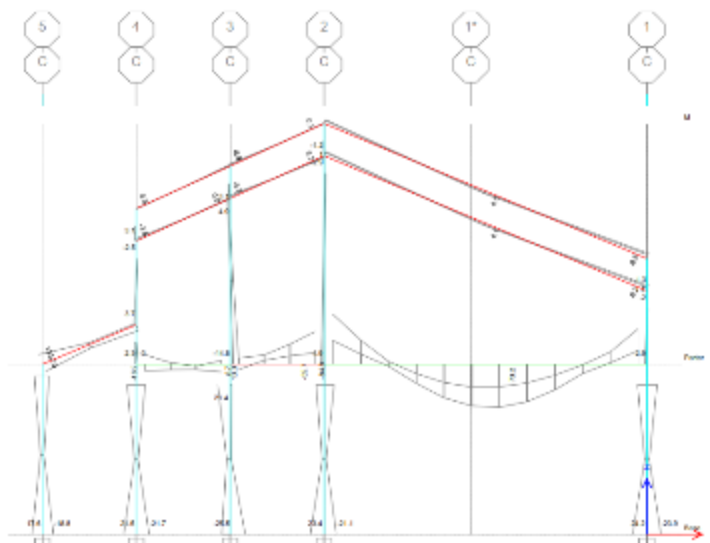
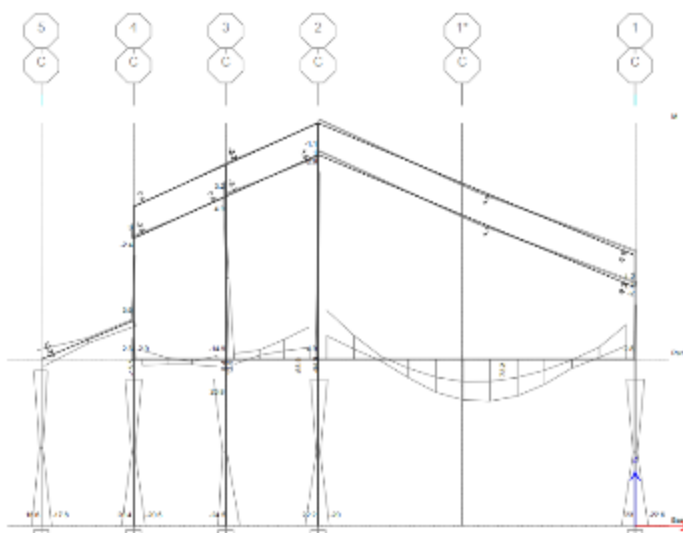


Diagrama de forțe tăietoare – Model 2 – Învelitoare Țiglă metalică



Se observă că în cele două modele diferențele de forțe tăietoare din elementele de cadru sunt ne semnificative.

**EVALUAREA COMPARATIVĂ A MOMENTELOR ÎNCOVOIETOARE ÎN CADRU  
TRANSVERSAL AX C**Diagrama de momente – **Model 1 – Învelitoare Țigă romană**Diagrama de momente – **Model 2 – Învelitoare Țigă metalică**

Se observă că în cele două modele diferențele de momente încovoietoare din elementele de cadru sunt ne semnificative.

## EVALUAREA COMPARATIVĂ A FORȚELOR TĂIETOARE ÎN CADRU TRANSVERSAL AX C

Diagrama de forțe tăietoare – **Model 1 – Învelitoare Țiglă romană**

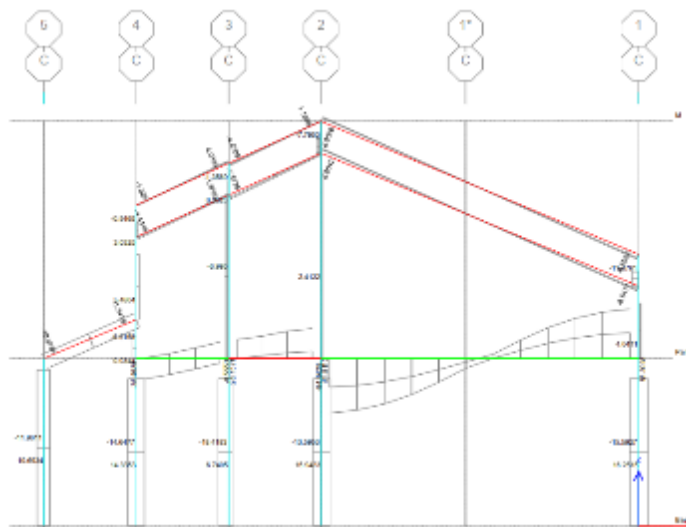
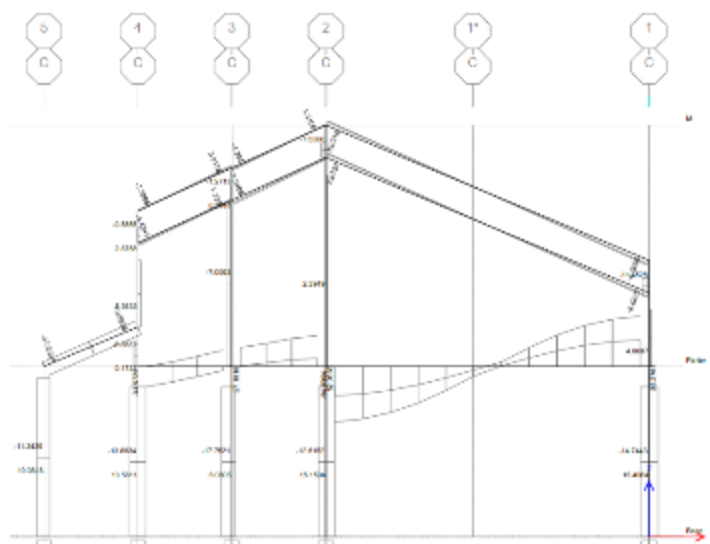


Diagrama de forțe tăietoare – **Model 2 – Învelitoare Țiglă metalică**

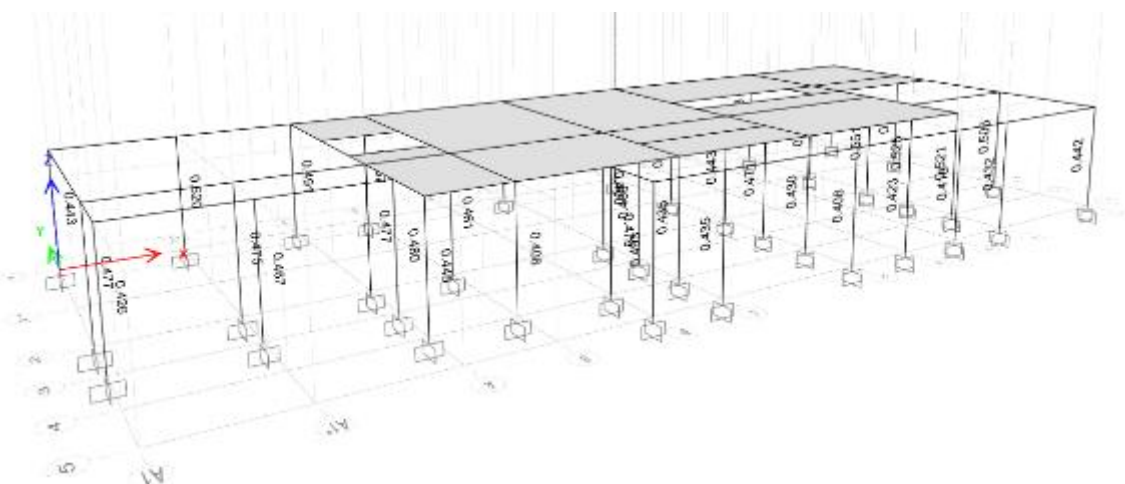


Se observă că în cele două modele diferențele de forțe tăietoare din elementele de cadru sunt nesemnificative.

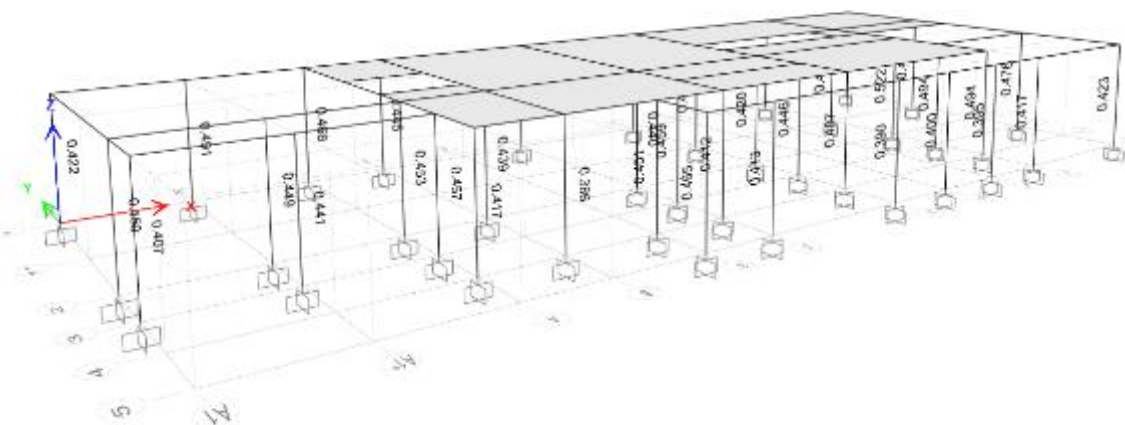


## EVALUAREA CAPACITATE STÂLPI

Rezultat grafic capacitate stâlpi – Model 1 – Învelitoare Țigă română



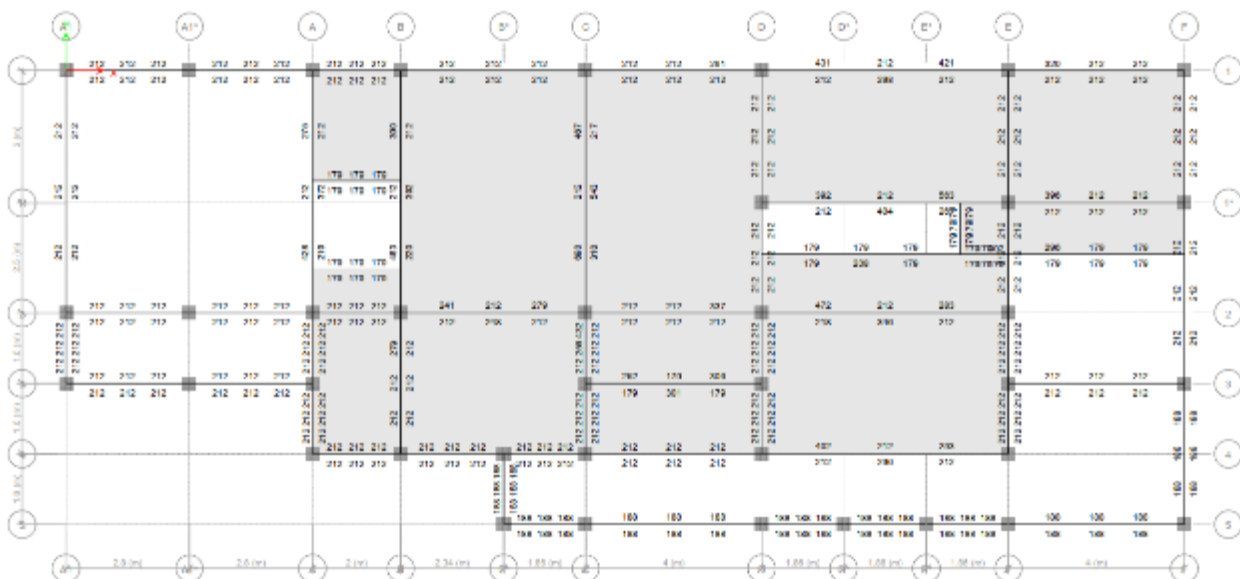
Rezultat grafic capacitate stâlpi – Model 2 – Învelitoare Țigă metalică



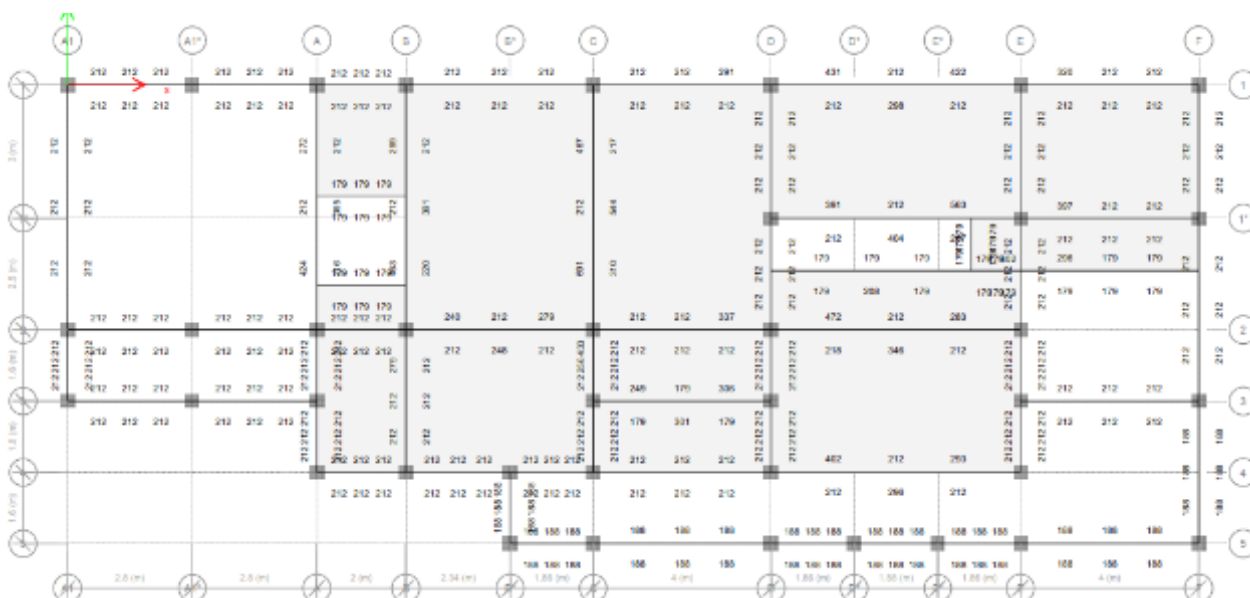
Se observă că în cele două modele verificarea cerință / capacitate prezintă diferențe ne semnificative.

**ARII NECESARE DE ARMĂTURĂ LONGITUDINALĂ GRINZI PARTER (mm<sup>2</sup>)**

Rezultat grafic arii necesare de armătură longitudinală grinzi parter – Model 1 – Înelitoare Țiglă romană



Rezultat grafic arii necesare de armătură longitudinală grinzi parter – Model 2 – Înelitoare Țiglă metalică



Se observă că în cele două modele ariile de armătură longitudinală necesară în grinzi de la parter prezintă diferențe ne semnificative.

## EVALUAREA COMPARATIVĂ A MOMENTELOR ÎNCOVOIETOARE ÎN PLACA DE BETON ARMAT DE PESTE PARTER

Diagrama M11 placă peste parter – **Model 1 – Învélitoare Țiglă romană**

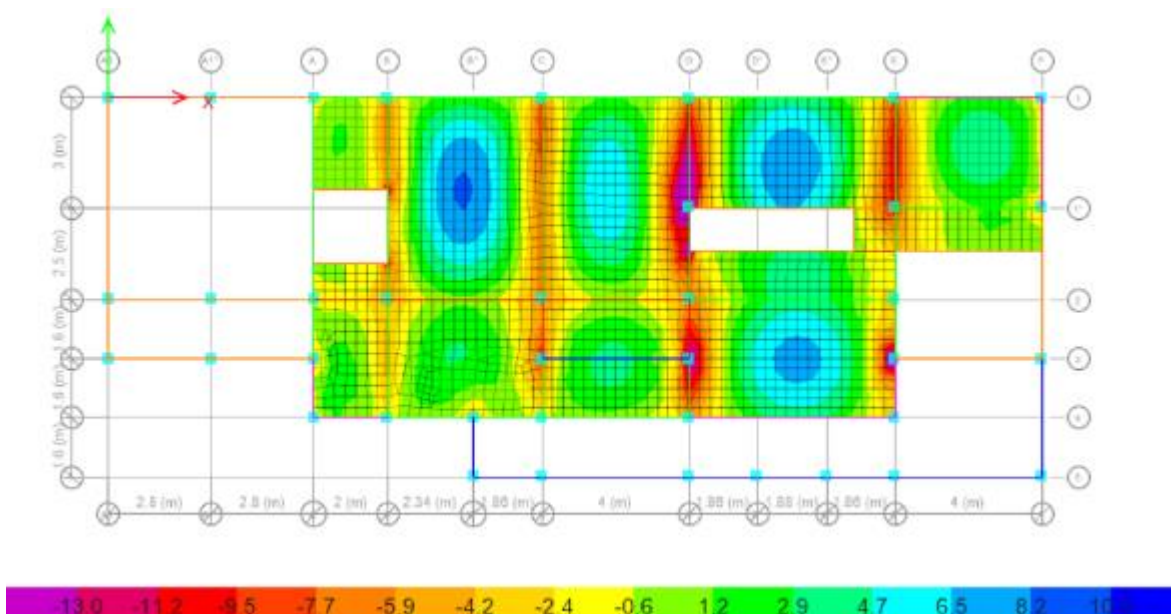
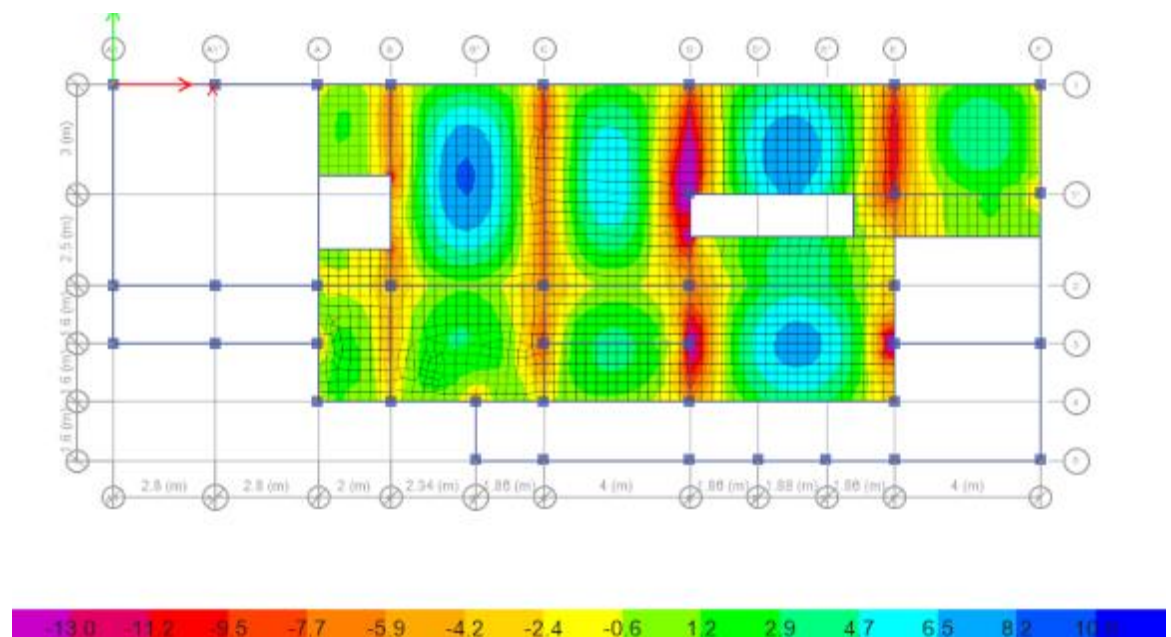


Diagrama M11 placă peste parter – **Model 2 – Învélitoare Țiglă metalică**



Se observă grafic că în cele două modele momentele încovoietoare pe direcția (x) sunt similare.

Diagrama M22 placă peste parter – Model 1 – Învelitoare Țiglă romană

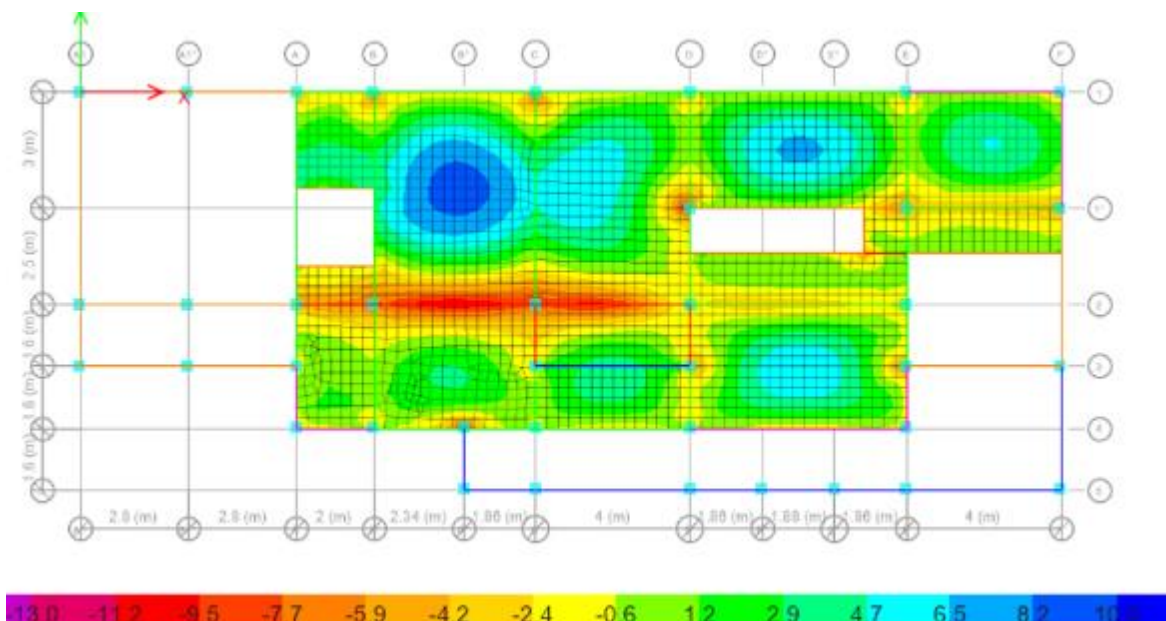
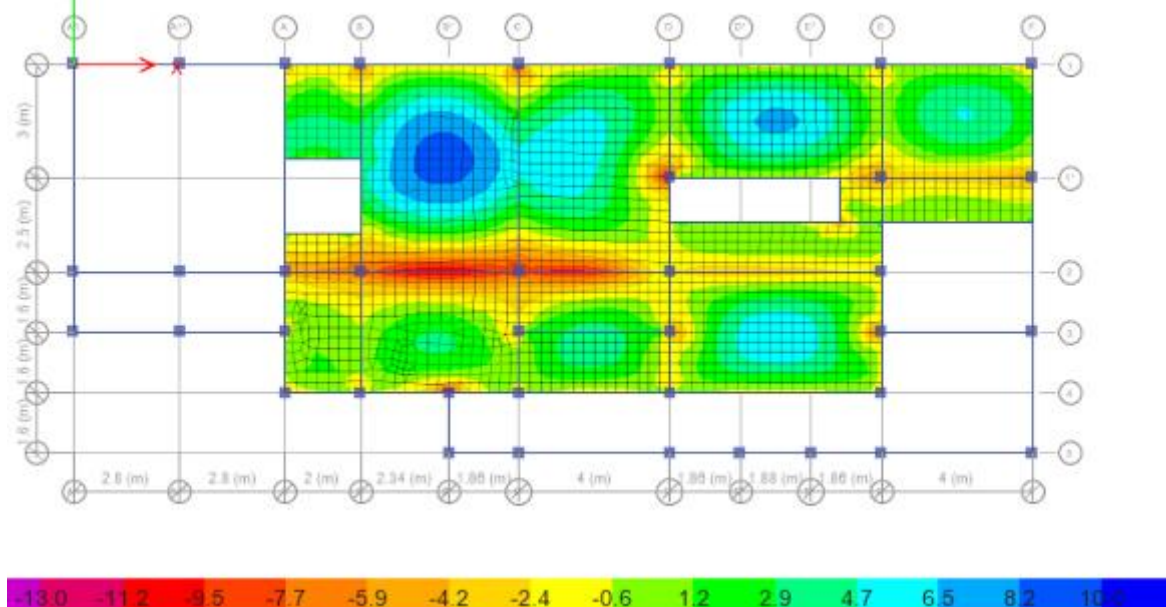


Diagrama M11 placă peste parter – Model 2 – Învelitoare Țiglă metalică



Se observă grafic că în cele două modele momentele încovoietoare pe direcția (y) sunt similare.

### 3.2.5.1. CALCUL ȘI DIMENSIONARE GRINZI

Pentru exemplificarea dimensionării s-a calculat grinda de la nivelul parterului din axul 1/D-E. Eforturile de tip moment încovoietor și forță tăietoare rezultate din cele două modele de calcul sunt similare pe acest element (situație ce caracterizează marea majoritate a elementelor).

#### Caracteristici de material

Clasa betonului	<b>C20/25</b>
$f_{ck}$ =	20 MPa
$E_c$ =	30 GPa
$\epsilon_{c2}$ =	0.20%
$\epsilon_{cu2}$ =	0.35%

tip oțel armatura longitudinală	<b>BSt500</b>
$f_{yk}$ =	500 MPa
$E_s$ =	210000 N/mm <sup>2</sup>
$\epsilon_s$ =	0.21%

#### tip oțel armatura transversală

	<b>BSt500</b>	
$f_{ywk}$ =	500 MPa	
$\gamma_c$ =	<b>1.5</b>	coeficienți parțiali de siguranță
$\gamma_s$ =	<b>1.15</b>	
$\alpha_{cc}$ =	<b>1</b>	
$\alpha_{ct}$ =	<b>1</b>	
$f_{ctm}$ =	2.21 N/mm <sup>2</sup>	rezistență medie la întindere axială
$f_{cd}$ =	13.33 N/mm <sup>2</sup>	rezistențe de calcul beton
$f_{ctd}$ =	1.00 N/mm <sup>2</sup>	
$f_{yd}$ =	434.78 N/mm <sup>2</sup>	
$f_{ywd}$ =	434.78 N/mm <sup>2</sup>	

#### Stare de eforturi

	$N_{ed}$ =	<b>0.00kN</b>	forța axială în grindă dacă există
(-) sus	$M_{ed}$ =	<b>55.70kNm</b>	momentul de calcul - partea superioară
(+) jos	$M_{ed}$ =	<b>40.80kNm</b>	momentul de calcul + partea inferioară
GF	$V_{0-}$ =	<b>66.01kN</b>	forța tăietoare - din programul de calcul
GF	$V_{0+}$ =	<b>65.58kN</b>	forța tăietoare + din programul de calcul
GS	$V_{GS}$ =	<b>41.90kN</b>	forța tăietoare din gruparea specială
	$L_0$ =	<b>5.30m</b>	lumina grinzii
	acțiune=	<b>seismică</b>	

#### Caracteristici geometrice placă/grindă

$h_w$ =	350.00mm	
$d$ =	296.04mm	înălțimea utilă a grinzii
$b_w$ =	300.00mm	lățimea grinzii
$h_s$ =	242.07mm	
$A_c$ =	105000.00mm <sup>2</sup>	aria secțiunii transversale

SUS	as2.1=	38.00mm	as2=	38mm			
	as2.2=	102.00mm	d2=	312mm			
	as2.3=	167.00mm					
	c2=	25.00mm	acoperirea cu beton				
	As2.1=	<b>3</b>	<b>Ø14</b>	+	<b>0</b>	<b>Ø8</b>	14.0
	As2.2=	<b>0</b>	<b>Ø14</b>	+	<b>0</b>	<b>Ø10</b>	
	As2.3=	<b>0</b>	<b>Ø16</b>	+	<b>0</b>	<b>Ø0</b>	
	As2=	461.81mm <sup>2</sup>					
JOS	as1.1=	53.00mm	as1=	70mm			
	as1.2=	116.00mm	d1=	280mm			
	as1.3=	172.00mm					
	c1=	40.00mm	acoperirea cu beton				
	As1.1=	<b>2</b>	<b>Ø14</b>	+	<b>0</b>	<b>Ø12</b>	14.0
	As1.2=	<b>1</b>	<b>Ø12</b>	+	<b>0</b>	<b>Ø0</b>	12.0
	As1.3=	<b>0</b>	<b>Ø0</b>	+	<b>0</b>	<b>Ø0</b>	
	As1=	420.97mm <sup>2</sup>					
	Es=	<b>210000 N/mm<sup>2</sup></b>					
	z=	266.43 mm					
	xmin=	93.03 mm					
	xb=	186.01 mm					
	λ=	0.80					
	x-=	59.24 mm					
	x+=	53.35 mm					
SUS	<b>Mrd=-</b>	<b>57.37kNm</b>	<b>momentul capabil sus</b>				
JOS	<b>Mrd+=</b>	<b>47.15kNm</b>	<b>momentul capabil jos</b>				
	Med-/Mrd=-	0.97					
	Med+/Mrd+=	0.87					
	As=-	418.37mm <sup>2</sup>	aria necesara de armatura longitudinala				
	As+=	386.08mm <sup>2</sup>	aria necesara de armatura longitudinala				

**Calcul la forta taietoare**

	<b>Ved=</b>	<b>65.57kN</b>	
	ρ1=	0.005	coeficient de armare longitudinala
	k1=	<b>0.15</b>	
	η1=	1	pentru beton greu
	k=	1.82	
	σcp=	0.00	
	cRd,c=	0.12	pentru beton greu
	<b>VRd,c=</b>	<b>41.10kN</b>	capacitatea portanta a sectiunii de beton
	Ved/VRd,c=	1.60	
<b>DACA</b>	<b>VEd &lt; VRd,c</b>	<b>calculeaza etrieri</b>	

Aria de armatura transversala uniform distribuita si necesare

566 mm<sup>2</sup>/m

Distanța rezulta s= 100 mm

etrieri smax= 444 mm

s din procent minim= 263 mm

Aleg etrieri **Ø6**ne= **2** nr de brateAsw= 57mm<sup>2</sup>

δ= 1mm

s1max= 92mm

Vedmax= 66 kN

ξ= -0.28

(2+ξ)\*bw\*d\*fctd= 153 kN verificare necesitatii armaturilor inclinate

**nu sunt necesare armaturi inclinate**

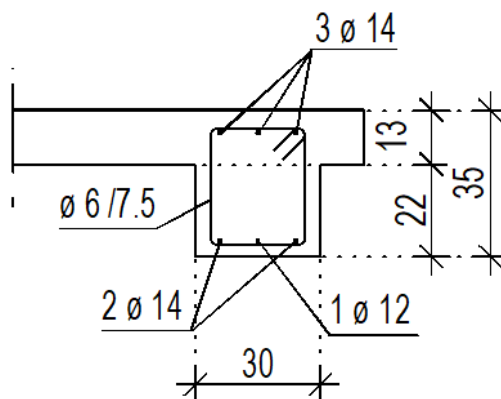
Aleg	<b>s=</b>	<b>75mm</b>	distanța între etrieri
	<b>ctgθ=</b>	<b>1</b>	pentru θ=45 grade rez cantitatea maxima de arm.transv
	θ=	45 °	pentru alte valori ale lui θ se reface calculul ctgθ
	VRd,s=	87 kN	forța tăietoare capabilă
	Ved/VRd,s=	<b>0.75</b>	
	αcp=	0.00	efortul unitar mediu sub efectul forței axiale Ned
	αcw=	1.00	coeficient care ține seama de starea de efort în fibra comprim
	ν1=	0.552	coef de reducere pentru betoane de clasa până la C60/75
	Vrdmax=	<b>294.14kN</b>	capacitatea portantă a diagonalelor comprimate de beton
	pmin=	0.07%	
	<b>p=</b>	<b>0.25%</b>	procentul de armare transversal
	Ved,tot=	87 kN	

**Verificare condiție de non-fragilitate (longitudinal)**

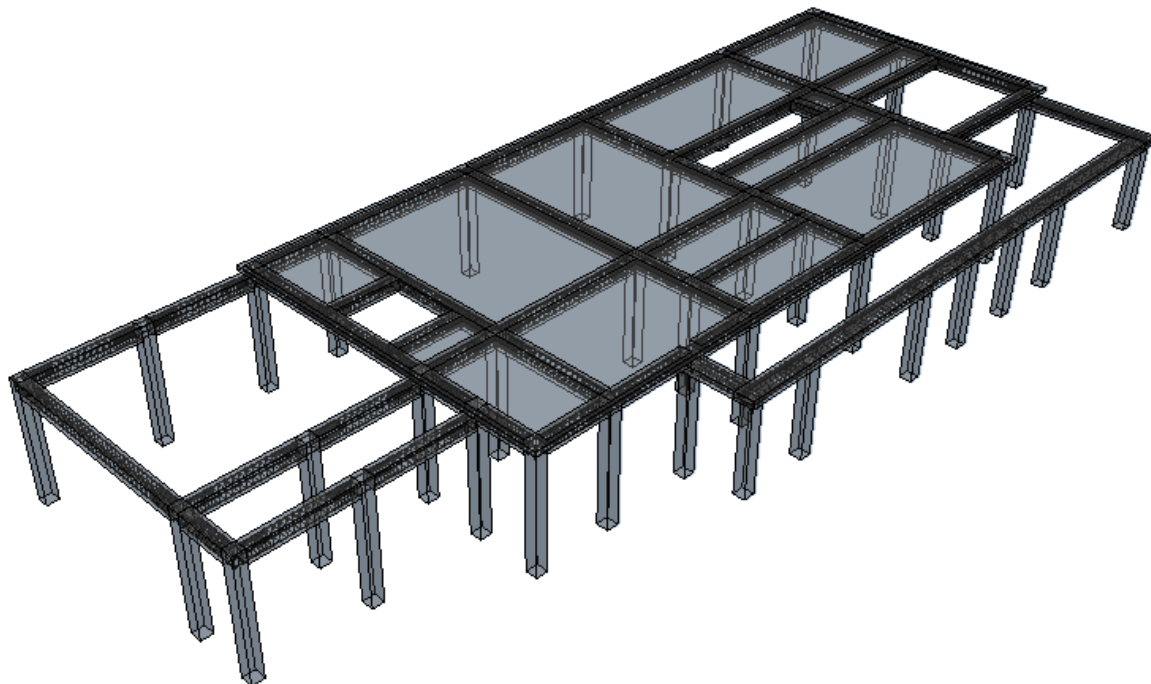
pmin= 0.22% pmin sus= 0.52%

p tot= 0.99% pmin jos= 0.47%

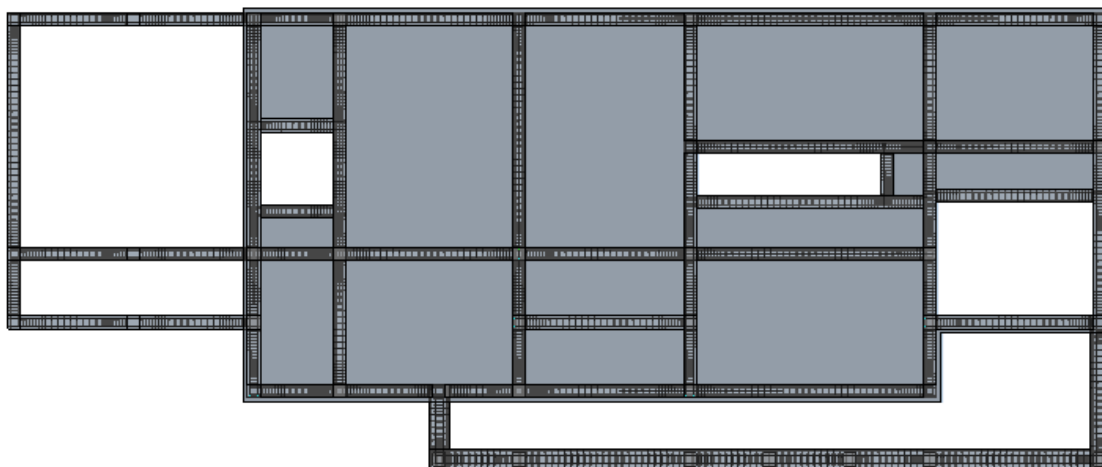
Rezultă pentru grinda prezentată o armare longitudinală la partea de jos de 2Φ14+1Φ12, iar la partea superioară de 3Φ14. Armarea transversală rezultă în zonele critice Φ6/75 mm și Φ6/150 mm în zonele curente.



Vedere 3D armare grinzi peste parter

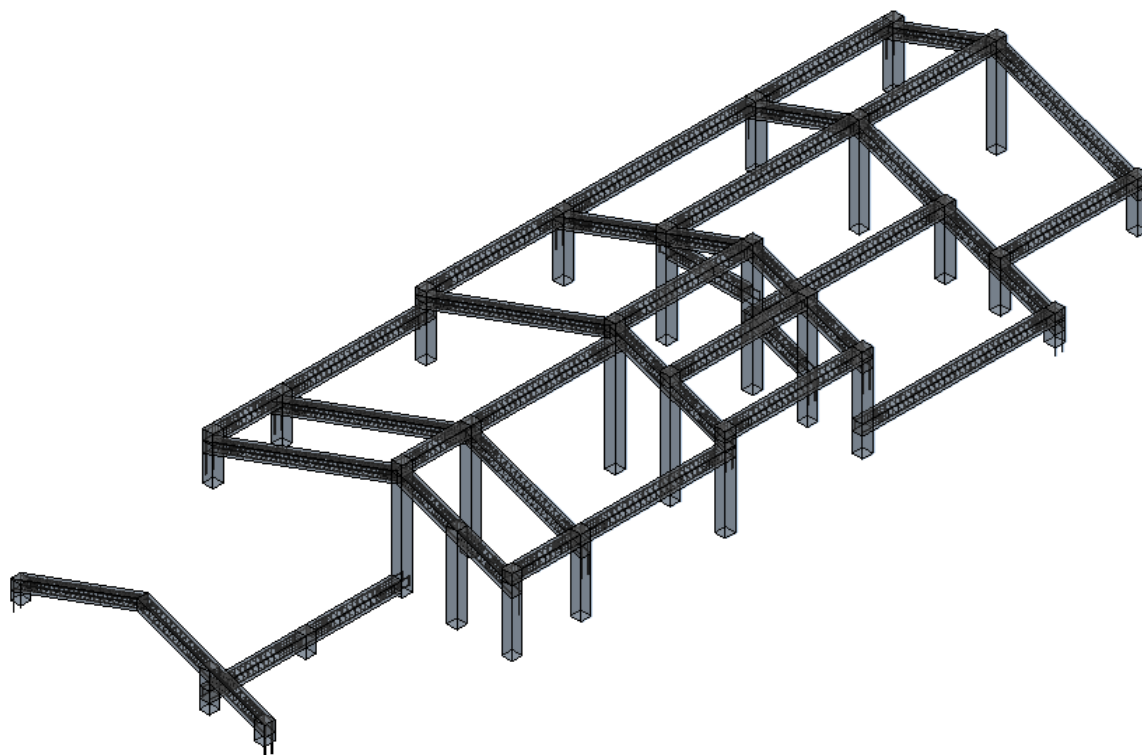


Vedere plan armare grinzi peste parter

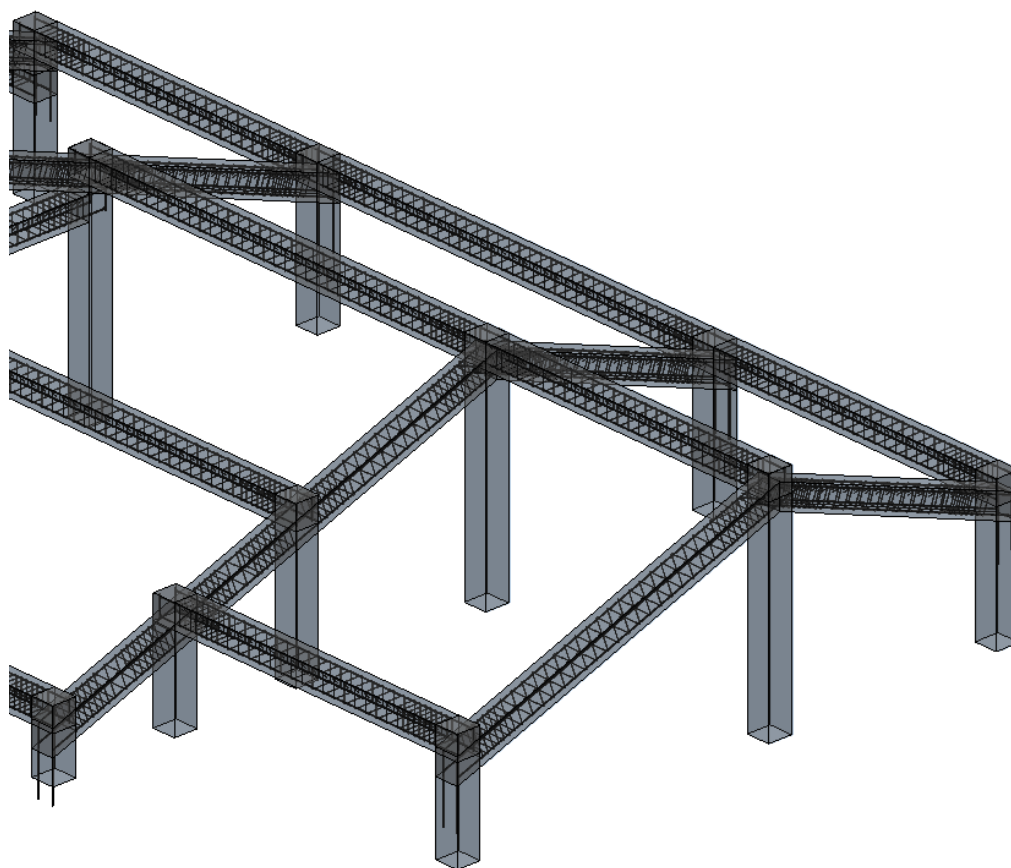




Vedere 3D armare grinzi mansardă



Vedere 3D armare grinzi mansardă



**3.2.5.2. CALCUL ȘI DIMENSIONARE STĂLPI**

Pentru exemplificarea dimensionării, s-a calculat stâlpul de la nivelul parterului din axul 1\*/E.

Eforturile de tip moment încovoietor și forță tăietoare rezultate din cele două modele de calcul prezintă diferențe ne semnificative (vezi tabel eforturi), iar pentru dimensionare s-a ales limita superioară care acoperă ambele modele. În orice situație, diferențele de eforturi nu modifică armarea în cele două cazuri (model 1 – „țiglă romană”  $M_{ed}^x = 27.6$  kNm,  $M_{ed}^y = 25.10$  kNm; model 2 – „țiglă metalică”  $M_{ed}^x = 26.4$  kNm,  $M_{ed}^y = 23.8$  kNm).

**Sectiuni stalp**

b1,x=	300 mm
b2,y=	300 mm
fyk=	500 N/mm <sup>2</sup>
γs=	1.15
fyd=	434.78 N/mm <sup>2</sup>
fck=	20 N/mm <sup>2</sup>
γc=	1.5
fcd=	13.33 N/mm <sup>2</sup>

	<b>Seism X</b>		<b>Seism Y</b>		
Ned=	71 KN	Mrc,Rc=	53.6 KNm	Mrc,Rc=	54 KNm
Ned=	210 KN	Mrc,Rc=	66 KNm	Mrc,Rc=	65.6 KNm
Ned,max=	214 KN	.....Mrc,Rc=	66.2 KNm	Mrc,Rc=	66.2 KNm

Coeficientul de armare longitudinală minim este 0.01. Se propune astfel o armare longitudinală de 8Φ12, câte 3 bare/latură. Armarea longitudinală s-a verificat cu ajutorul programului de calcul.

**GRINZI PESTE PARTER****Grinzi adiacente nodului directia X**

Armare grinda stanga	30x35	Armare grinda dreapta	30x35
sus	3fi14+2fi12	sus	3fi14+2fi12
As,sus=	688 mm <sup>2</sup>	As,sus=	688 mm <sup>2</sup>
Mrd,sus=	71.7 KNm	Mrd,sus=	71.7 KNm
jos	2fi14+1fi12	jos	2fi14+1fi12
As,jos=	421 mm <sup>2</sup>	As,jos=	421 mm <sup>2</sup>
Mrd,jos=	51 KNm	Mrd,jos=	51 KNm

**Grinzi adiacente nodului directia Y**

Armare grinda dedesubt	30x35	Armare grinda deasupra	30x35
sus	2fi14	sus	2fi14
As,sus=	308 mm <sup>2</sup>	As,sus=	308 mm <sup>2</sup>
Mrd,sus=	40.06 KNm	Mrd,sus=	40.06 KNm
jos	2fi14	jos	2fi14
As,jos=	308 mm <sup>2</sup>	As,jos=	308 mm <sup>2</sup>
Mrd,jos=	37.5 KNm	Mrd,jos=	37.5 KNm

Calcul la forță tăietoare:

Momentele de la capetele stâlpilor asociate mobilizării mecanismul de plastificare  $M_{db}$ :

$$M_{db,i} = \gamma_{Rd} M_{Rc,i} \min \left( 1, \frac{\sum M_{Rb}}{\sum M_{Rc}} \right)$$

Cu limitarea minimă:

$$M_{db,i} \geq \gamma_{Rd} M'_{Ed,i}$$

Valorile de proiectare ale forțelor tăietoare se determină prin scrierea ecuației de echilibru al stâlpului încărcat la capete cu momentele  $M_{db}$  și forțele tăietoare corespunzătoare.

$$V_{Ed} = \frac{M_{db,jos} + M_{db,sus}}{L_{cl}}$$

	X		Y
Mdc,jos=	86.06 KNm	Mdc,jos=	86.06 KNm
Med'=	26.4 KNm	Med'=	23.8 KNm
Med* $\gamma_{Rd}$ =	34.32 KNm	Med* $\gamma_{Rd}$ =	30.94 KNm
Mdc,sus=	79.44 KNm	Mdc,sus=	51.5 KNm
Med'=	22.7 KNm	Med'=	17.14 KNm
Med* $\gamma_{Rd}$ =	27.24 KNm	Med* $\gamma_{Rd}$ =	20.568 KNm
L0=	2.53 m	L0=	2.53 m
Ved,X=	65.415 KN	Ved,Y=	54.38 KN
Ved'=	20 KN	Ved'=	16 KN
1.5Ved'=	30 KN	1.5Ved'=	24 KN
qVed'=	138 KN	qVed'=	110.4 KN
Ved,X fin=	65.415 KN	Ved,Y fin=	54.38 KN
As, nec,X =	50.152 mm <sup>2</sup>	As, nec,Y =	41.69 mm <sup>2</sup>

**ZONA CRITICA BAZA**

	X		Y
Procent minim		Procent minim	
$\rho$	0.005	$\rho$	0.005
s =	75 mm	s =	75 mm
b1,x=	300 mm	b2,y=	300 mm
Asw,min=	112.5 mm <sup>2</sup>	Asw,min=	112.5 mm <sup>2</sup>

**Propun**

etr perimetral	$\Phi$	8 mm	A,1fi8=	50.27 mm <sup>2</sup>
etr int	$\Phi$	6 mm	A,1fi6=	28.27 mm <sup>2</sup>

**GADO CONS CONSTRUCT S.R.L.**

STUDIU TEHNIC PRIVIND EFICIENȚA ECONOMICĂ A UTILIZĂRII ÎNVELITORILOR DE TIP BRAMAC PRIN ANALIZA INFLUENȚELOR STRUCTURALE GENERATE DE TIPUL DE ÎNVELITOARE ASUPRA SISTEMULUI STRUCTURAL AL UNEI CLĂDIRI CU REGIM DE ÎNĂLȚIME P+M

**STUDIU  
TEHNIC**

L1,x,fi ext=	250 mm	L1,Y,fi12=	250 mm
Nr. Buc. L1=	2 buc	Nr. Buc. L1=	2 buc
L2,x,fi int=	150 mm	L2,Y,fi10=	150 mm
nr. Buc L2=	1.41 buc	nr. Buc L2=	1.41 buc

Vol etr de confinare= 62225.526 mm<sup>3</sup>

Vol miezului de bet conf= 4687500 mm<sup>3</sup>

wd= 0.43 >= 0.12

	X		Y
etr perimetr $\Phi$ =	8 mm	etr perimetr $\Phi$ =	8 mm
nr brate	2 brate	nr brate	2 brate
etr int $\Phi$ =	6 mm	etr int $\Phi$ =	6 mm
nr brate	1.41 brate	nr brate	1.41 brate

As,eff,X= 140.40 mm<sup>2</sup>

As,eff,Y= 140.4 mm<sup>2</sup>

Vrd,s= 183.13 mm<sup>2</sup>

Vrd,s= 183.13 mm<sup>2</sup>

$\eta$ = 0.552

Vrd,max,X= 298.08 KN

Vrd,max,X= 298.08 KN

**ZONA CRITICA REST**

Procent minim		Procent minim	
$\rho$	0.0035	$\rho$	0.0035
s =	75 mm	s =	75 mm
b1,x=	300 mm	b2,y=	300 mm
Asw,min=	78.75 mm <sup>2</sup>	Asw,min=	78.75 mm <sup>2</sup>

**Propun**

etr perimetral $\Phi$ =	8 mm	A,1fi8=	50.27 mm <sup>2</sup>
etr int $\Phi$ =	6 mm	A,1fi6=	28.27 mm <sup>2</sup>

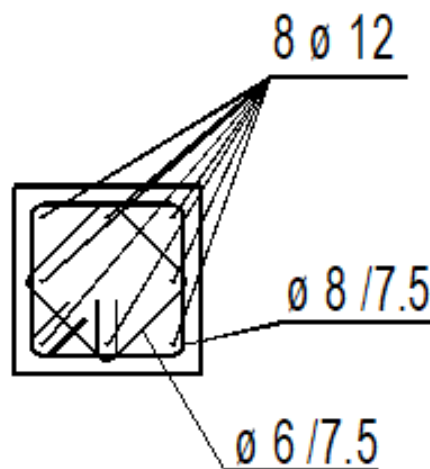
L1,x,fi ext	250 mm	L1,Y,fi ext	250 mm
Nr. Buc. L1	2 buc	Nr. Buc. L1	2 buc
L2,x,fi int	150 mm	L2,Y,fi int	150 mm
nr. Buc L2	1.41 buc	nr. Buc L2	1.41 buc

	X		Y
etr perimetr $\Phi$ =	8 mm	etr perimetr $\Phi$ =	8 mm
nr brate	2 brate	nr brate	2 brate
etr int $\Phi$ =	6 mm	etr int $\Phi$ =	6 mm
nr brate	1.41 brate	nr brate	1.41 brate

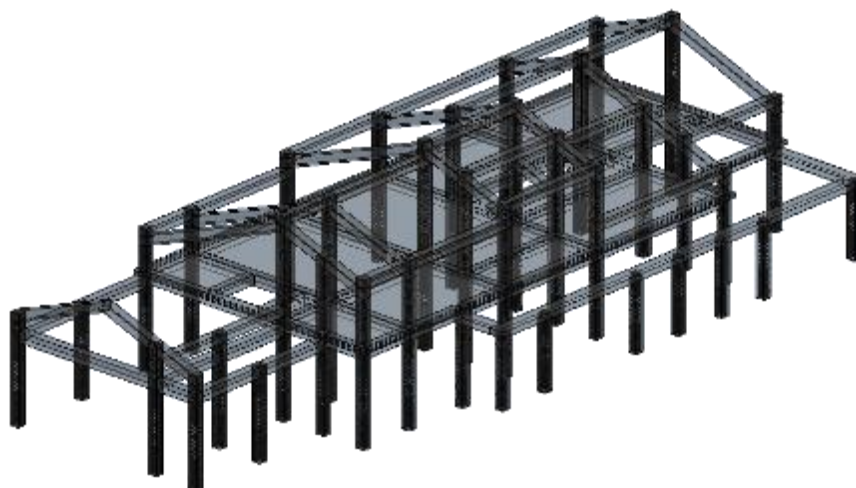
As,eff,X= 140.40 mm<sup>2</sup>

As,eff,Y= 140.398 mm<sup>2</sup>

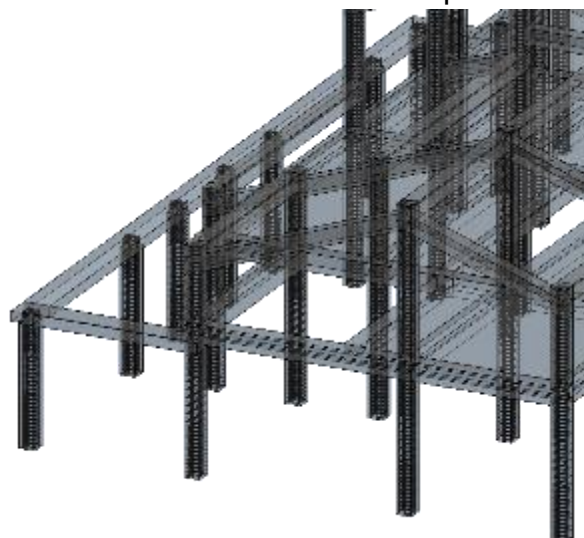
Rezultă pentru stâlpi o armare longitudinală de  $8\Phi 12$ . Armarea transversală rezultă în zonele critice etr.  $\Phi 8/75$  mm perimetral și etr.  $\Phi 6/75$  mm interior de tip romb, iar în zonele curente similar dispuși la pas de 150mm.



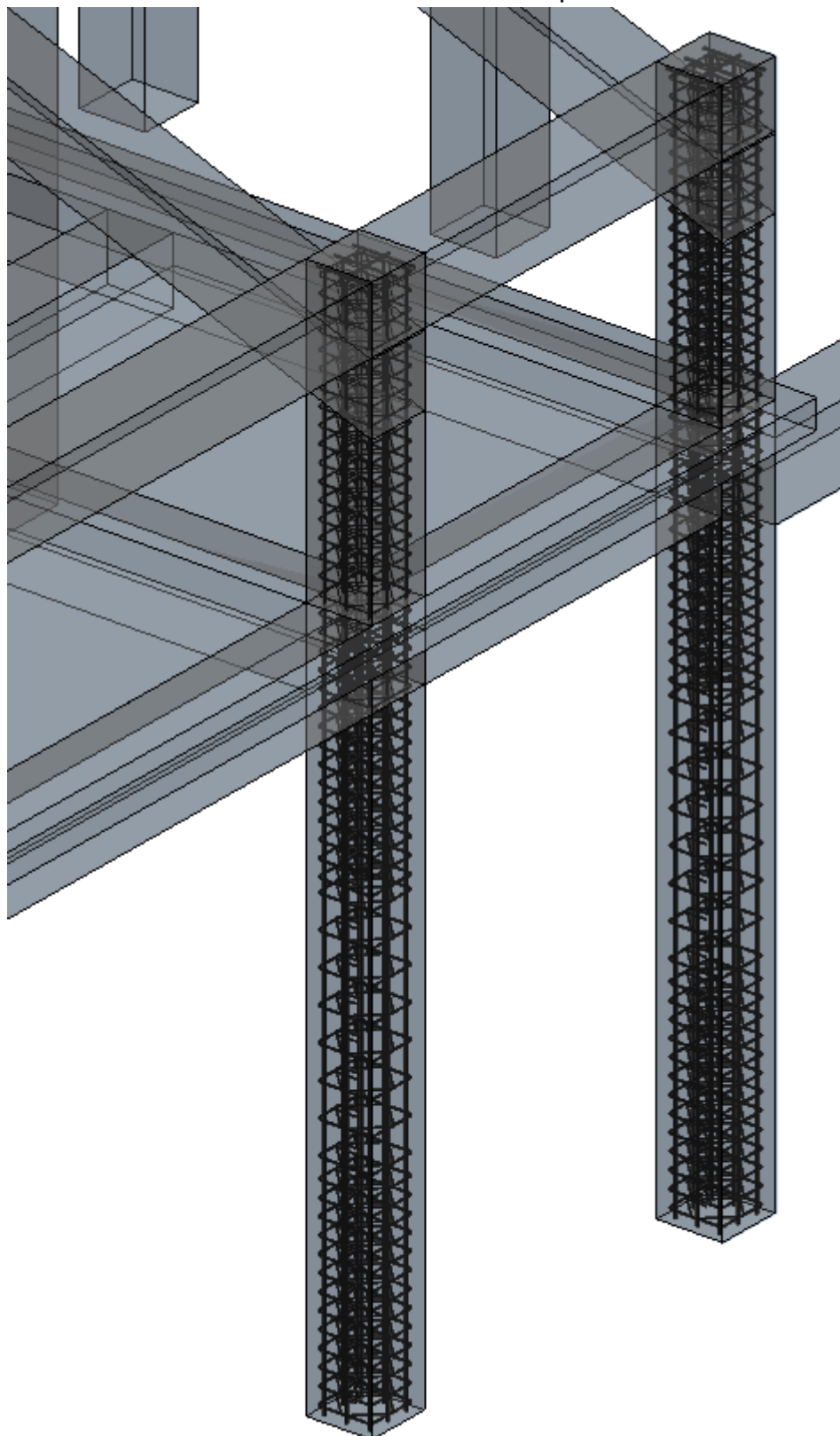
Vedere 3D armare stâlpi



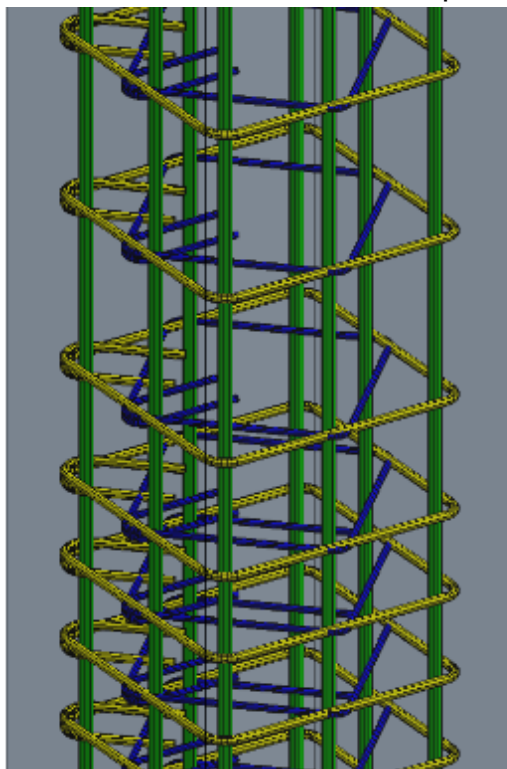
Vedere 3D armare stâlpi



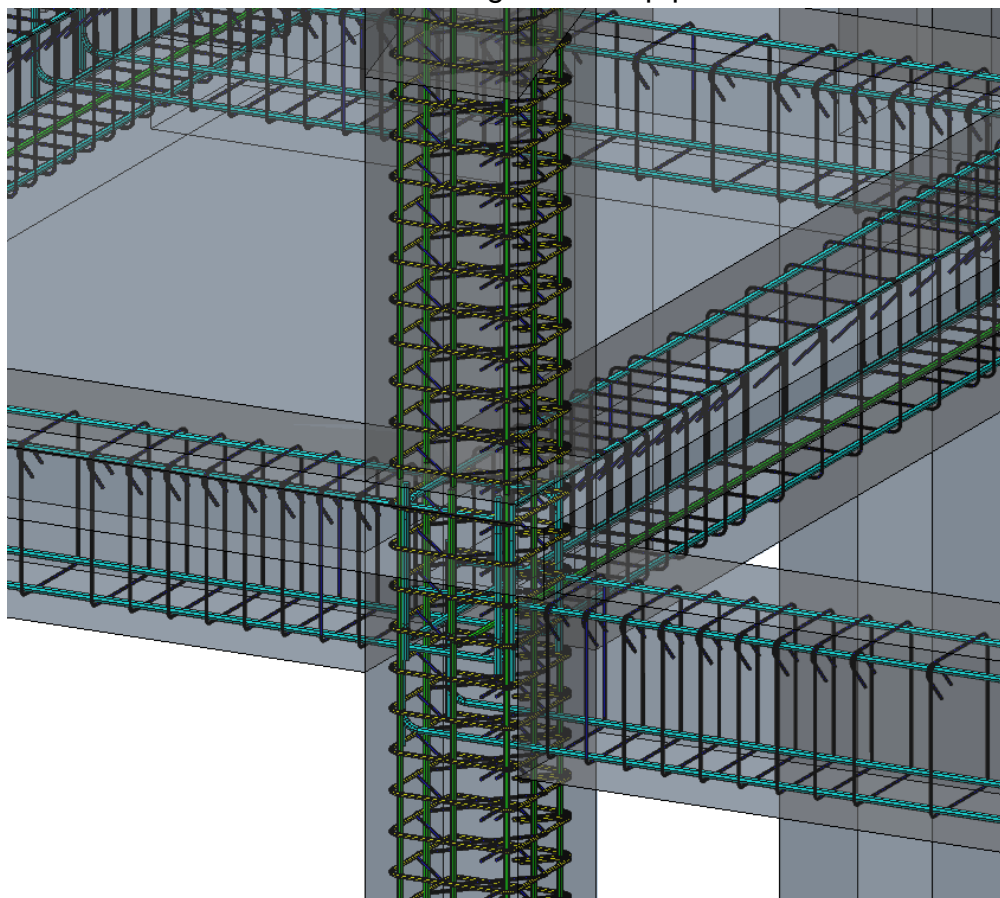
Vedere 3D armare stâlpi



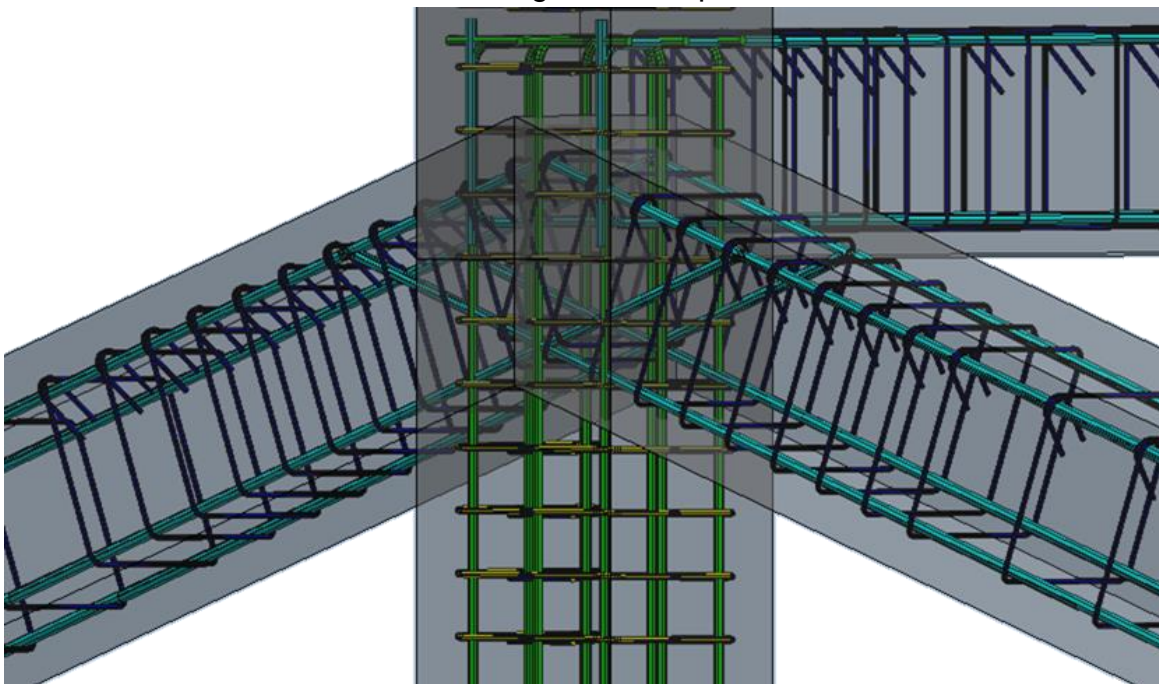
Vedere 3D armături stâlp



Vedere 3D nod grindă- stâlp parter



## Vedere 3D nod grindă - stâlp mansardă

**3.2.5.3. CALCUL ȘI DIMENSIONARE PLACĂ**

Pentru exemplificarea calcului, se va determina armarea curentă din placa de la nivelul parterului.

Eforturile de tip moment încovoietor pe cele două direcții sunt similare între cele două modele de calcul.

**Caracteristici de material**

Clasa betonului	<b>C20/25</b>
$f_{ck}$ =	20 MPa
$E_c$ =	30 GPa
$\epsilon_{c2}$ =	0.20%
$\epsilon_{cu2}$ =	0.35%

tip oțel armatura lon	<b>BSt500</b>
$f_{yk}$ =	500 MPa
$E_s$ =	210000 N/mm <sup>2</sup>
$\epsilon_s$ =	0.21%

**Caracteristici geometrice placa**

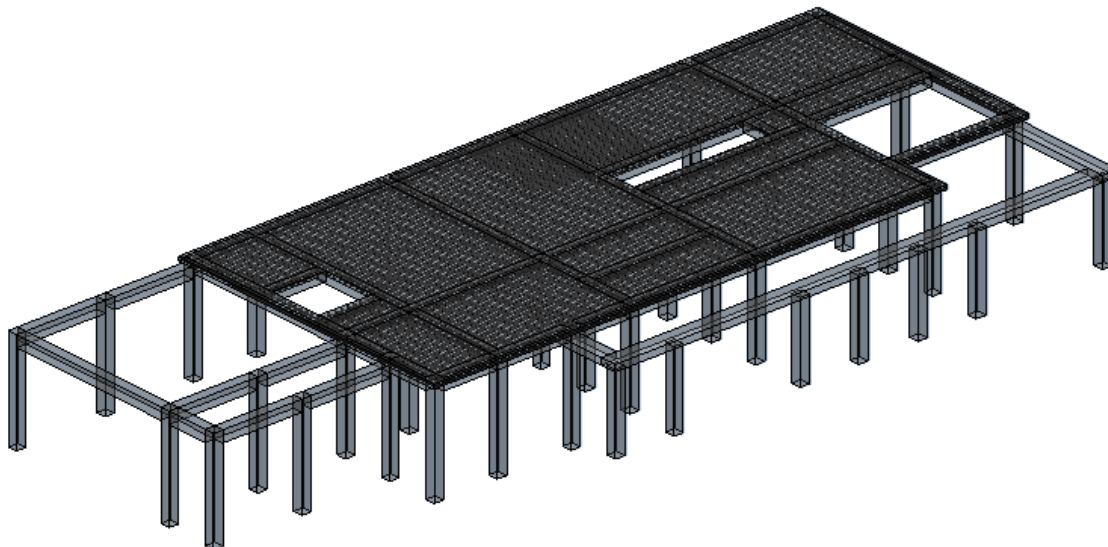
$h_w$ =	130.00mm	
$d$ =	105.00mm	înălțimea utilă a grinzii
$b_w$ =	1000.00mm	lățimea grinzii
$h_s$ =	80.00mm	
$A_c$ =	130000.00mm <sup>2</sup>	aria secțiunii transversale



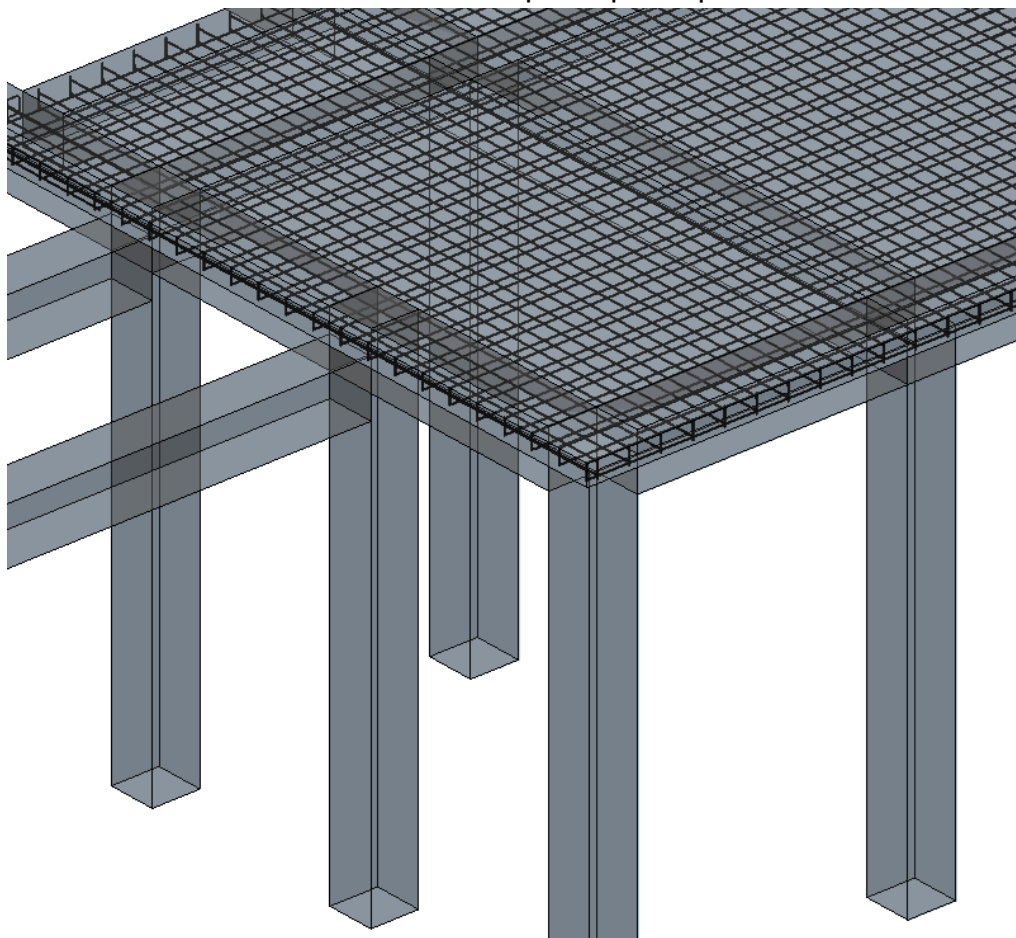
SUS	as2.1=	25.00mm	as2=	25mm				
	as2.2=	85.00mm	d2=	105mm				
	as2.3=	149.00mm						
	c2=	15.00mm	acoperirea cu beton					
	As2.1=	5	Ø8	+	0	Ø8	8.0	
	As2.2=	0	Ø12	+	0	Ø10		
	As2.3=	0	Ø16	+	0	Ø0		
	As2=	251.33mm <sup>2</sup>						
JOS	as1.1=	25.00mm	as1=	25mm				
	as1.2=	85.00mm	d1=	105mm				
	as1.3=	141.00mm						
	c1=	15.00mm	acoperirea cu beton					
	As1.1=	5	Ø8	+	0	Ø12	8.0	
	As1.2=	0	Ø12	+	0	Ø0		
	As1.3=	0	Ø0	+	0	Ø0		
		As1=	251.33mm <sup>2</sup>					
		Es=	210000 N/mm <sup>2</sup>					
		z=	94.50 mm					
		xmin=	61.21 mm					
	xb=	65.97 mm						
	λ=	0.80						
	x-=	10.24 mm						
	x+=	10.24 mm						
SUS	<b>Mrd=-</b>	<b>11.03kNm</b>	<b>momentul capabil sus</b>					
JOS	<b>Mrd+=</b>	<b>11.03kNm</b>	<b>momentul capabil jos</b>					

Rezultă pentru placa studiată o armare curentă la partea de jos și la partea de sus de Ø8/20cm, excepție făcând zona de reazem din axul D acolo unde se evidențiază o supraarmare.

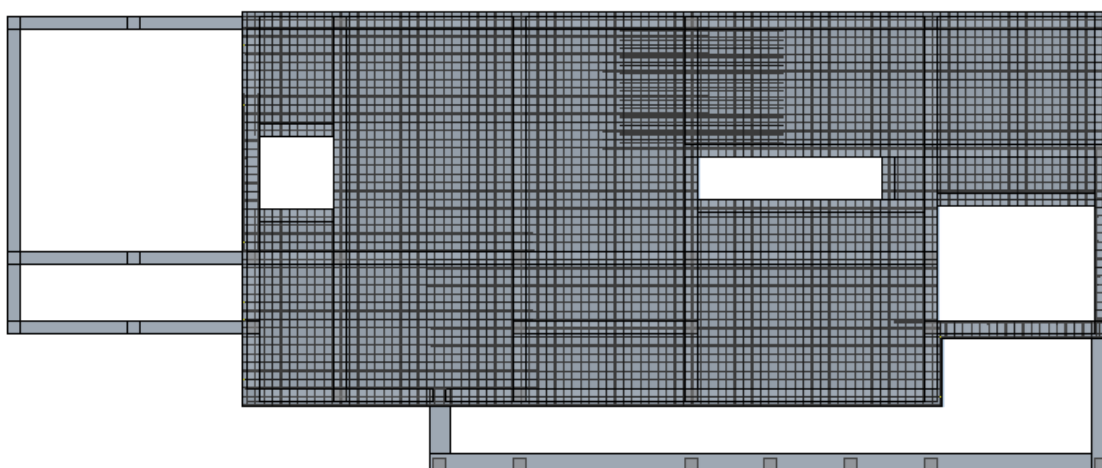
Vedere 3D armare placă peste parter



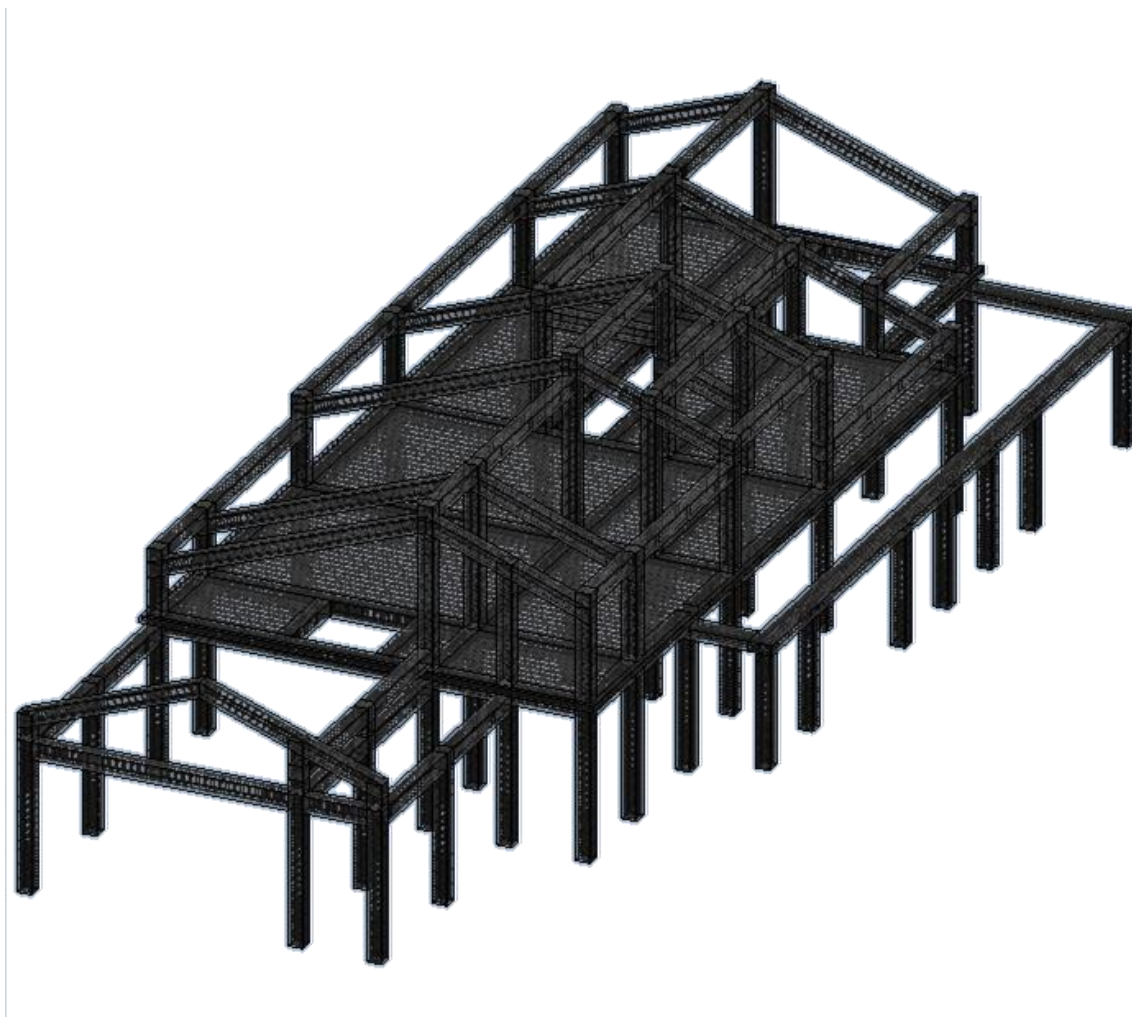
Vedere 3D armare placă peste parter



Vedere plană armare placă peste parter



Vedere 3D armaturi clădire



#### **3.2.5.4. CALCUL ȘI DIMENSIONARE ELEMENTE ȘARPANTĂ**

La dimensionarea elementelor de șarpantă s-a avut în vedere utilizarea unui material lemnos de clasă de rezistență minimă în conformitate cu prevederile normativelor actuale, respectiv lemn de rășinoase clasa de rezistență C14 și clasa de umiditate II (umiditate  $\leq 20\%$ ). Alegerea materialului lemnos de calitate inferioară corespunde situațiilor curente de execuție pe plan național, în mare măsură în România utilizându-se în cazul șarpantelor material lemnos achiziționat din diverse surse fără documente de certificare a calității.

În ceea ce privește alegerea secțiunilor de lemn s-a avut în vedere utilizarea unor elemente uzuale care se regăsesc pe piața autohtonă și se folosesc în mod curent în șantiere. Totodată, la dimensionarea și alegerea secțiunilor s-a luat în considerare utilizarea unor elemente care să satisfacă în mod optim raportul de rezistență/consum material lemnos. Astfel, în cazul elementelor de tip pană și căprior solicitarea predominantă este de încovoiere, iar din acest punct de vedere înălțimea secțiunii are aportul cel mai însemnat în momentul de inerție al secțiunii ( $I = bh^3/12$ ). În consecință, utilizarea elementelor pătrate este ineficientă din punct de vedere al consumului de material lemnos, iar alegerea secțiunilor rectangulare conduce la optimizări importante.

Un alt aspect important care este definitoriu în dimensionarea secțiunilor de lemn este atât conceptul arhitectural – structural pentru limitarea deschiderilor cât și alcătuirea spațială a acoperișului (volumetria acestuia).

În mod concret, în cadrul prezentului studiu s-au dimensionat elemente de lemn modulate la 50 mm care s-au utilizat în ambele modele analizate, diferențele rezumându-se la modul de dispunere al căpriorilor, respectiv la distanța dintre aceștia. Iterațiile de dimensionare au demonstrat că utilizarea unor secțiuni mai reduse pentru tipul de învelitoare ușoară („țiglă metalică”) conduce la îndeșirea căpriorilor, iar consumul de material lemnos total este mai mare. Micșorarea secțiunilor asigură în general capacitatea de rezistență necesară, însă de cele mai multe ori nu este satisfăcută verificarea deformațiilor (ale săgeții).

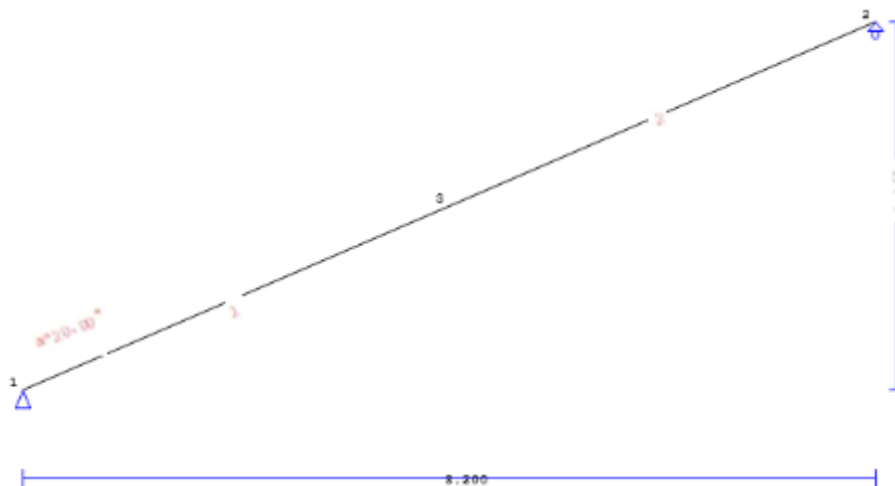
#### **Căpriori:**

În urma calculelor efectuate rezultă secțiunea căpriorilor de 5x20 cm dispuși la o distanță de 60 cm interax în cazul modelului 1 cu învelitoare Țiglă romană, respectiv aceeași secțiune la o distanță de 70 cm interax în cazul celui de al doilea model cu învelitoare din țiglă metalică. S-a avut în vedere utilizarea unui pas de căprior  $\geq 60$  cm din condiții constructive (sistem de izolații) și pentru optimizare consum material lemnos.

- i. Căprior 5x20 cm – **Model 1 – Învelitoare Țiglă romană – distanță 60cm interax**

1. ROOF -001

Monopitch roof



2. General description, assumptions, materials, loads

2.1. Construction type

Timber roof, from beams with timber C14. The roof type as sketch above.  
Span 3.200 m, height 1.165 m, roof pitch 20.00°, beam spacing 0.600m  
Finishing (rafter) from timber C14, of thickness 25 mm  
Elements , Cross section 50x200 [mm]  
Beam volume =0.034 m<sup>3</sup>, beam weight =0.097 kN

2.2. Design codes

EN1990:2002, Eurocode 0 Part 1-1, Basis of structural design  
EN1991-1-1:2002, Eurocode 1 Part 1-1, Actions on structures  
EN1991-1-3:2003, Eurocode 1 Part 1-3, Snow loads  
EN1991-1-4:2005, Eurocode 1 Part 1-4, Wind actions  
EN1995-1-1:2009, Eurocode 5 Part 1-1, Design of timber structures

2.3. Design methodology

All the load combinations according to Eurocode 1 and Eurocode 5 are taken into account, and the checks are performed in the most unfavourable loading conditions, for combined action, in ultimate limit state, according to EC5 EN1995-1-1:2009, §6. The connections are designed as bolted connections with metal plates according to EC5 EN1995-1-1:2009, §8. The deflections are checked in serviceability limit condition, according to EC5 EN1995-1-1:2009, §7.

2.4. Material properties (beam) (EC5 EN1995-1-1:2009, §3)

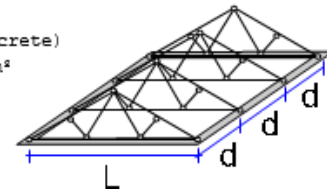
Timber class : C14  
Service classes : Class 2, moisture content ≤ 20% (EC5 §2.3.1.3)  
Material factor  $\gamma_M = 1.30$  (EC5 Tab. 2.3)  
Characteristic material properties for timber  
f<sub>m</sub>k = 14.0 MPa, f<sub>t0</sub>k = 7.2 MPa, f<sub>t90</sub>k = 0.4 MPa  
f<sub>c0</sub>k = 16.0 MPa, f<sub>c90</sub>k = 2.0 MPa, f<sub>v</sub>k = 3.0 MPa  
E<sub>0m</sub> = 7000 MPa, E<sub>005</sub> = 4700 MPa, E<sub>90m</sub> = 230 MPa  
G<sub>m</sub> = 440 MPa, ρ<sub>k</sub> = 290 Kg/m<sup>3</sup>, ρ<sub>m</sub> = 350 Kg/m<sup>3</sup>

**2.5. Material properties (timber, finishing) (EC5 EN1995-1-1:2009, §3)**

Timber class : C14  
 Service classes : Class 2, moisture content $\leq$ 20% (EC5 §2.3.1.3)  
 Material factor  $\gamma_M=1.30$  (EC5 Tab. 2.3)  
**Characteristic material properties for timber**  
 $f_{mk} = 14.0$  MPa,  $f_{t0k} = 7.2$  MPa,  $f_{t90k} = 0.4$  MPa  
 $f_{c0k} = 16.0$  MPa,  $f_{c90k} = 2.0$  MPa,  $f_{vk} = 3.0$  MPa  
 $E_{0m} = 7000$  MPa,  $E_{005} = 4700$  MPa,  $E_{90m} = 230$  MPa  
 $G_m = 440$  MPa,  $\rho_k = 290$  Kg/m<sup>3</sup>,  $\rho_m = 350$  Kg/m<sup>3</sup>

**2.6. Distributed roof loads**

Permanent load of roof covering  $G_e = 0.500$  kN/m<sup>2</sup> (Tiles from concrete)  
 Purlins, finishing, insulation  $G_t = 0.100$  kN/m<sup>2</sup>  $G_e+G_t = 0.600$  kN/m<sup>2</sup>  
 Load of ceiling under the roof  $G_c = 0.100$  kN/m<sup>2</sup>  
 Snow load on the ground  $S_k = 2.000$  kN/m<sup>2</sup>  
 Wind pressure on vertical surface  $Q_w = 0.765$  kN/m<sup>2</sup>  
 Imposed load (category H)  $Q_i = 0.400$  kN/m<sup>2</sup>

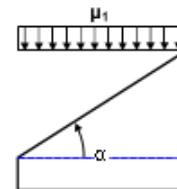


**3. Snow load (EC1 EN1991-1-3:2003 §5)**

Snow load on the ground  $S_k$  (EC1 EN1991-1-3:2003 §4, Annex C)  
 Climatic Region :Alpine Region, snow zone :2, altitude above sea level=500 m  
 $S_k = (0.642 \times 2 + 0.009) \times [1 + (500/728)^2] = 1.903$  kN/m<sup>2</sup>  
 Characteristic value of snow load on the ground:  $s_k = 2.000$  kN/m<sup>2</sup>

Snow load on the roof (EC1 EN1991-1-3:2003 §5)  
 Angle of pitch of roof :  $\alpha = 20.005^\circ$

Exposure coefficient :  $C_e = 1.000$  (EC1-1-3 §5.2(7))  
 Thermal coefficient :  $C_t = 1.000$  (EC1-1-3 §5.2(8))  
 Shape coefficients,  $\alpha = 20.00^\circ$ ,  $\mu_1 = 0.800$  (Table 5.2)



Snow load (EC1 EN1991-1-3:2003 §5.3.2)  
 $S_1 = \mu_1 \cdot C_e \cdot C_t \cdot S_k = 0.800 \times 1.000 \times 1.000 \times 2.000 = 1.600$  kN/m<sup>2</sup>

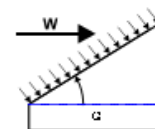
**4. Wind loading (EC1 EN1991-1-4:2005 §5)**

$v_{bo} = 31.00$  m/s, Romania SR, Zone: 3 ,  $v_b = C_{dir} \cdot C_{season} \cdot v_{bo} = 31.00$  m/s  
 Terrain category: IV,  $z = 10.000$ m,  $z_o = 1.000$ m,  $z_{min} = 10$ m,  $z_{max} = 200$ m,  $z_{oII} = 0.050$ m  
 $kr = 0.19 \cdot (1.000/0.05)^{0.07} = 0.234$   
 Roughness factor  $C_r(z) = kr \cdot \ln(z/z_o) = 0.234 \times \ln(10.000/1.000) = 0.540$   
 $H/Lu = 50/600 = 0.08$ ,  $0.05 < H/Lu = 0.08 \leq 0.30$ ,  $Le = 600.00$  m  
 $z = 10.00$  m,  $X/Le = 500/600 = 0.83$ ,  $z/Le = 10/600 = 0.10$ ,  $s = 0.396$   
 Orography factor  $C_o(z) = 1 + 2 \times 0.396 \times 0.083 = 1.066$   
 Turbulence factor  $K_t = 1.000$   
 Exposure factor  $C_e(z) = 1.274$   
 $q(z) = C_e(z) \cdot (\gamma_p) \cdot v_b^2 = [0.001] \times 1.274 \times 0.625 \times 31.00^2 = 0.765$  kN/m<sup>2</sup>

(EN1991-1-4, Tab.A.2)  
 (eq.A.7, ...A.10)  
 (eq.A.2)

(EN1991-1-4, §4.5)

Wind pressure on roof  $w_e = Q_{ref} \cdot C_e(z) \cdot C_{pe}$  (EC1 EN1991-1-4:2005, §5.2)  
External pressure coefficients (EC1 EN1991-1-4:2005 Tab. 7.3)  
 For pitch angle  $\alpha = 20.00^\circ$ ,  $C_{pe} = 0.27$   
 Wind pressure  $w_e = 0.204$  kN/m<sup>2</sup>



**5. Roof timber finishing (rafter)**

**Timber finishing (rafter) structural system**

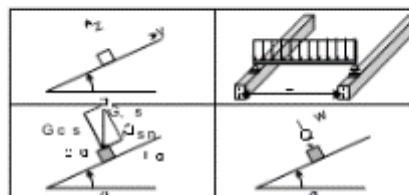
The timber finishing (rafter) is designed as simply supported beam with span  
 Spacing of trusses  $L = 0.600$ m, and width  $1.00$ m

**Dimensions of timber finishing (rafter)**

Timber of finishing (rafter): C14, service class: Class 2, moisture content  $\leq 20\%$   
 Spacing of beams  $L = 0.600\text{m}$ , roof pitch  $\alpha = 20.00^\circ$ , thickness of finishing  $25\text{mm}$

**Loading on timber finishing (rafter)**

Roof covering  $G_e = 0.500 \text{ kN/m}^2$   
 Self weight  $G_1 = 0.071 \text{ kN/m}^2$   
 Snow load  $Q_s = 1.600 \text{ kN/m}^2$   
 Wind load  $Q_w = 0.204 \text{ kN/m}^2$   
 Concentrated  $Q_p = 1.000 \text{ kN}$



**Internal forces of timber finishing (span  $L=0.600 \text{ m}$ , width  $=1.00 \text{ m}$ )**

Loading	Action	$\gamma_G$	$\gamma_Q$	$\psi_0$	$\max N [\text{kN}]$	$\max Q [\text{kN}]$	$\max M [\text{kNm}]$
(Gk) Permanent	$G_k = 0.571 [\text{kN/m}]$ Permanent	1.35	0.00	1.00	0.000	0.161	0.024
(Qk1) Snow	$Q_{ks} = 1.600 [\text{kN/m}]$ Short-term	0.00	1.50	0.50	0.000	0.424	0.064
(Qk2) Wind	$Q_{kw} = 0.204 [\text{kN/m}]$ Short-term	0.00	1.50	0.60	0.000	0.061	0.009
(Qk3) Concentrated	$Q_{kp} = 1.000 [\text{kN}]$ Instantaneous	0.00	1.00	0.00	0.000	0.470	0.321

**5.1. Serviceability limit state (EC5 EN1995-1-1:2009, §2.2.3, §7)**

Control of deflection (EC5 §7.2)

Loading	[kN/m]	$u [\text{mm}]$	Action	$\psi_0$	$\psi_1$	$\psi_2$	$K_{def}$
(Gk) Permanent	$G_k = 0.000 [\text{kN/m}]$	0.041	Permanent	1.00	1.00	1.00	0.80
(Qk1) Snow	$Q_{ks} = 0.000 [\text{kN/m}]$	0.109	Short-term	0.50	0.20	0.00	0.80
(Qk2) Wind	$Q_{kw} = 0.000 [\text{kN/m}]$	0.016	Short-term	0.60	0.20	0.00	0.80

Load combination	$w_{inst}$	$w_{fin} [\text{mm}]$
1 Gk	0.041	0.074
2 Gk + Qk1	0.150	0.183
3 Gk + Qk2	0.057	0.090
4 Gk + Qk1 + $\psi_0 \cdot Qk2$	0.159	0.192
5 Gk + Qk2 + $\psi_0 \cdot Qk1$	0.111	0.144

$w_{fin}, g = w_{inst}, g(1 + k_{def})$ ,  $w_{fin}, q = w_{inst}, q(1 + \psi_2 \cdot k_{def})$  (EC5 §2.2.3, Eq.2.3, Eq.2.4)

**Maximum deflection values**

$w_{inst} = 0.159 \text{ mm}$ ,  $w_{fin} = 0.192 \text{ mm}$

Check according to EC5 EN1995-1-1:2009 §7.2, Tab.7.2

**Final deflections**

$w_{inst} = 0.159 \text{ mm} < L/300 = 600/300 = 2.000 \text{ mm}$

$w_{net, fin} = 0.192 \text{ mm} < L/250 = 600/250 = 2.400 \text{ mm}$

$w_{fin} = 0.192 \text{ mm} < L/150 = 600/150 = 4.000 \text{ mm}$

The check is satisfied

**5.2. Check of finishing, Ultimate limit state of design (EC5 EN1995-1-1:2009, §6)**

L.C.	Load combination	Duration class	$k_{mod}$	$N/K_{mod}$	$V/K_{mod}$	$M/K_{mod}$
1	$\gamma_G \cdot G_k$	Permanent	0.60	0.000	0.362	0.054
2	$\gamma_G \cdot G_k + \gamma_Q \cdot Q_{k1}$	Short-term	0.90	0.000	0.948	0.142
3	$\gamma_G \cdot G_k + \gamma_Q \cdot Q_{k2}$	Short-term	0.90	0.000	0.343	0.052
4	$\gamma_G \cdot G_k + \gamma_Q \cdot Q_{k3}$	Instantaneous	1.10	0.000	0.625	0.322
5	$\gamma_G \cdot G_k + \gamma_Q \cdot Q_{k1} + \gamma_Q \cdot \psi_0 \cdot Q_{k2}$	Short-term	0.90	0.000	1.009	0.151
6	$\gamma_G \cdot G_k + \gamma_Q \cdot Q_{k2} + \gamma_Q \cdot \psi_0 \cdot Q_{k1}$	Short-term	0.90	0.000	0.697	0.104
	Maximum values			0.000	1.009	0.322

**Finishing, Load combination No 5**

Shear,  $F_v = 0.908 \text{ kN}$  (EC5 §6.1.7)

Rectangular cross section,  $b_{ef} = 0.67 \times 1000 = 670 \text{ mm}$ ,  $h = 25 \text{ mm}$ ,  $\lambda = 16 \text{ 750 mm}^2$

Modification factor  $K_{mod} = 0.90$  (Tab.3.1), Material factor  $\gamma_M = 1.30$  (Tab. 2.3)

$f_{vk} = 3.00 \text{ N/mm}^2$ ,  $f_{vd} = K_{mod} \cdot f_{vk} / \gamma_M = 0.90 \times 3.00 / 1.30 = 2.08 \text{ N/mm}^2$  (EC5 Eq.2.14)

$F_v = 0.908 \text{ kN}$ ,  $\tau_{v0d} = 1.50 F_v / (b_{ef} \cdot \lambda) = 1000 \times 1.50 \times 0.908 / (670 \times 16750) = 0.08 \text{ N/mm}^2 < 2.08 \text{ N/mm}^2 = f_{vd}$  (Eq.6.13)

The check is satisfied

Finishing, Load combination No 4

Bending,  $M_{yd}=0.354 \text{ kNm}$ ,  $M_{zd}=0.000 \text{ kNm}$  (EC5 §6.1.6)

Rectangular cross section,  $b=1000\text{mm}$ ,  $h=25\text{mm}$ ,  $A=2.50 \times 10^4 \text{ mm}^2$ ,  $W_y=1.04 \times 10^5 \text{ mm}^3$ ,  $W_z=4.17 \times 10^6 \text{ mm}^3$

Modification factor  $K_{mod}=1.10$  (Tab.3.1), Material factor  $\gamma_M=1.30$  (Tab. 2.3)

$f_{yk}=14.00 \text{ N/mm}^2$ ,  $f_{yd}=K_{mod} \cdot f_{yk} / \gamma_M = 1.10 \times 14.00 / 1.30 = 11.85 \text{ N/mm}^2$

$f_{mk}=14.00 \text{ N/mm}^2$ ,  $f_{mzd}=K_{mod} \cdot f_{mk} / \gamma_M = 1.10 \times 14.00 / 1.30 = 11.85 \text{ N/mm}^2$

Rectangular cross section  $K_m=0.70$  (EC5 §6.1.6.(2))

$\sigma_{myd}=M_{yd}/W_{my,netto}=10^{-6} \times 0.354 / (0.1042 \times 10^{-6}) = 3.40 \text{ N/mm}^2$

$\sigma_{mzd}=M_{zd}/W_{mz,netto}=10^{-6} \times 0.000 / (4.1667 \times 10^{-6}) = 0.00 \text{ N/mm}^2$

$\sigma_{myd}/f_{yd} + K_m \cdot \sigma_{mzd}/f_{mzd} = 0.287 + 0.000 = 0.29 < 1$  (EC5 Eq.6.11)

$K_m \cdot \sigma_{myd} + \sigma_{mzd} = 0.201 + 0.000 = 0.20 < 1$  (EC5 Eq.6.12)

The check is satisfied

6. Beam design

**Beam geometric characteristics**

Length  $L=3.200 \text{ m}$ , height  $H=1.165 \text{ m}$ , beam spacing  $d=0.600 \text{ m}$

Pitch =36.41%, angle  $\alpha=20.00^\circ$ ,  $\tan\alpha=0.364$ ,  $\sin\alpha=0.342$ ,  $\cos\alpha=0.940$

Number of nodes = 3, number of elements =2, supports 2

Nodal coordinates			Beam element properties								
Node	x[m]	y[m]	Sup.	Element	K1	K2	b x h [mm]	L[m]	A[mm <sup>2</sup> ]	I <sub>y</sub> [mm <sup>4</sup> ]	W <sub>y</sub> [mm <sup>3</sup> ]
1	0.000	0.000	11	1	1	3	50x200	1.703	10000	33.333x10 <sup>6</sup>	3.333x10 <sup>5</sup>
2	3.200	1.165	01	2	3	2	50x200	1.703	10000	33.333x10 <sup>6</sup>	3.333x10 <sup>5</sup>
3	1.600	0.582									

**Line loads per beam**

Timber density =290.00 kg/m<sup>3</sup>, beam self weight =0.097 kN

Beam spacing  $d=0.60 \text{ m}$ , weight of beam connections =0.010 kN

**Permanent line loads (kN/m) on beam**

Roof covering+self weight  $G_{k1} = 0.393 \text{ kN/m}$

Ceiling under roof  $G_{k2} = 0.060 \text{ kN/m}$

**Variable line loads of short term action (kN/m) on beam**

Imposed  $Q_{ki} = 0.40 \times 0.600 = 0.240 \text{ kN/m}$

Snow load  $Q_{k1} = 0.960 \text{ kN/m}$

Wind load  $Q_{k2} = 0.122 \text{ kN/m}$

**Design load combinations**

( $\gamma_g=1.35$ ,  $\gamma_q=1.50$ ,  $\psi_0(\text{ Live Qf})=0.70$ ,  $\psi_0(\text{ Snow Q1})=0.50$ ,  $\psi_0(\text{ Wind Q2})=0.60$ )

L.C.	Actions Permanent-Variable	Duration class
1	$\gamma_g \cdot G_k$	Permanent
2	$\gamma_g \cdot G_k + \gamma_q \cdot Q_{k1}$	Short-term
3	$\gamma_g \cdot G_k + \gamma_q \cdot Q_{k2}$	Short-term
4	$\gamma_g \cdot G_k + \gamma_q \cdot Q_{ki}$	Short-term
5	$\gamma_g \cdot G_k + \gamma_q \cdot Q_{k1} + \gamma_q \cdot \psi_0 \cdot Q_{k2}$	Short-term
6	$\gamma_g \cdot G_k + \gamma_q \cdot Q_{k2} + \gamma_q \cdot \psi_0 \cdot Q_{k1}$	Short-term
7	$\gamma_g \cdot G_k + \gamma_q \cdot Q_{ki} + \gamma_q \cdot \psi_0 \cdot Q_{k1} + \gamma_q \cdot \psi_0 \cdot Q_{k2}$	Short-term

7. Beam static analysis

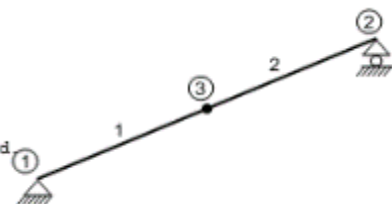
The roof structure is a continuous beam.

The internal forces are computed for separate loadings conditions

(permanent-live-snow-wind) and then from their combinations the

internal forces for the unfavourable load combinations are computed.

Number of nodes = 3, number of elements =2, supports 2





**7.1. Internal forces for applied loads**

Internal forces, Loading: (Gk) Dead Gk1 = 0.393, Gk2 = 0.060 [kN/m]

Elem.	Node-1	Node-2	N1[kN]	V1[kN]	M1[kNm]	N2[kN]	V2[kN]	M2[kNm]	Nm[kN]	Vm[kN]	Mm[kNm]
1	1	3	-0.26	0.73	0.00	0.00	0.00	0.62	0.00	0.00	0.62
2	3	2	0.00	0.00	0.62	0.26	-0.73	0.00	0.00	0.00	0.62

- (m point of maximum span moment for permanent load, or element middle point)

Internal forces, Loading: (Qk1) Snow Qks = 0.960 [kN/m]

Elem.	Node-1	Node-2	N1[kN]	V1[kN]	M1[kNm]	N2[kN]	V2[kN]	M2[kNm]	Nm[kN]	Vm[kN]	Mm[kNm]
1	1	3	-0.53	1.44	0.00	0.00	0.00	1.23	0.00	0.00	1.23
2	3	2	0.00	0.00	1.23	0.53	-1.44	0.00	0.00	0.00	1.23

- (m point of maximum span moment for permanent load, or element middle point)

Internal forces, Loading: (Qk2) Wind Qkw = 0.122 [kN/m]

Elem.	Node-1	Node-2	N1[kN]	V1[kN]	M1[kNm]	N2[kN]	V2[kN]	M2[kNm]	Nm[kN]	Vm[kN]	Mm[kNm]
1	1	3	0.08	0.21	0.00	0.08	0.00	0.18	0.08	0.00	0.18
2	3	2	0.08	0.00	0.18	0.08	-0.21	0.00	0.08	0.00	0.18

- (m point of maximum span moment for permanent load, or element middle point)

Internal forces, Loading: (Qki) Imposed (H) Qi = 0.240 [kN/m]

Elem.	Node-1	Node-2	N1[kN]	V1[kN]	M1[kNm]	N2[kN]	V2[kN]	M2[kNm]	Nm[kN]	Vm[kN]	Mm[kNm]
1	1	3	-0.14	0.38	0.00	0.00	0.00	0.33	0.00	0.00	0.33
2	3	2	0.00	0.00	0.33	0.14	-0.38	0.00	0.00	0.00	0.33

- (m point of maximum span moment for permanent load, or element middle point)

**7.2. Vertical nodal displacements (mm)**

Node	Gk	Qk1	Qk2	Qki
1	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00
3	-3.01	-5.98	-0.86	-1.59

-

**7.3. Support reactions (kN)**

Node	React.	Gk	Qk1	Qk2	Qki
1	Fx	0.00	0.00	-0.14	0.00
1	Fy	0.77	1.54	0.17	0.41
2	Fx	0.00	0.00	0.00	0.00
2	Fy	0.77	1.54	0.22	0.41

**8. Serviceability limit state**

- 8.1. Serviceability limit state** (EC5 EN1995-1-1:2009, §2.2.3, §7)  
Control of deflection at node 3 (EC5 §7.2)

Loading [kN/m]	u[mm]	Action	$\psi_0$	$\psi_1$	$\psi_2$	Kdef
( Gk) Dead Gk1 = 0.393, Gk2 = 0.060	-3.198	Permanent	1.00	1.00	1.00	0.80
(Qk1) Snow Qks = 0.960	-6.364	Short-term	0.50	0.20	0.00	0.00
(Qk2) Wind Qkw = 0.122	-0.919	Short-term	0.60	0.20	0.00	0.00

-

Load combination	w.inst	w.fin [mm]
1 Gk	3.198	5.757
2 Gk + Qk1	9.562	12.121
3 Gk + Qk2	4.117	6.675
4 Gk + Qk1 + $\psi_0$ .Qk2	10.113	12.672
5 Gk + Qk2 + $\psi_0$ .Qk1	7.299	9.857

w.fin,q=w.inst,g(1+kdef), w.fin,q=w.inst,q(1+ $\psi_2$ ·kdef) (EC5 §2.2.3, Eq.2.3, Eq.2.4)

**Maximum deflection values at node 3**

w.inst = 10.113 mm, w.fin = 12.672 mm

Check according to EC5 EN1995-1-1:2009 §7.2, Tab.7.2

**Final deflections at node 3**

w.inst = 10.113 mm < L/300=3405/300= 11.352 mm

w.net,fin = 12.672 mm < L/250=3405/250= 13.622 mm

w.fin = 12.672 mm < L/150=3405/150= 22.703 mm

The check is satisfied

**9.1. Ultimate limit state (EC5 EN1995-1-1:2009, §6)**

Rafter, elements: 1, 2

Loading [kN/m]	Action	$\gamma_G$	$\gamma_Q$	$\psi_0$
( Gk) Dead Gk1 = 0.393, Gk2 = 0.060	Permanent	1.35	0.00	1.00
(Qk1) Snow Qks = 0.960	Short-term	0.00	1.50	0.50
(Qk2) Wind Qkw = 0.122	Short-term	0.00	1.50	0.60
(Qki) Imposed (H) Qi = 0.240	Short-term	0.00	1.50	0.00

-

L.C.	Load combination	Duration class	kmod	-N/Kmod	+N/Kmod	V/Kmod	M/Kmod
1	$\gamma_G$ .Gk	Permanent	0.60	-0.594	0.595	1.632	1.389
2	$\gamma_G$ .Gk+ $\gamma_Q$ .Qk1	Short-term	0.90	-1.271	1.273	3.494	2.974
3	$\gamma_G$ .Gk+ $\gamma_Q$ .Qk2	Short-term	0.90	-0.269	0.523	1.435	1.222
4	$\gamma_G$ .Gk+ $\gamma_Q$ .Qki	Short-term	0.90	-0.629	0.630	1.728	1.471
5	$\gamma_G$ .Gk+ $\gamma_Q$ .Qk1+ $\gamma_Q$ . $\psi_0$ .Qk2	Short-term	0.90	-1.195	1.349	3.702	3.152
6	$\gamma_G$ .Gk+ $\gamma_Q$ .Qk2+ $\gamma_Q$ . $\psi_0$ .Qk1	Short-term	0.90	-0.707	0.961	2.638	2.246
7	$\gamma_G$ .Gk+ $\gamma_Q$ .Qki+ $\gamma_Q$ . $\psi_0$ .Qk1+ $\gamma_Q$ . $\psi_0$ .Qk2	Short-term	0.90	-0.990	1.144	3.139	2.673
	Maximum values			-1.271	1.349	3.702	3.152

**9.2. Check of cross section Rafter, elements: 1, 2**

**Rafter, elements: 1, 2, Load combination No 5**

Tension parallel to the grain, Ft0d=1.214 kN (EC5 §6.1.2)

Rectangular cross section, b=50 mm, h=200 mm, A= 10 000 mm<sup>2</sup>

Modification factor Kmod=0.90 (Tab.3.1), Material factor  $\gamma_M=1.30$  (Tab. 2.3)

ft0k=7.20 N/mm<sup>2</sup>, ft0d=Kmod·ft0k/ $\gamma_M=0.90 \times 7.20 / 1.30 = 4.98 \text{ N/mm}^2$  (EC5 Eq.2.14)

Ft0d=1.214 kN, ct0d=Ft0d/Anetto=1000x1.214/10000=0.12N/mm<sup>2</sup> < 4.98N/mm<sup>2</sup>=ft0d (Eq.6.1)

The check is satisfied

**Rafter, elements: 1, 2, Load combination No 2**

Compression parallel to the grain, Fc0d=-1.144 kN (EC5 §6.1.4)

Rectangular cross section, b=50 mm, h=200 mm, A= 10 000 mm<sup>2</sup>

Modification factor Kmod=0.90 (Tab.3.1), Material factor  $\gamma_M=1.30$  (Tab. 2.3)

fc0k=16.00 N/mm<sup>2</sup>, fc0d=Kmod·fc0k/ $\gamma_M=0.90 \times 16.00 / 1.30 = 11.08 \text{ N/mm}^2$  (EC5 Eq.2.14)

Fc0d=-1.144 kN, cc0d=Fc0d/Anetto=1000x1.144/10000=0.11N/mm<sup>2</sup> < 11.08N/mm<sup>2</sup>=fc0d (Eq.6.2)

The check is satisfied

Rafter, elements: 1, 2, Load combination No 5Shear,  $F_v=3.332 \text{ kN}$  (EC5 §6.1.7)Rectangular cross section,  $bef=0.67 \times 50=34 \text{ mm}$ ,  $h=200 \text{ mm}$ ,  $A=6800 \text{ mm}^2$ Modification factor  $K_{mod}=0.90$  (Tab.3.1), Material factor  $\gamma_M=1.30$  (Tab. 2.3) $f_{vk}=3.00 \text{ N/mm}^2$ ,  $f_{vd}=K_{mod} \cdot f_{vk} / \gamma_M = 0.90 \times 3.00 / 1.30 = 2.08 \text{ N/mm}^2$  (EC5 Eq.2.14) $F_v=3.332 \text{ kN}$ ,  $v_{0d}=1.50 F_v / (A \cdot netto) = 1000 \times 1.50 \times 3.332 / 6800 = 0.73 \text{ N/mm}^2 < 2.08 \text{ N/mm}^2 = f_{vd}$  (Eq.6.13)

The check is satisfied

Rafter, elements: 1, 2, Load combination No 5Bending,  $M_{yd}=2.837 \text{ kNm}$ ,  $M_{zd}=0.000 \text{ kNm}$  (EC5 §6.1.6)Rectangular cross section,  $b=50 \text{ mm}$ ,  $h=200 \text{ mm}$ ,  $A=1.00 \times 10^4 \text{ mm}^2$ ,  $W_y=3.33 \times 10^5 \text{ mm}^3$ ,  $W_z=8.33 \times 10^4 \text{ mm}^3$ Modification factor  $K_{mod}=0.90$  (Tab.3.1), Material factor  $\gamma_M=1.30$  (Tab. 2.3) $f_{myk}=14.00 \text{ N/mm}^2$ ,  $f_{myd}=K_{mod} \cdot f_{myk} / \gamma_M = 0.90 \times 14.00 / 1.30 = 9.69 \text{ N/mm}^2$  $f_{mzk}=14.00 \text{ N/mm}^2$ ,  $f_{mzd}=K_{mod} \cdot f_{mzk} / \gamma_M = 0.90 \times 14.00 / 1.30 = 9.69 \text{ N/mm}^2$ Rectangular cross section  $K_m=0.70$  (EC5 §6.1.6.(2)) $\sigma_{myd}=M_{yd} / W_y, netto = 10^6 \times 2.837 / (0.3333 \times 10^6) = 8.51 \text{ N/mm}^2$  $\sigma_{mzd}=M_{zd} / W_z, netto = 10^6 \times 0.000 / (0.0833 \times 10^6) = 0.00 \text{ N/mm}^2$  $\sigma_{myd} / f_{myd} + K_m \cdot \sigma_{mzd} / f_{mzd} = 0.878 + 0.000 = 0.88 < 1$  (EC5 Eq.6.11) $K_m \cdot \sigma_{myd} / f_{myd} + \sigma_{mzd} / f_{mzd} = 0.615 + 0.000 = 0.61 < 1$  (EC5 Eq.6.12)

The check is satisfied

Negligible compressive stress, combined bending-compression check is omitted (EC5 §6.2.4)

Rafter, elements: 1, 2, Load combination No 2Column stability with bending,  $F_{c0d}=-1.144 \text{ kN}$ ,  $M_{yd}=2.677 \text{ kNm}$ ,  $M_{zd}=0.000 \text{ kNm}$  (EC5 §6.3.2)Rectangular cross section,  $b=50 \text{ mm}$ ,  $h=200 \text{ mm}$ ,  $A=1.00 \times 10^4 \text{ mm}^2$ ,  $W_y=3.33 \times 10^5 \text{ mm}^3$ ,  $W_z=8.33 \times 10^4 \text{ mm}^3$ Modification factor  $K_{mod}=0.90$  (Tab.3.1), Material factor  $\gamma_M=1.30$  (Tab. 2.3,  $E_{005}=4700 \text{ MPa}$ ) $f_{c0k}=16.00 \text{ N/mm}^2$ ,  $f_{c0d}=K_{mod} \cdot f_{c0k} / \gamma_M = 0.90 \times 16.00 / 1.30 = 11.08 \text{ N/mm}^2$  $f_{myk}=14.00 \text{ N/mm}^2$ ,  $f_{myd}=K_{mod} \cdot f_{myk} / \gamma_M = 0.90 \times 14.00 / 1.30 = 9.69 \text{ N/mm}^2$  $f_{mzk}=14.00 \text{ N/mm}^2$ ,  $f_{mzd}=K_{mod} \cdot f_{mzk} / \gamma_M = 0.90 \times 14.00 / 1.30 = 9.69 \text{ N/mm}^2$ Rectangular cross section  $K_m=0.70$  (EC5 §6.1.6.(2)) $\sigma_{c0d}=F_{c0d} / A_{netto} = 1000 \times (-1.144) / 10000 = -0.11 \text{ N/mm}^2$  $\sigma_{myd}=M_{yd} / W_y, netto = 10^6 \times 2.677 / (0.3333 \times 10^6) = 8.03 \text{ N/mm}^2$  $\sigma_{mzd}=M_{zd} / W_z, netto = 10^6 \times 0.000 / (0.0833 \times 10^6) = 0.00 \text{ N/mm}^2$ Buckling length $S_{ky} = 1.00 \times 3.405 = 3.405 \text{ m} = 3405 \text{ mm}$  (most unfavourable) $S_{kz} = 0.09 \times 3.405 = 0.300 \text{ m} = 300 \text{ mm}$  ( $L_c/L = 0.30/3.41 = 0.09$ )Slenderness $i_y = \sqrt{(I_y/A)} = 0.289 \times 200 = 58 \text{ mm}$ ,  $\lambda_y = 3405 / 58 = 58.71$  $i_z = \sqrt{(I_z/A)} = 0.289 \times 50 = 14 \text{ mm}$ ,  $\lambda_z = 300 / 14 = 21.43$ Critical stresses $\sigma_{c, crity} = \pi^2 E_{005} / \lambda_y^2 = 13.46 \text{ N/mm}^2$ ,  $\lambda_{rel, y} = \sqrt{(f_{c0k} / \sigma_{c, crity})} = 1.09$  (EC5 Eq.6.21) $\sigma_{c, critz} = \pi^2 E_{005} / \lambda_z^2 = 101.01 \text{ N/mm}^2$ ,  $\lambda_{rel, z} = \sqrt{(f_{c0k} / \sigma_{c, critz})} = 0.40$  (EC5 Eq.6.22) $\beta_c = 0.20$  (solid timber) $k_y = 0.5 [1 + \beta_c (\lambda_{rel, y} - 0.3) + \lambda_{rel, y}^2] = 1.17$ ,  $K_{cy} = 1 / (k_y + \sqrt{(k_y^2 - \lambda_{rel, y}^2)}) = 0.622$  (Eq.6.27 6.25) $k_z = 0.5 [1 + \beta_c (\lambda_{rel, z} - 0.3) + \lambda_{rel, z}^2] = 0.59$ ,  $K_{cz} = 1 / (k_z + \sqrt{(k_z^2 - \lambda_{rel, z}^2)}) = 0.977$  (Eq.6.28 6.26) $\sigma_{c0d} / (K_{cy} \cdot f_{c0d}) + \sigma_{myd} / f_{myd} + K_m \cdot \sigma_{mzd} / f_{mzd} = 0.017 + 0.829 + 0.000 = 0.85 < 1$  (EC5 Eq.6.23) $\sigma_{c0d} / (K_{cz} \cdot f_{c0d}) + K_m \cdot \sigma_{myd} / f_{myd} + \sigma_{mzd} / f_{mzd} = 0.011 + 0.580 + 0.000 = 0.59 < 1$  (EC5 Eq.6.24)

The check is satisfied

Rafter, elements: 1, 2, Load combination No 5

Combined bending and axial tension,  $F_{t0d}=1.214\text{kN}$ ,  $M_{yd}=2.837\text{kNm}$ ,  $M_{zd}=0.000\text{kNm}$  (EC5 §6.2.3)  
 Rectangular cross section,  $b=50\text{mm}$ ,  $h=200\text{mm}$ ,  $A=1.00\times 10^4\text{mm}^2$ ,  $W_y=3.33\times 10^6\text{mm}^3$ ,  $W_z=8.33\times 10^4\text{mm}^3$   
 Modification factor  $K_{mod}=0.90$  (Tab.3.1), Material factor  $\gamma_M=1.30$  (Tab. 2.3)  
 $f_{t0k}=7.20\text{ N/mm}^2$ ,  $f_{t0d}=K_{mod}\cdot f_{t0k}/\gamma_M=0.90\times 7.20/1.30=4.98\text{N/mm}^2$   
 $f_{yk}=14.00\text{ N/mm}^2$ ,  $f_{yd}=K_{mod}\cdot f_{yk}/\gamma_M=0.90\times 14.00/1.30=9.69\text{N/mm}^2$   
 $f_{mk}=14.00\text{ N/mm}^2$ ,  $f_{mzd}=K_{mod}\cdot f_{mk}/\gamma_M=0.90\times 14.00/1.30=9.69\text{N/mm}^2$

Rectangular cross section  $K_m=0.70$  (EC5 §6.1.6.(2))  
 $\sigma_{0d}=F_{t0d}/A_{netto}=1000\times 1.214/10000=0.12\text{ N/mm}^2$   
 $\sigma_{myd}=M_{yd}/W_{my,netto}=10^6\times 2.837/(0.3333\times 10^6)=8.51\text{ N/mm}^2$   
 $\sigma_{mzd}=M_{zd}/W_{mz,netto}=10^6\times 0.000/(0.0833\times 10^6)=0.00\text{ N/mm}^2$

$\sigma_{0d}/f_{t0d}+\sigma_{myd}/f_{myd}+K_m\cdot\sigma_{mzd}/f_{mzd}=0.024+0.878+0.000=0.90 < 1$  (EC5 Eq.6.17)

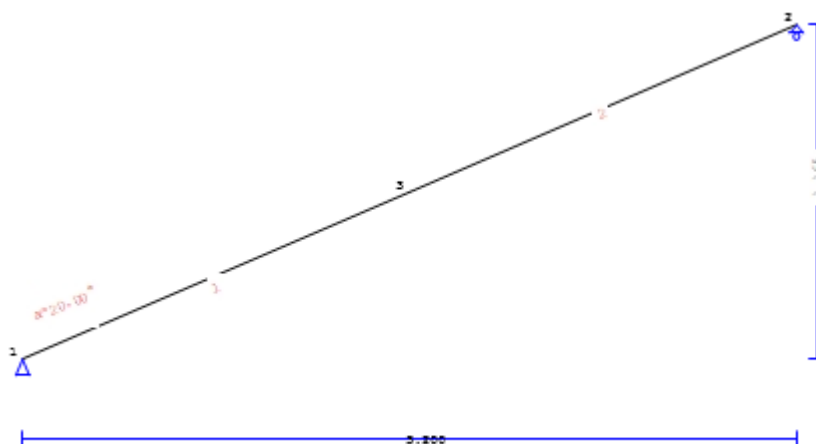
$\sigma_{0d}/f_{t0d}+K_m\cdot\sigma_{myd}/f_{myd}+\sigma_{mzd}/f_{mzd}=0.024+0.615+0.000=0.64 < 1$  (EC5 Eq.6.18)

The check is satisfied

ii. Căprior 5x20 cm – Model 2 – Învelitoare Țiglă metalică – distanță 70 cm interax

1. ROOF -001

Monopitch roof



2. General description, assumptions, materials, loads

2.1. Construction type

Timber roof, from beams with timber C14. The roof type as sketch above.  
 Span 3.200 m, height 1.165 m, roof pitch 20.00°, beam spacing 0.700m  
 Finishing (rafter) from timber C14, of thickness 25 mm  
 Elements, Cross section 50x200 [mm]  
 Beam volume =0.034 m³, beam weight =0.097 kN

2.2. Design codes

EN1990:2002, Eurocode 0 Part 1-1, Basis of structural design  
 EN1991-1-1:2002, Eurocode 1 Part 1-1, Actions on structures  
 EN1991-1-3:2003, Eurocode 1 Part 1-3, Snow loads  
 EN1991-1-4:2005, Eurocode 1 Part 1-4, Wind actions  
 EN1995-1-1:2009, Eurocode 5 Part 1-1, Design of timber structures

**2.3. Design methodology**

All the load combinations according to Eurocode 1 and Eurocode 5 are taken into account, and the checks are performed in the most unfavourable loading conditions, for combined action, in ultimate limit state, according to EC5 EN1995-1-1:2009, §6. The connections are designed as bolted connections with metal plates according to EC5 EN1995-1-1:2009, §8. The deflections are checked in serviceability limit condition, according to EC5 EN1995-1-1:2009, §7.

**2.4. Material properties (beam) (EC5 EN1995-1-1:2009, §3)**

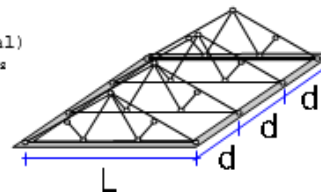
Timber class : C14  
 Service classes : Class 2, moisture content $\leq$ 20% (EC5 §2.3.1.3)  
 Material factor  $\gamma_M=1.30$  (EC5 Tab. 2.3)  
**Characteristic material properties for timber**  
 $f_{mk} = 14.0$  MPa,  $f_{t0k} = 7.2$  MPa,  $f_{t90k} = 0.4$  MPa  
 $f_{c0k} = 16.0$  MPa,  $f_{c90k} = 2.0$  MPa,  $f_{vk} = 3.0$  MPa  
 $E_{0m} = 7000$  MPa,  $E_{005} = 4700$  MPa,  $E_{90m} = 230$  MPa  
 $G_m = 440$  MPa,  $\rho_k = 290$  Kg/m<sup>3</sup>,  $\rho_m = 350$  Kg/m<sup>3</sup>

**2.5. Material properties (timber, finishing) (EC5 EN1995-1-1:2009, §3)**

Timber class : C14  
 Service classes : Class 2, moisture content $\leq$ 20% (EC5 §2.3.1.3)  
 Material factor  $\gamma_M=1.30$  (EC5 Tab. 2.3)  
**Characteristic material properties for timber**  
 $f_{mk} = 14.0$  MPa,  $f_{t0k} = 7.2$  MPa,  $f_{t90k} = 0.4$  MPa  
 $f_{c0k} = 16.0$  MPa,  $f_{c90k} = 2.0$  MPa,  $f_{vk} = 3.0$  MPa  
 $E_{0m} = 7000$  MPa,  $E_{005} = 4700$  MPa,  $E_{90m} = 230$  MPa  
 $G_m = 440$  MPa,  $\rho_k = 290$  Kg/m<sup>3</sup>,  $\rho_m = 350$  Kg/m<sup>3</sup>

**2.6. Distributed roof loads**

Permanent load of roof covering	$G_e = 0.050$ kN/m <sup>2</sup> (Corrugated metal)
Purlins, finishing, insulation	$G_t = 0.100$ kN/m <sup>2</sup> $G_e+G_t = 0.150$ kN/m <sup>2</sup>
Load of ceiling under the roof	$G_c = 0.100$ kN/m <sup>2</sup>
Snow load on the ground	$S_k = 2.000$ kN/m <sup>2</sup>
Wind pressure on vertical surface	$Q_w = 0.765$ kN/m <sup>2</sup>
Imposed load (category H)	$Q_i = 0.400$ kN/m <sup>2</sup>

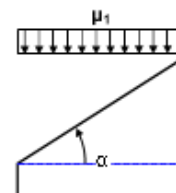


**3. Snow load (EC1 EN1991-1-3:2003 §5)**

**Snow load on the ground  $S_k$  (EC1 EN1991-1-3:2003 §4, Annex C)**  
 Climatic Region :Alpine Region, snow zone :2, altitude above sea level=500 m  
 $S_k = (0.642 \times 2 + 0.009) \times [1 + (500/728)^2] = 1.903$  kN/m<sup>2</sup>  
 Characteristic value of snow load on the ground:  $s_k = 2.000$  kN/m<sup>2</sup>

**Snow load on the roof (EC1 EN1991-1-3:2003 §5)**  
 Angle of pitch of roof :  $\alpha = 20.005^\circ$

Exposure coefficient :  $C_e = 1.000$  (EC1-1-3 §5.2(7))  
 Thermal coefficient :  $C_t = 1.000$  (EC1-1-3 §5.2(8))  
 Shape coefficients,  $\alpha = 20.00^\circ$ ,  $\mu_1 = 0.800$  (Table 5.2)



**Snow load (EC1 EN1991-1-3:2003 §5.3.2)**  
 $S_1 = \mu_1 \cdot C_e \cdot C_t \cdot S_k = 0.800 \times 1.000 \times 1.000 \times 2.000 = 1.600$  kN/m<sup>2</sup>

**4. Wind loading** (EC1 EN1991-1-4:2005 §5)

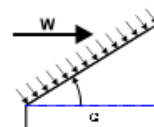
$v_{bo}=31.00$  m/s, Romania SR, Zone: 3 ,  $v_b=C_{dir} \cdot C_{season} \cdot V_{bo} = 31.00$  m/s  
 Terrain category: IV,  $z=10.000$ m,  $z_o=1.000$ m,  $z_{min}=10$ m,  $z_{max}=200$ m,  $z_{oII}=0.050$ m  
 $k_r=0.19 \cdot (1.000/0.05)^{0.07}=0.234$   
 Roughness factor  $C_r(z)=k_r \cdot \ln(z/z_o)=0.234 \times \ln(10.000/1.000)=0.540$   
 $H/Lu=50/600=0.08$ ,  $0.05 < H/Lu=0.08 < 0.30$ ,  $L_e=600.00$  m (EN1991-1-4, Tab.A.2)  
 $z=10.00$  m,  $X/L_e=500/600=0.83$ ,  $z/L_e=10/600=0.10$ ,  $s=0.396$  (eq.A.7, ...A.10)  
 Orography factor  $C_o(z)=1+2 \times 0.396 \times 0.083=1.066$  (eq.A.2)  
 Turbulence factor  $K_t=1.000$   
 Exposure factor  $C_e(z)=1.274$  (EN1991-1-4, §4.5)  
 $q(z)=C_e(z) \cdot (\psi_0) \cdot V_b^2=[0.001] \times 1.274 \times 0.625 \times 31.00^2=0.765$  kN/m<sup>2</sup>

Wind pressure on roof  $w_e=Q_{ref} \cdot C_e(z) \cdot C_{pe}$  (EC1 EN1991-1-4:2005, §5.2)

External pressure coefficients (EC1 EN1991-1-4:2005 Tab. 7.3)

For pitch angle  $\alpha=20.00^\circ$ ,  $C_{pe}=0.27$

Wind pressure  $w_e=0.204$  kN/m<sup>2</sup>



**5. Roof timber finishing (rafter)**

**Timber finishing (rafter) structural system**

The timber finishing (rafter) is designed as simply supported beam with span

Spacing of trusses  $L=0.700$ m, and width  $1.00$ m

**Dimensions of timber finishing (rafter)**

Timber of finishing (rafter): C14, service class: Class 2, moisture content  $\leq 20\%$

Spacing of beams  $L=0.700$ m, roof pitch  $\alpha=20.00^\circ$ , thickness of finishing  $25$ mm

**Loading on timber finishing (rafter)**

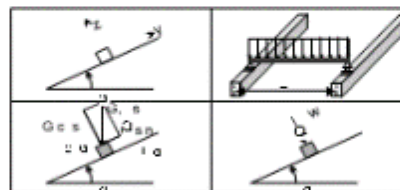
Roof covering  $G_e=0.050$  kN/m<sup>2</sup>

Self weight  $G_l=0.071$  kN/m<sup>2</sup>

Snow load  $Q_s=1.600$  kN/m<sup>2</sup>

Wind load  $Q_w=0.204$  kN/m<sup>2</sup>

Concentrated  $Q_p=1.000$  kN



**Internal forces of timber finishing (span  $L=0.700$  m, width  $=1.00$  m)**

Loading	Action	$\gamma_G$	$\gamma_Q$	$\psi_0$	maxN [kN]	maxQ [kN]	maxM [kNm]
(Gk) Permanent	$G_k=0.121$ [kN/m] Permanent	1.35	0.00	1.00	0.000	0.040	0.007
(Qk1) Snow	$Q_{ks}=1.600$ [kN/m] Short-term	0.00	1.50	0.50	0.000	0.494	0.087
(Qk2) Wind	$Q_{kw}=0.204$ [kN/m] Short-term	0.00	1.50	0.60	0.000	0.071	0.012
(Qk3) Concentrated	$Q_{kp}=1.000$ [kN] Instantaneous	0.00	1.00	0.00	0.000	0.470	0.321

**5.1. Serviceability limit state** (EC5 EN1995-1-1:2009, §2.2.3, §7)

**Control of deflection** (EC5 §7.2)

Loading	[kN/m]	$u$ [mm]	Action	$\psi_0$	$\psi_1$	$\psi_2$	Kdef
(Gk) Permanent	$G_k=0.000$ [kN/m]	0.016	Permanent	1.00	1.00	0.00	0.80
(Qk1) Snow	$Q_{ks}=0.000$ [kN/m]	0.201	Short-term	0.50	0.20	0.00	0.80
(Qk2) Wind	$Q_{kw}=0.000$ [kN/m]	0.029	Short-term	0.60	0.20	0.00	0.80

Load combination	w.inst	w.fin [mm]
1 Gk	0.016	0.029
2 Gk + Qk1	0.217	0.230
3 Gk + Qk2	0.045	0.058
4 Gk + Qk1 + $\psi_0 \cdot Qk2$	0.235	0.248
5 Gk + Qk2 + $\psi_0 \cdot Qk1$	0.146	0.159

$w_{.fin}, g=w_{.inst}, g(1+k_{def}), w_{.fin}, q=w_{.inst}, q(1+\psi_2 \cdot k_{def})$  (EC5 §2.2.3, Eq.2.3, Eq.2.4)

**Maximum deflection values**

$w_{.inst} = 0.235$  mm,  $w_{.fin} = 0.248$  mm

Check according to EC5 EN1995-1-1:2009 §7.2, Tab.7.2

Final deflections

w.inst = 0.235 mm < L/300=700/300= 2.333 mm

w.net,fin = 0.248 mm < L/250=700/250= 2.800 mm

w.fin = 0.248 mm < L/150=700/150= 4.667 mm

The check is satisfied

5.2. Check of finishing, Ultimate limit state of design (EC5 EN1995-1-1:2009, §6)

L.C.	Load combination	Duration class	kmod	N/Kmod	V/Kmod	M/Kmod
1	γg.Gk	Permanent	0.60	0.000	0.090	0.016
2	γg.Gk + γq.Qk1	Short-term	0.90	0.000	0.884	0.155
3	γg.Gk + γq.Qk2	Short-term	0.90	0.000	0.179	0.031
4	γg.Gk + γq.Qk3	Instantaneous	1.10	0.000	0.476	0.301
5	γg.Gk + γq.Qk1 + γq.ψ0.Qk2	Short-term	0.90	0.000	0.955	0.167
6	γg.Gk + γq.Qk2 + γq.ψ0.Qk1	Short-term	0.90	0.000	0.591	0.103
	Maximum values			0.000	0.955	0.301

Finishing, Load combination No 5

Shear, Fv=0.860 kN (EC5 §6.1.7)

Rectangular cross section, bef=0.67x1000=670 mm, h=25 mm, A= 16 750 mm<sup>2</sup>

Modification factor Kmod=0.90 (Tab.3.1), Material factor γM=1.30 (Tab. 2.3)

fvk=3.00 N/mm<sup>2</sup>, fvd=Kmod·fvk/γM=0.90x3.00/1.30=2.08N/mm<sup>2</sup> (EC5 Eq.2.14)

Fv=0.860 kN, τv0d=1.50Fv0d/Anetto=1000x1.50x0.860/16750=0.08N/mm<sup>2</sup> < 2.08N/mm<sup>2</sup>=fv0d (Eq.6.13)

The check is satisfied

Finishing, Load combination No 4

Bending, Myd=0.331 kNm, Mzd=0.000 kNm (EC5 §6.1.6)

Rectangular cross section, b=1000mm, h=25mm, A=2.50x10<sup>4</sup> mm<sup>2</sup>, Wy=1.04x10<sup>5</sup> mm<sup>3</sup>, Wz=4.17x10<sup>6</sup> mm<sup>3</sup>

Modification factor Kmod=1.10 (Tab.3.1), Material factor γM=1.30 (Tab. 2.3)

fmyk=14.00 N/mm<sup>2</sup>, fmyd=Kmod·fmyk/γM=1.10x14.00/1.30=11.85N/mm<sup>2</sup>

fmzk=14.00 N/mm<sup>2</sup>, fmzd=Kmod·fmzk/γM=1.10x14.00/1.30=11.85N/mm<sup>2</sup>

Rectangular cross section Km=0.70 (EC5 §6.1.6.(2))

omyd=Myd/Wmy,netto=10<sup>6</sup>x0.331/(0.1042x10<sup>6</sup>)= 3.18 N/mm<sup>2</sup>

omzd=Mzd/Wmz,netto=10<sup>6</sup>x0.000/(4.1667x10<sup>6</sup>)= 0.00 N/mm<sup>2</sup>

omyd/fmyd+Km.omzd/fmzd=0.268+0.000= 0.27 < 1 (EC5 Eq.6.11)

Km.omyd/fmyd+omzd/fmzd=0.188+0.000= 0.19 < 1 (EC5 Eq.6.12)

The check is satisfied

6. Beam design

Beam geometric characteristics

Length L=3.200 m, height H=1.165 m, beam spacing d=0.700 m

Pitch =36.41%, angle α=20.00 °, tano=0.364, sino=0.342, coso=0.940

Number of nodes = 3, number of elements =2, supports 2

Nodal coordinates			Beam element properties								
Node	x(m)	y(m)	Sup.	Element	K1	K2	b x h (mm)	L(m)	A(mm <sup>2</sup> )	<sup>2</sup> Iy (mm <sup>4</sup> )	<sup>4</sup> Wy (mm <sup>3</sup> )
1	0.000	0.000	11	1	1	3	50x200	1.703	10000	33.333x10 <sup>6</sup>	<sup>6</sup> 3.333x10 <sup>5</sup>
2	3.200	1.165	01	2	3	2	50x200	1.703	10000	33.333x10 <sup>6</sup>	<sup>6</sup> 3.333x10 <sup>5</sup>
3	1.600	0.582									

Line loads per beam

Timber density =290.00 kg/m<sup>3</sup>, beam self weight =0.097 kN

Beam spacing d=0.70 m, weight of beam connections =0.010 kN

Permanent line loads (kN/m) on beam

Roof covering+self weight Gk1= 0.138 kN/m

Ceiling under roof Gk2= 0.070 kN/m

**Variable line loads of short term action (kN/m) on beam**

Imposed  $Q_{ki} = 0.40 \times 0.700 = 0.280$  kN/m

Snow load  $Q_{k1} = 1.120$  kN/m

Wind load  $Q_{k2} = 0.143$  kN/m

**Design load combinations**

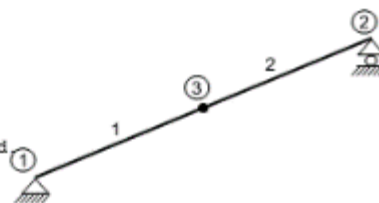
( $\gamma_g = 1.35$ ,  $\gamma_q = 1.50$ ,  $\psi_0$ ( Live  $Q_f$ ) = 0.70,  $\psi_0$ ( Snow  $Q_1$ ) = 0.50,  $\psi_0$ ( Wind  $Q_2$ ) = 0.60)

L.C.	Actions Permanent-Variable	Duration class
1	$\gamma_g \cdot G_k$	Permanent
2	$\gamma_g \cdot G_k + \gamma_q \cdot Q_{k1}$	Short-term
3	$\gamma_g \cdot G_k + \gamma_q \cdot Q_{k2}$	Short-term
4	$\gamma_g \cdot G_k + \gamma_q \cdot Q_{ki}$	Short-term
5	$\gamma_g \cdot G_k + \gamma_q \cdot Q_{k1} + \gamma_q \cdot \psi_0 \cdot Q_{k2}$	Short-term
6	$\gamma_g \cdot G_k + \gamma_q \cdot Q_{k2} + \gamma_q \cdot \psi_0 \cdot Q_{k1}$	Short-term
7	$\gamma_g \cdot G_k + \gamma_q \cdot Q_{ki} + \gamma_q \cdot \psi_0 \cdot Q_{k1} + \gamma_q \cdot \psi_0 \cdot Q_{k2}$	Short-term

**7. Beam static analysis**

The roof structure is a continuous beam.

The internal forces are computed for separate loadings conditions (permanent-live-snow-wind) and then from their combinations the internal forces for the unfavourable load combinations are computed  
Number of nodes = 3, number of elements = 2, supports 2



**7.1. Internal forces for applied loads**

Internal forces, Loading: (  $G_k$  ) Dead  $G_{k1} = 0.138$ ,  $G_{k2} = 0.070$  [kN/m]

Elem.	Node-1	Node-2	N1 [kN]	V1 [kN]	M1 [kNm]	N2 [kN]	V2 [kN]	M2 [kNm]	Nm [kN]	Vm [kN]	Mm [kNm]
1	1	3	-0.12	0.33	0.00	0.00	0.00	0.28	0.00	0.00	0.28
2	3	2	0.00	0.00	0.28	0.12	-0.33	0.00	0.00	0.00	0.28

(m point of maximum span moment for permanent load, or element middle point)

Internal forces, Loading: (  $Q_{k1}$  ) Snow  $Q_{ks} = 1.120$  [kN/m]

Elem.	Node-1	Node-2	N1 [kN]	V1 [kN]	M1 [kNm]	N2 [kN]	V2 [kN]	M2 [kNm]	Nm [kN]	Vm [kN]	Mm [kNm]
1	1	3	-0.61	1.68	0.00	0.00	0.00	1.43	0.00	0.00	1.43
2	3	2	0.00	0.00	1.43	0.61	-1.68	0.00	0.00	0.00	1.43

(m point of maximum span moment for permanent load, or element middle point)

Internal forces, Loading: (  $Q_{k2}$  ) Wind  $Q_{kw} = 0.143$  [kN/m]

Elem.	Node-1	Node-2	N1 [kN]	V1 [kN]	M1 [kNm]	N2 [kN]	V2 [kN]	M2 [kNm]	Nm [kN]	Vm [kN]	Mm [kNm]
1	1	3	0.09	0.24	0.00	0.09	0.00	0.21	0.09	0.00	0.21
2	3	2	0.09	0.00	0.21	0.09	-0.24	0.00	0.09	0.00	0.21

(m point of maximum span moment for permanent load, or element middle point)

Internal forces, Loading: (  $Q_{ki}$  ) Imposed (H)  $Q_i = 0.280$  [kN/m]

Elem.	Node-1	Node-2	N1 [kN]	V1 [kN]	M1 [kNm]	N2 [kN]	V2 [kN]	M2 [kNm]	Nm [kN]	Vm [kN]	Mm [kNm]
1	1	3	-0.16	0.45	0.00	0.00	0.00	0.38	0.00	0.00	0.38
2	3	2	0.00	0.00	0.38	0.16	-0.45	0.00	0.00	0.00	0.38

(m point of maximum span moment for permanent load, or element middle point)



**7.2. Vertical nodal displacements (mm)**

Node	Gk	Qk1	Qk2	Qki
1	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00
3	-1.38	-6.98	-1.01	-1.86

**7.3. Support reactions (kN)**

Node	React.	Gk	Qk1	Qk2	Qki
1	Fx	0.00	0.00	-0.17	0.00
1	Fy	0.35	1.79	0.20	0.48
2	Fx	0.00	0.00	0.00	0.00
2	Fy	0.35	1.79	0.26	0.48

**8. Serviceability limit state**

**8.1. Serviceability limit state** (EC5 EN1995-1-1:2009, §2.2.3, §7)

Control of deflection at node 3 (EC5 §7.2)

Loading [kN/m]	u[mm]	Action	$\psi_0$	$\psi_1$	$\psi_2$	Kdef
( Gk) Dead Gk1 = 0.138, Gk2 = 0.070	-1.470	Permanent	1.00	1.00	1.00	0.80
(Qk1) Snow Qks = 1.120	-7.425	Short-term	0.50	0.20	0.00	0.00
(Qk2) Wind Qkw = 0.143	-1.072	Short-term	0.60	0.20	0.00	0.00

-

Load combination	w.inst	w.fin [mm]
1 Gk	1.470	2.645
2 Gk + Qk1	8.894	10.070
3 Gk + Qk2	2.541	3.717
4 Gk + Qk1 + $\psi_0$ .Qk2	9.538	10.713
5 Gk + Qk2 + $\psi_0$ .Qk1	6.254	7.430

-

w.fin,q=w.inst,g(1+kdef), w.fin,q=w.inst,q(1+ $\psi_2$ ·kdef) (EC5 §2.2.3, Eq.2.3, Eq.2.4)

Maximum deflection values at node 3

w.inst = 9.538 mm, w.fin = 10.713 mm

Check according to EC5 EN1995-1-1:2009 §7.2, Tab.7.2

Final deflections at node 3

w.inst = 9.538 mm < L/300=3405/300= 11.352 mm

w.net,fin = 10.713 mm < L/250=3405/250= 13.622 mm

w.fin = 10.713 mm < L/150=3405/150= 22.703 mm

The check is satisfied

**9.1. Ultimate limit state** (EC5 EN1995-1-1:2009, §6)

Rafter, elements: 1, 2

Loading [kN/m]	Action	$\gamma_g$	$\gamma_q$	$\psi_0$
( Gk) Dead Gk1 = 0.138, Gk2 = 0.070	Permanent	1.35	0.00	1.00
(Qk1) Snow Qks = 1.120	Short-term	0.00	1.50	0.50
(Qk2) Wind Qkw = 0.143	Short-term	0.00	1.50	0.60
(Qki) Imposed (H) Qi = 0.280	Short-term	0.00	1.50	0.00

L.C.	Load combination	Duration class	kmod	-N/Kmod	+N/Kmod	V/Kmod	M/Kmod
1	$\gamma_g$ .Gk	Permanent	0.60	-0.273	0.273	0.750	0.638
2	$\gamma_g$ .Gk+ $\gamma_q$ .Qk1	Short-term	0.90	-1.203	1.205	3.307	2.815
3	$\gamma_g$ .Gk+ $\gamma_q$ .Qk2	Short-term	0.90	-0.034	0.330	0.905	0.771
4	$\gamma_g$ .Gk+ $\gamma_q$ .Qki	Short-term	0.90	-0.453	0.454	1.247	1.061
5	$\gamma_g$ .Gk+ $\gamma_q$ .Qk1+ $\gamma_q$ . $\psi_0$ .Qk2	Short-term	0.90	-1.114	1.293	3.550	3.022
6	$\gamma_g$ .Gk+ $\gamma_q$ .Qk2+ $\gamma_q$ . $\psi_0$ .Qk1	Short-term	0.90	-0.545	0.841	2.309	1.965
7	$\gamma_g$ .Gk+ $\gamma_q$ .Qki+ $\gamma_q$ . $\psi_0$ .Qk1+ $\gamma_q$ . $\psi_0$ .Qk4	Short-term	0.90	-0.875	1.054	2.893	2.463
	Maximum values			-1.203	1.293	3.550	3.022

**9.2. Check of cross section Rafter, elements: 1, 2****Rafter, elements: 1, 2, Load combination No 5**

Tension parallel to the grain,  $F_{t0d}=1.164 \text{ kN}$  (EC5 §6.1.2)  
 Rectangular cross section,  $b=50 \text{ mm}$ ,  $h=200 \text{ mm}$ ,  $A=10\,000 \text{ mm}^2$   
 Modification factor  $K_{mod}=0.90$  (Tab.3.1), Material factor  $\gamma_M=1.30$  (Tab. 2.3)  
 $f_{t0k}=7.20 \text{ N/mm}^2$ ,  $f_{t0d}=K_{mod} \cdot f_{t0k} / \gamma_M = 0.90 \times 7.20 / 1.30 = 4.98 \text{ N/mm}^2$  (EC5 Eq.2.14)  
 $F_{t0d}=1.164 \text{ kN}$ ,  $\sigma_{t0d}=F_{t0d}/A_{netto}=1000 \times 1.164 / 10000 = 0.12 \text{ N/mm}^2 < 4.98 \text{ N/mm}^2 = f_{t0d}$  (Eq.6.1)  
 The check is satisfied

**Rafter, elements: 1, 2, Load combination No 2**

Compression parallel to the grain,  $F_{c0d}=-1.082 \text{ kN}$  (EC5 §6.1.4)  
 Rectangular cross section,  $b=50 \text{ mm}$ ,  $h=200 \text{ mm}$ ,  $A=10\,000 \text{ mm}^2$   
 Modification factor  $K_{mod}=0.90$  (Tab.3.1), Material factor  $\gamma_M=1.30$  (Tab. 2.3)  
 $f_{c0k}=16.00 \text{ N/mm}^2$ ,  $f_{c0d}=K_{mod} \cdot f_{c0k} / \gamma_M = 0.90 \times 16.00 / 1.30 = 11.08 \text{ N/mm}^2$  (EC5 Eq.2.14)  
 $F_{c0d}=-1.082 \text{ kN}$ ,  $\sigma_{c0d}=F_{c0d}/A_{netto}=1000 \times 1.082 / 10000 = 0.11 \text{ N/mm}^2 < 11.08 \text{ N/mm}^2 = f_{c0d}$  (Eq.6.2)  
 The check is satisfied

**Rafter, elements: 1, 2, Load combination No 5**

Shear,  $F_v=3.195 \text{ kN}$  (EC5 §6.1.7)  
 Rectangular cross section,  $b_{ef}=0.67 \times 50 = 34 \text{ mm}$ ,  $h=200 \text{ mm}$ ,  $A=6\,800 \text{ mm}^2$   
 Modification factor  $K_{mod}=0.90$  (Tab.3.1), Material factor  $\gamma_M=1.30$  (Tab. 2.3)  
 $f_{vk}=3.00 \text{ N/mm}^2$ ,  $f_{vd}=K_{mod} \cdot f_{vk} / \gamma_M = 0.90 \times 3.00 / 1.30 = 2.08 \text{ N/mm}^2$  (EC5 Eq.2.14)  
 $F_v=3.195 \text{ kN}$ ,  $\tau_{v0d}=1.50 F_{v0d} / A_{netto} = 1000 \times 1.50 \times 3.195 / 6800 = 0.70 \text{ N/mm}^2 < 2.08 \text{ N/mm}^2 = f_{vd}$  (Eq.6.13)  
 The check is satisfied

**Rafter, elements: 1, 2, Load combination No 5**

Bending,  $M_{yd}=2.720 \text{ kNm}$ ,  $M_{zd}=0.000 \text{ kNm}$  (EC5 §6.1.6)  
 Rectangular cross section,  $b=50 \text{ mm}$ ,  $h=200 \text{ mm}$ ,  $A=1.00 \times 10^4 \text{ mm}^2$ ,  $W_y=3.33 \times 10^5 \text{ mm}^3$ ,  $W_z=8.33 \times 10^4 \text{ mm}^3$   
 Modification factor  $K_{mod}=0.90$  (Tab.3.1), Material factor  $\gamma_M=1.30$  (Tab. 2.3)  
 $f_{yk}=14.00 \text{ N/mm}^2$ ,  $f_{myd}=K_{mod} \cdot f_{yk} / \gamma_M = 0.90 \times 14.00 / 1.30 = 9.69 \text{ N/mm}^2$   
 $f_{mk}=14.00 \text{ N/mm}^2$ ,  $f_{mzd}=K_{mod} \cdot f_{mk} / \gamma_M = 0.90 \times 14.00 / 1.30 = 9.69 \text{ N/mm}^2$   
 Rectangular cross section  $K_m=0.70$  (EC5 §6.1.6.(2))  
 $\sigma_{myd}=M_{yd}/W_{my,netto}=10^6 \times 2.720 / (0.3333 \times 10^6) = 8.16 \text{ N/mm}^2$   
 $\sigma_{mzd}=M_{zd}/W_{mz,netto}=10^6 \times 0.000 / (0.0833 \times 10^6) = 0.00 \text{ N/mm}^2$   
 $\sigma_{myd}/f_{myd} + K_m \cdot \sigma_{mzd}/f_{mzd} = 0.842 + 0.000 = 0.84 < 1$  (EC5 Eq.6.11)  
 $K_m \cdot \sigma_{myd}/f_{myd} + \sigma_{mzd}/f_{mzd} = 0.589 + 0.000 = 0.59 < 1$  (EC5 Eq.6.12)  
 The check is satisfied

Negligible compressive stress, combined bending-compression check is omitted (EC5 §6.2.4)

**Rafter, elements: 1, 2, Load combination No 2**

Column stability with bending,  $F_{c0d}=-1.082 \text{ kN}$ ,  $M_{yd}=2.533 \text{ kNm}$ ,  $M_{zd}=0.000 \text{ kNm}$  (EC5 §6.3.2)  
 Rectangular cross section,  $b=50 \text{ mm}$ ,  $h=200 \text{ mm}$ ,  $A=1.00 \times 10^4 \text{ mm}^2$ ,  $W_y=3.33 \times 10^5 \text{ mm}^3$ ,  $W_z=8.33 \times 10^4 \text{ mm}^3$   
 Modification factor  $K_{mod}=0.90$  (Tab.3.1), Material factor  $\gamma_M=1.30$  (Tab. 2.3,  $E_{005}=4700 \text{ MPa}$ )  
 $f_{c0k}=16.00 \text{ N/mm}^2$ ,  $f_{c0d}=K_{mod} \cdot f_{c0k} / \gamma_M = 0.90 \times 16.00 / 1.30 = 11.08 \text{ N/mm}^2$   
 $f_{yk}=14.00 \text{ N/mm}^2$ ,  $f_{myd}=K_{mod} \cdot f_{yk} / \gamma_M = 0.90 \times 14.00 / 1.30 = 9.69 \text{ N/mm}^2$   
 $f_{mk}=14.00 \text{ N/mm}^2$ ,  $f_{mzd}=K_{mod} \cdot f_{mk} / \gamma_M = 0.90 \times 14.00 / 1.30 = 9.69 \text{ N/mm}^2$

Rectangular cross section  $K_m=0.70$  (EC5 §6.1.6.(2))  
 $\sigma_{c0d}=F_{c0d}/A_{netto}=1000 \times 1.082 / 10000 = 0.11 \text{ N/mm}^2$   
 $\sigma_{myd}=M_{yd}/W_{my,netto}=10^6 \times 2.533 / (0.3333 \times 10^6) = 7.60 \text{ N/mm}^2$   
 $\sigma_{mzd}=M_{zd}/W_{mz,netto}=10^6 \times 0.000 / (0.0833 \times 10^6) = 0.00 \text{ N/mm}^2$

**Buckling length**

$S_{ky} = 1.00 \times 3.405 = 3.405 \text{ m} = 3405 \text{ mm}$  (most unfavourable)  
 $S_{kz} = 0.09 \times 3.405 = 0.300 \text{ m} = 300 \text{ mm}$  ( $L_c/L = 0.30/3.41 = 0.09$ )

**Slenderness**

$i_y = \sqrt{(I_y/A)} = 0.289 \times 200 = 58 \text{ mm}$ ,  $\lambda_y = 3405 / 58 = 58.71$   
 $i_z = \sqrt{(I_z/A)} = 0.289 \times 50 = 14 \text{ mm}$ ,  $\lambda_z = 300 / 14 = 21.43$

Critical stresses

$\sigma_{c,crity} = n^2 E 005 / \lambda y^2 = 13.46 \text{ N/mm}^2$ ,  $\lambda_{rel,y} = \sqrt{(f_{c0k} / \sigma_{c,crity})} = 1.09$  (EC5 Eq.6.21)  
 $\sigma_{c,critz} = n^2 E 005 / \lambda z^2 = 101.01 \text{ N/mm}^2$ ,  $\lambda_{rel,z} = \sqrt{(f_{c0k} / \sigma_{c,critz})} = 0.40$  (EC5 Eq.6.22)

$\beta_c = 0.20$  (solid timber)

$k_y = 0.5 [1 + \beta_c (\lambda_{rel,y} - 0.3) + \lambda_{rel,y}^2] = 1.17$ ,  $K_{cy} = 1 / (k_y + \sqrt{(k_y^2 - \lambda_{rel,y}^2)}) = 0.622$  (Eq.6.27 6.25)

$k_z = 0.5 [1 + \beta_c (\lambda_{rel,z} - 0.3) + \lambda_{rel,z}^2] = 0.59$ ,  $K_{cz} = 1 / (k_z + \sqrt{(k_z^2 - \lambda_{rel,z}^2)}) = 0.977$  (Eq.6.28 6.26)

$\sigma_{c0d} / (K_{cy} \cdot f_{c0d}) + \sigma_{myd} / f_{myd} + K_{m,c} \sigma_{mzd} / f_{mzd} = 0.016 + 0.784 + 0.000 = 0.80 < 1$  (EC5 Eq.6.23)

$\sigma_{c0d} / (K_{cz} \cdot f_{c0d}) + K_{m,c} \sigma_{myd} / f_{myd} + \sigma_{mzd} / f_{mzd} = 0.010 + 0.549 + 0.000 = 0.56 < 1$  (EC5 Eq.6.24)

The check is satisfied

Rafter, elements: 1, 2, Load combination No 5

Combined bending and axial tension,  $F_{t0d} = 1.164 \text{ kN}$ ,  $M_{yd} = 2.720 \text{ kNm}$ ,  $M_{zd} = 0.000 \text{ kNm}$  (EC5 §6.2.3)

Rectangular cross section,  $b = 50 \text{ mm}$ ,  $h = 200 \text{ mm}$ ,  $A = 1.00 \times 10^4 \text{ mm}^2$ ,  $W_y = 3.33 \times 10^5 \text{ mm}^3$ ,  $W_z = 8.33 \times 10^4 \text{ mm}^3$

Modification factor  $K_{mod} = 0.90$  (Tab.3.1), Material factor  $\gamma_M = 1.30$  (Tab. 2.3)

$f_{t0k} = 7.20 \text{ N/mm}^2$ ,  $f_{t0d} = K_{mod} \cdot f_{t0k} / \gamma_M = 0.90 \times 7.20 / 1.30 = 4.98 \text{ N/mm}^2$

$f_{myk} = 14.00 \text{ N/mm}^2$ ,  $f_{myd} = K_{mod} \cdot f_{myk} / \gamma_M = 0.90 \times 14.00 / 1.30 = 9.69 \text{ N/mm}^2$

$f_{mzk} = 14.00 \text{ N/mm}^2$ ,  $f_{mzd} = K_{mod} \cdot f_{mzk} / \gamma_M = 0.90 \times 14.00 / 1.30 = 9.69 \text{ N/mm}^2$

Rectangular cross section  $K_m = 0.70$  (EC5 §6.1.6.(2))

$\sigma_{t0d} = F_{t0d} / A_{netto} = 1000 \times 1.164 / 10000 = 0.12 \text{ N/mm}^2$

$\sigma_{myd} = M_{yd} / W_{my,netto} = 10^6 \times 2.720 / (0.3333 \times 10^6) = 8.16 \text{ N/mm}^2$

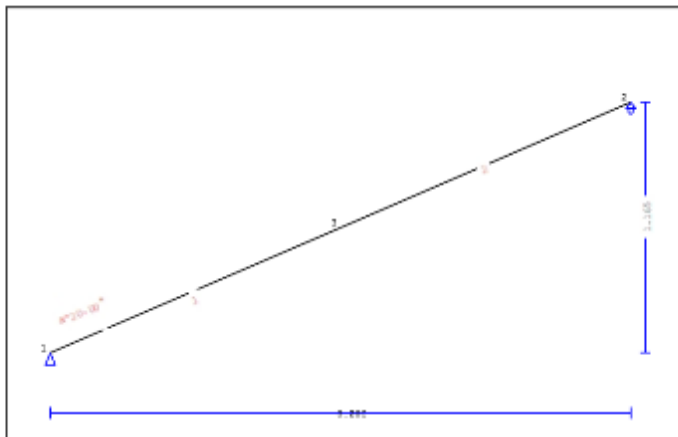
$\sigma_{mzd} = M_{zd} / W_{mz,netto} = 10^6 \times 0.000 / (0.0833 \times 10^6) = 0.00 \text{ N/mm}^2$

$\sigma_{t0d} / f_{t0d} + \sigma_{myd} / f_{myd} + K_m \sigma_{mzd} / f_{mzd} = 0.023 + 0.842 + 0.000 = 0.87 < 1$  (EC5 Eq.6.17)

$\sigma_{t0d} / f_{t0d} + K_m \sigma_{myd} / f_{myd} + \sigma_{mzd} / f_{mzd} = 0.023 + 0.589 + 0.000 = 0.61 < 1$  (EC5 Eq.6.18)

The check is satisfied

Dacă se dorește utilizarea unor secțiuni mai reduse în cazul învelitorii de tablă, ca de exemplu căpriori 5x15 cm, aceștia trebuie dispuși la un pas de 35 cm pentru a satisface verificările de rezistență și deformații (vezi breviar mai jos). În consecință, dublarea numărului total de căpriori conduce la un consum mai mare de material lemnos. Totodată, trebuie precizat că elementele de tip căpriori aduc aportul cel mai mare în consumul de material lemnos global.



2. General description, assumptions, materials, loads

2.1. Construction type

Timber roof, from beams with timber C14. The roof type as sketch above.

Span 3.200 m, height 1.165 m, roof pitch 20.00°, beam spacing 0.350m

Finishing (water) from timber C14, of thickness 25 mm

Elements, Cross section 50x150 [mm]

Beam volume -0.026 m³, beam weight -0.073 kN

**8. Serviceability limit state****8.1. Serviceability limit state** (EC5 EN1995-1-1:2009, §2.2.3, §7)**Control of deflection at node 3** (EC5 §7.2)

Loading [kN/m]	u[mm]	Action	$\psi_0$	$\psi_1$	$\psi_2$	Kdef
{ Gk} Dead Gk1 = 0.077, Gk2 = 0.035	-1.881	Permanent	1.00	1.00	1.00	0.80
{Qk1} Snow Qks = 0.560	-8.798	Short-term	0.50	0.20	0.00	0.00
{Qk2} Wind Qkw = 0.071	-1.270	Short-term	0.60	0.20	0.00	0.00

Load combination	w.inst	w.fin [mm]
1 Gk	1.881	3.385
2 Gk + Qk1	10.679	12.184
3 Gk + Qk2	3.151	4.656
4 Gk + Qk1 + $\psi_0 \cdot Qk2$	11.441	12.946
5 Gk + Qk2 + $\psi_0 \cdot Qk1$	7.550	9.055

w.fin, q-w.inst, g(1+kdef), w.fin, q-w.inst, q(1+ $\psi_2 \cdot kdef$ ) (EC5 §2.2.3, Eq.2.3, Eq.2.4)

**Maximum deflection values at node 3**

w.inst = 11.441 mm, w.fin = 12.946 mm

Check according to EC5 EN1995-1-1:2009 §7.2, Tab.7.2

**Final deflections at node 3**

w.inst = 11.441 mm < L/300=3405/300= 11.352 mm

w.net,fin = 12.946 mm < L/250=3405/250= 13.622 mm

w.fin = 12.946 mm < L/150=3405/150= 22.703 mm

The check is satisfied

**Rafter, elements: 1, 2, Load combination No 5**

Bending, Myd=1.375 kNm, Mzd=0.000 kNm (EC5 §6.1.6)

Rectangular cross section, b=50mm, h=150mm, A=7.50x10<sup>3</sup>mm<sup>2</sup>, Wy=1.88x10<sup>5</sup>mm<sup>3</sup>, Wz=6.25x10<sup>4</sup>mm<sup>3</sup>

Modification factor Kmod=0.90 (Tab.3.1), Material factor  $\gamma_M=1.30$  (Tab. 2.3)

fmyk=14.00 N/mm<sup>2</sup>, fmyd=Kmod·fmyk/ $\gamma_M=0.90 \times 14.00 / 1.30=9.69$ N/mm<sup>2</sup>

fmzk=14.00 N/mm<sup>2</sup>, fmzd=Kmod·fmzk/ $\gamma_M=0.90 \times 14.00 / 1.30=9.69$ N/mm<sup>2</sup>

Rectangular cross section Km=0.70 (EC5 §6.1.6.(2))

$\sigma_{myd} = Myd / W_{ny, netto} = 10^6 \times 1.375 / (0.1875 \times 10^6) = 7.33$  N/mm<sup>2</sup>

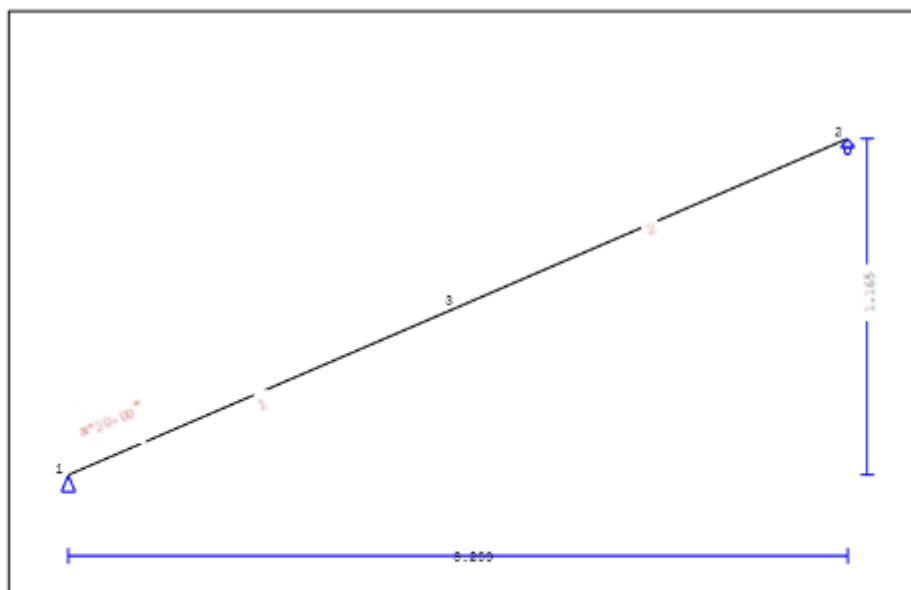
$\sigma_{mzd} = Mzd / W_{mz, netto} = 10^6 \times 0.000 / (0.0625 \times 10^6) = 0.00$  N/mm<sup>2</sup>

$\sigma_{myd} / f_{myd} + K_m \cdot \sigma_{mzd} / f_{mzd} = 0.757 + 0.000 = 0.76 < 1$  (EC5 Eq.6.11)

$K_m \cdot \sigma_{myd} / f_{myd} + \sigma_{mzd} / f_{mzd} = 0.530 + 0.000 = 0.53 < 1$  (EC5 Eq.6.12)

The check is satisfied

Pentru modelul 2 de învelitoare (țiglă metalică) utilizarea secțiunii propuse de 5x20 cm la un pas de 70 cm este echivalentă din perspectivă structurală (verificare la rezistență și deformații) cu o secțiune de 10x15 cm dispusă la pas de 70 cm (vezi breviar mai jos). În consecință, utilizarea unei secțiuni mai puțin înalte conduce la majorare însemnată a grosimii elementului pentru obținerea aceluiași performanțe structurale. Utilizarea unei secțiuni de 10x15 la pas de 70 cm conduce la un consum mai mare de material lemnos (căpriori 10x150 cm A=150 mm<sup>2</sup>, respectiv căprior 5x20 cm A=100 mm<sup>2</sup>).



**2. General description, assumptions, materials, loads**

**2.1. Construction type**

Timber roof, from beams with timber C14. The roof type as sketch above.  
 Span 3.200 m, height 1.165 m, roof pitch 20.00°, beam spacing 0.700m  
 Finishing (rafter) from timber C14, of thickness 25 mm  
 Elements , Cross section 100x150 [mm]  
 Beam volume =0.051 m³, beam weight =0.145 kN

**6. Serviceability limit state**

**6.1. Serviceability limit state** (EC5 EN1995-1-1:2005, §2.2.3, §7)

Control of deflection at node 3 (EC5 §7.2)

Loading [kN/m]	u[mm]	Action	ψ0	ψ1	ψ2	Kdef
( Gk) Dead Gk1 = 0.155, Gk2 = 0.070	-1.861	Permanent	1.00	1.00	1.00	0.60
(Qk1) Snow Qks = 1.120	-6.799	Short-term	0.50	0.20	0.00	0.00
(Qk2) wind Qkw = 0.143	-1.270	Short-term	0.60	0.20	0.00	0.00

Load combination	w.inst	w.fin [mm]
1 Gk	1.861	3.385
2 Gk + Qk1	10.679	12.184
3 Gk + Qk2	3.151	4.656
4 Gk + Qk1 + ψ0.Qk2	11.441	12.946
5 Gk + Qk2 + ψ0.Qk1	7.550	9.055

w.fin,q=w.inst,q(1+kdef), w.fin,q=w.inst,q(1+ψ2.kdef) (EC5 §2.2.3, Eq.2.3, Eq.2.4)

**Maximum deflection values at node 3**

w.inst = 11.441 mm, w.fin = 12.946 mm

**Check according to** EC5 EN1995-1-1:2005 §7.2, Tab.7.2

**Final deflections at node 3**

w.inst = 11.441 mm <= L/300=3405/300= 11.352 mm

w.net,fin = 12.946 mm < L/250=3405/250= 13.622 mm

w.fin = 12.946 mm < L/150=3405/150= 22.703 mm

The check is satisfied

**Rafter, elements: 1, 2, Load combination No 5**Bending,  $M_{yd}=2.750 \text{ kNm}$ ,  $M_{zd}=0.000 \text{ kNm}$  (EC5 §6.1.6)Rectangular cross section,  $b=100\text{mm}$ ,  $h=150\text{mm}$ ,  $A=1.50 \times 10^4 \text{ mm}^2$ ,  $W_y=3.75 \times 10^5 \text{ mm}^3$ ,  $W_z=2.50 \times 10^5 \text{ mm}^3$ Modification factor  $K_{mod}=0.90$  (Tab.3.1), Material factor  $\gamma_M=1.30$  (Tab. 2.3) $f_{myk}=14.00 \text{ N/mm}^2$ ,  $f_{myd}=K_{mod} \cdot f_{myk} / \gamma_M = 0.90 \times 14.00 / 1.30 = 9.69 \text{ N/mm}^2$  $f_{mzk}=14.00 \text{ N/mm}^2$ ,  $f_{mzd}=K_{mod} \cdot f_{mzk} / \gamma_M = 0.90 \times 14.00 / 1.30 = 9.69 \text{ N/mm}^2$ Rectangular cross section  $K_m=0.70$  (EC5 §6.1.6.(2)) $\sigma_{myd} = M_{yd} / W_{my,netto} = 10^6 \times 2.750 / (0.3750 \times 10^6) = 7.33 \text{ N/mm}^2$  $\sigma_{mzd} = M_{zd} / W_{mz,netto} = 10^6 \times 0.000 / (0.2500 \times 10^6) = 0.00 \text{ N/mm}^2$  $\sigma_{myd} / f_{myd} + K_m \cdot \sigma_{mzd} / f_{mzd} = 0.757 + 0.000 = 0.76 < 1$  (EC5 Eq.6.11) $K_m \cdot \sigma_{myd} / f_{myd} + \sigma_{mzd} / f_{mzd} = 0.530 + 0.000 = 0.53 < 1$  (EC5 Eq.6.12)

The check is satisfied

În concluzie, varianta optimă privind secțiunea căpriorilor dispuși pentru varianta cu învelitoare ușoară de tip țiglă metalică este cu căpriori de 5x20 cm dispuși la pas de 70 cm.

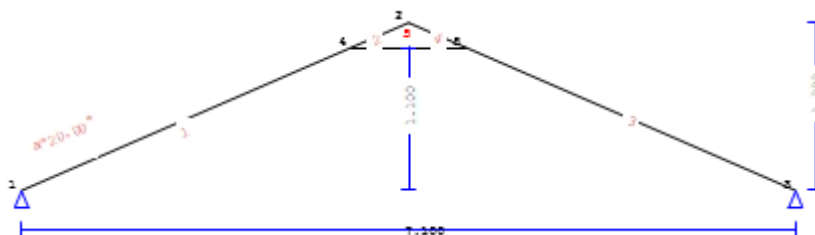
**Clești:**

În urma calculelor efectuate rezultă secțiunea cleștilor de 2 buc x 2.5x15 cm dispuși la o distanță de 75 cm interax în cazul modelului 1 cu învelitoare Țiglă romană, respectiv 85cm interax în cazul celui de al doilea model cu învelitoare din țiglă metalică. Cleștii vor fi dispuși deasupra zonei de garaj.

- i. Clești 2x2.5x15 cm – **Model 1 – Învelitoare Țiglă romană** – distanță 75cm interax

**1. ROOF -002**

Trussed rafter roof type A

**2. General description, assumptions, materials, loads****2.1. Construction type**

Timber roof, from trusses with timber C14. The truss type as sketch above.

Truss span 7.100 m, height 1.292 m, roof pitch 20.00°, truss spacing 0.750m

Finishing (rafter) from timber C14, of thickness 25 mm

Truss element cross sections BxH [mm]

Elements 1, 2, 3, 4, Cross section 50x150 [mm]

Elements 5, Cross section 50x150 [mm]

Truss volume =0.065 m<sup>3</sup>, truss weight =0.184 kN**2.2. Design codes**

EN1990:2002, Eurocode 0 Part 1-1, Basis of structural design

EN1991-1-1:2002, Eurocode 1 Part 1-1, Actions on structures

EN1991-1-3:2003, Eurocode 1 Part 1-3, Snow loads

EN1991-1-4:2005, Eurocode 1 Part 1-4, Wind actions

EN1995-1-1:2009, Eurocode 5 Part 1-1, Design of timber structures

**2.3. Design methodology**

The internal forces of the roof trusses are computed with finite element analysis. The truss is considered as a two dimensional frame. The stiffness of the connections is adjusted according to the selected degree of stiffness. In order to compute the design values for internal forces in various loading conditions, the internal forces are first computed in unit loading, and then from their combination the internal forces in various loading conditions are obtained. All the load combinations according to Eurocode 1 and Eurocode 5 are taken into account, and the checks are performed in the most unfavourable loading conditions, for combined action, in ultimate limit state, according to EC5 EN1995-1-1:2009, §6. The connections are designed as screwed connections with metal plates according to EC5 EN1995-1-1:2009, §8. The deflections are checked in serviceability limit condition, according to EC5 EN1995-1-1:2009, §7.

**2.4. Material properties (truss) (EC5 EN1995-1-1:2009, §3)**

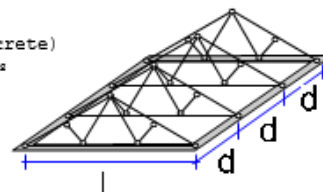
Timber class : C14  
 Service classes : Class 2, moisture content ≤ 20% (EC5 §2.3.1.3)  
 Material factor  $\gamma_M = 1.30$  (EC5 Tab. 2.3)  
**Characteristic material properties for timber**  
 $f_{mk} = 14.0$  MPa,  $f_{t0k} = 7.2$  MPa,  $f_{t90k} = 0.4$  MPa  
 $f_{c0k} = 16.0$  MPa,  $f_{c90k} = 2.0$  MPa,  $f_{vk} = 3.0$  MPa  
 $E_{0m} = 7000$  MPa,  $E_{005} = 4700$  MPa,  $E_{90m} = 230$  MPa  
 $G_m = 440$  MPa,  $\rho_k = 290$  Kg/m<sup>3</sup>,  $\rho_m = 350$  Kg/m<sup>3</sup>

**2.5. Material properties (timber, finishing) (EC5 EN1995-1-1:2009, §3)**

Timber class : C14  
 Service classes : Class 2, moisture content ≤ 20% (EC5 §2.3.1.3)  
 Material factor  $\gamma_M = 1.30$  (EC5 Tab. 2.3)  
**Characteristic material properties for timber**  
 $f_{mk} = 14.0$  MPa,  $f_{t0k} = 7.2$  MPa,  $f_{t90k} = 0.4$  MPa  
 $f_{c0k} = 16.0$  MPa,  $f_{c90k} = 2.0$  MPa,  $f_{vk} = 3.0$  MPa  
 $E_{0m} = 7000$  MPa,  $E_{005} = 4700$  MPa,  $E_{90m} = 230$  MPa  
 $G_m = 440$  MPa,  $\rho_k = 290$  Kg/m<sup>3</sup>,  $\rho_m = 350$  Kg/m<sup>3</sup>

**2.6. Distributed roof loads**

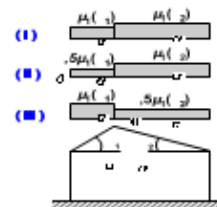
Permanent load of roof covering	$G_e = 0.500$ kN/m <sup>2</sup>	(Tiles from concrete)
Purlins, finishing, insulation	$G_t = 0.100$ kN/m <sup>2</sup>	$G_e + G_t = 0.600$ kN/m <sup>2</sup>
Load of ceiling under the roof	$G_c = 0.100$ kN/m <sup>2</sup>	
Snow load on the ground	$S_k = 2.000$ kN/m <sup>2</sup>	
Wind pressure on vertical surface	$Q_w = 0.765$ kN/m <sup>2</sup>	
Imposed load (category H)	$Q_i = 0.400$ kN/m <sup>2</sup>	



**3. Snow load (EC1 EN1991-1-3:2003 §5)**

**Snow load on the ground  $S_k$  (EC1 EN1991-1-3:2003 §4, Annex C)**  
 Climatic Region : Alpine Region, snow zone : 2, altitude above sea level = 500 m  
 $S_k = (0.642x^2 + 0.009)x[1 + (500/728)^2] = 1.903$  kN/m<sup>2</sup>  
 Characteristic value of snow load on the ground:  $s_k = 2.000$  kN/m<sup>2</sup>

**Snow load on the roof (EC1 EN1991-1-3:2003 §5)**  
 Angle of pitch of roof :  $\alpha = 19.999^\circ$   
 Exposure coefficient :  $C_e = 1.000$  (EC1-1-3 §5.2(7))  
 Thermal coefficient :  $C_t = 1.000$  (EC1-1-3 §5.2(8))  
 Shape coefficients,  $\alpha_1 = \alpha_2 = 20.00^\circ$ ,  $\mu_1(\alpha_1) = \mu_1(\alpha_2) = 0.800$  (Table 5.2)  
 $S(\alpha_1) = \mu_1(\alpha_1) \cdot C_e \cdot C_t \cdot S_k = 0.800 \times 1.00 \times 1.00 \times 2.000 = 1.600$  kN/m<sup>2</sup> (§5.2)  
 $S(\alpha_2) = \mu_1(\alpha_2) \cdot C_e \cdot C_t \cdot S_k = 0.800 \times 1.00 \times 1.00 \times 2.000 = 1.600$  kN/m<sup>2</sup>



**Snow load (EC1 EN1991-1-3:2003 §5.3.3)**

Load case (I)	, $S(\text{Left}) = S(\alpha_1) = 1.600$ kN/m <sup>2</sup> ,	$S(\text{Right}) = S(\alpha_2) = 1.600$ kN/m <sup>2</sup>
Load case (II)	, $S(\text{Left}) = 0.5 \times S(\alpha_1) = 0.800$ kN/m <sup>2</sup> ,	$S(\text{Right}) = S(\alpha_2) = 1.600$ kN/m <sup>2</sup>
Load case (III)	, $S(\text{Left}) = S(\alpha_1) = 1.600$ kN/m <sup>2</sup> ,	$S(\text{Right}) = 0.5 \times S(\alpha_2) = 0.800$ kN/m <sup>2</sup>

**4. Wind loading** (EC1 EN1991-1-4:2005 §5)

$v_{bo}=31.00$  m/s, Romania SR, Zona: 3 ,  $v_b=C_{dir} \cdot C_{season} \cdot V_{bo} = 31.00$  m/s  
 Terrain category: IV,  $z=10.000$ m,  $z_o=1.000$ m,  $z_{min}=10$ m,  $z_{max}=200$ m,  $z_{oII}=0.050$ m  
 $k_r=0.19 \cdot (1.000/0.05)^{0.07}=0.234$   
 Roughness factor  $C_r(z)=k_r \cdot \ln(z/z_o)=0.234 \times \ln(10.000/1.000)=0.540$  (EN1991-1-4, Tab.A.2)  
 $H/L_u=50/600=0.08$ ,  $0.05 < H/L_u=0.08 < 0.30$ ,  $L_e=600.00$  m (eq.A.7, ...A.10)  
 $z=10.00$  m,  $X/L_e=500/600=0.83$ ,  $z/L_e=10/600=0.10$ ,  $s=0.396$  (eq.A.2)  
 Orography factor  $C_o(z)=1+2 \times 0.396 \times 0.083=1.066$   
 Turbulence factor  $K_t=1.000$   
 Exposure factor  $C_e(z)=1.274$  (EN1991-1-4, §4.5)  
 $q(z)=C_e(z) \cdot (k_p) \cdot V_b^2=[0.001] \times 1.274 \times 0.625 \times 31.00^2=0.765$  kN/m<sup>2</sup>

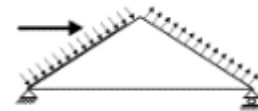
Wind pressure on roof  $w_e=Q_{ref} \cdot C_e(z) \cdot C_{pe}$  (EC1 EN1991-1-4:2005, §5.2)

External pressure coefficients (EC1 EN1991-1-4:2005 Table 7.4)

For pitch angle  $\alpha=20.00^\circ$ ,  $C_{pe}(+)=0.32$ ,  $C_{pe}(-)=-0.57$

Wind pressure  $w_e(\text{Left}) = 0.242$  kN/m<sup>2</sup>

Wind pressure  $w_e(\text{Right}) = -0.434$  kN/m<sup>2</sup>



**5. Roof timber finishing (rafter)**

Timber finishing (rafter) structural system

The timber finishing (rafter) is designed as simply supported beam with span

Spacing of trusses  $L=0.750$ m, and width  $1.00$ m

Dimensions of timber finishing (rafter)

Timber of finishing (rafter): C14, service class: Class 2, moisture content  $\leq 20\%$

Spacing of trusses  $L=0.750$ m, roof pitch  $\alpha=20.00^\circ$ , thickness of finishing  $25$ mm

Loading on timber finishing (rafter)

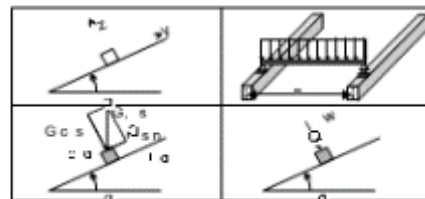
Roof covering  $G_e=0.500$  kN/m<sup>2</sup>

Self weight  $G_l=0.071$  kN/m<sup>2</sup>

Snow load  $Q_s=1.600$  kN/m<sup>2</sup>

Wind load  $Q_w=0.242$  kN/m<sup>2</sup>

Concentrated  $Q_p=1.000$  kN



Internal forces of timber finishing (span  $L=0.750$  m, width  $=1.00$  m)

Loading	Action	$\gamma_g$	$\gamma_q$	$\psi_0$	$\max N$ [kN]	$\max Q$ [kN]	$\max M$ [kNm]	
(Gk) Permanent	$G_k=0.571$ [kN/m]	Permanent	1.35	0.00	1.00	0.000	0.201	0.038
(Qk1) Snow	$Q_{ks}=1.600$ [kN/m]	Short-term	0.00	1.50	0.50	0.000	0.530	0.099
(Qk2) Wind	$Q_{kw}=0.242$ [kN/m]	Short-term	0.00	1.50	0.60	0.000	0.091	0.017
(Qk3) Concentrated	$Q_{kp}=1.000$ [kN]	Instantaneous	0.00	1.00	0.00	0.000	0.470	0.321



**5.1. Serviceability limit state** (EC5 EN1995-1-1:2009, §2.2.3, §7)

Control of deflection (EC5 §7.2)

Loading	[kN/m]		u [mm]	Action	$\psi_0$	$\psi_1$	$\psi_2$	Kdef
(Gk)	Permanent	Gk = 0.000 [kN/m]	0.101	Permanent	1.00	1.00	1.00	0.80
(Qk1)	Snow	Qks = 0.000 [kN/m]	0.265	Short-term	0.50	0.20	0.00	0.80
(Qk2)	Wind	Qkw = 0.000 [kN/m]	0.045	Short-term	0.60	0.20	0.00	0.80

-

Load combination	w.inst	w.fin [mm]
1 Gk	0.101	0.181
2 Gk + Qk1	0.366	0.446
3 Gk + Qk2	0.146	0.227
4 Gk + Qk1 + $\psi_0 \cdot Qk2$	0.393	0.474
5 Gk + Qk2 + $\psi_0 \cdot Qk1$	0.279	0.359

w.fin,q = w.inst, g(1+kdef), w.fin,q = w.inst, q(1+ $\psi_2 \cdot kdef$ ) (EC5 §2.2.3, Eq.2.3, Eq.2.4)

**Maximum deflection values**

w.inst = 0.393 mm, w.fin = 0.474 mm

Check according to EC5 EN1995-1-1:2009 §7.2, Tab.7.2

**Final deflections**

w.inst = 0.393 mm < L/300 = 750/300 = 2.500 mm

w.net,fin = 0.474 mm < L/250 = 750/250 = 3.000 mm

w.fin = 0.474 mm < L/150 = 750/150 = 5.000 mm

The check is satisfied

**5.2. Check of finishing, Ultimate limit state of design** (EC5 EN1995-1-1:2009, §6)

L.C.	Load combination	Duration class	kmod	N/Kmod	V/Kmod	M/Kmod
1	$\gamma_g \cdot G_k$	Permanent	0.60	0.000	0.453	0.085
2	$\gamma_g \cdot G_k + \gamma_q \cdot Q_{k1}$	Short-term	0.90	0.000	1.185	0.222
3	$\gamma_g \cdot G_k + \gamma_q \cdot Q_{k2}$	Short-term	0.90	0.000	0.453	0.085
4	$\gamma_g \cdot G_k + \gamma_q \cdot Q_{k3}$	Instantaneous	1.10	0.000	0.674	0.338
5	$\gamma_g \cdot G_k + \gamma_q \cdot Q_{k1} + \gamma_q \cdot \psi_0 \cdot Q_{k2}$	Short-term	0.90	0.000	1.276	0.239
6	$\gamma_g \cdot G_k + \gamma_q \cdot Q_{k2} + \gamma_q \cdot \psi_0 \cdot Q_{k1}$	Short-term	0.90	0.000	0.895	0.168
	Maximum values		0.000	1.276	0.338	

-

**Finishing, Load combination No 5**

Shear, Fv = 1.148 kN (EC5 §6.1.7)

Rectangular cross section, bef = 0.67 x 1000 = 670 mm, h = 25 mm, A = 16 750 mm<sup>2</sup>

Modification factor Kmod = 0.90 (Tab.3.1), Material factor  $\gamma_M = 1.30$  (Tab. 2.3)

fvk = 3.00 N/mm<sup>2</sup>, fvd = Kmod · fvk /  $\gamma_M = 0.90 \times 3.00 / 1.30 = 2.08 \text{ N/mm}^2$  (EC5 Eq.2.14)

Fv = 1.148 kN,  $v_{0d} = 1.50 F_{v0d} / A_{netto} = 1000 \times 1.148 / 16750 = 0.10 \text{ N/mm}^2 < 2.08 \text{ N/mm}^2 = f_{v0d}$  (Eq. 6.13)

The check is satisfied

**Finishing, Load combination No 4**

Bending, Myd = 0.372 kNm, Mzd = 0.000 kNm (EC5 §6.1.6)

Rectangular cross section, b = 1000 mm, h = 25 mm, A = 2.50 x 10<sup>4</sup> mm<sup>2</sup>, Wy = 1.04 x 10<sup>5</sup> mm<sup>3</sup>, Wz = 4.17 x 10<sup>6</sup> mm<sup>3</sup>

Modification factor Kmod = 1.10 (Tab.3.1), Material factor  $\gamma_M = 1.30$  (Tab. 2.3)

fmyk = 14.00 N/mm<sup>2</sup>, fmyd = Kmod · fmyk /  $\gamma_M = 1.10 \times 14.00 / 1.30 = 11.85 \text{ N/mm}^2$

fmzk = 14.00 N/mm<sup>2</sup>, fmzd = Kmod · fmzk /  $\gamma_M = 1.10 \times 14.00 / 1.30 = 11.85 \text{ N/mm}^2$

Rectangular cross section Km = 0.70 (EC5 §6.1.6.(2))

cmzd = Myd / Wmy, netto = 10<sup>6</sup> x 0.372 / (0.1042 x 10<sup>5</sup>) = 3.57 N/mm<sup>2</sup>

cmzd = Mzd / Wmz, netto = 10<sup>6</sup> x 0.000 / (4.1667 x 10<sup>6</sup>) = 0.00 N/mm<sup>2</sup>

cmzd / fmyd + Km · cmzd / fmzd = 0.302 + 0.000 = 0.30 < 1 (EC5 Eq.6.11)

Km · cmzd / fmyd + cmzd / fmzd = 0.211 + 0.000 = 0.21 < 1 (EC5 Eq.6.12)

The check is satisfied

**6. Truss design**

**Truss geometric characteristics**

Length L=7.100 m, height H=1.292 m, truss spacing d=0.750 m  
 Pitch =36.39%, angle  $\alpha=20.00^\circ$ ,  $\tan\alpha=0.364$ ,  $\sin\alpha=0.342$ ,  $\cos\alpha=0.940$   
 Number of nodes = 5, number of elements =5, supports 2

Nodal coordinates				Truss element properties								
Node	x[m]	y[m]	Sup.	Element	K1	K2	bxh[mm]	L[m]	A[mm <sup>2</sup> ]	<sup>2)</sup> Iy[mm <sup>4</sup> ]	<sup>4)</sup> Wy[mm <sup>3</sup> ]	<sup>5)</sup>
1	0.000	0.000	11	1	1	4	50x150	3.216	7500	14.063x10 <sup>6</sup>	6	1.875x10 <sup>5</sup>
2	3.550	1.292		2	4	2	50x150	0.561	7500	14.063x10 <sup>6</sup>	6	1.875x10 <sup>5</sup>
3	7.100	0.000	11	3	5	3	50x150	3.216	7500	14.063x10 <sup>6</sup>	6	1.875x10 <sup>5</sup>
4	3.022	1.100		4	2	5	50x150	0.561	7500	14.063x10 <sup>6</sup>	6	1.875x10 <sup>5</sup>
5	4.078	1.100		5	4	5	50x150	1.055	7500	14.063x10 <sup>6</sup>	6	1.875x10 <sup>5</sup>

**Line loads per truss**

Timber density =290.00 kg/m<sup>3</sup>, truss self weight =0.184 kN  
 Truss spacing d=0.75 m, weight of truss connections =0.018 kN

**Permanent line loads (kN/m) on truss**

Roof covering+self weight Gk1= 0.478 kN/m  
 Ceiling under roof Gk2= 0.075 kN/m

**Variable line loads of short term action (kN/m) on truss**

Imposed Qki= 0.40x0.750= 0.300 kN/m  
 Snow (Left ) Qk1l= 1.200 kN/m (Right ) Qk1r= 1.200 kN/m  
 Snow (Left ) Qk2l= 0.600 kN/m (Right ) Qk2r= 1.200 kN/m  
 Snow (Left ) Qk3l= 1.200 kN/m (Right ) Qk3r= 0.600 kN/m  
 Wind (Left ) Qk4l= 0.182 kN/m (Right ) Qk4r= -0.325 kN/m  
 Wind (Left ) Qk5l= -0.325 kN/m (Right ) Qk5r= 0.182 kN/m

**Design load combinations**

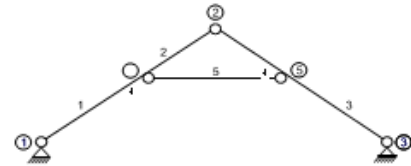
( $\gamma_g=1.35$ ,  $\gamma_q=1.50$ ,  $\psi_0(\text{Live Qf})=0.70$ ,  $\psi_0(\text{Snow Q1,Q2,Q3})=0.50$ ,  $\psi_0(\text{Wind Q4,Q5})=0.60$ )

L.C. Actions Permanent-Variable Duration class

1	$\gamma_g \cdot G_k$	Permanent
2	$\gamma_g \cdot G_k + \gamma_q \cdot Q_{k1}$	Short-term
3	$\gamma_g \cdot G_k + \gamma_q \cdot Q_{k2}$	Short-term
4	$\gamma_g \cdot G_k + \gamma_q \cdot Q_{k3}$	Short-term
5	$\gamma_g \cdot G_k + \gamma_q \cdot Q_{k4}$	Short-term
6	$\gamma_g \cdot G_k + \gamma_q \cdot Q_{k5}$	Short-term
7	$\gamma_g \cdot G_k + \gamma_q \cdot Q_{ki}$	Short-term
8	$\gamma_g \cdot G_k + \gamma_q \cdot Q_{k1} + \gamma_q \cdot \psi_0 \cdot Q_{k4}$	Short-term
9	$\gamma_g \cdot G_k + \gamma_q \cdot Q_{k1} + \gamma_q \cdot \psi_0 \cdot Q_{k5}$	Short-term
10	$\gamma_g \cdot G_k + \gamma_q \cdot Q_{k2} + \gamma_q \cdot \psi_0 \cdot Q_{k4}$	Short-term
11	$\gamma_g \cdot G_k + \gamma_q \cdot Q_{k2} + \gamma_q \cdot \psi_0 \cdot Q_{k5}$	Short-term
12	$\gamma_g \cdot G_k + \gamma_q \cdot Q_{k3} + \gamma_q \cdot \psi_0 \cdot Q_{k4}$	Short-term
13	$\gamma_g \cdot G_k + \gamma_q \cdot Q_{k3} + \gamma_q \cdot \psi_0 \cdot Q_{k5}$	Short-term
14	$\gamma_g \cdot G_k + \gamma_q \cdot Q_{k4} + \gamma_q \cdot \psi_0 \cdot Q_{k1}$	Short-term
15	$\gamma_g \cdot G_k + \gamma_q \cdot Q_{k4} + \gamma_q \cdot \psi_0 \cdot Q_{k2}$	Short-term
16	$\gamma_g \cdot G_k + \gamma_q \cdot Q_{k4} + \gamma_q \cdot \psi_0 \cdot Q_{k3}$	Short-term
17	$\gamma_g \cdot G_k + \gamma_q \cdot Q_{k5} + \gamma_q \cdot \psi_0 \cdot Q_{k1}$	Short-term
18	$\gamma_g \cdot G_k + \gamma_q \cdot Q_{k5} + \gamma_q \cdot \psi_0 \cdot Q_{k2}$	Short-term
19	$\gamma_g \cdot G_k + \gamma_q \cdot Q_{k5} + \gamma_q \cdot \psi_0 \cdot Q_{k3}$	Short-term
20	$\gamma_g \cdot G_k + \gamma_q \cdot Q_{ki} + \gamma_q \cdot \psi_0 \cdot Q_{k1} + \gamma_q \cdot \psi_0 \cdot Q_{k4}$	Short-term
21	$\gamma_g \cdot G_k + \gamma_q \cdot Q_{ki} + \gamma_q \cdot \psi_0 \cdot Q_{k1} + \gamma_q \cdot \psi_0 \cdot Q_{k5}$	Short-term
22	$\gamma_g \cdot G_k + \gamma_q \cdot Q_{ki} + \gamma_q \cdot \psi_0 \cdot Q_{k2} + \gamma_q \cdot \psi_0 \cdot Q_{k4}$	Short-term
23	$\gamma_g \cdot G_k + \gamma_q \cdot Q_{ki} + \gamma_q \cdot \psi_0 \cdot Q_{k2} + \gamma_q \cdot \psi_0 \cdot Q_{k5}$	Short-term
24	$\gamma_g \cdot G_k + \gamma_q \cdot Q_{ki} + \gamma_q \cdot \psi_0 \cdot Q_{k3} + \gamma_q \cdot \psi_0 \cdot Q_{k4}$	Short-term
25	$\gamma_g \cdot G_k + \gamma_q \cdot Q_{ki} + \gamma_q \cdot \psi_0 \cdot Q_{k3} + \gamma_q \cdot \psi_0 \cdot Q_{k5}$	Short-term

**7. Truss static analysis**

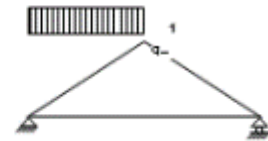
Design for connections with reduced stiffness (factor 0.20)  
 The truss is designed as frame structure (EN1995-1-1 §5.4.1)  
 with reduced connection stiffness according to the above factor  
 The rafter and the tie are considered as continuous elements.  
 The truss is first solved for various unit load conditions,  
 and from them are computed the internal forces  
 for the various loading conditions and load combinations.  
 Number of nodes = 5, number of elements =5, supports 2



**7.1. Static solutions for unit loads**

Internal forces for unit loading (1 kN/m left rafter downwards)

Elem.	Node-1	Node-2	N1[kN]	V1[kN]	M1[kNm]	N2[kN]	V2[kN]	M2[kNm]
1	1	4	-3.92	1.41	0.00	-2.89	-1.43	-0.04
2	4	2	1.93	0.32	-0.04	2.11	-0.17	0.00
3	5	3	-3.31	0.26	-0.84	-3.31	0.26	0.00
4	2	5	1.51	-1.49	-0.01	1.51	-1.49	-0.84
5	4	5	-5.13	0.00	0.00	-5.13	0.00	0.00



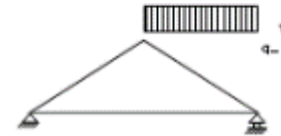
Element end forces for unit loading (1 kN/m left rafter downwards)

Elem.	Node-1	Node-2	F1x[kN]	F1y[kN]	M1[kNm]	F2x[kN]	F2y[kN]	M2[kNm]
1	1	4	3.20	2.66	0.00	-3.20	0.36	0.04
2	4	2	-1.93	-0.36	-0.04	1.93	0.89	0.00
3	5	3	3.20	-0.89	-0.84	-3.20	0.89	0.00
4	2	5	-1.93	-0.89	-0.01	1.93	0.89	0.84
5	4	5	5.13	0.00	0.00	-5.13	0.00	0.00

(element end forces in global coordinate system x-y)

Internal forces for unit loading (1 kN/m right rafter downwards)

Elem.	Node-1	Node-2	N1[kN]	V1[kN]	M1[kNm]	N2[kN]	V2[kN]	M2[kNm]
1	1	4	-3.31	-0.26	0.00	-3.31	-0.26	-0.84
2	4	2	1.51	1.49	-0.84	1.51	1.49	-0.01
3	5	3	-2.89	1.43	-0.04	-3.92	-1.41	0.00
4	2	5	2.11	0.17	0.00	1.93	-0.32	-0.04
5	4	5	-5.13	0.00	0.00	-5.13	0.00	0.00



Element end forces for unit loading (1 kN/m right rafter downwards)

Elem.	Node-1	Node-2	F1x[kN]	F1y[kN]	M1[kNm]	F2x[kN]	F2y[kN]	M2[kNm]
1	1	4	3.20	0.89	0.00	-3.20	-0.89	0.84
2	4	2	-1.93	0.89	-0.84	1.93	-0.89	0.01
3	5	3	3.20	0.36	-0.04	-3.20	2.66	0.00
4	2	5	-1.93	0.89	0.00	1.93	-0.36	0.04
5	4	5	5.13	0.00	0.00	-5.13	0.00	0.00

(element end forces in global coordinate system x-y)

Internal forces for unit loading (1 kN/m tie downwards)

Elem.	Node-1	Node-2	N1[kN]	V1[kN]	M1[kNm]	N2[kN]	V2[kN]	M2[kNm]
1	1	4	-1.53	0.00	0.00	-1.53	0.00	0.01
2	4	2	-0.07	-0.03	0.02	-0.07	-0.03	0.00
3	5	3	-1.53	0.00	0.01	-1.53	0.00	0.00
4	2	5	-0.07	0.03	0.00	-0.07	0.03	0.02
5	4	5	-1.36	0.53	0.00	-1.36	-0.53	0.00



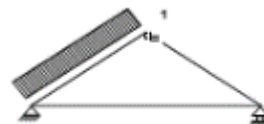
**Element end forces for unit loading (1 kN/m tie downwards)**

Elem.	Node-1	Node-2	F1x[kN]	F1y[kN]	M1[kNm]	F2x[kN]	F2y[kN]	M2[kNm]
1	1	4	1.44	0.53	0.00	-1.44	-0.53	-0.01
2	4	2	0.08	0.00	0.02	-0.08	0.00	0.00
3	5	3	1.44	-0.53	0.01	-1.44	0.53	0.00
4	2	5	0.08	0.00	0.00	-0.08	0.00	-0.02
5	4	5	1.36	0.53	0.00	-1.36	0.53	0.00

—  
(element end forces in global coordinate system x-y)

**Internal forces for unit loading (1 kN/m left rafter pressure)**

Elem.	Node-1	Node-2	N1[kN]	V1[kN]	M1[kNm]	N2[kN]	V2[kN]	M2[kNm]
1	1	4	-3.07	1.59	0.00	-3.07	-1.62	-0.05
2	4	2	2.40	0.37	-0.05	2.40	-0.19	0.00
3	5	3	-3.75	0.30	-0.96	-3.75	0.30	0.00
4	2	5	1.72	-1.69	-0.01	1.72	-1.69	-0.96
5	4	5	-5.82	0.00	0.00	-5.82	0.00	0.00



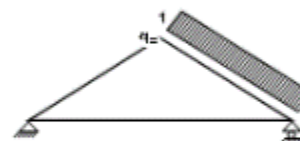
**Element end forces for unit loading (1 kN/m left rafter pressure)**

Elem.	Node-1	Node-2	F1x[kN]	F1y[kN]	M1[kNm]	F2x[kN]	F2y[kN]	M2[kNm]
1	1	4	2.34	2.55	0.00	-3.44	0.48	0.05
2	4	2	-2.38	-0.48	-0.05	2.19	1.00	0.00
3	5	3	3.63	-1.00	-0.96	-3.63	1.00	0.00
4	2	5	-2.19	-1.00	-0.01	2.19	1.00	0.96
5	4	5	5.82	0.00	0.00	-5.82	0.00	0.00

—  
(element end forces in global coordinate system x-y)

**Internal forces for unit loading (1 kN/m right rafter pressure)**

Elem.	Node-1	Node-2	N1[kN]	V1[kN]	M1[kNm]	N2[kN]	V2[kN]	M2[kNm]
1	1	4	-3.75	-0.30	0.00	-3.75	-0.30	-0.96
2	4	2	1.72	1.69	-0.96	1.72	1.69	-0.01
3	5	3	-3.07	1.62	-0.05	-3.07	-1.59	0.00
4	2	5	2.40	0.19	0.00	2.40	-0.37	-0.05
5	4	5	-5.82	0.00	0.00	-5.82	0.00	0.00



**Element end forces for unit loading (1 kN/m right rafter pressure)**

Elem.	Node-1	Node-2	F1x[kN]	F1y[kN]	M1[kNm]	F2x[kN]	F2y[kN]	M2[kNm]
1	1	4	3.63	1.00	0.00	-3.63	-1.00	0.96
2	4	2	-2.19	1.00	-0.96	2.19	-1.00	0.01
3	5	3	3.44	0.48	-0.05	-2.34	2.55	0.00
4	2	5	-2.19	1.00	0.00	2.38	-0.48	0.05
5	4	5	5.82	0.00	0.00	-5.82	0.00	0.00

—  
(element end forces in global coordinate system x-y)

**7.2. Internal forces for applied loads**

Internal forces, Loading: ( Gk) Dead Gk1 = 0.478, Gk2 = 0.075 [kN/m]

Elem.	Node-1	Node-2	N1[kN]	V1[kN]	M1[kNm]	N2[kN]	V2[kN]	M2[kNm]	Nm[kN]	Vm[kN]	Mm[kNm]
1	1	4	-3.80	0.58	0.00	-3.27	-0.86	-0.45	-3.59	0.00	0.38
2	4	2	1.75	0.92	-0.45	1.84	0.67	0.00	1.79	0.80	-0.21
3	5	3	-3.27	0.86	-0.45	-3.80	-0.58	0.00	-3.59	0.00	0.38
4	2	5	1.84	-0.67	0.00	1.75	-0.92	-0.45	1.79	-0.80	-0.21
5	4	5	-5.33	0.04	0.00	-5.33	-0.04	0.00	-5.33	0.04	0.02

—  
(m point of maximum span moment for permanent load, or element middle point)

**GADO CONS CONSTRUCT S.R.L.**

STUDIU TEHNIC PRIVIND EFICIENȚA ECONOMICĂ A UTILIZĂRII ÎNVELITORILOR DE TIP BRAMAC PRIN  
ANALIZA INFLUENȚELOR STRUCTURALE GENERATE DE TIPUL DE ÎNVELITOARE ASUPRA SISTEMULUI  
STRUCTURAL AL UNEI CLĂDIRI CU REGIM DE ÎNĂLȚIME P+M

**STUDIU  
TEHNIC**

Internal forces, Loading: (Qk1) Snow Q<sub>ksL</sub>= 1.200, Q<sub>ksR</sub>= 1.200 [kN/m]

Elem.	Node-1	Node-2	N1 [kN]	V1 [kN]	M1 [kNm]	N2 [kN]	V2 [kN]	M2 [kNm]	Nm [kN]	Vm [kN]	Mm [kNm]
1	1	4	-8.68	1.37	0.00	-7.44	-2.03	-1.06	-8.18	0.00	0.89
2	4	2	4.13	2.18	-1.06	4.35	1.58	0.00	4.24	1.88	-0.49
3	5	3	-7.44	2.03	-1.06	-8.68	-1.37	0.00	-8.18	0.00	0.89
4	2	5	4.35	-1.58	0.00	4.13	-2.18	-1.06	4.24	-1.88	-0.49
5	4	5	-12.31	0.00	0.00	-12.31	0.00	0.00	-12.31	0.00	0.00

(m point of maximum span moment for permanent load, or element middle point)

Internal forces, Loading: (Qk2) Snow Q<sub>ksL</sub>= 0.600, Q<sub>ksR</sub>= 1.200 [kN/m]

Elem.	Node-1	Node-2	N1 [kN]	V1 [kN]	M1 [kNm]	N2 [kN]	V2 [kN]	M2 [kNm]	Nm [kN]	Vm [kN]	Mm [kNm]
1	1	4	-6.33	0.53	0.00	-5.71	-1.17	-1.04	-6.08	-0.16	0.24
2	4	2	2.97	1.98	-1.04	3.08	1.69	-0.01	3.03	1.84	-0.50
3	5	3	-5.45	1.88	-0.55	-6.69	-1.53	0.00	-6.19	-0.16	1.10
4	2	5	3.44	-0.69	0.00	3.23	-1.28	-0.55	3.33	-0.98	-0.24
5	4	5	-9.24	0.00	0.00	-9.24	0.00	0.00	-9.24	0.00	0.00

Internal forces, Loading: (Qk3) Snow Q<sub>ksL</sub>= 1.200, Q<sub>ksR</sub>= 0.600 [kN/m]

Elem.	Node-1	Node-2	N1 [kN]	V1 [kN]	M1 [kNm]	N2 [kN]	V2 [kN]	M2 [kNm]	Nm [kN]	Vm [kN]	Mm [kNm]
1	1	4	-6.69	1.53	0.00	-5.45	-1.88	-0.55	-6.19	0.16	1.10
2	4	2	3.23	1.28	-0.55	3.44	0.69	0.00	3.33	0.98	-0.24
3	5	3	-5.71	1.17	-1.04	-6.33	-0.53	0.00	-6.08	0.16	0.24
4	2	5	3.08	-1.69	-0.01	2.97	-1.98	-1.04	3.03	-1.84	-0.50
5	4	5	-9.24	0.00	0.00	-9.24	0.00	0.00	-9.24	0.00	0.00

(m point of maximum span moment for permanent load, or element middle point)

Internal forces, Loading: (Qk5) Wind Q<sub>kwL</sub>=-0.325, Q<sub>kwR</sub>= 0.182 [kN/m]

Elem.	Node-1	Node-2	N1 [kN]	V1 [kN]	M1 [kNm]	N2 [kN]	V2 [kN]	M2 [kNm]	Nm [kN]	Vm [kN]	Mm [kNm]
1	1	4	0.32	-0.57	0.00	0.32	0.47	-0.16	0.32	-0.15	-0.47
2	4	2	-0.47	0.19	-0.16	-0.47	0.37	0.00	-0.47	0.28	-0.09
3	5	3	0.66	0.20	0.30	0.66	-0.39	0.00	0.66	-0.15	0.35
4	2	5	-0.12	0.59	0.00	-0.12	0.48	0.30	-0.12	0.53	0.16
5	4	5	0.83	0.00	0.00	0.83	0.00	0.00	0.83	0.00	0.00

Internal forces, Loading: (Qki) Imposed (H) Q<sub>i</sub> = 0.300 [kN/m]

Elem.	Node-1	Node-2	N1 [kN]	V1 [kN]	M1 [kNm]	N2 [kN]	V2 [kN]	M2 [kNm]	Nm [kN]	Vm [kN]	Mm [kNm]
1	1	4	-2.17	0.34	0.00	-1.86	-0.51	-0.27	-2.04	0.00	0.22
2	4	2	1.03	0.54	-0.26	1.09	0.40	0.00	1.06	0.47	-0.12
3	5	3	-1.86	0.51	-0.27	-2.17	-0.34	0.00	-2.04	0.00	0.22
4	2	5	1.09	-0.40	0.00	1.03	-0.54	-0.26	1.06	-0.47	-0.12
5	4	5	-3.08	0.00	0.00	-3.08	0.00	0.00	-3.08	0.00	0.00

(m point of maximum span moment for permanent load, or element middle point)

**7.3. Element end forces for applied loads**

Element end forces, Loading: ( Gk ) Dead Gk1 = 0.478, Gk2 = 0.075 [kN/m]

Elem.	Node-1	Node-2	F1x[kN]	F1y[kN]	M1[kNm]	F2x[kN]	F2y[kN]	M2[kNm]
1	1	4	3.37	1.85	0.00	-3.37	-0.31	0.45
2	4	2	-1.96	0.27	-0.45	1.96	0.00	0.00
3	5	3	3.37	-0.31	-0.45	-3.37	1.85	0.00
4	2	5	-1.96	0.00	0.00	1.96	0.27	0.45
5	4	5	5.33	0.04	0.00	-5.33	0.04	0.00

-  
(element end forces in global coordinate system x-y)

Element end forces, Loading: ( Qk1 ) Snow QksL= 1.200, QksR= 1.200 [kN/m]

Elem.	Node-1	Node-2	F1x[kN]	F1y[kN]	M1[kNm]	F2x[kN]	F2y[kN]	M2[kNm]
1	1	4	7.69	4.26	0.00	-7.69	-0.63	1.06
2	4	2	-4.63	0.63	-1.06	4.63	0.00	0.00
3	5	3	7.69	-0.63	-1.06	-7.69	4.26	0.00
4	2	5	-4.63	0.00	0.00	4.63	0.63	1.06
5	4	5	12.31	0.00	0.00	-12.31	0.00	0.00

-  
(element end forces in global coordinate system x-y)

Element end forces, Loading: ( Qk2 ) Snow QksL= 0.600, QksR= 1.200 [kN/m]

Elem.	Node-1	Node-2	F1x[kN]	F1y[kN]	M1[kNm]	F2x[kN]	F2y[kN]	M2[kNm]
1	1	4	5.76	2.66	0.00	-5.76	-0.85	1.04
2	4	2	-3.47	0.85	-1.04	3.47	-0.53	0.01
3	5	3	5.76	-0.10	-0.55	-5.76	3.73	0.00
4	2	5	-3.47	0.53	0.00	3.47	0.10	0.55
5	4	5	9.24	0.00	0.00	-9.24	0.00	0.00

-  
(element end forces in global coordinate system x-y)

Element end forces, Loading: ( Qk3 ) Snow QksL= 1.200, QksR= 0.600 [kN/m]

Elem.	Node-1	Node-2	F1x[kN]	F1y[kN]	M1[kNm]	F2x[kN]	F2y[kN]	M2[kNm]
1	1	4	5.76	3.73	0.00	-5.76	-0.10	0.55
2	4	2	-3.47	0.10	-0.55	3.47	0.53	0.00
3	5	3	5.76	-0.85	-1.04	-5.76	2.66	0.00
4	2	5	-3.47	-0.53	-0.01	3.47	0.85	1.04
5	4	5	9.24	0.00	0.00	-9.24	0.00	0.00

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(element end forces in global coordinate system x-y)

Element end forces, Loading: ( Qk4 ) Wind QkwL= 0.182, QkwR=-0.325 [kN/m]

Elem.	Node-1	Node-2	F1x[kN]	F1y[kN]	M1[kNm]	F2x[kN]	F2y[kN]	M2[kNm]
1	1	4	-0.76	0.14	0.00	0.56	0.41	-0.30
2	4	2	0.28	-0.41	0.30	-0.31	0.51	0.00
3	5	3	-0.46	-0.34	-0.16	0.10	-0.65	0.00
4	2	5	0.31	-0.51	0.00	-0.38	0.34	0.16
5	4	5	-0.83	0.00	0.00	0.83	0.00	0.00

-  
(element end forces in global coordinate system x-y)

Element end forces, Loading: (Qk5) Wind QkwL=-0.325, QkwR= 0.182 [kN/m]

Elem.	Node-1	Node-2	F1x[kN]	F1y[kN]	M1[kNm]	F2x[kN]	F2y[kN]	M2[kNm]
1	1	4	-0.10	-0.65	0.00	0.46	-0.34	0.16
2	4	2	0.38	0.34	-0.16	-0.31	-0.51	0.00
3	5	3	-0.56	0.41	0.30	0.76	0.14	0.00
4	2	5	0.31	0.51	0.00	-0.28	-0.41	-0.30
5	4	5	-0.83	0.00	0.00	0.83	0.00	0.00

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(element end forces in global coordinate system x-y)

Element end forces, Loading: (Qki) Imposed (H) Qi = 0.300 [kN/m]

Elem.	Node-1	Node-2	F1x[kN]	F1y[kN]	M1[kNm]	F2x[kN]	F2y[kN]	M2[kNm]
1	1	4	1.92	1.07	0.00	-1.92	-0.16	0.27
2	4	2	-1.16	0.16	-0.26	1.16	0.00	0.00
3	5	3	1.92	-0.16	-0.27	-1.92	1.06	0.00
4	2	5	-1.16	0.00	0.00	1.16	0.16	0.26
5	4	5	3.08	0.00	0.00	-3.08	0.00	0.00

—  
(element end forces in global coordinate system x-y)

**7.4. Vertical nodal displacements (mm)**

Node	Gk	Qk1	Qk2	Qk3	Qk4	Qk5	Qki
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	-0.58	-1.31	-0.98	-0.98	0.08	0.08	-0.46
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	-0.78	-1.79	1.77	-4.45	-2.86	3.08	-1.25
5	-0.78	-1.79	-4.45	1.77	3.08	-2.86	0.00

**7.5. Support reactions (kN)**

Node	React.	Gk	Qk1	Qk2	Qk3	Qk4	Qk5	Qki
1	Fx	3.37	7.69	5.76	5.76	-0.76	-0.10	1.92
1	Fy	1.85	4.26	2.66	3.73	0.14	-0.65	1.07
3	Fx	-3.37	-7.69	-5.76	-5.76	0.10	0.76	-1.92
3	Fy	1.85	4.26	3.73	2.66	-0.65	0.14	1.06

**8. Support reactions for load combinations (kN)**

Loading	[kN/m]	Action	yg	yg	ψo
( Gk)	Dead Gk1 = 0.478, Gk2 = 0.075	Permanent	1.35	0.00	1.00
(Qk1)	Snow QksL= 1.200, QksR= 1.200	Short-term	0.00	1.50	0.50
(Qk2)	Snow QksL= 0.600, QksR= 1.200	Short-term	0.00	1.50	0.50
(Qk3)	Snow QksL= 1.200, QksR= 0.600	Short-term	0.00	1.50	0.50
(Qk4)	Wind QkwL= 0.182, QkwR=-0.325	Short-term	0.00	1.50	0.60
(Qk5)	Wind QkwL=-0.325, QkwR= 0.182	Short-term	0.00	1.50	0.60
(Qki)	Imposed (H) Qi = 0.300	Short-term	0.00	1.50	0.00

**8.1. Reactions at node : 1 (kN)**

L.C.	Load combination	Duration class	kmod	Fx	Fy	Fx/Kmod	Fy/Kmod
1	yg.Gk	Permanent	0.60	4.549	2.494	7.581	4.156
2	yg.Gk+yg.Qk1	Short-term	0.90	16.078	8.884	17.865	9.871
3	yg.Gk+yg.Qk2	Short-term	0.90	13.196	6.486	14.662	7.207
4	yg.Gk+yg.Qk3	Short-term	0.90	13.196	8.086	14.662	8.984
5	yg.Gk+yg.Qk4	Short-term	0.90	3.416	2.698	3.795	2.998
6	yg.Gk+yg.Qk5	Short-term	0.90	4.398	1.525	4.887	1.695
7	yg.Gk+yg.Qki	Short-term	0.90	7.431	4.091	8.257	4.546
8	yg.Gk+yg.Qk1+yg.ψo.Qk4	Short-term	0.90	15.399	9.006	17.110	10.007
9	yg.Gk+yg.Qk1+yg.ψo.Qk5	Short-term	0.90	15.988	8.303	17.765	9.225
10	yg.Gk+yg.Qk2+yg.ψo.Qk4	Short-term	0.90	12.516	6.609	13.907	7.343
11	yg.Gk+yg.Qk2+yg.ψo.Qk5	Short-term	0.90	13.106	5.905	14.562	6.561
12	yg.Gk+yg.Qk3+yg.ψo.Qk4	Short-term	0.90	12.516	8.209	13.907	9.121
13	yg.Gk+yg.Qk3+yg.ψo.Qk5	Short-term	0.90	13.106	7.505	14.562	8.339
14	yg.Gk+yg.Qk4+yg.ψo.Qk1	Short-term	0.90	9.181	5.893	10.201	6.548
15	yg.Gk+yg.Qk4+yg.ψo.Qk2	Short-term	0.90	7.739	4.694	8.599	5.216
16	yg.Gk+yg.Qk4+yg.ψo.Qk3	Short-term	0.90	7.739	5.494	8.599	6.105
17	yg.Gk+yg.Qk5+yg.ψo.Qk1	Short-term	0.90	10.163	4.720	11.292	5.245
18	yg.Gk+yg.Qk5+yg.ψo.Qk2	Short-term	0.90	8.722	3.521	9.691	3.913
19	yg.Gk+yg.Qk5+yg.ψo.Qk3	Short-term	0.90	8.722	4.321	9.691	4.802
20	yg.Gk+yg.Qki+yg.ψo.Qk1+yg.ψo.Qk4	Short-term	0.90	12.516	7.409	13.907	8.232
21	yg.Gk+yg.Qki+yg.ψo.Qk1+yg.ψo.Qk5	Short-term	0.90	13.106	6.705	14.562	7.450
22	yg.Gk+yg.Qki+yg.ψo.Qk2+yg.ψo.Qk4	Short-term	0.90	11.075	6.210	12.306	6.900
23	yg.Gk+yg.Qki+yg.ψo.Qk2+yg.ψo.Qk5	Short-term	0.90	11.664	5.506	12.960	6.118
24	yg.Gk+yg.Qki+yg.ψo.Qk3+yg.ψo.Qk4	Short-term	0.90	11.075	7.010	12.306	7.789
25	yg.Gk+yg.Qki+yg.ψo.Qk3+yg.ψo.Qk5	Short-term	0.90	11.664	6.306	12.960	7.007
	Maximum values			16.078	9.006	17.865	10.007
26	yg.Gk+yg.Qk4=0.9Gk+1.5Qk4, (EQU)	Short-term	0.90	1.900	1.867	2.111	2.074
27	yg.Gk+yg.Qk5=0.9Gk+1.5Qk5, (EQU)	Short-term	0.90	2.882	0.694	3.202	0.771

**8.2. Reactions at node : 3 (kN)**

L.C.	Load combination	Duration class	kmod	Fx	Fy	Fx/Kmod	Fy/Kmod
1	yg.Gk	Permanent	0.60	-4.549	2.494	-7.581	4.156
2	yg.Gk+yg.Qk1	Short-term	0.90	-16.078	8.884	-17.865	9.871
3	yg.Gk+yg.Qk2	Short-term	0.90	-13.196	6.486	-14.662	7.207
4	yg.Gk+yg.Qk3	Short-term	0.90	-13.196	8.086	-14.662	8.984
5	yg.Gk+yg.Qk4	Short-term	0.90	-4.398	1.525	-4.887	1.695
6	yg.Gk+yg.Qk5	Short-term	0.90	-3.416	2.698	-3.795	2.998
7	yg.Gk+yg.Qki	Short-term	0.90	-7.431	4.091	-8.257	4.546
8	yg.Gk+yg.Qk1+yg.ψo.Qk4	Short-term	0.90	-15.988	8.303	-17.765	9.225
9	yg.Gk+yg.Qk1+yg.ψo.Qk5	Short-term	0.90	-15.399	9.006	-17.110	10.007
10	yg.Gk+yg.Qk2+yg.ψo.Qk4	Short-term	0.90	-13.106	7.505	-14.562	8.339
11	yg.Gk+yg.Qk2+yg.ψo.Qk5	Short-term	0.90	-12.516	8.209	-13.907	9.121
12	yg.Gk+yg.Qk3+yg.ψo.Qk4	Short-term	0.90	-13.106	5.905	-14.562	6.561
13	yg.Gk+yg.Qk3+yg.ψo.Qk5	Short-term	0.90	-12.516	6.609	-13.907	7.343
14	yg.Gk+yg.Qk4+yg.ψo.Qk1	Short-term	0.90	-10.163	4.720	-11.292	5.245
15	yg.Gk+yg.Qk4+yg.ψo.Qk2	Short-term	0.90	-8.722	4.321	-9.691	4.802
16	yg.Gk+yg.Qk4+yg.ψo.Qk3	Short-term	0.90	-8.722	3.521	-9.691	3.913
17	yg.Gk+yg.Qk5+yg.ψo.Qk1	Short-term	0.90	-9.181	5.893	-10.201	6.548
18	yg.Gk+yg.Qk5+yg.ψo.Qk2	Short-term	0.90	-7.739	5.494	-8.599	6.105
19	yg.Gk+yg.Qk5+yg.ψo.Qk3	Short-term	0.90	-7.739	4.694	-8.599	5.216
20	yg.Gk+yg.Qki+yg.ψo.Qk1+yg.ψo.Qk4	Short-term	0.90	-13.106	6.705	-14.562	7.450
21	yg.Gk+yg.Qki+yg.ψo.Qk1+yg.ψo.Qk5	Short-term	0.90	-12.516	7.409	-13.907	8.232
22	yg.Gk+yg.Qki+yg.ψo.Qk2+yg.ψo.Qk4	Short-term	0.90	-11.664	6.306	-12.960	7.007
23	yg.Gk+yg.Qki+yg.ψo.Qk2+yg.ψo.Qk5	Short-term	0.90	-11.075	7.010	-12.306	7.789
24	yg.Gk+yg.Qki+yg.ψo.Qk3+yg.ψo.Qk4	Short-term	0.90	-11.664	5.506	-12.960	6.118
25	yg.Gk+yg.Qki+yg.ψo.Qk3+yg.ψo.Qk5	Short-term	0.90	-11.075	6.210	-12.306	6.900
	Maximum values			16.078	9.006	17.865	10.007
26	yg.Gk+yg.Qk4=0.9Gk+1.5Qk4, (EQU)	Short-term	0.90	-2.882	0.694	-3.202	0.771
27	yg.Gk+yg.Qk5=0.9Gk+1.5Qk5, (EQU)	Short-term	0.90	-1.900	1.867	-2.111	2.074



**9. Serviceability limit state****9.1. Serviceability limit state** (EC5 EN1995-1-1:2009, §2.2.3, §7)

Control of deflection at node 4 (EC5 §7.2)

Loading [kN/m]	u[mm]	Action	$\psi_0$	$\psi_1$	$\psi_2$	Kdef
( Gk) Dead Gk1 = 0.478, Gk2 = 0.075	-0.783	Permanent	1.00	1.00	1.00	0.80
(Qk1) Snow QksL= 1.200, QksR= 1.200	-1.791	Short-term	0.50	0.20	0.00	0.80
(Qk2) Snow QksL= 0.600, QksR= 1.200	1.766	Short-term	0.50	0.20	0.00	0.80
(Qk3) Snow QksL= 1.200, QksR= 0.600	-4.452	Short-term	0.50	0.20	0.00	0.80
(Qk4) Wind QkwL= 0.182, QkwR=-0.325	-2.862	Short-term	0.60	0.20	0.00	0.80
(Qk5) Wind QkwL=-0.325, QkwR= 0.182	3.085	Short-term	0.60	0.20	0.00	0.80

Load combination	w.inst	w.fin [mm]
1 Gk	0.783	1.410
2 Gk + Qk1	2.574	3.200
3 Gk + Qk2	0.783	1.410
4 Gk + Qk3	5.235	5.862
5 Gk + Qk4	3.646	4.272
6 Gk + Qk5	0.783	1.410
7 Gk + Qk1 + $\psi_0$ .Qk4	4.291	4.918
8 Gk + Qk1 + $\psi_0$ .Qk5	2.574	3.200
9 Gk + Qk2 + $\psi_0$ .Qk4	2.501	3.127
10 Gk + Qk2 + $\psi_0$ .Qk5	0.783	1.410
11 Gk + Qk3 + $\psi_0$ .Qk4	6.953	7.579
12 Gk + Qk3 + $\psi_0$ .Qk5	5.235	5.862
13 Gk + Qk4 + $\psi_0$ .Qk1	4.541	5.168
14 Gk + Qk4 + $\psi_0$ .Qk2	3.646	4.272
15 Gk + Qk4 + $\psi_0$ .Qk3	5.872	6.498
16 Gk + Qk5 + $\psi_0$ .Qk1	1.679	2.305
17 Gk + Qk5 + $\psi_0$ .Qk2	0.783	1.410
18 Gk + Qk5 + $\psi_0$ .Qk3	3.009	3.636

 $w_{fin}, g = w_{inst}, g(1+k_{def}), w_{fin}, q = w_{inst}, q(1+\psi_2 \cdot k_{def})$  (EC5 §2.2.3, Eq.2.3, Eq.2.4)
**Maximum deflection values at node 4**

w.inst = 6.953 mm, w.fin = 7.579 mm

Check according to EC5 EN1995-1-1:2009 §7.2, Tab.7.2

**Final deflections at node 4**

w.inst = 6.953 mm &lt; L/300=7100/300= 23.667 mm

w.net,fin = 7.579 mm &lt; L/250=7100/250= 28.400 mm

w.fin = 7.579 mm &lt; L/150=7100/150= 47.333 mm

The check is satisfied

**9.2. Serviceability limit state** (EC5 EN1995-1-1:2009, §2.2.3, §7)

Control of deflection in middle of element 1 (EC5 §7.2)

Loading [kN/m]	u[mm]	Action	$\psi_0$	$\psi_1$	$\psi_2$	Kdef
( Gk) Dead Gk1 = 0.478, Gk2 = 0.075	2.648	Permanent	1.00	1.00	1.00	0.80
(Qk1) Snow QksL= 1.200, QksR= 1.200	6.641	Short-term	0.50	0.20	0.00	0.80
(Qk2) Snow QksL= 0.600, QksR= 1.200	3.321	Short-term	0.50	0.20	0.00	0.80
(Qk3) Snow QksL= 1.200, QksR= 0.600	6.641	Short-term	0.50	0.20	0.00	0.80
(Qk4) Wind QkwL= 0.182, QkwR=-0.325	1.070	Short-term	0.60	0.20	0.00	0.80
(Qk5) Wind QkwL=-0.325, QkwR= 0.182	-1.915	Short-term	0.60	0.20	0.00	0.80

Load combination	w.inst	w.fin [mm]
1 Gk	2.648	4.766
2 Gk + Qk1	9.289	11.408
3 Gk + Qk2	5.969	8.087
4 Gk + Qk3	9.289	11.408
5 Gk + Qk4	3.718	5.836
6 Gk + Qk5	2.648	4.766
7 Gk + Qk1 + $\psi_0$ .Qk4	9.931	12.050
8 Gk + Qk1 + $\psi_0$ .Qk5	9.289	11.408
9 Gk + Qk2 + $\psi_0$ .Qk4	6.611	8.729
10 Gk + Qk2 + $\psi_0$ .Qk5	5.969	8.087
11 Gk + Qk3 + $\psi_0$ .Qk4	9.931	12.050
12 Gk + Qk3 + $\psi_0$ .Qk5	9.289	11.408
13 Gk + Qk4 + $\psi_0$ .Qk1	7.039	9.157
14 Gk + Qk4 + $\psi_0$ .Qk2	5.378	7.497
15 Gk + Qk4 + $\psi_0$ .Qk3	7.039	9.157
16 Gk + Qk5 + $\psi_0$ .Qk1	5.969	8.087
17 Gk + Qk5 + $\psi_0$ .Qk2	4.308	6.427
18 Gk + Qk5 + $\psi_0$ .Qk3	5.969	8.087

w.fin, g=w.inst, g(1+kdef), w.fin, q=w.inst, q(1+ $\psi_2$ ·kdef) (EC5 §2.2.3, Eq.2.3, Eq.2.4)

Maximum deflection values in middle of element 1

w.inst = 9.931 mm, w.fin = 12.050 mm

Check according to EC5 EN1995-1-1:2009 §7.2, Tab.7.2

Final deflections in middle of element 1

w.inst = 9.931 mm < L/300=3216/300= 10.721 mm

w.net,fin = 12.050 mm < L/250=3216/250= 12.866 mm

w.fin = 12.050 mm < L/150=3216/150= 21.443 mm

The check is satisfied

## 10. Ultimate limit state

10.1. Ultimate limit state (EC5 EN1995-1-1:2009, §6)

Rafter, elements: 1, 2, 3, 4

Loading [kN/m]	Action	yg	yg	$\psi_0$
( Gk) Dead Gk1 = 0.478, Gk2 = 0.075	Permanent	1.35	0.00	1.00
(Qk1) Snow QksL= 1.200, QksR= 1.200	Short-term	0.00	1.50	0.50
(Qk2) Snow QksL= 0.600, QksR= 1.200	Short-term	0.00	1.50	0.50
(Qk3) Snow QksL= 1.200, QksR= 0.600	Short-term	0.00	1.50	0.50
(Qk4) Wind QkwL= 0.182, QkwR=-0.325	Short-term	0.00	1.50	0.60
(Qk5) Wind QkwL=-0.325, QkwR= 0.182	Short-term	0.00	1.50	0.60
(Qki) Imposed (H) Qi = 0.300	Short-term	0.00	1.50	0.00

L.C.	Load combination	Duration class	kmod	-N/Kmod	+N/Kmod	V/Kmod	M/Kmod
1	yg.Gk	Permanent	0.60	-8.545	4.139	2.074	1.011
2	yg.Gk+yg.Qk1	Short-term	0.90	-20.163	10.007	5.012	2.442
3	yg.Gk+yg.Qk2	Short-term	0.90	-16.851	8.498	4.689	2.402
4	yg.Gk+yg.Qk3	Short-term	0.90	-16.851	8.498	4.689	2.402
5	yg.Gk+yg.Qk4	Short-term	0.90	-5.697	2.759	1.696	1.148
6	yg.Gk+yg.Qk5	Short-term	0.90	-5.697	2.759	1.696	1.148
7	yg.Gk+yg.Qki	Short-term	0.90	-9.313	4.571	2.290	1.116
8	yg.Gk+yg.Qk1+yg.ψo.Qk4	Short-term	0.90	-20.163	10.007	5.200	2.598
9	yg.Gk+yg.Qk1+yg.ψo.Qk5	Short-term	0.90	-20.163	10.007	5.200	2.598
10	yg.Gk+yg.Qk2+yg.ψo.Qk4	Short-term	0.90	-16.851	8.029	4.689	2.400
11	yg.Gk+yg.Qk2+yg.ψo.Qk5	Short-term	0.90	-16.243	8.498	4.877	2.742
12	yg.Gk+yg.Qk3+yg.ψo.Qk4	Short-term	0.90	-16.243	8.498	4.877	2.742
13	yg.Gk+yg.Qk3+yg.ψo.Qk5	Short-term	0.90	-16.851	8.029	4.689	2.400
14	yg.Gk+yg.Qk4+yg.ψo.Qk1	Short-term	0.90	-12.930	6.383	3.510	1.891
15	yg.Gk+yg.Qk4+yg.ψo.Qk2	Short-term	0.90	-11.274	5.326	3.036	1.537
16	yg.Gk+yg.Qk4+yg.ψo.Qk3	Short-term	0.90	-10.970	5.629	3.349	2.062
17	yg.Gk+yg.Qk5+yg.ψo.Qk1	Short-term	0.90	-12.930	6.383	3.510	1.891
18	yg.Gk+yg.Qk5+yg.ψo.Qk2	Short-term	0.90	-10.970	5.629	3.349	2.062
19	yg.Gk+yg.Qk5+yg.ψo.Qk3	Short-term	0.90	-11.274	5.326	3.036	1.537
20	yg.Gk+yg.Qki+yg.ψo.Qk1+yg.ψo.Qk4	Short-term	0.90	-16.547	8.195	4.292	2.157
21	yg.Gk+yg.Qki+yg.ψo.Qk1+yg.ψo.Qk5	Short-term	0.90	-16.547	8.195	4.292	2.157
22	yg.Gk+yg.Qki+yg.ψo.Qk2+yg.ψo.Qk4	Short-term	0.90	-14.890	7.138	3.943	1.978
23	yg.Gk+yg.Qki+yg.ψo.Qk2+yg.ψo.Qk5	Short-term	0.90	-14.587	7.440	4.131	2.201
24	yg.Gk+yg.Qki+yg.ψo.Qk3+yg.ψo.Qk4	Short-term	0.90	-14.587	7.441	4.131	2.201
25	yg.Gk+yg.Qki+yg.ψo.Qk3+yg.ψo.Qk5	Short-term	0.90	-14.890	7.138	3.943	1.978
Maximum values				-20.163	10.007	5.200	2.742

**10.2. Check of cross section Rafter, elements: 1, 2, 3, 4**

**Rafter, elements: 1, 2, 3, 4, Load combination No 8**

Tension parallel to the grain,  $F_{t0d}=9.006 \text{ kN}$  (ECS §6.1.2)

Rectangular cross section,  $b=50 \text{ mm}$ ,  $h=150 \text{ mm}$ ,  $A= 7 500 \text{ mm}^2$

Modification factor  $K_{mod}=0.90$  (Tab.3.1), Material factor  $\gamma_M=1.30$  (Tab. 2.3)

$f_{t0k}=7.20 \text{ N/mm}^2$ ,  $f_{t0d}=K_{mod} \cdot f_{t0k} / \gamma_M = 0.90 \times 7.20 / 1.30 = 4.98 \text{ N/mm}^2$  (ECS Eq.2.14)

$F_{t0d}=9.006 \text{ kN}$ ,  $\sigma_{t0d}=F_{t0d}/A_{netto}=1000 \times 9.006 / 7500 = 1.20 \text{ N/mm}^2 < 4.98 \text{ N/mm}^2 = f_{t0d}$  (Eq.6.1)

The check is satisfied

**Rafter, elements: 1, 2, 3, 4, Load combination No 9**

Compression parallel to the grain,  $F_{c0d}=-18.147 \text{ kN}$  (ECS §6.1.4)

Rectangular cross section,  $b=50 \text{ mm}$ ,  $h=150 \text{ mm}$ ,  $A= 7 500 \text{ mm}^2$

Modification factor  $K_{mod}=0.90$  (Tab.3.1), Material factor  $\gamma_M=1.30$  (Tab. 2.3)

$f_{c0k}=16.00 \text{ N/mm}^2$ ,  $f_{c0d}=K_{mod} \cdot f_{c0k} / \gamma_M = 0.90 \times 16.00 / 1.30 = 11.08 \text{ N/mm}^2$  (ECS Eq.2.14)

$F_{c0d}=-18.147 \text{ kN}$ ,  $\sigma_{c0d}=F_{c0d}/A_{netto}=1000 \times 18.147 / 7500 = 2.42 \text{ N/mm}^2 < 11.08 \text{ N/mm}^2 = f_{c0d}$  (Eq.6.2)

The check is satisfied

**Rafter, elements: 1, 2, 3, 4, Load combination No 9**

Shear,  $F_v=4.680 \text{ kN}$  (ECS §6.1.7)

Rectangular cross section,  $b_{ef}=0.67 \times 50 = 34 \text{ mm}$ ,  $h=150 \text{ mm}$ ,  $A= 5 100 \text{ mm}^2$

Modification factor  $K_{mod}=0.90$  (Tab.3.1), Material factor  $\gamma_M=1.30$  (Tab. 2.3)

$f_{vk}=3.00 \text{ N/mm}^2$ ,  $f_{vd}=K_{mod} \cdot f_{vk} / \gamma_M = 0.90 \times 3.00 / 1.30 = 2.08 \text{ N/mm}^2$  (ECS Eq.2.14)

$F_v=4.680 \text{ kN}$ ,  $\tau_{v0d}=1.50 F_{v0d} / A_{netto}=1000 \times 1.50 \times 4.680 / 5100 = 1.38 \text{ N/mm}^2 < 2.08 \text{ N/mm}^2 = f_{vd}$  (Eq.6.13)

The check is satisfied

**10.3. Ultimate limit state** (ECS EN1995-1-1:2009, §6)

**Tie, elements: 5**

Loading [kN/m]	Action	yg	yg	ψo
( Gk) Dead Gk1 = 0.478, Gk2 = 0.075	Permanent	1.35	0.00	1.00
(Qk1) Snow QksL= 1.200, QksR= 1.200	Short-term	0.00	1.50	0.50
(Qk2) Snow QksL= 0.600, QksR= 1.200	Short-term	0.00	1.50	0.50
(Qk3) Snow QksL= 1.200, QksR= 0.600	Short-term	0.00	1.50	0.50
(Qk4) Wind QkwL= 0.182, QkwR=-0.325	Short-term	0.00	1.50	0.60
(Qk5) Wind QkwL=-0.325, QkwR= 0.182	Short-term	0.00	1.50	0.60
(Qki) Imposed (H) Qi = 0.300	Short-term	0.00	1.50	0.00

L.C.	Load combination	Duration class	kmod	-N/Kmod	+N/Kmod	V/Kmod	M/Kmod
1	yg.Gk	Permanent	0.60	-11.986	0.000	0.089	0.047
2	yg.Gk+yg.Qk1	Short-term	0.90	-28.514	0.000	0.059	0.030
3	yg.Gk+yg.Qk2	Short-term	0.90	-23.383	0.000	0.060	0.030
4	yg.Gk+yg.Qk3	Short-term	0.90	-23.383	0.000	0.060	0.030
5	yg.Gk+yg.Qk4	Short-term	0.90	-6.599	0.000	0.060	0.031
6	yg.Gk+yg.Qk5	Short-term	0.90	-6.599	0.000	0.060	0.031
7	yg.Gk+yg.Qki	Short-term	0.90	-13.121	0.000	0.059	0.031
8	yg.Gk+yg.Qk1+yg.ψo.Qk4	Short-term	0.90	-27.679	0.000	0.060	0.030
9	yg.Gk+yg.Qk1+yg.ψo.Qk5	Short-term	0.90	-27.679	0.000	0.060	0.030
10	yg.Gk+yg.Qk2+yg.ψo.Qk4	Short-term	0.90	-22.548	0.000	0.060	0.030
11	yg.Gk+yg.Qk2+yg.ψo.Qk5	Short-term	0.90	-22.548	0.000	0.060	0.030
12	yg.Gk+yg.Qk3+yg.ψo.Qk4	Short-term	0.90	-22.548	0.000	0.060	0.030
13	yg.Gk+yg.Qk3+yg.ψo.Qk5	Short-term	0.90	-22.548	0.000	0.060	0.030
14	yg.Gk+yg.Qk4+yg.ψo.Qk1	Short-term	0.90	-16.861	0.000	0.060	0.030
15	yg.Gk+yg.Qk4+yg.ψo.Qk2	Short-term	0.90	-14.296	0.000	0.060	0.031
16	yg.Gk+yg.Qk4+yg.ψo.Qk3	Short-term	0.90	-14.296	0.000	0.060	0.031
17	yg.Gk+yg.Qk5+yg.ψo.Qk1	Short-term	0.90	-16.861	0.000	0.060	0.030
18	yg.Gk+yg.Qk5+yg.ψo.Qk2	Short-term	0.90	-14.296	0.000	0.060	0.031
19	yg.Gk+yg.Qk5+yg.ψo.Qk3	Short-term	0.90	-14.296	0.000	0.060	0.031
20	yg.Gk+yg.Qki+yg.ψo.Qk1+yg.ψo.Qk4	Short-term	0.90	-22.548	0.000	0.060	0.030
21	yg.Gk+yg.Qki+yg.ψo.Qk1+yg.ψo.Qk5	Short-term	0.90	-22.548	0.000	0.060	0.030
22	yg.Gk+yg.Qki+yg.ψo.Qk2+yg.ψo.Qk4	Short-term	0.90	-19.983	0.000	0.059	0.030
23	yg.Gk+yg.Qki+yg.ψo.Qk2+yg.ψo.Qk5	Short-term	0.90	-19.983	0.000	0.060	0.030
24	yg.Gk+yg.Qki+yg.ψo.Qk3+yg.ψo.Qk4	Short-term	0.90	-19.983	0.000	0.060	0.030
25	yg.Gk+yg.Qki+yg.ψo.Qk3+yg.ψo.Qk5	Short-term	0.90	-19.983	0.000	0.059	0.030
	Maximum values			-28.514	0.000	0.089	0.047

**10.4. Check of cross section Tie, elements: 5**

**Tie, elements: 5, Load combination No 2**

Compression parallel to the grain,  $F_{c0d} = -25.663 \text{ kN}$  (ECS §6.1.4)

Rectangular cross section,  $b=50 \text{ mm}$ ,  $h=150 \text{ mm}$ ,  $A= 7\,500 \text{ mm}^2$

Modification factor  $K_{mod}=0.90$  (Tab.3.1), Material factor  $\gamma_M=1.30$  (Tab. 2.3)

$f_{c0k}=16.00 \text{ N/mm}^2$ ,  $f_{c0d}=K_{mod} \cdot f_{c0k} / \gamma_M = 0.90 \times 16.00 / 1.30 = 11.08 \text{ N/mm}^2$  (ECS Eq.2.14)

$F_{c0d} = -25.663 \text{ kN}$ ,  $\sigma_{c0d} = F_{c0d} / A_{netto} = 1000 \times 25.663 / 7500 = 3.42 \text{ N/mm}^2 < 11.08 \text{ N/mm}^2 = f_{c0d}$  (Eq.6.2)

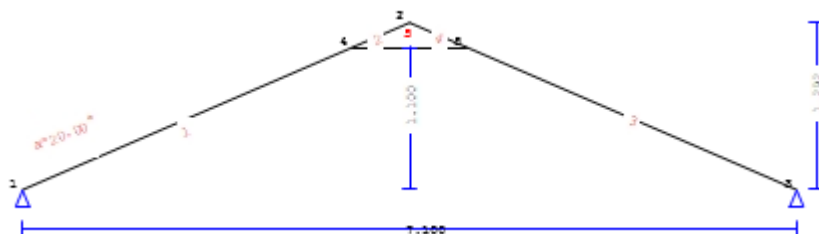
The check is satisfied

Negligible shear stress, shear check is omitted (ECS §6.1.7)

- ii. Clești 2x2.5x15 cm – **Model 2 – Învelitoare Țiglă metalică** – distanță 85 cm interax

**1. ROOF -002**

Trussed rafter roof type A

**2. General description, assumptions, materials, loads****2.1. Construction type**

Timber roof, from trusses with timber C14. The truss type as sketch above.  
 Truss span 7.100 m, height 1.292 m, roof pitch 20.00°, truss spacing 0.850m  
 Finishing (rafter) from timber C14, of thickness 25 mm  
 Truss element cross sections BxH [mm]  
 Elements 1, 2, 3, 4, Cross section 50x150 [mm]  
 Elements 5, Cross section 50x150 [mm]  
 Truss volume =0.065 m<sup>3</sup>, truss weight =0.184 kN

**2.2. Design codes**

EN1990:2002, Eurocode 0 Part 1-1, Basis of structural design  
 EN1991-1-1:2002, Eurocode 1 Part 1-1, Actions on structures  
 EN1991-1-3:2003, Eurocode 1 Part 1-3, Snow loads  
 EN1991-1-4:2005, Eurocode 1 Part 1-4, Wind actions  
 EN1995-1-1:2009, Eurocode 5 Part 1-1, Design of timber structures

**2.3. Design methodology**

The internal forces of the roof trusses are computed with finite element analysis. The truss is considered as a two dimensional frame. The stiffness of the connections is adjusted according to the selected degree of stiffness. In order to compute the design values for internal forces in various loading conditions, the internal forces are first computed in unit loading, and then from their combination the internal forces in various loading conditions are obtained. All the load combinations according to Eurocode 1 and Eurocode 5 are taken into account, and the checks are performed in the most unfavourable loading conditions, for combined action, in ultimate limit state, according to EC5 EN1995-1-1:2009, §6. The connections are designed as screwed connections with metal plates according to EC5 EN1995-1-1:2009, §8. The deflections are checked in serviceability limit condition, according to EC5 EN1995-1-1:2009, §7.

**2.4. Material properties (truss)** (EC5 EN1995-1-1:2009, §3)

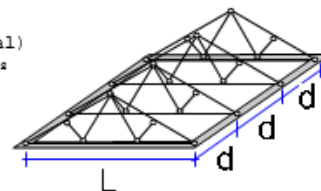
Timber class : C14  
 Service classes : Class 2, moisture content ≤20% (EC5 §2.3.1.3)  
 Material factor  $\gamma_M=1.30$  (EC5 Tab. 2.3)  
**Characteristic material properties for timber**  
 $f_{mk} = 14.0$  MPa,  $f_{t0k} = 7.2$  MPa,  $f_{t90k} = 0.4$  MPa  
 $f_{c0k} = 16.0$  MPa,  $f_{c90k} = 2.0$  MPa,  $f_{vk} = 3.0$  MPa  
 $E_{0m} = 7000$  MPa,  $E_{005} = 4700$  MPa,  $E_{90m} = 230$  MPa  
 $G_m = 440$  MPa,  $\rho_k = 290$  Kg/m<sup>3</sup>,  $\rho_m = 350$  Kg/m<sup>3</sup>

**2.5. Material properties (timber, finishing)** (EC5 EN1995-1-1:2009, §3)

Timber class : C14  
 Service classes : Class 2, moisture content ≤ 20% (EC5 §2.3.1.3)  
 Material factor  $\gamma_M=1.30$  (EC5 Tab. 2.3)  
**Characteristic material properties for timber**  
 $f_{mk} = 14.0$  MPa,  $f_{t0k} = 7.2$  MPa,  $f_{t90k} = 0.4$  MPa  
 $f_{c0k} = 16.0$  MPa,  $f_{c90k} = 2.0$  MPa,  $f_{vk} = 3.0$  MPa  
 $E_{0m} = 7000$  MPa,  $E_{005} = 4700$  MPa,  $E_{90m} = 230$  MPa  
 $G_m = 440$  MPa,  $\rho_k = 290$  Kg/m<sup>3</sup>,  $\rho_m = 350$  Kg/m<sup>3</sup>

**2.6. Distributed roof loads**

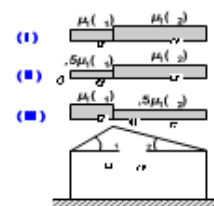
Permanent load of roof covering	$G_e = 0.050$ kN/m <sup>2</sup>	(Corrugated metal)
Purlins, finishing, insulation	$G_t = 0.100$ kN/m <sup>2</sup>	$G_e + G_t = 0.150$ kN/m <sup>2</sup>
Load of ceiling under the roof	$G_c = 0.100$ kN/m <sup>2</sup>	
Snow load on the ground	$S_k = 2.000$ kN/m <sup>2</sup>	
Wind pressure on vertical surface	$Q_w = 0.765$ kN/m <sup>2</sup>	
Imposed load (category H)	$Q_i = 0.400$ kN/m <sup>2</sup>	



**3. Snow load** (EC1 EN1991-1-3:2003 §5)

**Snow load on the ground  $S_k$**  (EC1 EN1991-1-3:2003 §4, Annex C)  
 Climatic Region : Alpine Region, snow zone : 2, altitude above sea level = 500 m  
 $S_k = (0.642 \times 2 + 0.009) \times [1 + (500/728)^2] = 1.903$  kN/m<sup>2</sup>  
 Characteristic value of snow load on the ground:  $s_k = 2.000$  kN/m<sup>2</sup>

**Snow load on the roof** (EC1 EN1991-1-3:2003 §5)  
 Angle of pitch of roof :  $\alpha = 19.999^\circ$   
 Exposure coefficient :  $C_e = 1.000$  (EC1-1-3 §5.2(7))  
 Thermal coefficient :  $C_t = 1.000$  (EC1-1-3 §5.2(8))  
 Shape coefficients,  $\alpha_1 = \alpha_2 = 20.00^\circ$ ,  $\mu_1(\alpha_1) = \mu_1(\alpha_2) = 0.800$  (Table 5.2)  
 $S(\alpha_1) = \mu_1(\alpha_1) \cdot C_e \cdot C_t \cdot S_k = 0.800 \times 1.000 \times 1.000 \times 2.000 = 1.600$  kN/m<sup>2</sup> (§5.2)  
 $S(\alpha_2) = \mu_1(\alpha_2) \cdot C_e \cdot C_t \cdot S_k = 0.800 \times 1.000 \times 1.000 \times 2.000 = 1.600$  kN/m<sup>2</sup>



**Snow load** (EC1 EN1991-1-3:2003 §5.3.3)

Load case (I), S(Left) =	$S(\alpha_1) = 1.600$ kN/m <sup>2</sup> ,	S(Right) = $S(\alpha_2) = 1.600$ kN/m <sup>2</sup>
Load case (II), S(Left) =	$0.5 \times S(\alpha_1) = 0.800$ kN/m <sup>2</sup> ,	S(Right) = $S(\alpha_2) = 1.600$ kN/m <sup>2</sup>
Load case (III), S(Left) =	$S(\alpha_1) = 1.600$ kN/m <sup>2</sup> ,	S(Right) = $0.5 \times S(\alpha_2) = 0.800$ kN/m <sup>2</sup>

**4. Wind loading** (EC1 EN1991-1-4:2005 §5)

$v_{bo} = 31.00$  m/s, Romania SR, Zone: 3,  $v_b = C_{dir} \cdot C_{season} \cdot v_{bo} = 31.00$  m/s  
 Terrain category: IV,  $z = 10.000$  m,  $z_0 = 1.000$  m,  $z_{min} = 10$  m,  $z_{max} = 200$  m,  $z_{0II} = 0.050$  m  
 $k_r = 0.19 \cdot (1.000/0.05)^{0.07} = 0.234$   
 Roughness factor  $C_r(z) = k_r \cdot \ln(z/z_0) = 0.234 \times \ln(10.000/1.000) = 0.540$   
 $H/Lu = 80/600 = 0.08$ ,  $0.05 < H/Lu = 0.08 < 0.30$ ,  $Le = 600.00$  m  
 $z = 10.00$  m,  $X/Le = 500/600 = 0.83$ ,  $z/Le = 10/600 = 0.10$ ,  $s = 0.396$   
 Orography factor  $C_o(z) = 1 + 2 \times 0.396 \times 0.083 = 1.066$   
 Turbulence factor  $K_t = 1.000$   
 Exposure factor  $C_e(z) = 1.274$   
 $q(z) = C_e(z) \cdot (k_p) \cdot v_b^2 = [0.001] \times 1.274 \times 0.625 \times 31.00^2 = 0.765$  kN/m<sup>2</sup>

(EN1991-1-4, Tab.A.2)  
 (eq.A.7, ...A.10)  
 (eq.A.2)

(EN1991-1-4, §4.5)

**Wind pressure on roof  $w_e = q_{ref} \cdot C_e(z) \cdot C_{pe}$**  (EC1 EN1991-1-4:2005, §5.2)

**External pressure coefficients** (EC1 EN1991-1-4:2005 Table 7.4)

For pitch angle  $\alpha = 20.00^\circ$ ,  $C_{pe}(+) = 0.32$ ,  $C_{pe}(-) = -0.57$   
 Wind pressure  $w_e(\text{Left}) = 0.242$  kN/m<sup>2</sup>  
 Wind pressure  $w_e(\text{Right}) = -0.434$  kN/m<sup>2</sup>



**5. Roof timber finishing (rafter)**

**Timber finishing (rafter) structural system**

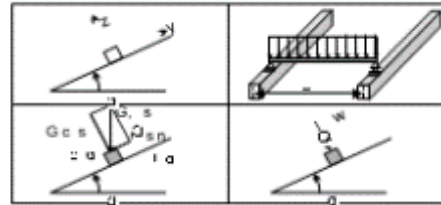
The timber finishing (rafter) is designed as simply supported beam with span  
 Spacing of trusses  $L = 0.850$  m, and width  $1.00$  m

**Dimensions of timber finishing (rafter)**

Timber of finishing (rafter): C14, service class: Class 2, moisture content  $\leq 20\%$   
 Spacing of trusses  $L = 0.850\text{m}$ , roof pitch  $\alpha = 20.00^\circ$ , thickness of finishing 25mm

**Loading on timber finishing (rafter)**

Roof covering  $G_e = 0.050\text{ kN/m}^2$   
 Self weight  $G_l = 0.071\text{ kN/m}^2$   
 Snow load  $Q_s = 1.600\text{ kN/m}^2$   
 Wind load  $Q_w = 0.242\text{ kN/m}^2$   
 Concentrated  $Q_p = 1.000\text{ kN}$



**Internal forces of timber finishing (span  $L=0.850\text{ m}$ , width  $=1.00\text{ m}$ )**

Loading	Action	$\gamma_g$	$\gamma_q$	$\psi_0$	maxN[kN]	maxQ[kN]	maxM[kNm]
(Gk) Permanent	$G_k = 0.121\text{ [kN/m]}$ Permanent	1.35	0.00	1.00	0.000	0.048	0.010
(Qk1) Snow	$Q_{ks} = 1.600\text{ [kN/m]}$ Short-term	0.00	1.50	0.50	0.000	0.600	0.128
(Qk2) Wind	$Q_{kw} = 0.242\text{ [kN/m]}$ Short-term	0.00	1.50	0.60	0.000	0.103	0.022
(Qk3) Concentrated	$Q_{kp} = 1.000\text{ [kN]}$ Instantaneous	0.00	1.00	0.00	0.000	0.470	0.321

**5.1. Serviceability limit state (EC5 EN1995-1-1:2009, §2.2.3, §7)**

Control of deflection (EC5 §7.2)

Loading [kN/m]		u[mm]	Action	$\psi_0$	$\psi_1$	$\psi_2$	Kdef
(Gk) Permanent	$G_k = 0.000\text{ [kN/m]}$	0.035	Permanent	1.00	1.00	1.00	0.80
(Qk1) Snow	$Q_{ks} = 0.000\text{ [kN/m]}$	0.437	Short-term	0.50	0.20	0.00	0.80
(Qk2) Wind	$Q_{kw} = 0.000\text{ [kN/m]}$	0.075	Short-term	0.60	0.20	0.00	0.80

Load combination	w.inst	w.fin [mm]
1 Gk	0.035	0.063
2 Gk + Qk1	0.473	0.501
3 Gk + Qk2	0.110	0.138
4 Gk + Qk1 + $\psi_0 \cdot Qk2$	0.518	0.546
5 Gk + Qk2 + $\psi_0 \cdot Qk1$	0.329	0.357

$w_{fin, g} = w_{inst, g}(1+kdef)$ ,  $w_{fin, q} = w_{inst, q}(1+\psi_2 \cdot kdef)$  (EC5 §2.2.3, Eq.2.3, Eq.2.4)

**Maximum deflection values**

$w_{inst} = 0.518\text{ mm}$ ,  $w_{fin} = 0.546\text{ mm}$

**Check according to EC5 EN1995-1-1:2009 §7.2, Tab.7.2**

**Final deflections**

$w_{inst} = 0.518\text{ mm} < L/300 = 850/300 = 2.833\text{ mm}$   
 $w_{net, fin} = 0.546\text{ mm} < L/250 = 850/250 = 3.400\text{ mm}$   
 $w_{fin} = 0.546\text{ mm} < L/150 = 850/150 = 5.667\text{ mm}$

The check is satisfied

**5.2. Check of finishing, Ultimate limit state of design (EC5 EN1995-1-1:2009, §6)**

L.C.	Load combination	Duration class	$k_{mod}$	N/Kmod	V/Kmod	M/Kmod
1	$\gamma_g \cdot G_k$	Permanent	0.60	0.000	0.109	0.023
2	$\gamma_g \cdot G_k + \gamma_q \cdot Q_{k1}$	Short-term	0.90	0.000	1.073	0.228
3	$\gamma_g \cdot G_k + \gamma_q \cdot Q_{k2}$	Short-term	0.90	0.000	0.244	0.052
4	$\gamma_g \cdot G_k + \gamma_q \cdot Q_{k3}$	Instantaneous	1.10	0.000	0.486	0.305
5	$\gamma_g \cdot G_k + \gamma_q \cdot Q_{k1} + \gamma_q \cdot \psi_0 \cdot Q_{k2}$	Short-term	0.90	0.000	1.176	0.250
6	$\gamma_g \cdot G_k + \gamma_q \cdot Q_{k2} + \gamma_q \cdot \psi_0 \cdot Q_{k1}$	Short-term	0.90	0.000	0.744	0.158
	Maximum values		0.000	1.176	0.305	

**Finishing, Load combination No 5**

Shear,  $F_v = 1.059\text{ kN}$  (EC5 §6.1.7)

Rectangular cross section,  $b_{ef} = 0.67 \times 1000 = 670\text{ mm}$ ,  $h = 25\text{ mm}$ ,  $A = 16\,750\text{ mm}^2$

Modification factor  $K_{mod} = 0.90$  (Tab.3.1), Material factor  $\gamma_M = 1.30$  (Tab. 2.3)

$f_{vk} = 3.00\text{ N/mm}^2$ ,  $f_{vd} = K_{mod} \cdot f_{vk} / \gamma_M = 0.90 \times 3.00 / 1.30 = 2.08\text{ N/mm}^2$  (EC5 Eq.2.14)

$F_v = 1.059\text{ kN}$ ,  $\tau_{v0d} = 1.50 F_v / 0d / A_{net0} = 1000 \times 1.50 \times 1.059 / 16750 = 0.09\text{ N/mm}^2 < 2.08\text{ N/mm}^2 = f_{vd}$  (Eq.6.13)

The check is satisfied

**Finishing, Load combination No 4**

Bending,  $M_{yd}=0.335 \text{ kNm}$ ,  $M_{zd}=0.000 \text{ kNm}$  (ECS §6.1.6)

Rectangular cross section,  $b=1000\text{mm}$ ,  $h=25\text{mm}$ ,  $A=2.50 \times 10^4 \text{ mm}^2$ ,  $W_y=1.04 \times 10^5 \text{ mm}^3$ ,  $W_z=4.17 \times 10^6 \text{ mm}^3$

Modification factor  $K_{mod}=1.10$  (Tab.3.1), Material factor  $\gamma_M=1.30$  (Tab. 2.3)

$f_{myk}=14.00 \text{ N/mm}^2$ ,  $f_{myd}=K_{mod} \cdot f_{myk} / \gamma_M = 1.10 \times 14.00 / 1.30 = 11.85 \text{ N/mm}^2$

$f_{mk}=14.00 \text{ N/mm}^2$ ,  $f_{mzd}=K_{mod} \cdot f_{mk} / \gamma_M = 1.10 \times 14.00 / 1.30 = 11.85 \text{ N/mm}^2$

Rectangular cross section  $K_m=0.70$  (ECS §6.1.6.(2))

$\sigma_{myd}=M_{yd}/W_{my,netto}=10^{-6} \times 0.335 / (0.1042 \times 10^{-6}) = 3.22 \text{ N/mm}^2$

$\sigma_{mzd}=M_{zd}/W_{mz,netto}=10^{-6} \times 0.000 / (4.1667 \times 10^{-6}) = 0.00 \text{ N/mm}^2$

$\sigma_{myd}/f_{myd} + K_m \cdot \sigma_{mzd}/f_{mzd} = 0.272 + 0.000 = 0.27 < 1$  (ECS Eq.6.11)

$K_m \cdot \sigma_{myd}/f_{myd} + \sigma_{mzd}/f_{mzd} = 0.190 + 0.000 = 0.19 < 1$  (ECS Eq.6.12)

The check is satisfied

**6. Truss design**

**Truss geometric characteristics**

Length  $L=7.100 \text{ m}$ , height  $H=1.292 \text{ m}$ , truss spacing  $d=0.850 \text{ m}$

Pitch =36.39%, angle  $\alpha=20.00^\circ$ ,  $\tan\alpha=0.364$ ,  $\sin\alpha=0.342$ ,  $\cos\alpha=0.940$

Number of nodes = 5, number of elements =5, supports 2

Nodal coordinates			Truss element properties								
Node	x[m]	y[m]	Sup.	Element	K1	K2	bxh[mm]	L[m]	A[mm <sup>2</sup> ]	Iy[mm <sup>4</sup> ]	Wy[mm <sup>3</sup> ]
1	0.000	0.000	11	1	1	4	50x150	3.216	7500	14.063x10 <sup>6</sup>	1.875x10 <sup>5</sup>
2	3.550	1.292		2	4	2	50x150	0.561	7500	14.063x10 <sup>6</sup>	1.875x10 <sup>5</sup>
3	7.100	0.000	11	3	5	3	50x150	3.216	7500	14.063x10 <sup>6</sup>	1.875x10 <sup>5</sup>
4	3.022	1.100		4	2	5	50x150	0.561	7500	14.063x10 <sup>6</sup>	1.875x10 <sup>5</sup>
5	4.078	1.100		5	4	5	50x150	1.055	7500	14.063x10 <sup>6</sup>	1.875x10 <sup>5</sup>

**Line loads per truss**

Timber density =290.00 kg/m<sup>3</sup>, truss self weight =0.184 kN

Truss spacing  $d=0.85 \text{ m}$ , weight of truss connections =0.018 kN

**Permanent line loads (kN/m) on truss**

Roof covering+self weight  $G_{k1}= 0.156 \text{ kN/m}$

Ceiling under roof  $G_{k2}= 0.085 \text{ kN/m}$

**Variable line loads of short term action (kN/m) on truss**

Imposed  $Q_{ki}= 0.40 \times 0.850 = 0.340 \text{ kN/m}$

Snow (Left )  $Q_{k1l}= 1.360 \text{ kN/m}$  (Right )  $Q_{k1r}= 1.360 \text{ kN/m}$

Snow (Left )  $Q_{k2l}= 0.680 \text{ kN/m}$  (Right )  $Q_{k2r}= 1.360 \text{ kN/m}$

Snow (Left )  $Q_{k3l}= 1.360 \text{ kN/m}$  (Right )  $Q_{k3r}= 0.680 \text{ kN/m}$

Wind (Left )  $Q_{k4l}= 0.206 \text{ kN/m}$  (Right )  $Q_{k4r}= -0.368 \text{ kN/m}$

Wind (Left )  $Q_{k5l}= -0.368 \text{ kN/m}$  (Right )  $Q_{k5r}= 0.206 \text{ kN/m}$



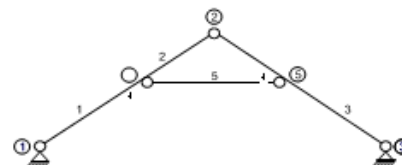
**Design load combinations**

( $\gamma_g=1.35$ ,  $\gamma_q=1.50$ ,  $\psi_0(\text{ Live Qf})=0.70$ ,  $\psi_0(\text{ Snow Q1,Q2,Q3})=0.50$ ,  $\psi_0(\text{ Wind Q4,Q5})=0.60$ )

L.C.	Actions Permanent-Variable	Duration class
1	$\gamma_g.G_k$	Permanent
2	$\gamma_g.G_k+\gamma_q.Q_{k1}$	Short-term
3	$\gamma_g.G_k+\gamma_q.Q_{k2}$	Short-term
4	$\gamma_g.G_k+\gamma_q.Q_{k3}$	Short-term
5	$\gamma_g.G_k+\gamma_q.Q_{k4}$	Short-term
6	$\gamma_g.G_k+\gamma_q.Q_{k5}$	Short-term
7	$\gamma_g.G_k+\gamma_q.Q_{k1}$	Short-term
8	$\gamma_g.G_k+\gamma_q.Q_{k1}+\gamma_q.\psi_0.Q_{k4}$	Short-term
9	$\gamma_g.G_k+\gamma_q.Q_{k1}+\gamma_q.\psi_0.Q_{k5}$	Short-term
10	$\gamma_g.G_k+\gamma_q.Q_{k2}+\gamma_q.\psi_0.Q_{k4}$	Short-term
11	$\gamma_g.G_k+\gamma_q.Q_{k2}+\gamma_q.\psi_0.Q_{k5}$	Short-term
12	$\gamma_g.G_k+\gamma_q.Q_{k3}+\gamma_q.\psi_0.Q_{k4}$	Short-term
13	$\gamma_g.G_k+\gamma_q.Q_{k3}+\gamma_q.\psi_0.Q_{k5}$	Short-term
14	$\gamma_g.G_k+\gamma_q.Q_{k4}+\gamma_q.\psi_0.Q_{k1}$	Short-term
15	$\gamma_g.G_k+\gamma_q.Q_{k4}+\gamma_q.\psi_0.Q_{k2}$	Short-term
16	$\gamma_g.G_k+\gamma_q.Q_{k4}+\gamma_q.\psi_0.Q_{k3}$	Short-term
17	$\gamma_g.G_k+\gamma_q.Q_{k5}+\gamma_q.\psi_0.Q_{k1}$	Short-term
18	$\gamma_g.G_k+\gamma_q.Q_{k5}+\gamma_q.\psi_0.Q_{k2}$	Short-term
19	$\gamma_g.G_k+\gamma_q.Q_{k5}+\gamma_q.\psi_0.Q_{k3}$	Short-term
20	$\gamma_g.G_k+\gamma_q.Q_{k1}+\gamma_q.\psi_0.Q_{k1}+\gamma_q.\psi_0.Q_{k4}$	Short-term
21	$\gamma_g.G_k+\gamma_q.Q_{k1}+\gamma_q.\psi_0.Q_{k1}+\gamma_q.\psi_0.Q_{k5}$	Short-term
22	$\gamma_g.G_k+\gamma_q.Q_{k1}+\gamma_q.\psi_0.Q_{k2}+\gamma_q.\psi_0.Q_{k4}$	Short-term
23	$\gamma_g.G_k+\gamma_q.Q_{k1}+\gamma_q.\psi_0.Q_{k2}+\gamma_q.\psi_0.Q_{k5}$	Short-term
24	$\gamma_g.G_k+\gamma_q.Q_{k1}+\gamma_q.\psi_0.Q_{k3}+\gamma_q.\psi_0.Q_{k4}$	Short-term
25	$\gamma_g.G_k+\gamma_q.Q_{k1}+\gamma_q.\psi_0.Q_{k3}+\gamma_q.\psi_0.Q_{k5}$	Short-term

**7. Truss static analysis**

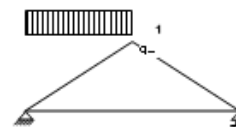
Design for connections with reduced stiffness (factor 0.20)  
 The truss is designed as frame structure (EN1995-1-1 §5.4.1)  
 with reduced connection stiffness according to the above factor  
 The rafter and the tie are considered as continuous elements.  
 The truss is first solved for various unit load conditions,  
 and from them are computed the internal forces  
 for the various loading conditions and load combinations.  
 Number of nodes = 5, number of elements =5, supports 2



**7.1. Static solutions for unit loads**

Internal forces for unit loading (1 kN/m left rafter downwards)

Elem.	Node-1	Node-2	N1 [kN]	V1 [kN]	M1 [kNm]	N2 [kN]	V2 [kN]	M2 [kNm]
1	1	4	-3.92	1.41	0.00	-2.89	-1.43	-0.04
2	4	2	1.93	0.32	-0.04	2.11	-0.17	0.00
3	5	3	-3.31	0.26	-0.84	-3.31	0.26	0.00
4	2	5	1.51	-1.49	-0.01	1.51	-1.49	-0.84
5	4	5	-5.13	0.00	0.00	-5.13	0.00	0.00



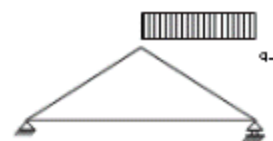
Element end forces for unit loading (1 kN/m left rafter downwards)

Elem.	Node-1	Node-2	F1x [kN]	F1y [kN]	M1 [kNm]	F2x [kN]	F2y [kN]	M2 [kNm]
1	1	4	3.20	2.66	0.00	-3.20	0.36	0.04
2	4	2	-1.93	-0.36	-0.04	1.93	0.89	0.00
3	5	3	3.20	-0.89	-0.84	-3.20	0.89	0.00
4	2	5	-1.93	-0.89	-0.01	1.93	0.89	0.84
5	4	5	5.13	0.00	0.00	-5.13	0.00	0.00

(element end forces in global coordinate system x-y)

**Internal forces for unit loading (1 kN/m right rafter downwards)**

Elem.	Node-1	Node-2	N1[kN]	V1[kN]	M1[kNm]	N2[kN]	V2[kN]	M2[kNm]
1	1	4	-3.31	-0.26	0.00	-3.31	-0.26	-0.84
2	4	2	1.51	1.49	-0.84	1.51	1.49	-0.01
3	5	3	-2.89	1.43	-0.04	-3.92	-1.41	0.00
4	2	5	2.11	0.17	0.00	1.93	-0.32	-0.04
5	4	5	-5.13	0.00	0.00	-5.13	0.00	0.00



**Element end forces for unit loading (1 kN/m right rafter downwards)**

Elem.	Node-1	Node-2	Fix[kN]	Fly[kN]	M1[kNm]	F2x[kN]	F2y[kN]	M2[kNm]
1	1	4	3.20	0.89	0.00	-3.20	-0.89	0.84
2	4	2	-1.93	0.89	-0.84	1.93	-0.89	0.01
3	5	3	3.20	0.36	-0.04	-3.20	2.66	0.00
4	2	5	-1.93	0.89	0.00	1.93	-0.36	0.04
5	4	5	5.13	0.00	0.00	-5.13	0.00	0.00

(element end forces in global coordinate system x-y)

**Internal forces for unit loading (1 kN/m tie downwards)**

Elem.	Node-1	Node-2	N1[kN]	V1[kN]	M1[kNm]	N2[kN]	V2[kN]	M2[kNm]
1	1	4	-1.53	0.00	0.00	-1.53	0.00	0.01
2	4	2	-0.07	-0.03	0.02	-0.07	-0.03	0.00
3	5	3	-1.53	0.00	0.01	-1.53	0.00	0.00
4	2	5	-0.07	0.03	0.00	-0.07	0.03	0.02
5	4	5	-1.36	0.53	0.00	-1.36	-0.53	0.00



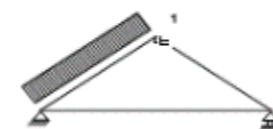
**Element end forces for unit loading (1 kN/m tie downwards)**

Elem.	Node-1	Node-2	Fix[kN]	Fly[kN]	M1[kNm]	F2x[kN]	F2y[kN]	M2[kNm]
1	1	4	1.44	0.53	0.00	-1.44	-0.53	-0.01
2	4	2	0.08	0.00	0.02	-0.08	0.00	0.00
3	5	3	1.44	-0.53	0.01	-1.44	0.53	0.00
4	2	5	0.08	0.00	0.00	-0.08	0.00	-0.02
5	4	5	1.36	0.53	0.00	-1.36	0.53	0.00

(element end forces in global coordinate system x-y)

**Internal forces for unit loading (1 kN/m left rafter pressure)**

Elem.	Node-1	Node-2	N1[kN]	V1[kN]	M1[kNm]	N2[kN]	V2[kN]	M2[kNm]
1	1	4	-3.07	1.59	0.00	-3.07	-1.62	-0.05
2	4	2	2.40	0.37	-0.05	2.40	-0.19	0.00
3	5	3	-3.75	0.30	-0.96	-3.75	0.30	0.00
4	2	5	1.72	-1.69	-0.01	1.72	-1.69	-0.96
5	4	5	-5.82	0.00	0.00	-5.82	0.00	0.00



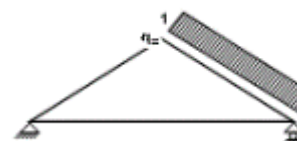
**Element end forces for unit loading (1 kN/m left rafter pressure)**

Elem.	Node-1	Node-2	Fix[kN]	Fly[kN]	M1[kNm]	F2x[kN]	F2y[kN]	M2[kNm]
1	1	4	2.34	2.55	0.00	-3.44	0.48	0.05
2	4	2	-2.38	-0.48	-0.05	2.19	1.00	0.00
3	5	3	3.63	-1.00	-0.96	-3.63	1.00	0.00
4	2	5	-2.19	-1.00	-0.01	2.19	1.00	0.96
5	4	5	5.82	0.00	0.00	-5.82	0.00	0.00

(element end forces in global coordinate system x-y)

**Internal forces for unit loading (1 kN/m right rafter pressure)**

Elem.	Node-1	Node-2	N1[kN]	V1[kN]	M1[kNm]	N2[kN]	V2[kN]	M2[kNm]
1	1	4	-3.75	-0.30	0.00	-3.75	-0.30	-0.96
2	4	2	1.72	1.69	-0.96	1.72	1.69	-0.01
3	5	3	-3.07	1.62	-0.05	-3.07	-1.59	0.00
4	2	5	2.40	0.19	0.00	2.40	-0.37	-0.05
5	4	5	-5.82	0.00	0.00	-5.82	0.00	0.00



**Element end forces for unit loading (1 kN/m right rafter pressure)**

Elem.	Node-1	Node-2	F1x[kN]	F1y[kN]	M1[kNm]	F2x[kN]	F2y[kN]	M2[kNm]
1	1	4	3.63	1.00	0.00	-3.63	-1.00	0.96
2	4	2	-2.19	1.00	-0.96	2.19	-1.00	0.01
3	5	3	3.44	0.48	-0.05	-2.34	2.55	0.00
4	2	5	-2.19	1.00	0.00	2.38	-0.48	0.05
5	4	5	5.82	0.00	0.00	-5.82	0.00	0.00

(element end forces in global coordinate system x-y)

**7.2. Internal forces for applied loads**

**Internal forces, Loading: ( Gk) Dead Gk1 = 0.156, Gk2 = 0.085 [kN/m]**

Elem.	Node-1	Node-2	N1[kN]	V1[kN]	M1[kNm]	N2[kN]	V2[kN]	M2[kNm]	Nm[kN]	Vm[kN]	Mm[kNm]
1	1	4	-1.33	0.19	0.00	-1.16	-0.28	-0.15	-1.26	0.00	0.12
2	4	2	0.57	0.30	-0.15	0.60	0.22	0.00	0.58	0.26	-0.07
3	5	3	-1.16	0.28	-0.15	-1.33	-0.19	0.00	-1.26	0.00	0.12
4	2	5	0.60	-0.22	0.00	0.57	-0.30	-0.15	0.58	-0.26	-0.07
5	4	5	-1.82	0.04	0.00	-1.82	-0.04	0.00	-1.82	0.04	0.02

(m point of maximum span moment for permanent load, or element middle point)

**Internal forces, Loading: ( Qk1) Snow QksL= 1.360, QksR= 1.360 [kN/m]**

Elem.	Node-1	Node-2	N1[kN]	V1[kN]	M1[kNm]	N2[kN]	V2[kN]	M2[kNm]	Nm[kN]	Vm[kN]	Mm[kNm]
1	1	4	-9.84	1.56	0.00	-8.43	-2.31	-1.20	-9.27	0.00	1.01
2	4	2	4.68	2.47	-1.20	4.93	1.79	-0.01	4.81	2.13	-0.56
3	5	3	-8.43	2.31	-1.20	-9.84	-1.56	0.00	-9.27	0.00	1.01
4	2	5	4.93	-1.79	-0.01	4.68	-2.47	-1.20	4.81	-2.13	-0.56
5	4	5	-13.96	0.00	0.00	-13.96	0.00	0.00	-13.96	0.00	0.00

(m point of maximum span moment for permanent load, or element middle point)

**Internal forces, Loading: ( Qk2) Snow QksL= 0.680, QksR= 1.360 [kN/m]**

Elem.	Node-1	Node-2	N1[kN]	V1[kN]	M1[kNm]	N2[kN]	V2[kN]	M2[kNm]	Nm[kN]	Vm[kN]	Mm[kNm]
1	1	4	-7.17	0.60	0.00	-6.47	-1.33	-1.18	-6.89	-0.18	0.27
2	4	2	3.37	2.25	-1.17	3.49	1.91	-0.01	3.43	2.08	-0.57
3	5	3	-6.18	2.13	-0.63	-7.58	-1.74	0.00	-7.02	-0.18	1.24
4	2	5	3.90	-0.78	0.00	3.66	-1.45	-0.63	3.78	-1.12	-0.27
5	4	5	-10.47	0.00	0.00	-10.47	0.00	0.00	-10.47	0.00	0.00

**Internal forces, Loading: ( Qk3) Snow QksL= 1.360, QksR= 0.680 [kN/m]**

Elem.	Node-1	Node-2	N1[kN]	V1[kN]	M1[kNm]	N2[kN]	V2[kN]	M2[kNm]	Nm[kN]	Vm[kN]	Mm[kNm]
1	1	4	-7.58	1.74	0.00	-6.18	-2.13	-0.63	-7.02	0.18	1.24
2	4	2	3.66	1.45	-0.63	3.90	0.78	0.00	3.78	1.12	-0.27
3	5	3	-6.47	1.33	-1.18	-7.17	-0.60	0.00	-6.89	0.18	0.27
4	2	5	3.49	-1.91	-0.01	3.37	-2.25	-1.17	3.43	-2.08	-0.57
5	4	5	-10.47	0.00	0.00	-10.47	0.00	0.00	-10.47	0.00	0.00

**Internal forces, Loading: ( Qk4) Wind QkwL= 0.206, QkwR=-0.368 [kN/m]**

Elem.	Node-1	Node-2	N1[kN]	V1[kN]	M1[kNm]	N2[kN]	V2[kN]	M2[kNm]	Nm[kN]	Vm[kN]	Mm[kNm]
1	1	4	0.75	0.44	0.00	0.75	-0.22	0.34	0.75	0.17	0.40
2	4	2	-0.14	-0.55	0.34	-0.14	-0.66	0.00	-0.14	-0.61	0.18
3	5	3	0.36	-0.54	-0.18	0.36	0.65	0.00	0.36	0.17	-0.53
4	2	5	-0.53	-0.42	0.00	-0.53	-0.21	-0.18	-0.53	-0.32	-0.11
5	4	5	0.95	0.00	0.00	0.95	0.00	0.00	0.95	0.00	0.00

(m point of maximum span moment for permanent load, or element middle point)

Internal forces, Loading: (Qk5) Wind QkwL=-0.368, QkwR= 0.206 [kN/m]

Elem.	Node-1	Node-2	N1[kN]	V1[kN]	M1[kNm]	N2[kN]	V2[kN]	M2[kNm]	Nm[kN]	Vm[kN]	Mm[kNm]
1	1	4	0.36	-0.65	0.00	0.36	0.54	-0.18	0.36	-0.17	-0.53
2	4	2	-0.53	0.21	-0.18	-0.53	0.42	0.00	-0.53	0.32	-0.11
3	5	3	0.75	0.22	0.34	0.75	-0.44	0.00	0.75	-0.17	0.40
4	2	5	-0.14	0.66	0.00	-0.14	0.55	0.34	-0.14	0.61	0.18
5	4	5	0.95	0.00	0.00	0.95	0.00	0.00	0.95	0.00	0.00

Internal forces, Loading: (Qki) Imposed (H) Qi = 0.340 [kN/m]

Elem.	Node-1	Node-2	N1[kN]	V1[kN]	M1[kNm]	N2[kN]	V2[kN]	M2[kNm]	Nm[kN]	Vm[kN]	Mm[kNm]
1	1	4	-2.46	0.39	0.00	-2.11	-0.58	-0.30	-2.32	0.00	0.25
2	4	2	1.17	0.62	-0.30	1.23	0.45	0.00	1.20	0.53	-0.14
3	5	3	-2.11	0.58	-0.30	-2.46	-0.39	0.00	-2.32	0.00	0.25
4	2	5	1.23	-0.45	0.00	1.17	-0.62	-0.30	1.20	-0.53	-0.14
5	4	5	-3.49	0.00	0.00	-3.49	0.00	0.00	-3.49	0.00	0.00

-  
(m point of maximum span moment for permanent load, or element middle point)**7.3. Element end forces for applied loads**

Element end forces, Loading: ( Gk) Dead Gk1 = 0.156, Gk2 = 0.085 [kN/m]

Elem.	Node-1	Node-2	F1x[kN]	F1y[kN]	M1[kNm]	F2x[kN]	F2y[kN]	M2[kNm]
1	1	4	1.19	0.63	0.00	-1.19	-0.13	0.15
2	4	2	-0.63	0.09	-0.15	0.63	0.00	0.00
3	5	3	1.19	-0.13	-0.15	-1.19	0.63	0.00
4	2	5	-0.63	0.00	0.00	0.63	0.09	0.15
5	4	5	1.82	0.04	0.00	-1.82	0.04	0.00

-  
(element end forces in global coordinate system x-y)

Element end forces, Loading: (Qk1) Snow QksL= 1.360, QksR= 1.360 [kN/m]

Elem.	Node-1	Node-2	F1x[kN]	F1y[kN]	M1[kNm]	F2x[kN]	F2y[kN]	M2[kNm]
1	1	4	8.71	4.83	0.00	-8.71	-0.72	1.20
2	4	2	-5.24	0.72	-1.20	5.24	0.00	0.01
3	5	3	8.71	-0.72	-1.20	-8.71	4.83	0.00
4	2	5	-5.24	0.00	-0.01	5.24	0.72	1.20
5	4	5	13.96	0.00	0.00	-13.96	0.00	0.00

-  
(element end forces in global coordinate system x-y)

Element end forces, Loading: (Qk2) Snow QksL= 0.680, QksR= 1.360 [kN/m]

Elem.	Node-1	Node-2	F1x[kN]	F1y[kN]	M1[kNm]	F2x[kN]	F2y[kN]	M2[kNm]
1	1	4	6.53	3.02	0.00	-6.53	-0.96	1.18
2	4	2	-3.93	0.96	-1.17	3.93	-0.60	0.01
3	5	3	6.53	-0.11	-0.63	-6.53	4.23	0.00
4	2	5	-3.93	0.60	0.00	3.93	0.12	0.63
5	4	5	10.47	0.00	0.00	-10.47	0.00	0.00

-  
(element end forces in global coordinate system x-y)

Element end forces, Loading: (Qk3) Snow QksL= 1.360, QksR= 0.680 [kN/m]

Elem.	Node-1	Node-2	F1x[kN]	F1y[kN]	M1[kNm]	F2x[kN]	F2y[kN]	M2[kNm]
1	1	4	6.53	4.23	0.00	-6.53	-0.11	0.63
2	4	2	-3.93	0.12	-0.63	3.93	0.60	0.00
3	5	3	6.53	-0.96	-1.18	-6.53	3.02	0.00
4	2	5	-3.93	-0.60	-0.01	3.93	0.96	1.17
5	4	5	10.47	0.00	0.00	-10.47	0.00	0.00

-  
(element end forces in global coordinate system x-y)

Element end forces, Loading: (Qk4) Wind QkwL= 0.206, QkwR=-0.368 [kN/m]

Elem.	Node-1	Node-2	F1x[kN]	F1y[kN]	M1[kNm]	F2x[kN]	F2y[kN]	M2[kNm]
1	1	4	-0.86	0.15	0.00	0.63	0.47	-0.34
2	4	2	0.32	-0.47	0.34	-0.36	0.58	0.00
3	5	3	-0.52	-0.38	-0.18	0.11	-0.73	0.00
4	2	5	0.36	-0.58	0.00	-0.43	0.38	0.18
5	4	5	-0.95	0.00	0.00	0.95	0.00	0.00

—  
(element end forces in global coordinate system x-y)

Element end forces, Loading: (Qk5) Wind QkwL=-0.368, QkwR= 0.206 [kN/m]

Elem.	Node-1	Node-2	F1x[kN]	F1y[kN]	M1[kNm]	F2x[kN]	F2y[kN]	M2[kNm]
1	1	4	-0.11	-0.73	0.00	0.52	-0.38	0.18
2	4	2	0.43	0.38	-0.18	-0.36	-0.58	0.00
3	5	3	-0.63	0.47	0.34	0.86	0.15	0.00
4	2	5	0.36	0.58	0.00	-0.32	-0.47	-0.34
5	4	5	-0.95	0.00	0.00	0.95	0.00	0.00

—  
(element end forces in global coordinate system x-y)

Element end forces, Loading: (Qki) Imposed (H) Qi = 0.340 [kN/m]

Elem.	Node-1	Node-2	F1x[kN]	F1y[kN]	M1[kNm]	F2x[kN]	F2y[kN]	M2[kNm]
1	1	4	2.18	1.21	0.00	-2.18	-0.18	0.30
2	4	2	-1.31	0.18	-0.30	1.31	0.00	0.00
3	5	3	2.18	-0.18	-0.30	-2.18	1.21	0.00
4	2	5	-1.31	0.00	0.00	1.31	0.18	0.30
5	4	5	3.49	0.00	0.00	-3.49	0.00	0.00

—  
(element end forces in global coordinate system x-y)

**7.4. Vertical nodal displacements (mm)**

Node	Gk	Qk1	Qk2	Qk3	Qk4	Qk5	Qki
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	-0.20	-1.48	-1.11	-1.11	0.09	0.09	-0.56
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	-0.27	-2.03	2.00	-5.05	-3.24	3.50	-1.33
5	-0.27	-2.03	-5.05	2.00	3.50	-3.24	-0.21

**7.5. Support reactions (kN)**

Node	React.	Gk	Qk1	Qk2	Qk3	Qk4	Qk5	Qki
1	Fx	1.19	8.71	6.53	6.53	-0.86	-0.11	2.18
1	Fy	0.63	4.83	3.02	4.23	0.15	-0.73	1.21
3	Fx	-1.19	-8.71	-6.53	-6.53	0.11	0.86	-2.18
3	Fy	0.63	4.83	4.23	3.02	-0.73	0.15	1.21

**8. Support reactions for load combinations (kN)**

Loading	[kN/m]	Action	γ <sub>G</sub>	γ <sub>Q</sub>	ψ <sub>0</sub>
( Gk) Dead	Gk1 = 0.156, Gk2 = 0.085	Permanent	1.35	0.00	1.00
(Qk1) Snow	QksL= 1.360, QksR= 1.360	Short-term	0.00	1.50	0.50
(Qk2) Snow	QksL= 0.680, QksR= 1.360	Short-term	0.00	1.50	0.50
(Qk3) Snow	QksL= 1.360, QksR= 0.680	Short-term	0.00	1.50	0.50
(Qk4) Wind	QkwL= 0.206, QkwR=-0.368	Short-term	0.00	1.50	0.60
(Qk5) Wind	QkwL=-0.368, QkwR= 0.206	Short-term	0.00	1.50	0.60
(Qki) Imposed (H)	Qi = 0.340	Short-term	0.00	1.50	0.00

**8.1. Reactions at node : 1 (kN)**

L.C.	Load combination	Duration class	kmod	Fx	Fy	Fx/Kmod	Fy/Kmod
1	yg.Gk	Permanent	0.60	1.600	0.856	2.667	1.427
2	yg.Gk+yq.Qk1	Short-term	0.90	14.667	8.098	16.297	8.998
3	yg.Gk+yq.Qk2	Short-term	0.90	11.401	5.381	12.667	5.979
4	yg.Gk+yq.Qk3	Short-term	0.90	11.401	7.194	12.667	7.993
5	yg.Gk+yq.Qk4	Short-term	0.90	0.316	1.088	0.352	1.209
6	yg.Gk+yq.Qk5	Short-term	0.90	1.430	-0.242	1.588	-0.268
7	yg.Gk+yq.Qki	Short-term	0.90	4.867	2.666	5.408	2.963
8	yg.Gk+yq.Qk1+yq.ψo.Qk4	Short-term	0.90	13.897	8.237	15.441	9.152
9	yg.Gk+yq.Qk1+yq.ψo.Qk5	Short-term	0.90	14.565	7.439	16.183	8.266
10	yg.Gk+yq.Qk2+yq.ψo.Qk4	Short-term	0.90	10.630	5.520	11.812	6.133
11	yg.Gk+yq.Qk2+yq.ψo.Qk5	Short-term	0.90	11.298	4.722	12.554	5.247
12	yg.Gk+yq.Qk3+yq.ψo.Qk4	Short-term	0.90	10.630	7.333	11.812	8.148
13	yg.Gk+yq.Qk3+yq.ψo.Qk5	Short-term	0.90	11.298	6.536	12.554	7.262
14	yg.Gk+yq.Qk4+yq.ψo.Qk1	Short-term	0.90	6.850	4.709	7.611	5.232
15	yg.Gk+yq.Qk4+yq.ψo.Qk2	Short-term	0.90	5.217	3.350	5.796	3.722
16	yg.Gk+yq.Qk4+yq.ψo.Qk3	Short-term	0.90	5.217	4.257	5.796	4.730
17	yg.Gk+yq.Qk5+yq.ψo.Qk1	Short-term	0.90	7.963	3.379	8.848	3.755
18	yg.Gk+yq.Qk5+yq.ψo.Qk2	Short-term	0.90	6.330	2.021	7.033	2.245
19	yg.Gk+yq.Qk5+yq.ψo.Qk3	Short-term	0.90	6.330	2.927	7.033	3.253
20	yg.Gk+yq.Qki+yq.ψo.Qk1+yq.ψo.Qk4	Short-term	0.90	10.630	6.427	11.812	7.141
21	yg.Gk+yq.Qki+yq.ψo.Qk1+yq.ψo.Qk5	Short-term	0.90	11.298	5.629	12.554	6.254
22	yg.Gk+yq.Qki+yq.ψo.Qk2+yq.ψo.Qk4	Short-term	0.90	8.997	5.068	9.997	5.631
23	yg.Gk+yq.Qki+yq.ψo.Qk2+yq.ψo.Qk5	Short-term	0.90	9.665	4.270	10.739	4.745
24	yg.Gk+yq.Qki+yq.ψo.Qk3+yq.ψo.Qk4	Short-term	0.90	8.997	5.975	9.997	6.638
25	yg.Gk+yq.Qki+yq.ψo.Qk3+yq.ψo.Qk5	Short-term	0.90	9.665	5.177	10.739	5.752
	Maximum values			14.667	8.237	16.297	9.152
26	yg.Gk+yq.Qk4=0.9Gk+1.5Qk4, (EQU)	Short-term	0.90	-0.217	0.802	-0.241	0.892
27	yg.Gk+yq.Qk5=0.9Gk+1.5Qk5, (EQU)	Short-term	0.90	0.896	-0.527	0.996	-0.585

**8.2. Reactions at node : 3 (kN)**

L.C.	Load combination	Duration class	kmod	Fx	Fy	Fx/Kmod	Fy/Kmod
1	yg.Gk	Permanent	0.60	-1.600	0.856	-2.667	1.427
2	yg.Gk+yq.Qk1	Short-term	0.90	-14.667	8.098	-16.297	8.998
3	yg.Gk+yq.Qk2	Short-term	0.90	-11.401	7.194	-12.667	7.993
4	yg.Gk+yq.Qk3	Short-term	0.90	-11.401	5.381	-12.667	5.979
5	yg.Gk+yq.Qk4	Short-term	0.90	-1.430	-0.242	-1.588	-0.268
6	yg.Gk+yq.Qk5	Short-term	0.90	-0.316	1.088	-0.352	1.209
7	yg.Gk+yq.Qki	Short-term	0.90	-4.867	2.666	-5.408	2.963
8	yg.Gk+yq.Qk1+yq.ψo.Qk4	Short-term	0.90	-14.565	7.439	-16.183	8.266
9	yg.Gk+yq.Qk1+yq.ψo.Qk5	Short-term	0.90	-13.897	8.237	-15.441	9.152
10	yg.Gk+yq.Qk2+yq.ψo.Qk4	Short-term	0.90	-11.298	6.536	-12.554	7.262
11	yg.Gk+yq.Qk2+yq.ψo.Qk5	Short-term	0.90	-10.630	7.333	-11.812	8.148
12	yg.Gk+yq.Qk3+yq.ψo.Qk4	Short-term	0.90	-11.298	4.722	-12.554	5.247
13	yg.Gk+yq.Qk3+yq.ψo.Qk5	Short-term	0.90	-10.630	5.520	-11.812	6.133
14	yg.Gk+yq.Qk4+yq.ψo.Qk1	Short-term	0.90	-7.963	3.379	-8.848	3.755
15	yg.Gk+yq.Qk4+yq.ψo.Qk2	Short-term	0.90	-6.330	2.927	-7.033	3.253
16	yg.Gk+yq.Qk4+yq.ψo.Qk3	Short-term	0.90	-6.330	2.021	-7.033	2.245
17	yg.Gk+yq.Qk5+yq.ψo.Qk1	Short-term	0.90	-6.850	4.709	-7.611	5.232
18	yg.Gk+yq.Qk5+yq.ψo.Qk2	Short-term	0.90	-5.217	4.257	-5.796	4.730
19	yg.Gk+yq.Qk5+yq.ψo.Qk3	Short-term	0.90	-5.217	3.350	-5.796	3.722
20	yg.Gk+yq.Qki+yq.ψo.Qk1+yq.ψo.Qk4	Short-term	0.90	-11.298	5.629	-12.554	6.254
21	yg.Gk+yq.Qki+yq.ψo.Qk1+yq.ψo.Qk5	Short-term	0.90	-10.630	6.427	-11.812	7.141
22	yg.Gk+yq.Qki+yq.ψo.Qk2+yq.ψo.Qk4	Short-term	0.90	-9.665	5.177	-10.739	5.752
23	yg.Gk+yq.Qki+yq.ψo.Qk2+yq.ψo.Qk5	Short-term	0.90	-8.997	5.975	-9.997	6.638
24	yg.Gk+yq.Qki+yq.ψo.Qk3+yq.ψo.Qk4	Short-term	0.90	-9.665	4.270	-10.739	4.745
25	yg.Gk+yq.Qki+yq.ψo.Qk3+yq.ψo.Qk5	Short-term	0.90	-8.997	5.068	-9.997	5.631
	Maximum values			14.667	8.237	16.297	9.152
26	yg.Gk+yq.Qk4=0.9Gk+1.5Qk4, (EQU)	Short-term	0.90	-0.896	-0.527	-0.996	-0.585
27	yg.Gk+yq.Qk5=0.9Gk+1.5Qk5, (EQU)	Short-term	0.90	0.217	0.802	0.241	0.892

**9. Serviceability limit state**

**9.1. Serviceability limit state** (EC5 EN1995-1-1:2009, §2.2.3, §7)

Control of deflection at node 4 (EC5 §7.2)

Loading [kN/m]	u[mm]	Action	$\psi_0$	$\psi_1$	$\psi_2$	Kdef
( Gk) Dead Gk1 = 0.156, Gk2 = 0.085	-0.274	Permanent	1.00	1.00	1.00	0.80
(Qk1) Snow QksL= 1.360, QksR= 1.360	-2.029	Short-term	0.50	0.20	0.00	0.80
(Qk2) Snow QksL= 0.680, QksR= 1.360	2.002	Short-term	0.50	0.20	0.00	0.80
(Qk3) Snow QksL= 1.360, QksR= 0.680	-5.046	Short-term	0.50	0.20	0.00	0.80
(Qk4) Wind QkwL= 0.206, QkwR=-0.368	-3.244	Short-term	0.60	0.20	0.00	0.80
(Qk5) Wind QkwL=-0.368, QkwR= 0.206	3.496	Short-term	0.60	0.20	0.00	0.80

Load combination	w.inst	w.fin [mm]
1 Gk	0.274	0.494
2 Gk + Qk1	2.304	2.523
3 Gk + Qk2	0.274	0.494
4 Gk + Qk3	5.320	5.539
5 Gk + Qk4	3.518	3.738
6 Gk + Qk5	0.274	0.494
7 Gk + Qk1 + $\psi_0$ .Qk4	4.250	4.469
8 Gk + Qk1 + $\psi_0$ .Qk5	2.304	2.523
9 Gk + Qk2 + $\psi_0$ .Qk4	2.221	2.440
10 Gk + Qk2 + $\psi_0$ .Qk5	0.274	0.494
11 Gk + Qk3 + $\psi_0$ .Qk4	7.267	7.486
12 Gk + Qk3 + $\psi_0$ .Qk5	5.320	5.539
13 Gk + Qk4 + $\psi_0$ .Qk1	4.533	4.752
14 Gk + Qk4 + $\psi_0$ .Qk2	3.518	3.738
15 Gk + Qk4 + $\psi_0$ .Qk3	6.041	6.261
16 Gk + Qk5 + $\psi_0$ .Qk1	1.289	1.508
17 Gk + Qk5 + $\psi_0$ .Qk2	0.274	0.494
18 Gk + Qk5 + $\psi_0$ .Qk3	2.797	3.017

$w_{fin}, q = w_{inst}, q(1 + k_{def})$ ,  $w_{fin}, q = w_{inst}, q(1 + \psi_2 \cdot k_{def})$  (EC5 §2.2.3, Eq.2.3, Eq.2.4)

**Maximum deflection values at node 4**

w.inst = 7.267 mm, w.fin = 7.486 mm

Check according to EC5 EN1995-1-1:2009 §7.2, Tab.7.2

**Final deflections at node 4**

w.inst = 7.267 mm < L/300=7100/300= 23.667 mm

w.net,fin = 7.486 mm < L/250=7100/250= 28.400 mm

w.fin = 7.486 mm < L/150=7100/150= 47.333 mm

The check is satisfied

**9.2. Serviceability limit state** (EC5 EN1995-1-1:2009, §2.2.3, §7)

Control of deflection in middle of element 1 (EC5 §7.2)

Loading [kN/m]	u[mm]	Action	$\psi_0$	$\psi_1$	$\psi_2$	Kdef
( Gk) Dead Gk1 = 0.156, Gk2 = 0.085	0.863	Permanent	1.00	1.00	1.00	0.80
(Qk1) Snow QksL= 1.360, QksR= 1.360	7.527	Short-term	0.50	0.20	0.00	0.80
(Qk2) Snow QksL= 0.680, QksR= 1.360	3.763	Short-term	0.50	0.20	0.00	0.80
(Qk3) Snow QksL= 1.360, QksR= 0.680	7.527	Short-term	0.50	0.20	0.00	0.80
(Qk4) Wind QkwL= 0.206, QkwR=-0.368	1.213	Short-term	0.60	0.20	0.00	0.80
(Qk5) Wind QkwL=-0.368, QkwR= 0.206	-2.170	Short-term	0.60	0.20	0.00	0.80

Load combination	w.inst	w.fin [mm]
1 Gk	0.863	1.554
2 Gk + Qk1	8.390	9.081
3 Gk + Qk2	4.627	5.317
4 Gk + Qk3	8.390	9.081
5 Gk + Qk4	2.076	2.766
6 Gk + Qk5	0.863	1.554
7 Gk + Qk1 + $\psi_0$ .Qk4	9.118	9.808
8 Gk + Qk1 + $\psi_0$ .Qk5	8.390	9.081
9 Gk + Qk2 + $\psi_0$ .Qk4	5.354	6.045
10 Gk + Qk2 + $\psi_0$ .Qk5	4.627	5.317
11 Gk + Qk3 + $\psi_0$ .Qk4	9.118	9.808
12 Gk + Qk3 + $\psi_0$ .Qk5	8.390	9.081
13 Gk + Qk4 + $\psi_0$ .Qk1	5.839	6.530
14 Gk + Qk4 + $\psi_0$ .Qk2	3.957	4.648
15 Gk + Qk4 + $\psi_0$ .Qk3	5.839	6.530
16 Gk + Qk5 + $\psi_0$ .Qk1	4.627	5.317
17 Gk + Qk5 + $\psi_0$ .Qk2	2.745	3.435
18 Gk + Qk5 + $\psi_0$ .Qk3	4.627	5.317

$\bar{w}.fin, g = w.inst, g(1+kdef), w.fin, q = w.inst, q(1+\psi_2 \cdot kdef)$  (EC5 §2.2.3, Eq.2.3, Eq.2.4)

Maximum deflection values in middle of element 1

w.inst = 9.118 mm, w.fin = 9.808 mm

Check according to EC5 EN1995-1-1:2009 §7.2, Tab.7.2

Final deflections in middle of element 1

w.inst = 9.118 mm < L/300=3216/300= 10.721 mm

w.net,fin = 9.808 mm < L/250=3216/250= 12.866 mm

w.fin = 9.808 mm < L/150=3216/150= 21.443 mm

The check is satisfied

## 10. Ultimate limit state

### 10.1. Ultimate limit state (EC5 EN1995-1-1:2009, §6)

Rafter, elements: 1, 2, 3, 4

Loading [kN/m]	Action	$\gamma_g$	$\gamma_q$	$\psi_0$
(Gk) Dead Gk1 = 0.156, Gk2 = 0.085	Permanent	1.35	0.00	1.00
(Qk1) Snow QksL= 1.360, QksR= 1.360	Short-term	0.00	1.50	0.50
(Qk2) Snow QksL= 0.680, QksR= 1.360	Short-term	0.00	1.50	0.50
(Qk3) Snow QksL= 1.360, QksR= 0.680	Short-term	0.00	1.50	0.50
(Qk4) Wind QkwL= 0.206, QkwR=-0.368	Short-term	0.00	1.50	0.60
(Qk5) Wind QkwL=-0.368, QkwR= 0.206	Short-term	0.00	1.50	0.60
(Qki) Imposed (H) Qi = 0.340	Short-term	0.00	1.50	0.00



L.C.	Load combination	Duration class	kmod	-N/Kmod	+N/Kmod	V/Kmod	M/Kmod
1	yg.Gk	Permanent	0.60	-2.994	1.339	0.673	0.328
2	yg.Gk+yg.Qk1	Short-term	0.90	-18.392	9.107	4.561	2.222
3	yg.Gk+yg.Qk2	Short-term	0.90	-14.637	7.396	4.196	2.256
4	yg.Gk+yg.Qk3	Short-term	0.90	-14.637	7.397	4.196	2.256
5	yg.Gk+yg.Qk4	Short-term	0.90	-1.996	0.893	1.024	0.844
6	yg.Gk+yg.Qk5	Short-term	0.90	-1.996	0.893	1.024	0.844
7	yg.Gk+yg.Qki	Short-term	0.90	-6.095	2.946	1.477	0.719
8	yg.Gk+yg.Qk1+yg.ψo.Qk4	Short-term	0.90	-18.392	9.107	4.774	2.400
9	yg.Gk+yg.Qk1+yg.ψo.Qk5	Short-term	0.90	-18.392	9.107	4.774	2.400
10	yg.Gk+yg.Qk2+yg.ψo.Qk4	Short-term	0.90	-14.637	6.865	4.196	2.256
11	yg.Gk+yg.Qk2+yg.ψo.Qk5	Short-term	0.90	-13.948	7.396	4.408	2.651
12	yg.Gk+yg.Qk3+yg.ψo.Qk4	Short-term	0.90	-13.948	7.397	4.408	2.651
13	yg.Gk+yg.Qk3+yg.ψo.Qk5	Short-term	0.90	-14.637	6.865	4.196	2.256
14	yg.Gk+yg.Qk4+yg.ψo.Qk1	Short-term	0.90	-10.194	5.000	2.859	1.686
15	yg.Gk+yg.Qk4+yg.ψo.Qk2	Short-term	0.90	-8.317	3.801	2.322	1.221
16	yg.Gk+yg.Qk4+yg.ψo.Qk3	Short-term	0.90	-7.972	4.145	2.676	1.879
17	yg.Gk+yg.Qk5+yg.ψo.Qk1	Short-term	0.90	-10.194	5.000	2.859	1.686
18	yg.Gk+yg.Qk5+yg.ψo.Qk2	Short-term	0.90	-7.972	4.145	2.677	1.879
19	yg.Gk+yg.Qk5+yg.ψo.Qk3	Short-term	0.90	-8.317	3.801	2.322	1.221
20	yg.Gk+yg.Qki+yg.ψo.Qk1+yg.ψo.Qk4	Short-term	0.90	-14.293	7.053	3.746	1.900
21	yg.Gk+yg.Qki+yg.ψo.Qk1+yg.ψo.Qk5	Short-term	0.90	-14.293	7.053	3.746	1.900
22	yg.Gk+yg.Qki+yg.ψo.Qk2+yg.ψo.Qk4	Short-term	0.90	-12.416	5.855	3.350	1.697
23	yg.Gk+yg.Qki+yg.ψo.Qk2+yg.ψo.Qk5	Short-term	0.90	-12.071	6.198	3.563	2.037
24	yg.Gk+yg.Qki+yg.ψo.Qk3+yg.ψo.Qk4	Short-term	0.90	-12.071	6.198	3.563	2.037
25	yg.Gk+yg.Qki+yg.ψo.Qk3+yg.ψo.Qk5	Short-term	0.90	-12.416	5.855	3.350	1.697
Maximum values				-18.392	9.107	4.774	2.651

**10.2. Check of cross section Rafter, elements: 1, 2, 3, 4**

**Rafter, elements: 1, 2, 3, 4, Load combination No 8**

Tension parallel to the grain, Ft0d=8.196 kN (EC5 §6.1.2)

Rectangular cross section, b=50 mm, h=150 mm, A= 7 500 mm²

Modification factor Kmod=0.90 (Tab.3.1), Material factor γM=1.30 (Tab. 2.3)

ft0k=7.20 N/mm², ft0d=Kmod·ft0k/γM=0.90x7.20/1.30=4.98N/mm² (EC5 Eq.2.14)

Ft0d=8.196 kN, σt0d=Ft0d/Anetto=1000x8.196/7500=1.09N/mm² < 4.98N/mm²=ft0d (Eq.6.1)

The check is satisfied

**Rafter, elements: 1, 2, 3, 4, Load combination No 9**

Compression parallel to the grain, Fc0d=-16.553 kN (EC5 §6.1.4)

Rectangular cross section, b=50 mm, h=150 mm, A= 7 500 mm²

Modification factor Kmod=0.90 (Tab.3.1), Material factor γM=1.30 (Tab. 2.3)

fc0k=16.00 N/mm², fc0d=Kmod·fc0k/γM=0.90x16.00/1.30=11.08N/mm² (EC5 Eq.2.14)

Fc0d=-16.553 kN, σc0d=Fc0d/Anetto=1000x16.553/7500=2.21N/mm² < 11.08N/mm²=fc0d (Eq.6.2)

The check is satisfied

**Rafter, elements: 1, 2, 3, 4, Load combination No 9**

Shear, Fv=4.297 kN (EC5 §6.1.7)

Rectangular cross section, bef=0.67x50=34 mm, h=150 mm, A= 5 100 mm²

Modification factor Kmod=0.90 (Tab.3.1), Material factor γM=1.30 (Tab. 2.3)

fvk=3.00 N/mm², fvd=Kmod·fvk/γM=0.90x3.00/1.30=2.08N/mm² (EC5 Eq.2.14)

Fv=4.297 kN, τv0d=1.50Fv0d/Anetto=1000x1.50x4.297/5100=1.26N/mm² < 2.08N/mm²=fv0d (Eq.6.13)

The check is satisfied

**10.3. Ultimate limit state (EC5 EN1995-1-1:2009, §6)**

Tie, elements: 5

Loading [kN/m]	Action	yg	yg	ψo
( Gk) Dead Gk1 = 0.156, Gk2 = 0.085	Permanent	1.35	0.00	1.00
(Qk1) Snow QksL= 1.360, QksR= 1.360	Short-term	0.00	1.50	0.50
(Qk2) Snow QksL= 0.680, QksR= 1.360	Short-term	0.00	1.50	0.50
(Qk3) Snow QksL= 1.360, QksR= 0.680	Short-term	0.00	1.50	0.50
(Qk4) Wind QkwL= 0.206, QkwR=-0.368	Short-term	0.00	1.50	0.60
(Qk5) Wind QkwL=-0.368, QkwR= 0.206	Short-term	0.00	1.50	0.60
(Qki) Imposed (H) Qi = 0.340	Short-term	0.00	1.50	0.00

L.C.	Load combination	Duration class	kmod	-N/Kmod	+N/Kmod	V/Kmod	M/Kmod
1	yg.Gk	Permanent	0.60	-4.092	0.000	0.101	0.053
2	yg.Gk+yg.Qk1	Short-term	0.90	-25.988	0.000	0.067	0.034
3	yg.Gk+yg.Qk2	Short-term	0.90	-20.173	0.000	0.068	0.034
4	yg.Gk+yg.Qk3	Short-term	0.90	-20.173	0.000	0.068	0.034
5	yg.Gk+yg.Qk4	Short-term	0.90	-1.151	0.000	0.068	0.036
6	yg.Gk+yg.Qk5	Short-term	0.90	-1.151	0.000	0.068	0.036
7	yg.Gk+yg.Qki	Short-term	0.90	-8.543	0.000	0.067	0.035
8	yg.Gk+yg.Qk1+yg.ψo.Qk4	Short-term	0.90	-25.042	0.000	0.068	0.034
9	yg.Gk+yg.Qk1+yg.ψo.Qk5	Short-term	0.90	-25.042	0.000	0.068	0.034
10	yg.Gk+yg.Qk2+yg.ψo.Qk4	Short-term	0.90	-19.227	0.000	0.067	0.035
11	yg.Gk+yg.Qk2+yg.ψo.Qk5	Short-term	0.90	-19.227	0.000	0.068	0.035
12	yg.Gk+yg.Qk3+yg.ψo.Qk4	Short-term	0.90	-19.227	0.000	0.068	0.035
13	yg.Gk+yg.Qk3+yg.ψo.Qk5	Short-term	0.90	-19.227	0.000	0.067	0.035
14	yg.Gk+yg.Qk4+yg.ψo.Qk1	Short-term	0.90	-12.781	0.000	0.068	0.035
15	yg.Gk+yg.Qk4+yg.ψo.Qk2	Short-term	0.90	-9.874	0.000	0.067	0.035
16	yg.Gk+yg.Qk4+yg.ψo.Qk3	Short-term	0.90	-9.874	0.000	0.068	0.035
17	yg.Gk+yg.Qk5+yg.ψo.Qk1	Short-term	0.90	-12.781	0.000	0.068	0.035
18	yg.Gk+yg.Qk5+yg.ψo.Qk2	Short-term	0.90	-9.874	0.000	0.068	0.035
19	yg.Gk+yg.Qk5+yg.ψo.Qk3	Short-term	0.90	-9.874	0.000	0.067	0.035
20	yg.Gk+yg.Qki+yg.ψo.Qk1+yg.ψo.Qk4	Short-term	0.90	-19.227	0.000	0.068	0.035
21	yg.Gk+yg.Qki+yg.ψo.Qk1+yg.ψo.Qk5	Short-term	0.90	-19.227	0.000	0.068	0.035
22	yg.Gk+yg.Qki+yg.ψo.Qk2+yg.ψo.Qk4	Short-term	0.90	-16.320	0.000	0.067	0.035
23	yg.Gk+yg.Qki+yg.ψo.Qk2+yg.ψo.Qk5	Short-term	0.90	-16.320	0.000	0.068	0.035
24	yg.Gk+yg.Qki+yg.ψo.Qk3+yg.ψo.Qk4	Short-term	0.90	-16.320	0.000	0.068	0.035
25	yg.Gk+yg.Qki+yg.ψo.Qk3+yg.ψo.Qk5	Short-term	0.90	-16.320	0.000	0.067	0.035
	Maximum values			-25.988	0.000	0.101	0.053

**10.4. Check of cross section Tie, elements: 5**

**Tie, elements: 5, Load combination No 2**

Compression parallel to the grain,  $F_{c0d} = -23.389 \text{ kN}$  (EC5 §6.1.4)

Rectangular cross section,  $b = 50 \text{ mm}$ ,  $h = 150 \text{ mm}$ ,  $A = 7500 \text{ mm}^2$

Modification factor  $K_{mod} = 0.90$  (Tab.3.1), Material factor  $\gamma_M = 1.30$  (Tab. 2.3)

$f_{c0k} = 16.00 \text{ N/mm}^2$ ,  $f_{c0d} = K_{mod} \cdot f_{c0k} / \gamma_M = 0.90 \times 16.00 / 1.30 = 11.08 \text{ N/mm}^2$  (EC5 Eq.2.14)

$F_{c0d} = -23.389 \text{ kN}$ ,  $\sigma_{c0d} = F_{c0d} / A_{netto} = 1000 \times 23.389 / 7500 = 3.12 \text{ N/mm}^2 < 11.08 \text{ N/mm}^2 = f_{c0d}$  (Eq.6.2)

The check is satisfied

Negligible shear stress, shear check is omitted (EC5 §6.1.7)

**Pană:**

În urma calculelor efectuate rezultă secțiunea panoulor intermediare (cele care nu reazemă pe centurile de beton armat) de 10x30 cm în ambele modele de calcul.

Încărcările la nivelul panoulor sunt următoarele:

Greutate volumica lemn=	600	kg/m3
Greutate volumica lemn=	6	KN/m3
Lungime Pana=	4	m
L aferenta pana=	1.75	m
Greutate proprie tigla=	0.5	KN/m2
Greutate proprie tabla=	0.05	KN/m2
Zapada=	1.6	KN/m2

<b>Incarcari pe pana model 1 - invelitoare tigla romana</b>				
Tip incarcari	h[m]	b[m]	nr.buc[-]	q[KN/m]
Greutate proprie astereala	0.025	-	-	0.26
Greutate proprie capriori	0.2	0.05	7	0.18
Greutate proprie invelitoare				0.88
<b>Total incarcari permanente</b>				<b>1.32</b>
<b>Zapada</b>				<b>2.80</b>

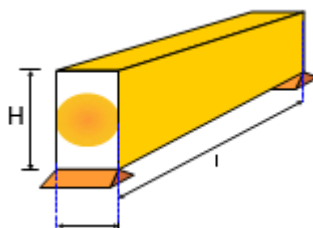
<b>Incarcari pe pana model 2 - invelitoare tigla metalica</b>				
Tip incarcari	h[m]	b[m]	nr.buc[-]	q[KN/m]
Greutate proprie astereala	0.025	-	-	0.26
Greutate proprie capriori	0.2	0.05	6	0.16
Greutate proprie invelitoare				0.09
<b>Total incarcari permanente</b>				<b>0.51</b>
<b>Zapada</b>				<b>2.80</b>

### i. Pană 10x30 cm – Model 1 – Învelitoare Țiglă romană

#### 1. FLOOR-001

Simply supported beam

#### 2. General description, assumptions, materials, loads



#### 2.1. Construction type

Timber floor, from timber C14

Beam free span 4.000 m

Beam cross section BxH=100mmx300mm

Lateral restrictions,  $L_c = 0.10 \times L = 0.400\text{m}$

#### 2.2. Design codes

EN1990:2002 Basis of structural design

EN1991-1-1:2002 Actions on structures

EN1995-1-1:2009 Design of timber structures

#### 2.3. Design methodology

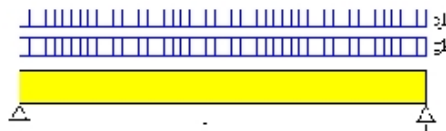
The internal forces are computed at the ends and the middle span of the floor beam, and the elastic deflections at midspan, for all the load combinations, according to EC 1 and EC 5. All the checks of Eurocode 5 are performed in ultimate limit state, (EC5 EN1995-1-1:2009, §6). The deflections are checked in serviceability limit state, according to EC5 EN1995-1-1:2009, §7.2. The Eurocode 5 considerations are taken into account for the check of beam vibrations (EC5 EN1995-1-1:2009, §7.3.3).

**2.4. Material properties (timber)** (EC5 EN1995-1-1:2009, §3)

Timber class : C14  
 Service classes : Class 2, moisture content  $\leq 20\%$  (EC5 §2.3.1.3)  
 Material factor  $\gamma_M = 1.30$  (EC5 Tab. 2.3)  
**Characteristic material properties for timber**  
 $f_{mk} = 14.0$  MPa,  $f_{t0k} = 7.2$  MPa,  $f_{t90k} = 0.4$  MPa  
 $f_{c0k} = 16.0$  MPa,  $f_{c90k} = 2.0$  MPa,  $f_{vk} = 3.0$  MPa  
 $E_{0m} = 7000$  MPa,  $E_{005} = 4700$  MPa,  $E_{90m} = 230$  MPa  
 $G_m = 440$  MPa,  $\rho_k = 290$  Kg/m<sup>3</sup>,  $\rho_m = 350$  Kg/m<sup>3</sup>

**2.5. Line load (kN/m) on the floor beams**

Dead =  $1.340 + 0.103 = 1.443$  kN/m  
 Permanent load  $g_k = 1.443$  kN/m  
 Live load  $q_k = 2.800$  kN/m



**2.6. Cross section characteristics of floor beams**

Cross section  $B \times H = 100 \text{ mm} \times 300 \text{ mm}$ ,  $A = 3.000 \times 10^{-4} \text{ m}^2$ ,  $I = 2.250 \times 10^{-8} \text{ m}^4$ ,  $W = 1.500 \times 10^{-6} \text{ m}^3$   
 beam self weight  $(100 \text{ mm} \times 300 \text{ mm} [10^{-6}]) \times (350 \times 9.81 / 1000) = 0.103$  kN/m

**3. Maximum internal beam forces and deflections (L=4.000m)**

Dead loads  $G_k = 1.443$  kN/m,  $\max V = 2.89$  kN,  $\max M = 2.89$  kNm,  $\max \Delta = 3.32$  mm  
 Live loads  $Q_k = 2.800$  kN/m,  $\max V = 5.60$  kN,  $\max M = 5.60$  kNm,  $\max \Delta = 6.44$  mm

**4. Serviceability limit state** (EC5 EN1995-1-1:2009, §2.2.3, §7)

Control of deflection in middle of beam span (EC5 §7.2)

Loading [kN/m]	u [mm]	Action	$\psi_0$	$\psi_1$	$\psi_2$	Kdef
(Gk) Dead $G_k = 1.443$	3.316	Permanent	1.00	1.00	1.00	0.80
(Qkf) Live $Q_k = 2.800$	6.435	Medium-term	0.70	0.50	0.30	0.80
<b>Load combination</b>	<b>w.inst</b>	<b>w.fin [mm]</b>				
1 Gk	3.316	5.969				
2 Qk1	6.435	7.979				
3 Gk+Qk1	9.751	13.949				

$w_{fin,g} = w_{inst,g}(1+k_{def})$ ,  $w_{fin,q} = w_{inst,q}(1+\psi_2 \cdot k_{def})$  (EC5 §2.2.3, Eq.2.3, Eq.2.4)

**Maximum deflection values**

$w_{inst} = 9.751$  mm,  $w_{fin} = 13.949$  mm

Check according to EC5 EN1995-1-1:2009 §7.2, Tab.7.2

**Final deflections**

$w_{inst} = 9.751$  mm  $< L/300 = 4000/300 = 13.333$  mm  
 $w_{net,fin} = 13.949$  mm  $< L/250 = 4000/250 = 16.000$  mm  
 $w_{fin} = 13.949$  mm  $< L/150 = 4000/150 = 26.667$  mm

The check is satisfied

**5. Ultimate limit state** (EC5 EN1995-1-1:2009, §6)

Loading [kN/m]	Action	$\gamma_G$	$\gamma_Q$	$\psi_0$
(Gk) Dead Gk = 1.443	Permanent	1.35	0.00	1.00
(Qkf) Live Qk = 2.800	Medium-term	0.00	1.50	0.70

L.C.	Load combination	Ved	Med	Duration class	kmod	V/Kmod	M/Kmod
1	$\gamma_G \cdot G_k$	3.896	3.896	Permanent	0.60	6.494	6.494
2	$\gamma_G \cdot G_k + \gamma_Q \cdot Q_{kf}$	12.296	12.296	Medium-term	0.80	15.370	15.370
Maximum values						15.370	15.370

Load combination 2,  $\gamma_G \cdot G_k + \gamma_Q \cdot Q_{kf}$  (Maximum values)

**Shear,  $F_v=12.296$  kN** (EC5 §6.1.7)

Rectangular cross section,  $b_{ef}=0.67 \times 100=67$  mm,  $h=300$  mm,  $A=20\,100$  mm<sup>2</sup>

Modification factor  $K_{mod}=0.80$  (Tab.3.1), Material factor  $\gamma_M=1.30$  (Tab. 2.3)

$f_{vk}=3.00$  N/mm<sup>2</sup>,  $f_{vd}=K_{mod} \cdot f_{vk} / \gamma_M = 0.80 \times 3.00 / 1.30 = 1.85$  N/mm<sup>2</sup> (EC5 Eq.2.14)

$F_v=12.296$  kN,  $\tau_{v0d}=1.50 F_v / A_{netto} = 1000 \times 1.50 \times 12.296 / 20100 = 0.92$  N/mm<sup>2</sup> <  $1.85$  N/mm<sup>2</sup> =  $f_{v0d}$

The check is satisfied

**Bending,  $M_{yd}=12.296$  kNm,  $M_{zd}=0.000$  kNm** (EC5 §6.1.6)

Rectangular cross section,  $b=100$  mm,  $h=300$  mm,  $A=3.00 \times 10^4$  mm<sup>2</sup>,  $W_y=1.50 \times 10^6$  mm<sup>3</sup>,  $W_z=5.00 \times 10^6$  mm<sup>3</sup>

Modification factor  $K_{mod}=0.80$  (Tab.3.1), Material factor  $\gamma_M=1.30$  (Tab. 2.3)

$f_{myk}=14.00$  N/mm<sup>2</sup>,  $f_{myd}=K_{mod} \cdot f_{myk} / \gamma_M = 0.80 \times 14.00 / 1.30 = 8.62$  N/mm<sup>2</sup>

$f_{mzk}=14.00$  N/mm<sup>2</sup>,  $f_{mzd}=K_{mod} \cdot f_{mzk} / \gamma_M = 0.80 \times 14.00 / 1.30 = 8.62$  N/mm<sup>2</sup>

Rectangular cross section  $K_m=0.70$  (EC5 §6.1.6.(2))

$\sigma_{myd} = M_{yd} / W_{my,netto} = 10^6 \times 12.296 / (1.5000 \times 10^6) = 8.20$  N/mm<sup>2</sup>

$\sigma_{mzd} = M_{zd} / W_{mz,netto} = 10^6 \times 0.000 / (0.5000 \times 10^6) = 0.00$  N/mm<sup>2</sup>

$\sigma_{myd} / f_{myd} + K_m \cdot \sigma_{mzd} / f_{mzd} = 0.951 + 0.000 = 0.95 < 1$  (EC5 Eq.6.11)

$K_m \cdot \sigma_{myd} / f_{myd} + \sigma_{mzd} / f_{mzd} = 0.666 + 0.000 = 0.67 < 1$  (EC5 Eq.6.12)

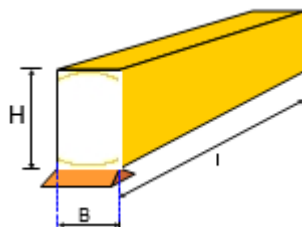
The check is satisfied

ii. Pană 10x30 cm – Model 2 – Învélitoare Țigla metalică

1. FLOOR-001

Simply supported beam

2. General description, assumptions, materials, loads



**2.1. Construction type**

Timber floor, from timber C14  
 Beam free span 4.000 m  
 Beam cross section BxH=100mmx300mm  
 Lateral restrictions,  $L_c = 0.10 \times L = 0.400m$

**2.2. Design codes**

EN1990:2002 Basis of structural design  
 EN1991-1-1:2002 Actions on structures  
 EN1995-1-1:2009 Design of timber structures

**2.3. Design methodology**

The internal forces are computed at the ends and the middle span of the floor beam, and the elastic deflections at midspan, for all the load combinations, according to EC 1 and EC 5. All the checks of Eurocode 5 are performed in ultimate limit state, (EC5 EN1995-1-1:2009, §6). The deflections are checked in serviceability limit state, according to EC5 EN1995-1-1:2009, §7.2. The Eurocode 5 considerations are taken into account for the check of beam vibrations (EC5 EN1995-1-1:2009, §7.3.3).

**2.4. Material properties (timber)** (EC5 EN1995-1-1:2009, §3)

Timber class : C14  
 Service classes : Class 2, moisture content  $\leq 20\%$  (EC5 §2.3.1.3)  
 Material factor  $\gamma_M = 1.30$  (EC5 Tab. 2.3)  
 Characteristic material properties for timber  
 $f_{mk} = 14.0$  MPa,  $f_{t0k} = 7.2$  MPa,  $f_{t90k} = 0.4$  MPa  
 $f_{c0k} = 16.0$  MPa,  $f_{c90k} = 2.0$  MPa,  $f_{vk} = 3.0$  MPa  
 $E_{0m} = 7000$  MPa,  $E_{005} = 4700$  MPa,  $E_{90m} = 230$  MPa  
 $G_m = 440$  MPa,  $\rho_k = 290$  Kg/m<sup>3</sup>,  $\rho_m = 350$  Kg/m<sup>3</sup>

**2.5. Line load (kN/m) on the floor beams**

Dead =  $0.500 + 0.103 = 0.603$  kN/m  
 Permanent load  $g_k = 0.603$  kN/m  
 Live load  $q_k = 2.800$  kN/m



**2.6. Cross section characteristics of floor beams**

Cross section BxH=100mmx300mm,  $A = 3.000 \times 10^{-4} m^2$ ,  $I = 2.250 \times 10^{-8} m^4$ ,  $W = 1.500 \times 10^{-6} m^3$   
 beam self weight  $(100mm \times 300mm [10^{-6}]) \times (350 \times 9.81 / 1000) = 0.103$  kN/m

**3. Maximum internal beam forces and deflections (L=4.000m)**

Dead loads  $G_k = 0.603$  kN/m,  $\max V = 1.21$  kN,  $\max M = 1.21$  kNm,  $\max \Delta = 1.39$  mm  
 Live loads  $Q_k = 2.800$  kN/m,  $\max V = 5.60$  kN,  $\max M = 5.60$  kNm,  $\max \Delta = 6.44$  mm

**4. Serviceability limit state** (EC5 EN1995-1-1:2009, §2.2.3, §7)

Control of deflection in middle of beam span (EC5 §7.2)

Loading [kN/m]	u [mm]	Action	$\psi_0$	$\psi_1$	$\psi_2$	Kdef
(Gk) Dead $G_k = 0.603$	1.386	Permanent	1.00	1.00	1.00	0.80
(Qkf) Live $Q_k = 2.800$	6.435	Medium-term	0.70	0.50	0.30	0.80
Load combination	w.inst	w.fin [mm]				
1 Gk	1.386	2.494				
2 Qk1	6.435	7.979				
3 Gk+Qk1	7.821	10.474				

$w_{fin, g} = w_{inst, g} (1 + k_{def})$ ,  $w_{fin, q} = w_{inst, q} (1 + \psi_2 \cdot k_{def})$  (EC5 §2.2.3, Eq.2.3, Eq.2.4)

**Maximum deflection values**

w.inst = 7.821 mm, w.fin = 10.474 mm

Check according to EC5 EN1995-1-1:2009 §7.2, Tab.7.2

**Final deflections**

w.inst = 7.821 mm < L/300=4000/300= 13.333 mm

w.net,fin = 10.474 mm < L/250=4000/250= 16.000 mm

w.fin = 10.474 mm < L/150=4000/150= 26.667 mm

The check is satisfied

**5. Ultimate limit state (EC5 EN1995-1-1:2009, §6)**

Loading [kN/m]	Action	γ <sub>G</sub>	γ <sub>Q</sub>	ψ <sub>0</sub>
(Gk) Dead Gk = 0.603	Permanent	1.35	0.00	1.00
(Qkf) Live Qk = 2.800	Medium-term	0.00	1.50	0.70

L.C.	Load combination	Ved	Med	Duration class	kmod	V/Kmod	M/Kmod
1	γ <sub>G</sub> ·Gk	1.628	1.628	Permanent	0.60	2.714	2.714
2	γ <sub>G</sub> ·Gk + γ <sub>Q</sub> ·Qkf	10.028	10.028	Medium-term	0.80	12.535	12.535
Maximum values						12.535	12.535

Load combination 2, γ<sub>G</sub>·Gk + γ<sub>Q</sub>·Qkf (Maximum values)

**Shear, F<sub>v</sub>=10.028 kN (EC5 §6.1.7)**

Rectangular cross section, b<sub>ef</sub>=0.67x100=67 mm, h=300 mm, A= 20 100 mm<sup>2</sup>

Modification factor K<sub>mod</sub>=0.80 (Tab.3.1), Material factor γ<sub>M</sub>=1.30 (Tab. 2.3)

f<sub>vk</sub>=3.00 N/mm<sup>2</sup>, f<sub>vd</sub>=K<sub>mod</sub>·f<sub>vk</sub>/γ<sub>M</sub>=0.80x3.00/1.30=1.85N/mm<sup>2</sup> (EC5 Eq.2.14)

F<sub>v</sub>=10.028 kN, τ<sub>v0d</sub>=1.50F<sub>v0d</sub>/A<sub>netto</sub>=1000x1.50x10.028/20100=0.75N/mm<sup>2</sup> < 1.85N/mm<sup>2</sup>=f<sub>vd</sub>

The check is satisfied

**Bending, M<sub>yd</sub>=10.028 kNm, M<sub>zd</sub>=0.000 kNm (EC5 §6.1.6)**

Rectangular cross section, b=100mm, h=300mm, A=3.00x10<sup>4</sup>mm<sup>2</sup>, W<sub>y</sub>=1.50x10<sup>6</sup>mm<sup>3</sup>, W<sub>z</sub>=5.00x10<sup>6</sup>mm<sup>3</sup>

Modification factor K<sub>mod</sub>=0.80 (Tab.3.1), Material factor γ<sub>M</sub>=1.30 (Tab. 2.3)

f<sub>myk</sub>=14.00 N/mm<sup>2</sup>, f<sub>myd</sub>=K<sub>mod</sub>·f<sub>myk</sub>/γ<sub>M</sub>=0.80x14.00/1.30=8.62N/mm<sup>2</sup>

f<sub>mzk</sub>=14.00 N/mm<sup>2</sup>, f<sub>mzd</sub>=K<sub>mod</sub>·f<sub>mzk</sub>/γ<sub>M</sub>=0.80x14.00/1.30=8.62N/mm<sup>2</sup>

Rectangular cross section K<sub>m</sub>=0.70 (EC5 §6.1.6.(2))

σ<sub>myd</sub>=M<sub>yd</sub>/W<sub>my,netto</sub>=10<sup>6</sup>x10.028/(1.5000x10<sup>6</sup>)= 6.69 N/mm<sup>2</sup>

σ<sub>mzd</sub>=M<sub>zd</sub>/W<sub>mz,netto</sub>=10<sup>6</sup>x0.000/(0.5000x10<sup>6</sup>)= 0.00 N/mm<sup>2</sup>

σ<sub>myd</sub>/f<sub>myd</sub>+K<sub>m</sub>·σ<sub>mzd</sub>/f<sub>mzd</sub>=0.776+0.000= 0.78 < 1 (EC5 Eq.6.11)

K<sub>m</sub>·σ<sub>myd</sub>/f<sub>myd</sub>+σ<sub>mzd</sub>/f<sub>mzd</sub>=0.543+0.000= 0.54 < 1 (EC5 Eq.6.12)

The check is satisfied

**Pop:**

În urma calculelor efectuate rezultă secțiunea popilor pe care reazemă paneele intermediare de 10x10cm în ambele modele de calcul.

Încărcările la nivelul celui mai zvelt pop sunt următoarele:

Greutate volumica lemn=	600	kg/m <sup>3</sup>
Greutate volumica lemn=	6	KN/m <sup>3</sup>
Greutate proprie tigla=	0.5	KN/m <sup>2</sup>
Greutate proprie tabla=	0.05	KN/m <sup>2</sup>
Aria aferenta,pop=	3.41	m <sup>2</sup>
Lungime descarcare pana	2.1	m
L,capriori aferent,pop=	1.75	m
Zapada=	1.6	KN/m <sup>2</sup>

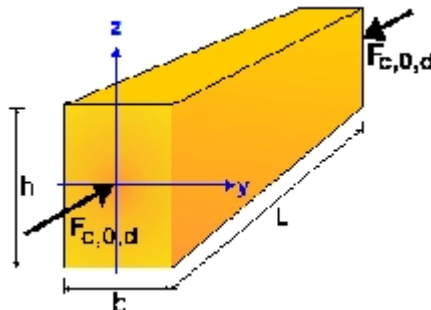
Incarcari pe pana model 1 - invelitoare tigla romana					
Tip incarcari	h[m]	b[m]	nr.buc[-]	N[KN]	N GF[KN]
Greutate proprie astereala	0.025	-	-	0.51	12.25
Greutate proprie pana	0.3	0.1	1	0.38	
Greutate proprie capriori	0.2	0.05	4	0.42	
Greutate proprie invelitoare				1.71	
<b>Total incarcari permanente</b>				<b>3.01</b>	
<b>Zapada</b>				<b>5.46</b>	

Incarcari pe pana model 2 - invelitoare tigla metalica					
Tip incarcari	h[m]	b[m]	nr.buc[-]	N[KN]	N GF[KN]
Greutate proprie astereala	0.025	-	-	0.51	10.18
Greutate proprie pana	0.3	0.1	1	0.38	
Greutate proprie capriori	0.2	0.05	4	0.42	
Greutate proprie invelitoare				0.17	
<b>Total incarcari permanente</b>				<b>1.48</b>	
<b>Zapada</b>				<b>5.46</b>	

i. Pop 10x10 cm – Model 1 – Învelitoare Țiglă romană

1. Pop 10cm

ULTIMATE LIMIT STATE, Stability  
(EC5 EN1995-1-1:2009, §6.3.2)



Material properties (EC5 EN1995-1-1:2009, §3)

Timber class : C14

Service classes : Class 2, moisture content ≤ 20% (§2.3.1.3)

Material factor  $\gamma_M=1.30$  (EC5 Tab. 2.3)

Load duration classes: Permanent (Table 2.1)

Cross section properties

Rectangular cross section,  $b=100\text{mm}$ ,  $h=100\text{mm}$ ,  $A=1.00 \times 10^4 \text{mm}^2$ ,  $W_y=1.67 \times 10^5 \text{mm}^3$ ,  $W_z=1.67 \times 10^5 \text{mm}^3$

Timber cross section reduction 0.0%,  $dA=0.00 \times 10^0 \text{mm}^2$ ,  $dW_y=0.00 \times 10^0 \text{mm}^3$ ,  $dW_z=0.00 \times 10^0 \text{mm}^3$

Effective cross section  $A_{\text{netto}}=1.00 \times 10^4 \text{mm}^2$ ,  $W_{y,\text{netto}}=1.67 \times 10^5 \text{mm}^3$ ,  $W_{z,\text{netto}}=1.67 \times 10^5 \text{mm}^3$

Characteristic material properties for timber

Modification factor  $K_{\text{mod}}=0.60$  (EC5 Tab.3.1)

Material factor  $\gamma_M=1.30$  (EC5 Tab. 2.3)

$E_{005}=4700\text{MPa}$

$f_{c0k}=16.00 \text{ N/mm}^2$ ,  $f_{c0d}=K_{\text{mod}} \cdot f_{c0k} / \gamma_M = 0.60 \times 16.00 / 1.30 = 7.38 \text{ N/mm}^2$  (EN1995-1-1, Eq.2.14)

$f_{myk}=14.00 \text{ N/mm}^2$ ,  $f_{myd}=K_{\text{mod}} \cdot f_{myk} / \gamma_M = 0.60 \times 14.00 / 1.30 = 6.46 \text{ N/mm}^2$

$f_{mzk}=14.00 \text{ N/mm}^2$ ,  $f_{mzd}=K_{\text{mod}} \cdot f_{mzk} / \gamma_M = 0.60 \times 14.00 / 1.30 = 6.46 \text{ N/mm}^2$



**Cross section loads**

$F_{c0d} = -12.250 \text{ kN}$

**Column stability** (EC5 EN1995-1-1:2009, §6.3.2)

Rectangular cross section  $K_m = 0.70$  (EC5 §6.1.6.(2))

$\sigma_{c0d} = F_{c0d} / A_{netto} = 1000 \times 12.250 / 10000 = 1.23 \text{ N/mm}^2$

**Buckling length**

$S_{ky} = 1.00 \times 2.550 = 2.550 \text{ m} = 2550 \text{ mm}$

$S_{kz} = 1.00 \times 2.550 = 2.550 \text{ m} = 2550 \text{ mm}$

**Slenderness**

$i_y = \sqrt{I_y / A} = 0.289 \times 100 = 29 \text{ mm}$ ,  $\lambda_y = 2550 / 29 = 87.93$

$i_z = \sqrt{I_z / A} = 0.289 \times 100 = 29 \text{ mm}$ ,  $\lambda_z = 2550 / 29 = 87.93$

**Critical stresses**

$\sigma_{c,crity} = \pi^2 E_{005} / \lambda_y^2 = 6.00 \text{ N/mm}^2$ ,  $\lambda_{rel,y} = \sqrt{f_{c0k} / \sigma_{c,crity}} = 1.63$  (EN1995-1-1, Eq.6.21)

$\sigma_{c,critz} = \pi^2 E_{005} / \lambda_z^2 = 6.00 \text{ N/mm}^2$ ,  $\lambda_{rel,z} = \sqrt{f_{c0k} / \sigma_{c,critz}} = 1.63$  (EN1995-1-1, Eq.6.22)

$\beta_c = 0.20$  (solid timber)

$k_y = 0.5 [1 + \beta_c (\lambda_{rel,y} - 0.3) + \lambda_{rel,y}^2] = 1.97$ ,  $K_{cy} = 1 / (k_y + \sqrt{k_y^2 - \lambda_{rel,y}^2}) = 0.327$  (Eq.6.27 6.25)

$k_z = 0.5 [1 + \beta_c (\lambda_{rel,z} - 0.3) + \lambda_{rel,z}^2] = 1.97$ ,  $K_{cz} = 1 / (k_z + \sqrt{k_z^2 - \lambda_{rel,z}^2}) = 0.327$  (Eq.6.28 6.26)

$\sigma_{c0d} / (K_{cy} \cdot f_{c0d}) = 0.51 < 1$  (EN1995-1-1, Eq.6.23)

$\sigma_{c0d} / (K_{cz} \cdot f_{c0d}) = 0.51 < 1$  (EN1995-1-1, Eq.6.24)

The check is satisfied

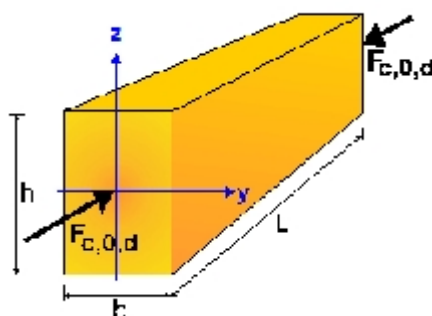
Percent of cross section used = 51%

ii. Pop 10x10 cm – Model 2 – Învelitoare Țigla metalică

1. Pop 10cm

**ULTIMATE LIMIT STATE, Stability**

(EC5 EN1995-1-1:2009, §6.3.2)



**Material properties** (EC5 EN1995-1-1:2009, §3)

Timber class : C14

Service classes : Class 2, moisture content  $\leq 20\%$  (§2.3.1.3)

Material factor  $\gamma_M = 1.30$  (EC5 Tab. 2.3)

Load duration classes: Permanent (Table 2.1)

**Cross section properties**

Rectangular cross section,  $b = 100 \text{ mm}$ ,  $h = 100 \text{ mm}$ ,  $A = 1.00 \times 10^4 \text{ mm}^2$ ,  $W_y = 1.67 \times 10^5 \text{ mm}^3$ ,  $W_z = 1.67 \times 10^5 \text{ mm}^3$

Timber cross section reduction 0.0%,  $dA = 0.00 \times 10^0 \text{ mm}^2$ ,  $dW_y = 0.00 \times 10^0 \text{ mm}^3$ ,  $dW_z = 0.00 \times 10^0 \text{ mm}^3$

Effective cross section  $A_{netto} = 1.00 \times 10^4 \text{ mm}^2$ ,  $W_{y,netto} = 1.67 \times 10^5 \text{ mm}^3$ ,  $W_{z,netto} = 1.67 \times 10^5 \text{ mm}^3$

**Characteristic material properties for timber**

Modification factor  $K_{mod}=0.60$  (EC5 Tab.3.1)  
 Material factor  $\gamma_M=1.30$  (EC5 Tab. 2.3)  
 $E_{005}=4700\text{MPa}$   
 $f_{c0k}=16.00\text{ N/mm}^2$ ,  $f_{c0d}=K_{mod}\cdot f_{c0k}/\gamma_M=0.60\times 16.00/1.30=7.38\text{N/mm}^2$  (EN1995-1-1, Eq.2.14)  
 $f_{myk}=14.00\text{ N/mm}^2$ ,  $f_{myd}=K_{mod}\cdot f_{myk}/\gamma_M=0.60\times 14.00/1.30=6.46\text{N/mm}^2$   
 $f_{mzk}=14.00\text{ N/mm}^2$ ,  $f_{mzd}=K_{mod}\cdot f_{mzk}/\gamma_M=0.60\times 14.00/1.30=6.46\text{N/mm}^2$

**Cross section loads**

$F_{c0d}=-10.180\text{ kN}$

**Column stability** (EC5 EN1995-1-1:2009, §6.3.2)

Rectangular cross section  $K_m=0.70$  (EC5 §6.1.6.(2))  
 $\sigma_{c0d}=F_{c0d}/A_{netto}=1000\times 10.180/10000=1.02\text{ N/mm}^2$

**Buckling length**

$S_{ky}=1.00\times 2.550=2.550\text{ m}=2550\text{ mm}$   
 $S_{kz}=1.00\times 2.550=2.550\text{ m}=2550\text{ mm}$

**Slenderness**

$i_y=\sqrt{(I_y/A)}=0.289\times 100=29\text{ mm}$ ,  $\lambda_y=2550/29=87.93$   
 $i_z=\sqrt{(I_z/A)}=0.289\times 100=29\text{ mm}$ ,  $\lambda_z=2550/29=87.93$

**Critical stresses**

$\sigma_{c,crity}=n^2 E_{005}/\lambda_y^2=6.00\text{ N/mm}^2$ ,  $\lambda_{rel,y}=\sqrt{(f_{c0k}/\sigma_{c,crity})}=1.63$  (EN1995-1-1, Eq.6.21)  
 $\sigma_{c,critz}=n^2 E_{005}/\lambda_z^2=6.00\text{ N/mm}^2$ ,  $\lambda_{rel,z}=\sqrt{(f_{c0k}/\sigma_{c,critz})}=1.63$  (EN1995-1-1, Eq.6.22)

$\beta_c=0.20$  (solid timber)

$k_y=0.5[1+\beta_c(\lambda_{rel,y}-0.3)+\lambda_{rel,y}^2]=1.97$ ,  $K_{cy}=1/(k_y+\sqrt{(k_y^2-\lambda_{rel,y}^2)})=0.327$  (Eq.6.27 6.25)  
 $k_z=0.5[1+\beta_c(\lambda_{rel,z}-0.3)+\lambda_{rel,z}^2]=1.97$ ,  $K_{cz}=1/(k_z+\sqrt{(k_z^2-\lambda_{rel,z}^2)})=0.327$  (Eq.6.28 6.26)

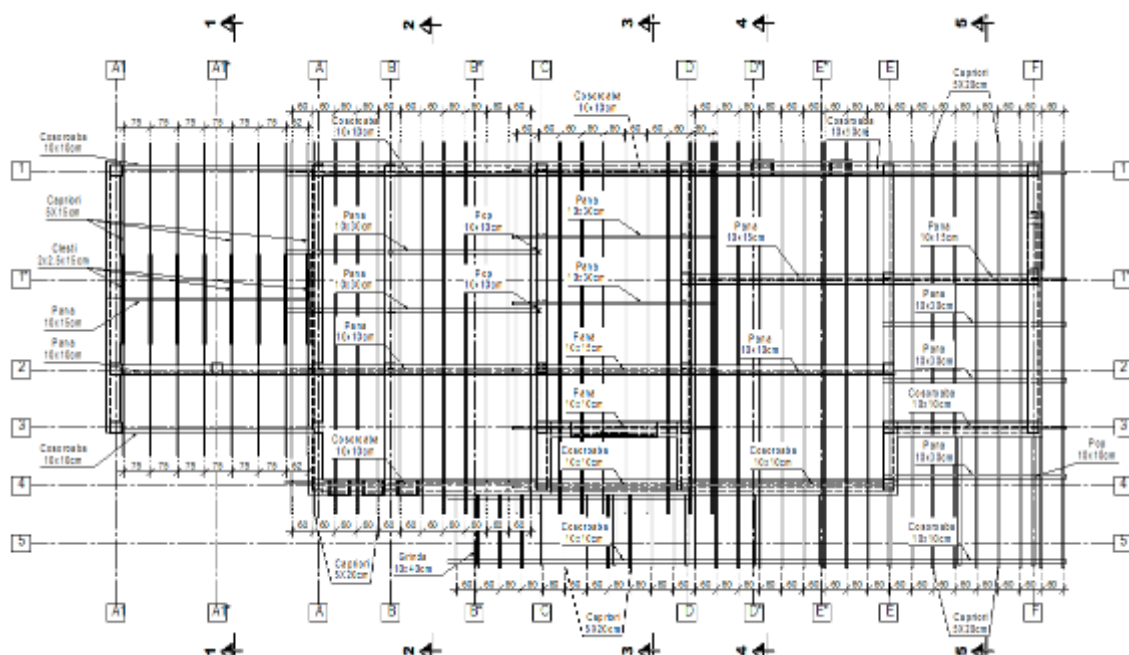
$\sigma_{c0d}/(K_{cy}\cdot f_{c0d})=0.42 < 1$  (EN1995-1-1, Eq.6.23)

$\sigma_{c0d}/(K_{cz}\cdot f_{c0d})=0.42 < 1$  (EN1995-1-1, Eq.6.24)

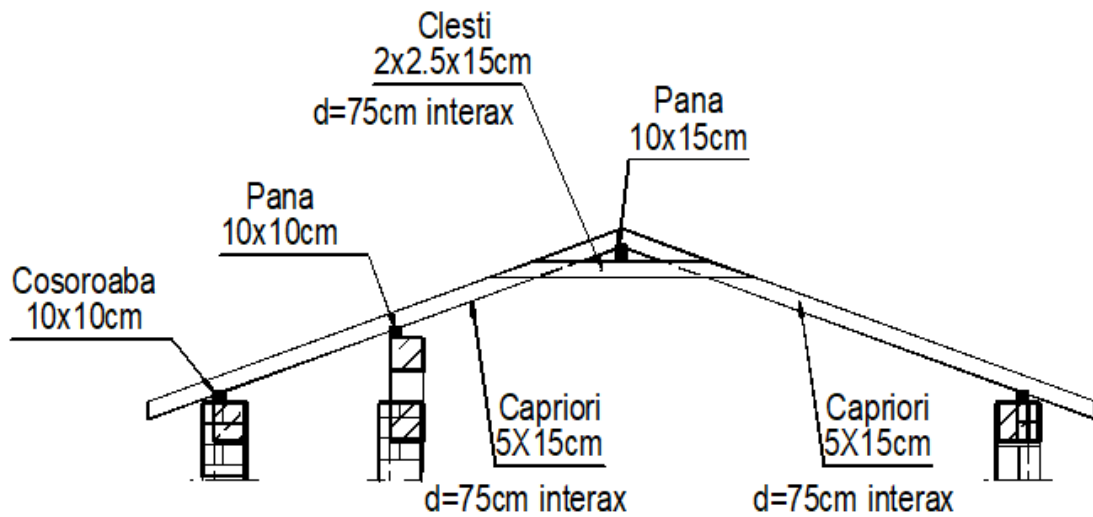
The check is satisfied

Percent of cross section used =42%

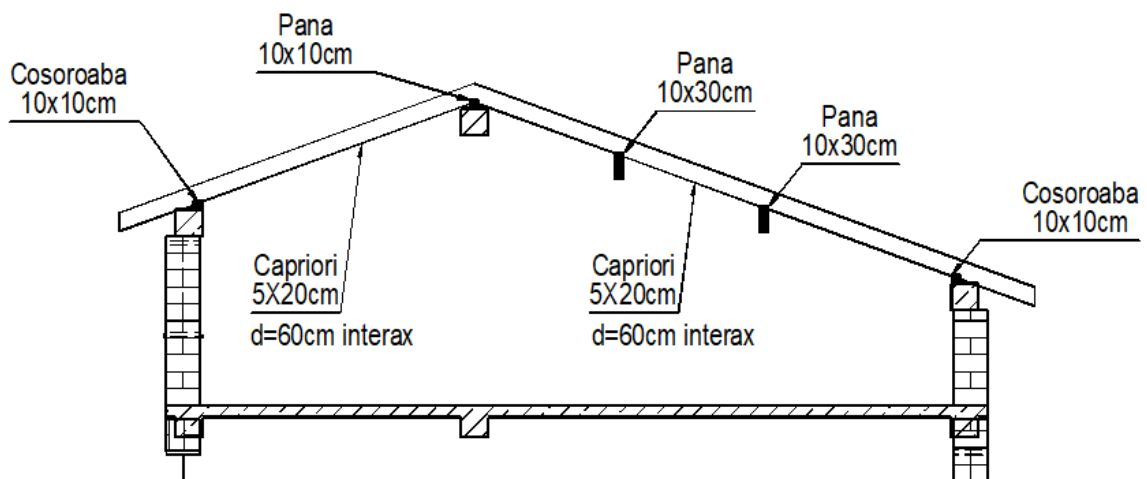
Poziționare elemente șarpanta Model 1 – învelitoare țiglă română

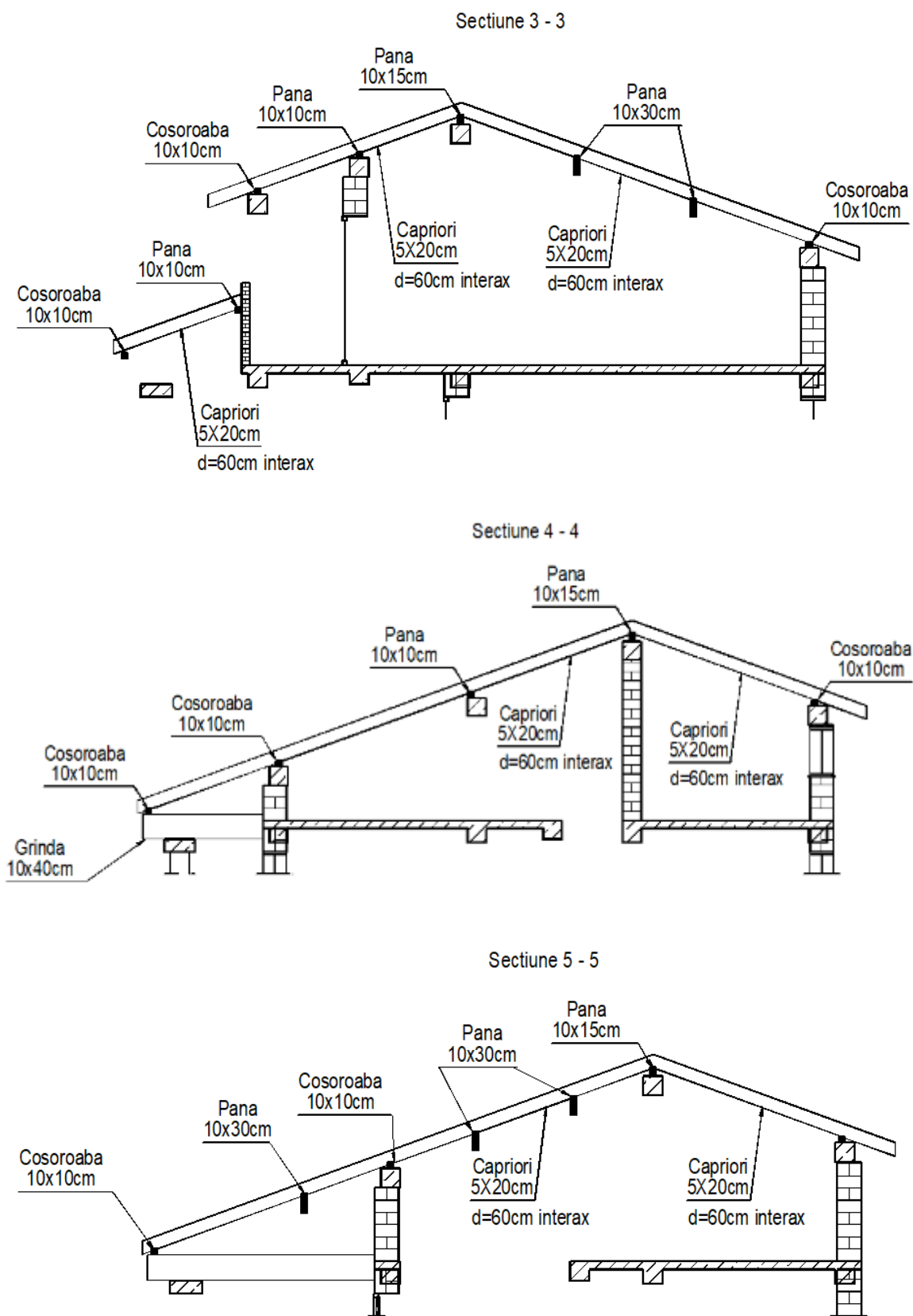


Secțiune 1 - 1

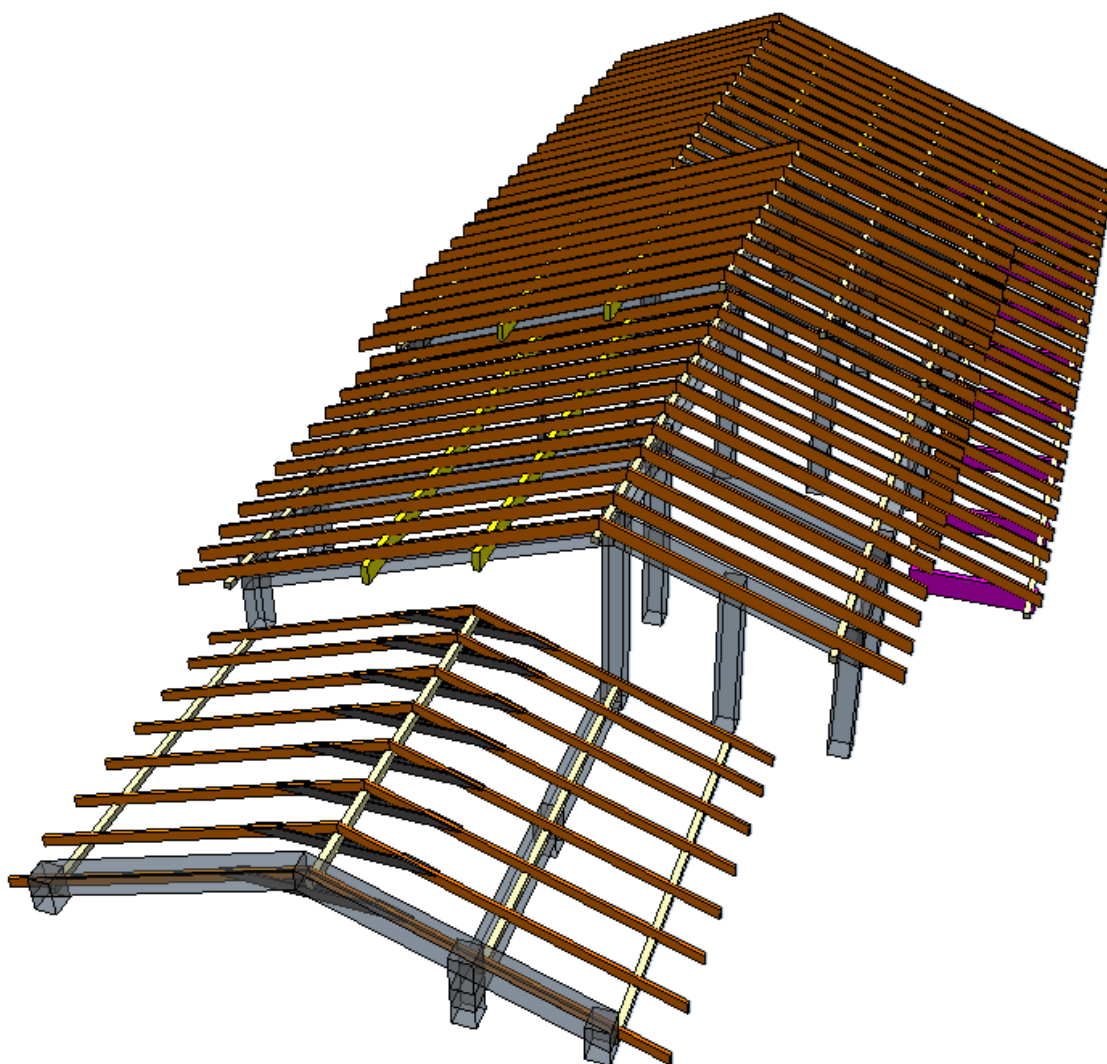


Secțiune 2 - 2

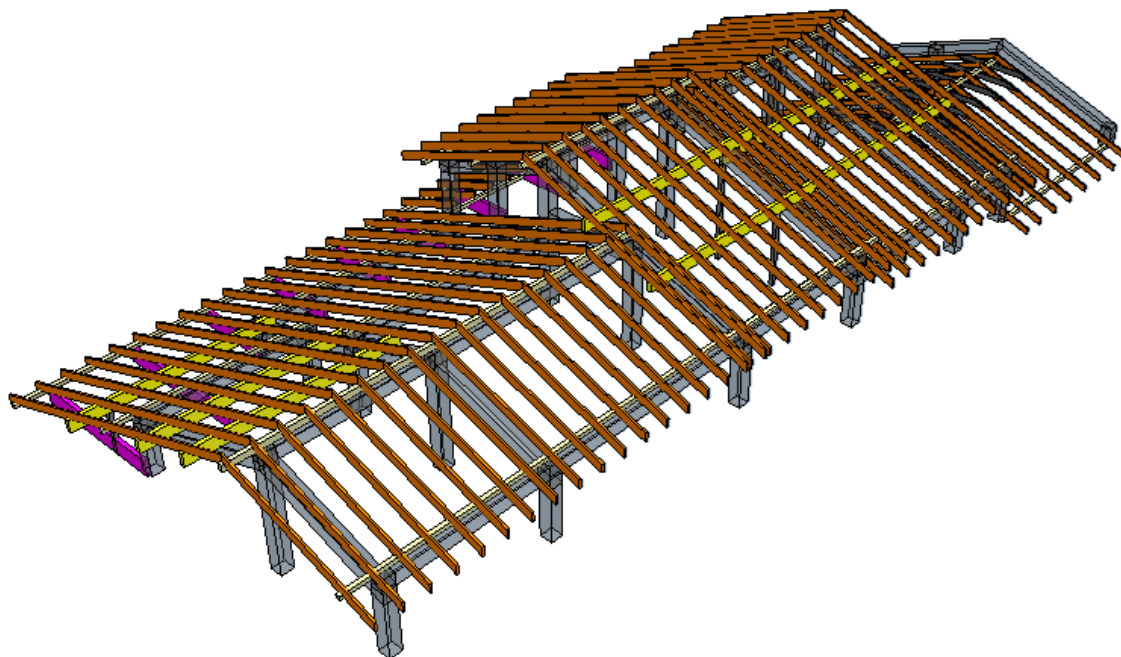




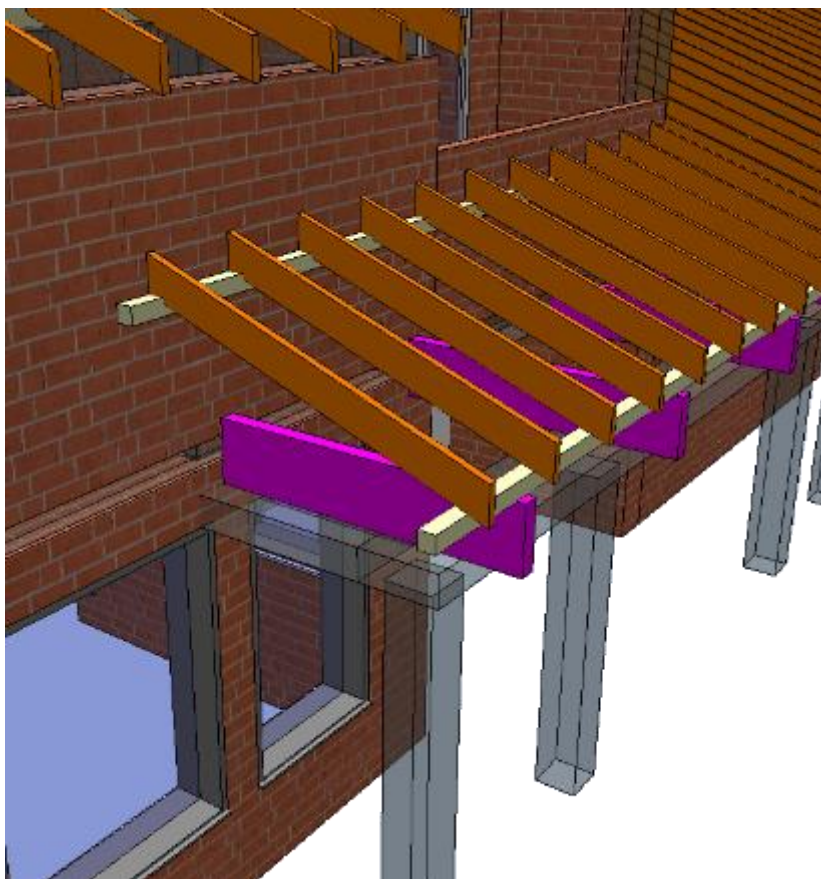
Vedere 3D șarpantă Model 1 – învelitoare țigla romană



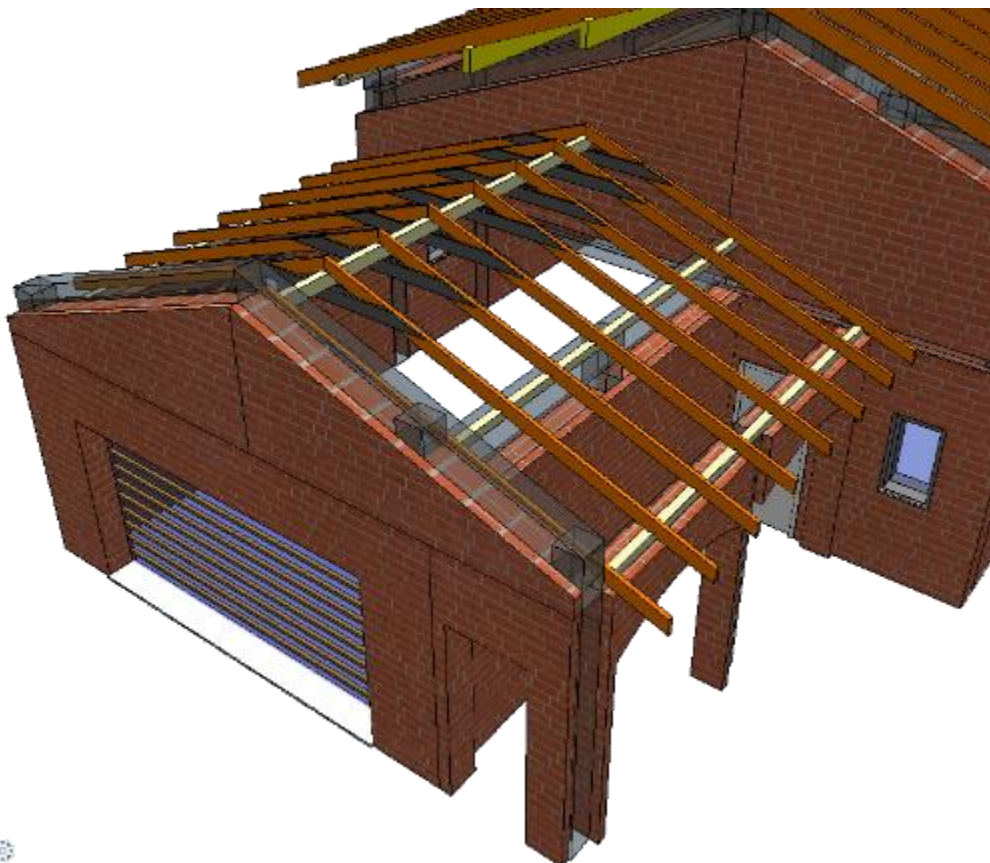
Vedere 3D șarpantă Model 1 – învelitoare țiglă romană



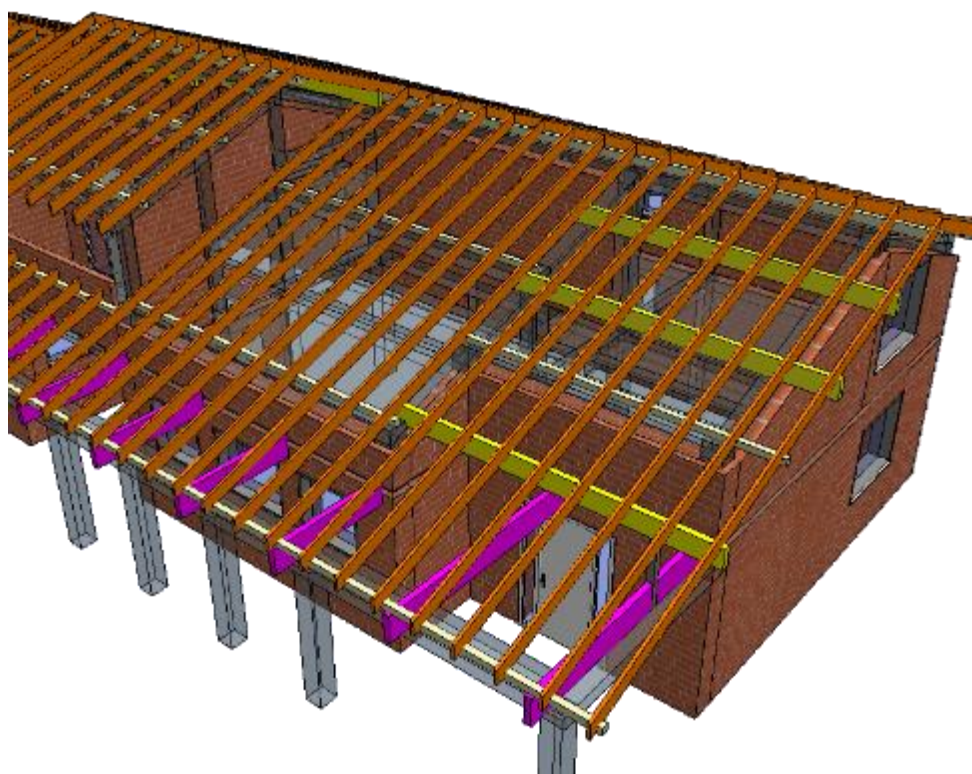
Vedere 3D șarpantă Model 1 – învelitoare țiglă romană



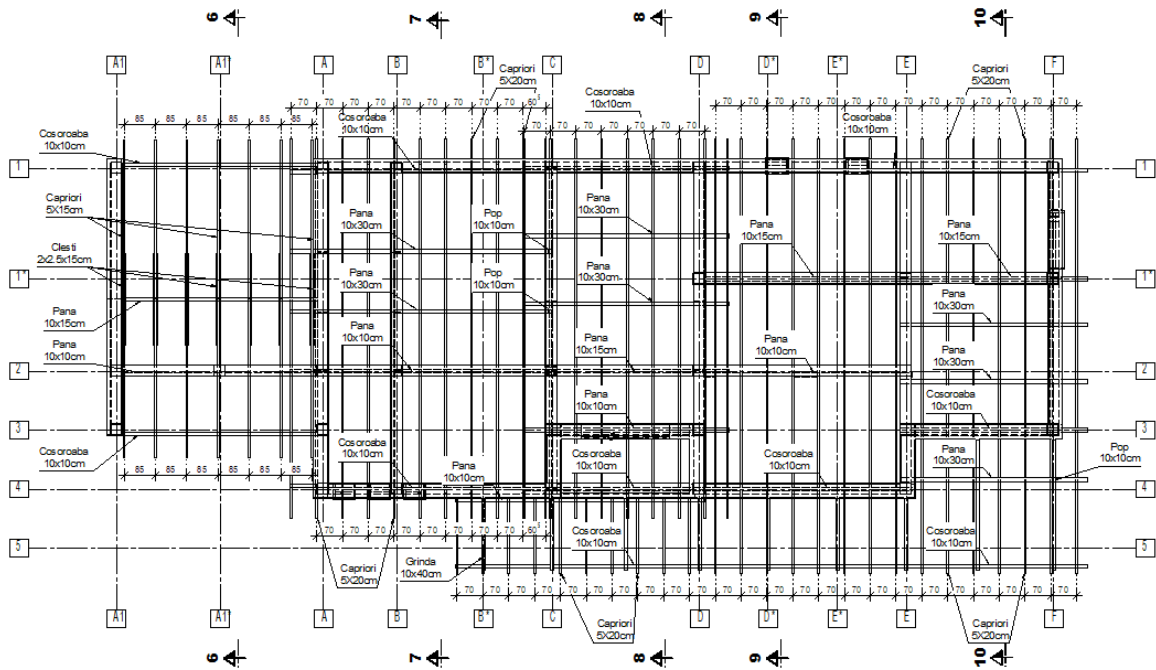
Vedere 3D șarpantă Model 1 – învelitoare țiglă romană



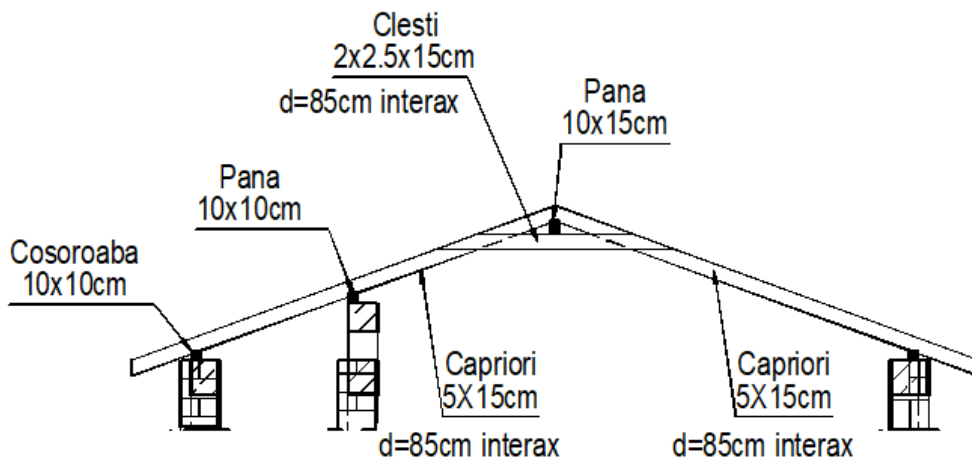
Vedere 3D șarpantă Model 1 – învelitoare țiglă romană



Poziționare elemente șarpanta Model 2 – învelitoare țiglă metalică

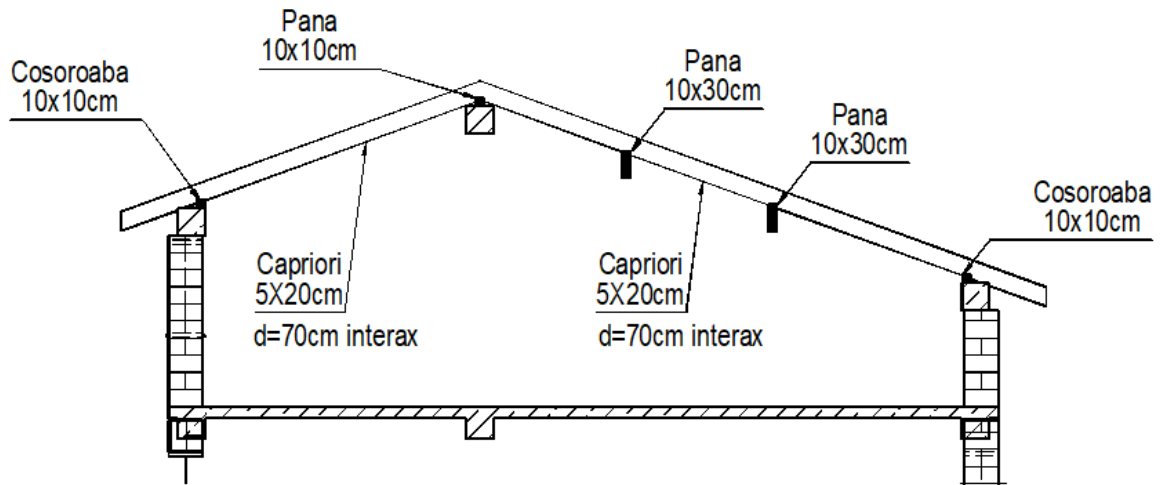


Sectiune 6 - 6

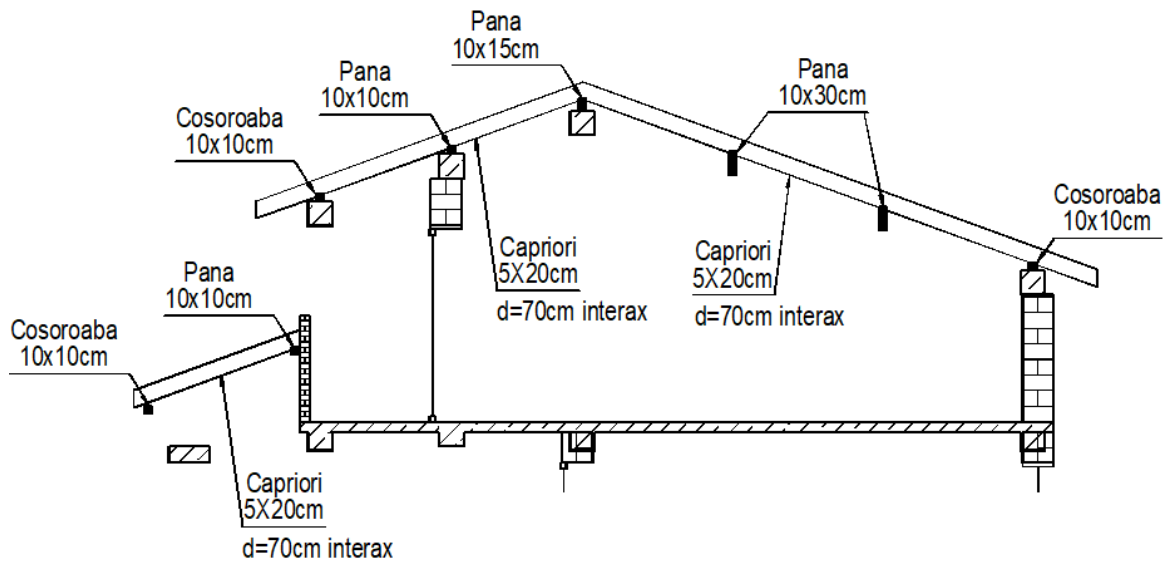




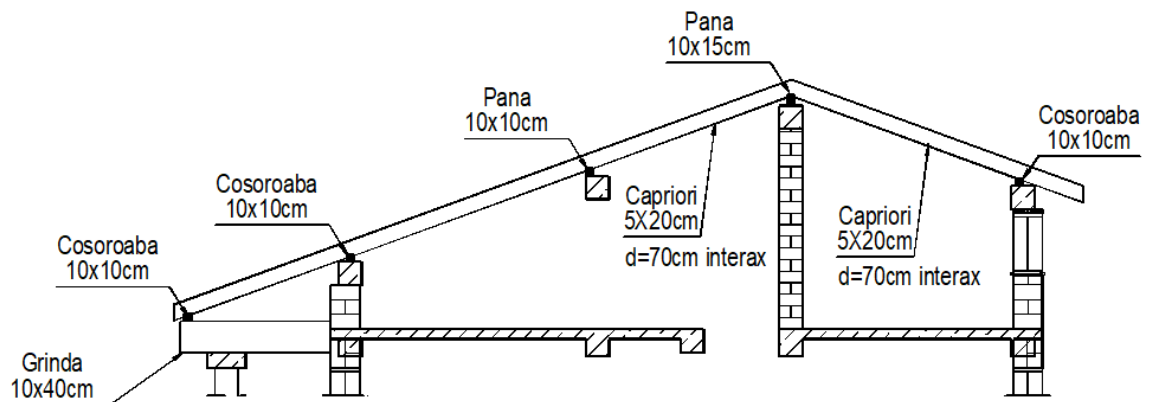
Sectiune 7 - 7

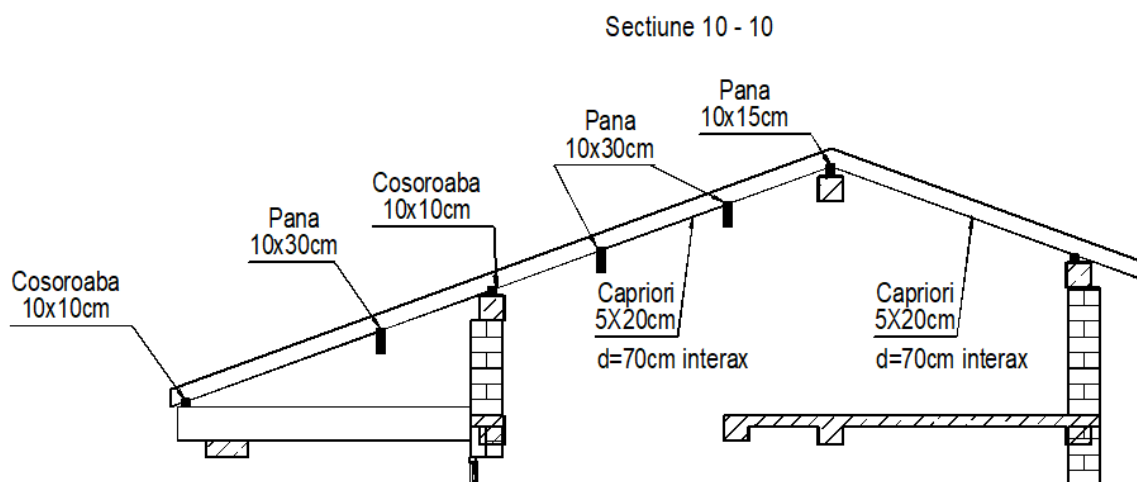


Sectiune 8 - 8

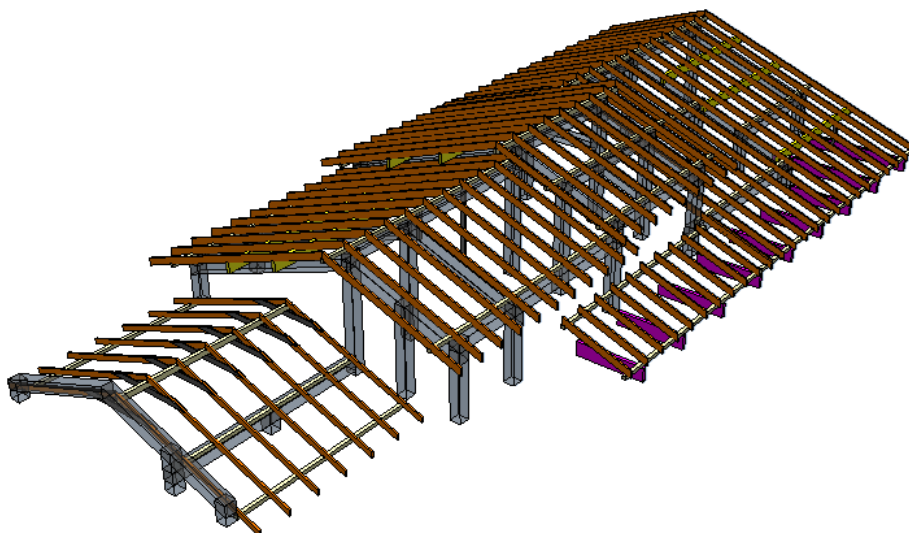


Sectiune 9 - 9

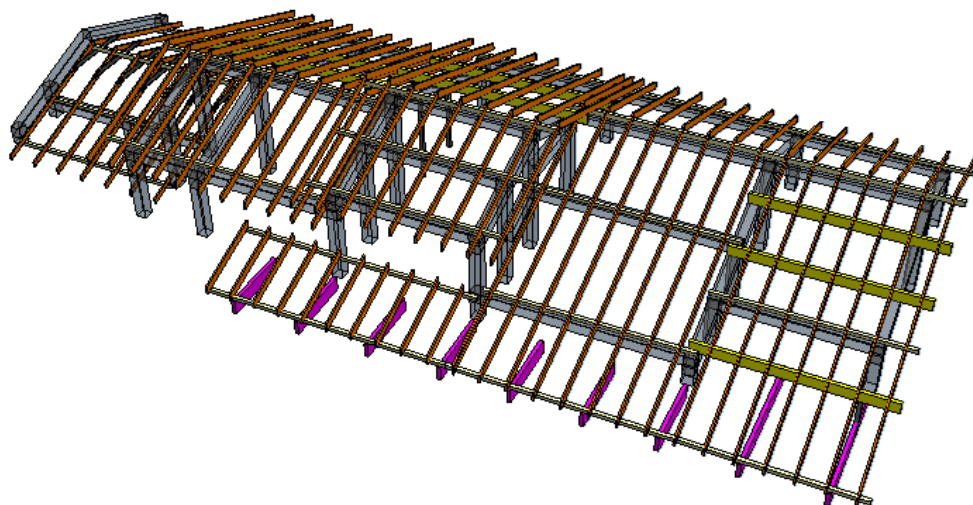




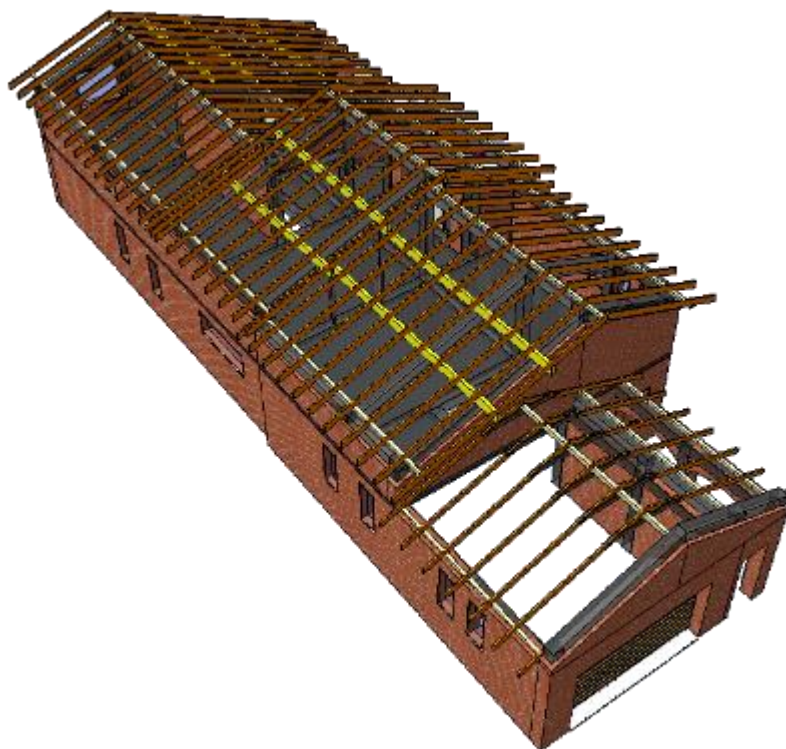
Vedere 3D șarpantă Model 2 – învelitoare țiglă metalică



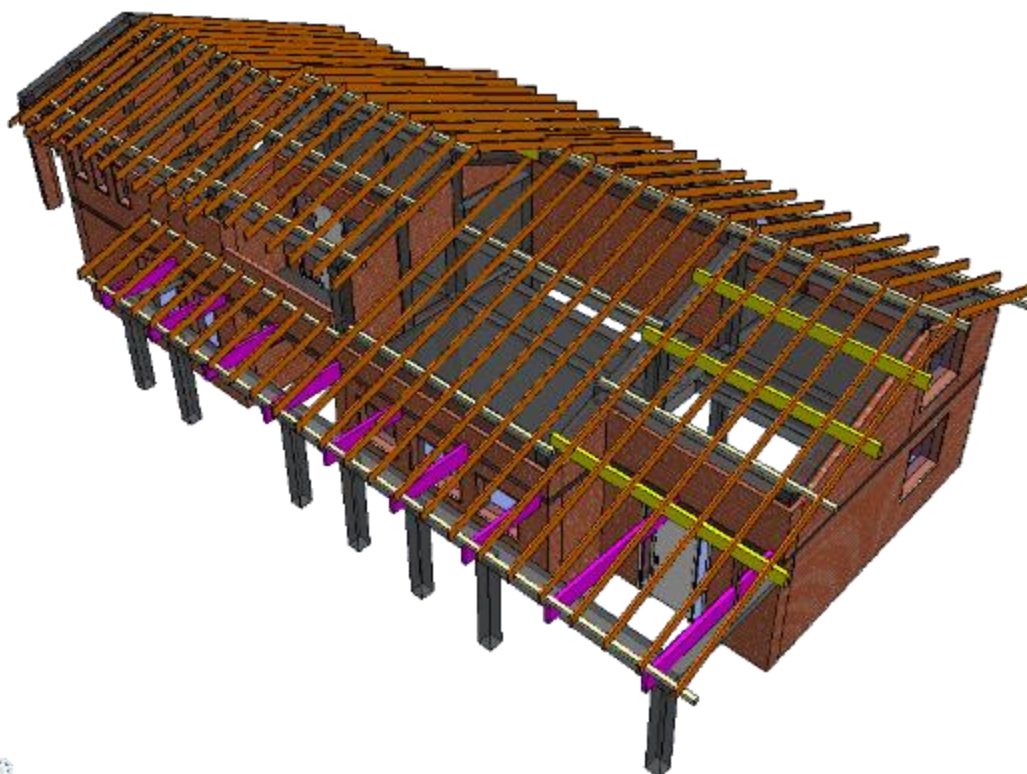
Vedere 3D șarpantă Model 2 – învelitoare țiglă metalică



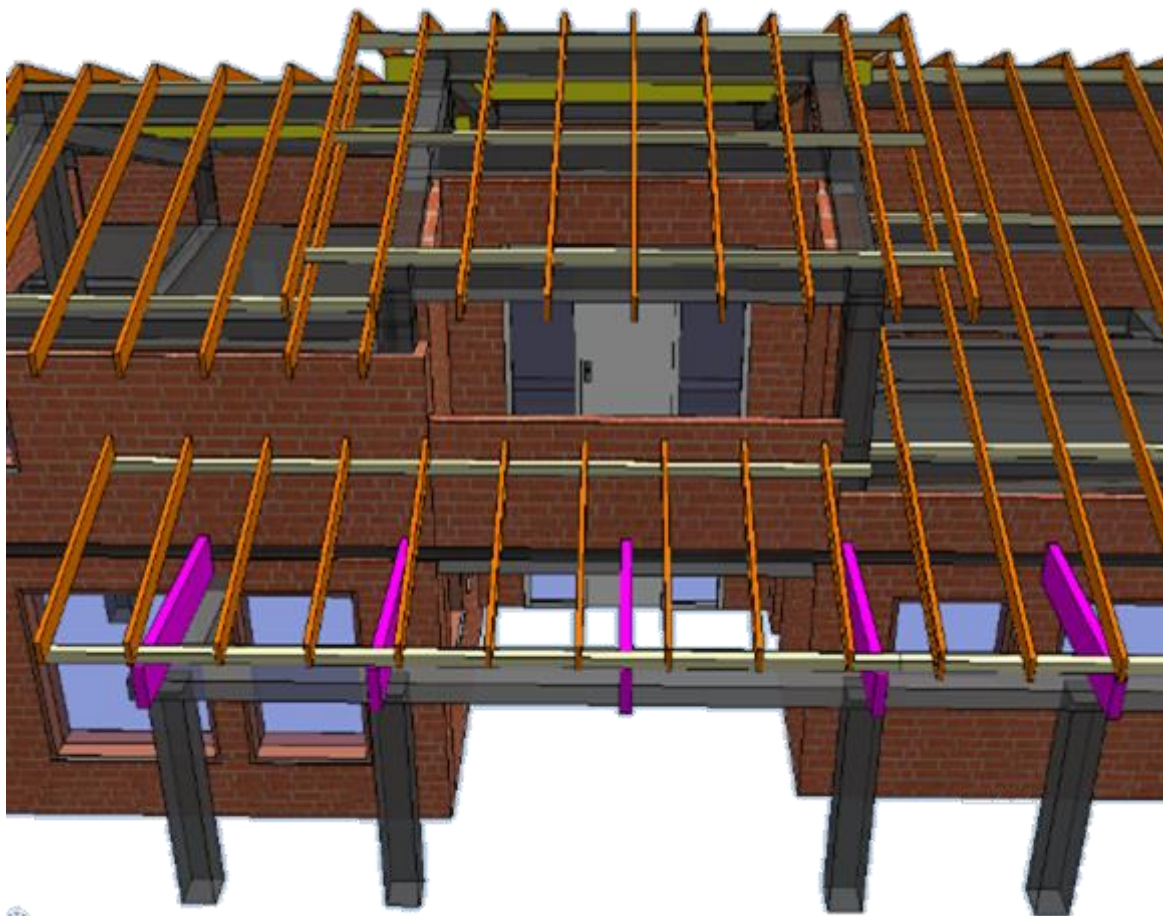
Vedere 3D șarpantă Model 2 – învelitoare țiglă metalică



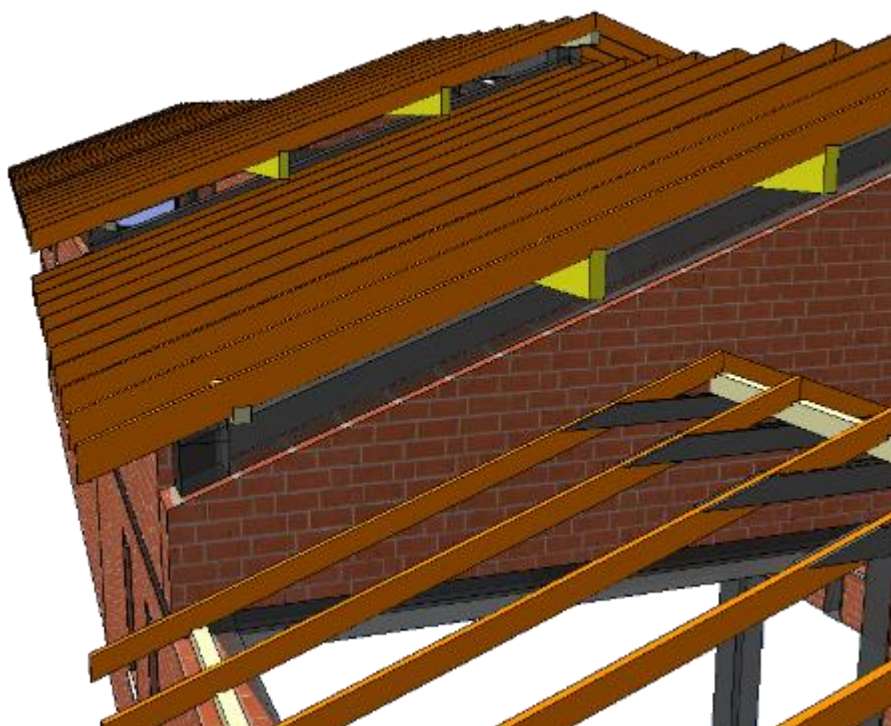
Vedere 3D șarpantă Model 2 – învelitoare țiglă metalică



Vedere 3D șarpantă Model 2 – învelitoare țiglă metalică



Vedere 3D șarpantă Model 2 – învelitoare țiglă metalică



## 4. COMPARAȚII NUMERICE ȘI GRAFICE PENTRU CELE DOUA MODELE

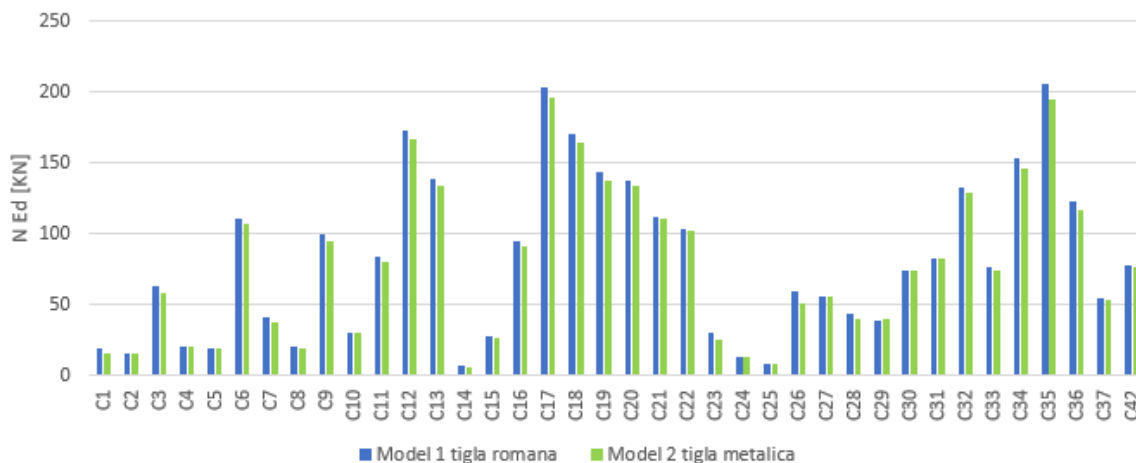
### 4.1. COMPARAȚII EFORTURI STĂLPI

Prezentarea comparativă tabelar și grafică a eforturilor din stâlpi (forță axială, forță tăietoare, moment încovoietor) din cele două modele, pentru cele două direcții ale clădirii:

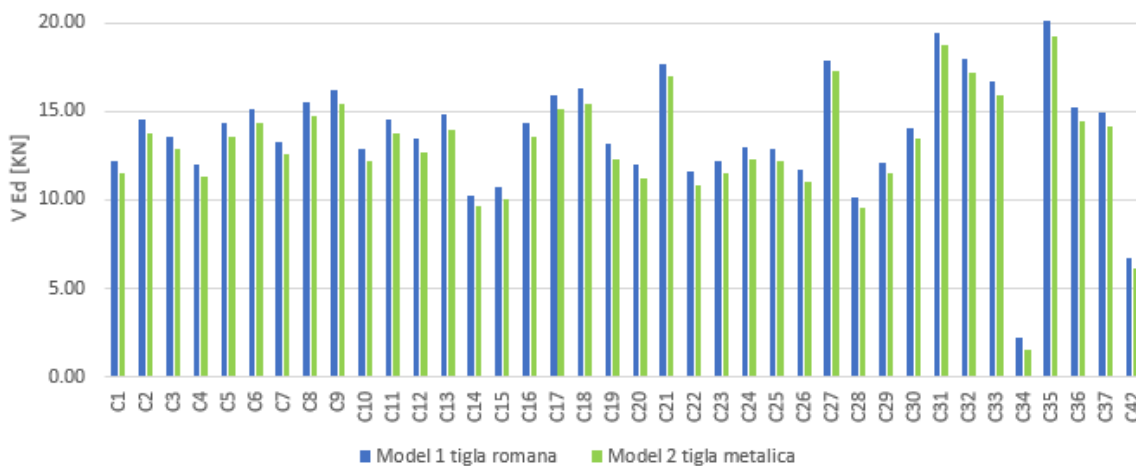
- Direcție X

TABLE: Element Forces - Columns											
Story	Column	Output Case	Model 1 tigla romana			Model 2 tigla metalica			Diferente procentuale		
			P	V2	M3	P	V2	M3	P	V2	M3
			kN	kN	kN-m	kN	kN	kN-m	[%]	[%]	[%]
Parter	C1	GS SX++	-19.52	12.21	19.60	-16.05	11.55	18.50	17.76%	5.43%	5.61%
Parter	C2	GS SX++	-15.43	14.55	21.80	-15.32	13.79	20.70	0.72%	5.27%	5.05%
Parter	C3	GS SX++	-63.08	13.59	20.90	-58.60	12.88	19.80	7.09%	5.21%	5.26%
Parter	C4	GS SX++	-20.27	11.95	19.40	-20.23	11.30	18.40	0.21%	5.46%	5.15%
Parter	C5	GS SX++	-19.12	14.36	21.80	-18.86	13.60	20.60	1.36%	5.31%	5.50%
Parter	C6	GS SX++	-110.38	15.12	22.50	-107.23	14.33	21.40	2.86%	5.24%	4.89%
Parter	C7	GS SX++	-41.66	13.29	21.30	-37.33	12.54	20.10	10.39%	5.61%	5.63%
Parter	C8	GS SX++	-20.00	15.53	23.40	-19.64	14.69	22.20	1.81%	5.43%	5.13%
Parter	C9	GS SX++	-99.79	16.24	24.20	-94.51	15.36	22.90	5.29%	5.38%	5.37%
Parter	C10	GS SX++	-29.55	12.89	20.10	-29.76	12.18	19.00	-0.68%	5.47%	5.47%
Parter	C11	GS SX++	-83.28	14.57	21.70	-80.74	13.79	20.60	3.05%	5.33%	5.07%
Parter	C12	GS SX++	-173.40	13.49	21.00	-166.60	12.68	19.80	3.92%	5.96%	5.71%
Parter	C13	GS SX++	-139.07	14.82	22.80	-134.10	13.95	21.50	3.57%	5.86%	5.70%
Parter	C14	GS SX++	6.81	10.23	17.10	6.09	9.68	16.20	10.45%	5.41%	5.26%
Parter	C15	GS SX++	-27.82	10.69	17.60	-26.48	10.08	16.60	4.83%	5.72%	5.68%
Parter	C16	GS SX++	-95.23	14.34	21.50	-91.66	13.58	20.40	3.74%	5.26%	5.12%
Parter	C17	GS SX++	-203.40	15.94	23.40	-195.97	15.16	22.20	3.65%	4.91%	5.13%
Parter	C18	GS SX++	-170.64	16.25	24.20	-165.05	15.41	23.00	3.28%	5.20%	4.96%
Parter	C19	GS SX++	-143.20	13.14	21.30	-138.06	12.30	20.00	3.59%	6.34%	6.10%
Parter	C20	GS SX++	-137.89	12.04	19.60	-134.09	11.25	18.40	2.76%	6.53%	6.12%
Parter	C21	GS SX++	-112.46	17.63	24.80	-110.39	16.94	23.70	1.85%	3.91%	4.44%
Parter	C22	GS SX++	-103.43	11.56	18.80	-101.90	10.84	17.70	1.47%	6.24%	5.85%
Parter	C23	GS SX++	-30.50	12.19	19.00	-25.53	11.53	18.00	16.31%	5.42%	5.26%
Parter	C24	GS SX++	-12.69	13.01	19.80	-12.54	12.28	18.70	1.15%	5.56%	5.56%
Parter	C25	GS SX++	-7.95	12.90	19.60	-8.01	12.21	18.60	-0.73%	5.36%	5.10%
Parter	C26	GS SX++	-59.80	11.69	18.50	-51.09	11.04	17.40	14.57%	5.55%	5.95%
Parter	C27	GS SX++	-55.58	17.87	24.80	-55.26	17.24	23.80	0.58%	3.53%	4.03%
Parter	C28	GS SX++	-43.18	10.10	16.90	-39.37	9.59	16.10	8.82%	5.00%	4.73%
Parter	C29	GS SX++	-39.13	12.13	19.50	-39.49	11.47	18.40	-0.91%	5.44%	5.64%
Parter	C30	GS SX++	-74.33	14.05	21.30	-73.91	13.41	20.30	0.56%	4.55%	4.69%
Parter	C31	GS SX++	-82.64	19.43	26.70	-82.06	18.75	25.60	0.70%	3.51%	4.12%
Parter	C32	GS SX++	-132.91	17.97	25.90	-129.21	17.13	24.70	2.78%	4.68%	4.63%
Parter	C33	GS SX++	-76.58	16.70	24.70	-74.59	15.94	23.50	2.60%	4.58%	4.86%
Parter	C34	GS SX++	-153.09	2.22	10.50	-146.36	1.55	9.40	4.40%	30.19%	10.48%
Parter	C35	GS SX++	-206.24	20.08	27.60	-195.36	19.27	26.40	5.27%	4.05%	4.35%
Parter	C36	GS SX++	-122.64	15.23	23.00	-117.22	14.48	21.80	4.42%	4.92%	5.22%
Parter	C37	GS SX++	-54.44	14.89	22.00	-53.87	14.12	20.90	1.04%	5.16%	5.00%
Parter	C42	GS SX++	-78.18	6.74	14.40	-75.92	6.08	13.30	2.89%	9.79%	7.64%

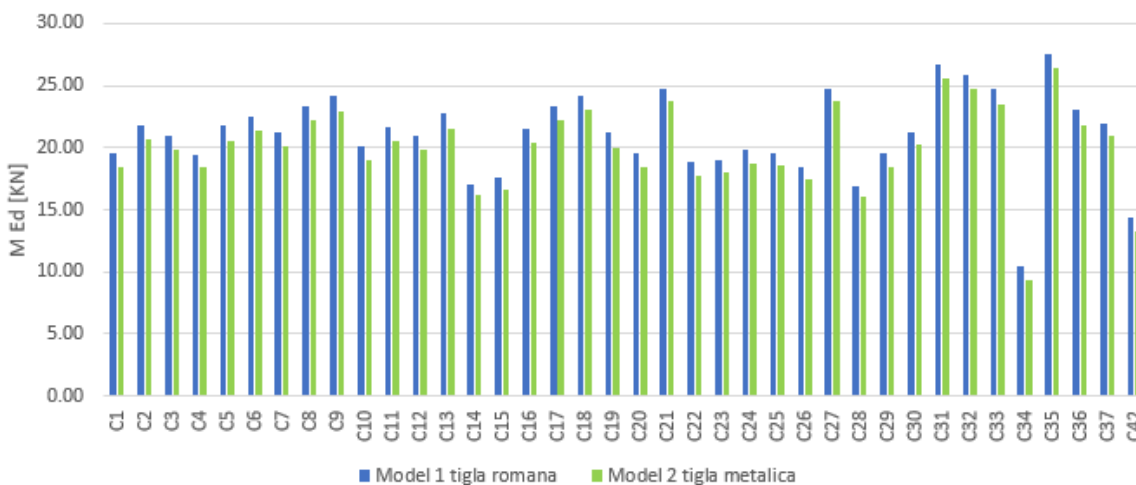
Comparatie forte axiale stalpi la baza parterului - directie X



Comparatie forte taietoare stalpi la baza parterului - directie X



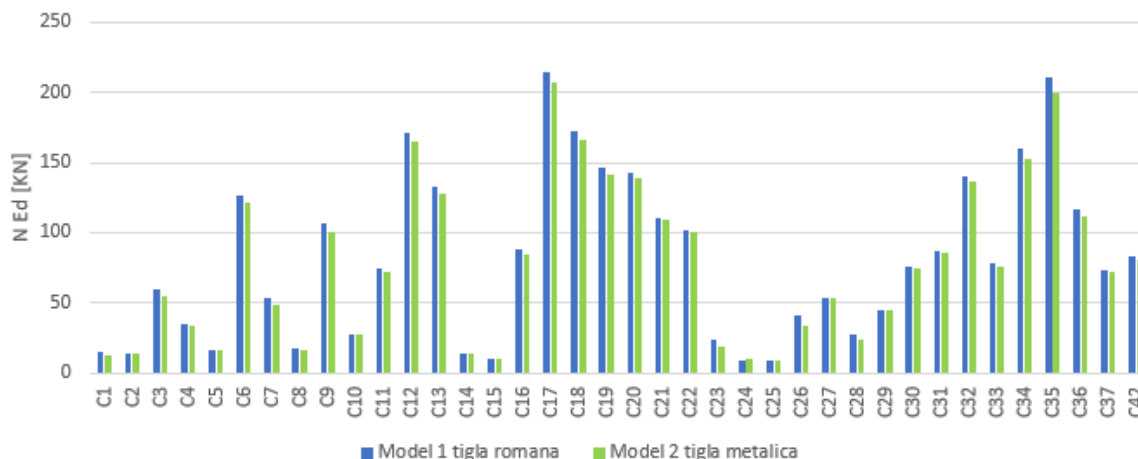
Comparatie momente taietoare stalpi la baza parterului - directie X



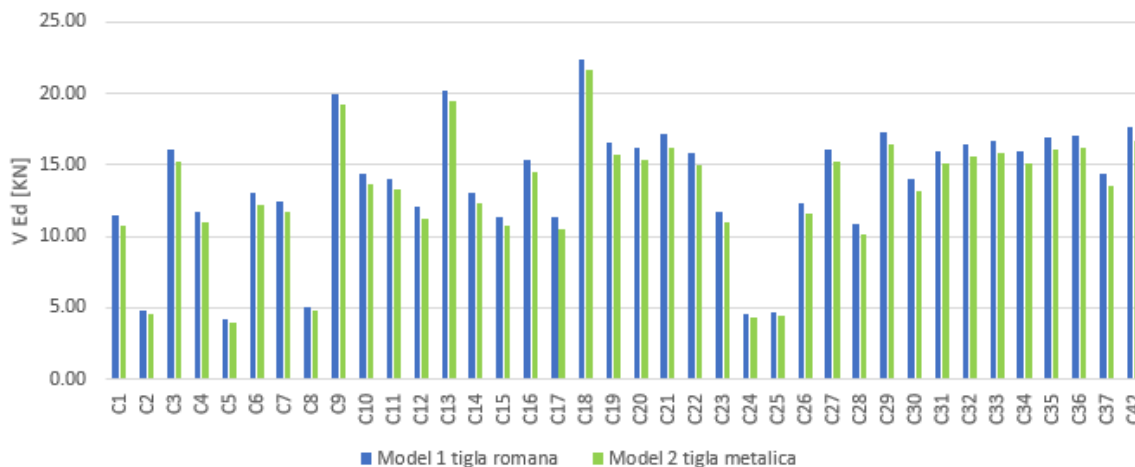
• Direcție Y

TABLE: Element Forces - Columns											
Story	Column	Output Case	Model 1 tigla romana			Model 2 tigla metalica			Diferente procentuale		
			P	V3	M2	P	V3	M2	P	V3	M2
			kN	kN	kN-m	kN	kN	kN-m	[%]	[%]	[%]
Parter	C1	GS SY++	-15.63	11.50	17.90	-12.35	10.80	16.80	20.95%	6.08%	6.15%
Parter	C2	GS SY++	-13.92	4.79	12.10	-13.91	4.52	11.40	0.07%	5.66%	5.79%
Parter	C3	GS SY++	-59.34	16.10	23.60	-55.11	15.23	22.30	7.13%	5.40%	5.51%
Parter	C4	GS SY++	-34.87	11.78	18.20	-34.00	11.00	17.00	2.48%	6.61%	6.59%
Parter	C5	GS SY++	-16.04	4.25	11.00	-15.94	4.00	10.40	0.61%	5.78%	5.45%
Parter	C6	GS SY++	-126.16	13.08	20.70	-122.15	12.19	19.40	3.18%	6.85%	6.28%
Parter	C7	GS SY++	-53.27	12.39	19.00	-48.39	11.72	17.90	9.16%	5.36%	5.79%
Parter	C8	GS SY++	-16.98	5.07	12.60	-16.75	4.79	11.80	1.34%	5.52%	6.35%
Parter	C9	GS SY++	-106.27	20.00	27.50	-100.59	19.22	26.30	5.35%	3.89%	4.36%
Parter	C10	GS SY++	-27.11	14.43	22.00	-27.46	13.65	20.80	-1.26%	5.41%	5.45%
Parter	C11	GS SY++	-74.24	14.06	21.80	-72.18	13.29	20.60	2.77%	5.49%	5.50%
Parter	C12	GS SY++	-171.34	12.12	19.90	-164.65	11.26	18.60	3.90%	7.04%	6.53%
Parter	C13	GS SY++	-132.76	20.24	27.70	-128.12	19.52	26.60	3.50%	3.56%	3.97%
Parter	C14	GS SY++	14.40	13.04	20.90	13.27	12.31	19.70	7.88%	5.60%	5.74%
Parter	C15	GS SY++	-10.02	11.40	19.30	-9.64	10.74	18.20	3.85%	5.78%	5.70%
Parter	C16	GS SY++	-87.70	15.37	23.30	-84.60	14.51	22.00	3.54%	5.58%	5.58%
Parter	C17	GS SY++	-214.68	11.41	19.50	-206.65	10.55	18.20	3.74%	7.56%	6.67%
Parter	C18	GS SY++	-172.05	22.37	30.00	-166.37	21.64	28.80	3.30%	3.24%	4.00%
Parter	C19	GS SY++	-146.20	16.51	24.50	-140.89	15.72	23.30	3.63%	4.80%	4.90%
Parter	C20	GS SY++	-142.63	16.21	24.20	-138.56	15.33	22.90	2.85%	5.42%	5.37%
Parter	C21	GS SY++	-110.89	17.15	25.10	-108.87	16.25	23.80	1.82%	5.26%	5.18%
Parter	C22	GS SY++	-101.23	15.81	23.80	-99.97	14.97	22.60	1.24%	5.29%	5.04%
Parter	C23	GS SY++	-23.88	11.72	19.80	-19.12	11.02	18.70	19.90%	5.97%	5.56%
Parter	C24	GS SY++	-9.48	4.62	12.80	-9.51	4.36	12.10	-0.27%	5.66%	5.47%
Parter	C25	GS SY++	-8.40	4.69	13.00	-8.45	4.43	12.20	-0.63%	5.58%	6.15%
Parter	C26	GS SY++	-41.29	12.32	20.70	-33.35	11.61	19.50	19.22%	5.73%	5.80%
Parter	C27	GS SY++	-53.60	16.08	24.20	-53.56	15.25	23.00	0.08%	5.17%	4.96%
Parter	C28	GS SY++	-27.10	10.83	19.30	-24.15	10.19	18.30	10.87%	5.89%	5.18%
Parter	C29	GS SY++	-44.27	17.36	25.50	-44.31	16.46	24.20	-0.10%	5.16%	5.10%
Parter	C30	GS SY++	-75.56	13.97	22.30	-75.10	13.18	21.10	0.61%	5.66%	5.38%
Parter	C31	GS SY++	-86.46	15.95	24.10	-85.67	15.09	22.80	0.92%	5.42%	5.39%
Parter	C32	GS SY++	-140.82	16.42	24.60	-136.70	15.63	23.40	2.93%	4.83%	4.88%
Parter	C33	GS SY++	-77.87	16.67	24.90	-75.82	15.89	23.70	2.64%	4.71%	4.82%
Parter	C34	GS SY++	-159.92	16.00	24.00	-152.84	15.13	22.70	4.43%	5.46%	5.42%
Parter	C35	GS SY++	-210.76	16.91	25.10	-199.70	16.04	23.80	5.25%	5.12%	5.18%
Parter	C36	GS SY++	-116.87	17.00	25.30	-111.73	16.16	24.00	4.40%	4.95%	5.14%
Parter	C37	GS SY++	-73.64	14.35	22.20	-72.01	13.56	20.90	2.22%	5.51%	5.86%
Parter	C42	GS SX++	-82.88	17.62	25.40	-80.36	16.72	24.10	3.04%	5.08%	5.12%

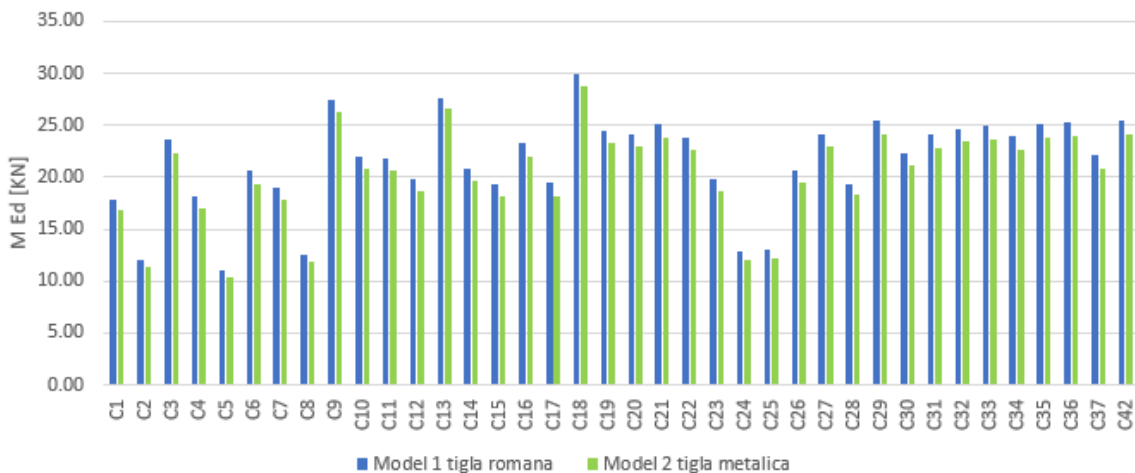
Comparatie forte axiale stalpi la baza parterului - directie Y



Comparatie forte taietoare stalpi la baza parterului - directie Y



Comparatie momente taietoare stalpi la baza parterului - directie Y





## 4.2. COMPARAȚII EFORTURI GRINZI

Prezentarea comparativă tabelar și grafică a eforturilor din grinzi (forță tăietoare, moment încovoietor) din cele două modele:

TABLE: Element Forces - Beams											
Story	Beam	Unique Name	Output Case	Step Type	Station	Model 1 tigla romana		Model 2 tigla metalica		Diferente procentuale	
						V2	M3	V2	M3	V2	M3
						m	kN	kN-m	kN	kN-m	[%]
Parter	B1	37	ENVE	Max	0.15	-4.93	-0.60	-5.07	-0.80	2.7%	33.3%
Parter	B1	37	ENVE	Max	0.62	-3.69	1.50	-3.83	1.30	3.6%	13.3%
Parter	B1	37	ENVE	Max	1.10	-2.45	2.90	-2.59	2.80	5.4%	3.4%
Parter	B1	37	ENVE	Max	1.57	-1.21	3.80	-1.34	3.70	11.0%	2.6%
Parter	B1	37	ENVE	Max	2.04	0.03	4.40	-0.10	4.50	454.4%	2.2%
Parter	B1	37	ENVE	Max	2.51	1.27	5.80	1.14	5.80	10.5%	0.0%
Parter	B1	37	ENVE	Max	2.99	2.51	6.50	2.38	6.40	5.3%	1.5%
Parter	B1	37	ENVE	Max	3.46	3.75	7.50	3.62	7.30	3.6%	2.7%
Parter	B1	37	ENVE	Max	3.93	4.99	8.00	4.86	7.70	2.7%	3.8%
Parter	B1	37	ENVE	Max	4.40	6.23	7.90	6.10	7.50	2.1%	5.1%
Parter	B1	37	ENVE	Max	4.88	7.47	7.20	7.34	6.70	1.8%	6.9%
Parter	B1	37	ENVE	Max	5.35	8.71	5.90	8.58	5.40	1.5%	8.5%
Parter	B2	38	ENVE	Max	0.15	7.33	14.00	6.80	13.20	7.3%	5.7%
Parter	B2	38	ENVE	Max	0.65	8.64	10.00	8.11	9.50	6.2%	5.0%
Parter	B2	38	ENVE	Max	1.15	9.95	5.40	9.42	5.10	5.3%	5.6%
Parter	B2	38	ENVE	Max	1.65	11.26	1.50	10.73	1.40	4.7%	6.7%
Parter	B2	38	ENVE	Max	2.15	12.58	5.50	12.05	5.20	4.2%	5.5%
Parter	B2	38	ENVE	Max	2.65	13.89	8.80	13.36	8.30	3.8%	5.7%
Parter	B3	39	ENVE	Max	0.15	1.29	5.10	1.08	4.80	16.8%	5.9%
Parter	B3	39	ENVE	Max	0.65	2.61	4.10	2.39	3.90	8.3%	4.9%
Parter	B3	39	ENVE	Max	1.15	3.92	2.50	3.70	2.40	5.5%	4.0%
Parter	B3	39	ENVE	Max	1.65	5.23	1.90	5.01	1.80	4.2%	5.3%
Parter	B3	39	ENVE	Max	2.15	6.54	4.20	6.33	4.10	3.3%	2.4%
Parter	B3	39	ENVE	Max	2.65	7.86	6.00	7.64	5.70	2.8%	5.0%
Parter	B4	50	ENVE	Max	0.15	-40.74	-28.80	-40.88	-29.10	0.3%	1.0%
Parter	B4	50	ENVE	Max	0.58	-34.38	-12.80	-34.52	-13.00	0.4%	1.6%
Parter	B4	50	ENVE	Max	1.00	-28.41	0.50	-28.55	0.40	0.5%	20.0%
Parter	B4	50	ENVE	Max	1.00	-24.91	0.60	-25.05	0.50	0.6%	16.7%
Parter	B4	50	ENVE	Max	1.50	-18.58	12.70	-18.73	12.80	0.8%	0.8%
Parter	B4	50	ENVE	Max	2.00	-12.26	26.40	-12.40	26.40	1.2%	0.0%
Parter	B4	50	ENVE	Max	2.50	-5.93	35.80	-6.08	35.80	2.4%	0.0%
Parter	B4	50	ENVE	Max	3.00	0.39	40.90	0.25	40.90	36.6%	0.0%
Parter	B4	50	ENVE	Max	3.00	4.96	40.70	4.82	40.70	2.8%	0.0%
Parter	B4	50	ENVE	Max	3.47	11.79	37.50	11.84	37.50	0.4%	0.0%
Parter	B4	50	ENVE	Max	3.94	23.78	29.20	23.83	29.20	0.2%	0.0%
Parter	B4	50	ENVE	Max	4.41	37.41	16.70	37.46	16.30	0.1%	2.4%
Parter	B4	50	ENVE	Max	4.88	50.19	4.10	50.24	3.60	0.1%	12.2%
Parter	B4	50	ENVE	Max	5.35	60.38	-12.10	60.43	-12.70	0.1%	5.0%
Parter	B5	41	ENVE	Max	0.15	6.91	13.30	6.67	13.00	3.5%	2.3%
Parter	B5	41	ENVE	Max	0.65	8.22	9.50	7.98	9.30	3.0%	2.1%
Parter	B5	41	ENVE	Max	1.15	9.53	5.10	9.29	5.00	2.5%	2.0%
Parter	B5	41	ENVE	Max	1.65	10.85	1.40	10.60	1.40	2.2%	0.0%
Parter	B5	41	ENVE	Max	2.15	12.16	5.20	11.92	5.10	2.0%	1.9%
Parter	B5	41	ENVE	Max	2.65	13.47	8.40	13.23	8.20	1.8%	2.4%
Parter	B6	42	ENVE	Max	0.15	1.32	5.00	1.07	4.80	18.5%	4.0%
Parter	B6	42	ENVE	Max	0.65	2.63	4.00	2.39	3.90	9.3%	2.5%
Parter	B6	42	ENVE	Max	1.15	3.94	2.40	3.70	2.40	6.2%	0.0%

Parter	B6	42	ENVE	Max	1.65	5.25	2.20	5.01	2.10	4.6%	4.5%
Parter	B6	42	ENVE	Max	2.15	6.57	4.80	6.32	4.50	3.7%	6.3%
Parter	B6	42	ENVE	Max	2.65	7.88	6.70	7.63	6.30	3.1%	6.0%
Parter	B7	43	ENVE	Max	0.15	9.83	11.10	9.02	10.50	8.3%	5.4%
Parter	B7	43	ENVE	Max	0.58	13.67	6.20	12.86	5.90	6.0%	4.8%
Parter	B7	43	ENVE	Max	1.00	18.70	0.30	17.89	0.30	4.4%	0.0%
Parter	B7	43	ENVE	Max	1.43	23.73	3.30	22.92	3.00	3.4%	9.1%
Parter	B7	43	ENVE	Max	1.85	27.58	4.40	26.76	3.70	3.0%	15.9%
Parter	B8	44	ENVE	Max	0.15	20.43	14.30	19.27	13.50	5.7%	5.6%
Parter	B8	44	ENVE	Max	0.58	21.57	5.20	20.41	4.90	5.4%	5.8%
Parter	B8	44	ENVE	Max	1.02	22.71	1.10	21.55	1.00	5.1%	9.1%
Parter	B8	44	ENVE	Max	1.45	23.84	6.60	22.68	6.10	4.9%	7.6%
Parter	B9	45	ENVE	Max	0.15	5.56	11.70	5.09	11.10	8.3%	5.1%
Parter	B9	45	ENVE	Max	0.65	6.87	8.60	6.41	8.20	6.7%	4.7%
Parter	B9	45	ENVE	Max	1.15	8.18	4.90	7.72	4.70	5.7%	4.1%
Parter	B9	45	ENVE	Max	1.65	9.49	1.10	9.03	1.10	4.9%	0.0%
Parter	B9	45	ENVE	Max	2.15	10.80	4.40	10.34	4.20	4.3%	4.5%
Parter	B9	45	ENVE	Max	2.65	12.12	7.00	11.65	6.60	3.8%	5.7%
Parter	B10	46	ENVE	Max	0.15	2.86	5.70	2.75	5.40	4.0%	5.3%
Parter	B10	46	ENVE	Max	0.65	4.18	3.90	4.06	3.70	2.7%	5.1%
Parter	B10	46	ENVE	Max	1.15	5.49	1.50	5.38	1.50	2.1%	0.0%
Parter	B10	46	ENVE	Max	1.65	6.80	3.20	6.69	3.30	1.7%	3.0%
Parter	B10	46	ENVE	Max	2.15	8.11	6.00	8.00	6.00	1.4%	0.0%
Parter	B10	46	ENVE	Max	2.65	9.43	8.00	9.31	8.00	1.2%	0.0%
Parter	B11	47	ENVE	Max	0.15	4.57	11.20	3.59	10.40	21.4%	7.1%
Parter	B11	47	ENVE	Max	0.58	11.10	7.80	10.12	7.50	8.8%	3.8%
Parter	B11	47	ENVE	Max	1.02	18.86	4.20	17.89	4.10	5.2%	2.4%
Parter	B11	47	ENVE	Max	1.45	27.20	11.20	26.22	10.60	3.6%	5.4%
Parter	B12	48	ENVE	Max	0.15	13.50	8.00	12.87	7.60	4.7%	5.0%
Parter	B12	48	ENVE	Max	0.58	21.84	0.40	21.20	0.20	2.9%	50.0%
Parter	B12	48	ENVE	Max	1.02	29.60	-4.40	28.97	-4.60	2.1%	4.5%
Parter	B12	48	ENVE	Max	1.45	36.13	-7.10	35.50	-7.70	1.8%	8.5%
Parter	B13	49	ENVE	Max	0.15	4.86	13.60	4.29	13.10	11.6%	3.7%
Parter	B13	49	ENVE	Max	0.58	9.97	10.50	9.41	10.20	5.7%	2.9%
Parter	B13	49	ENVE	Max	1.00	16.28	5.00	15.71	4.90	3.5%	2.0%
Parter	B13	49	ENVE	Max	1.43	22.58	4.40	22.02	4.20	2.5%	4.5%
Parter	B13	49	ENVE	Max	1.85	27.70	5.10	27.14	4.60	2.0%	9.8%
Parter	B15	51	ENVE	Max	0.15	8.00	6.60	7.48	6.20	6.5%	6.1%
Parter	B15	51	ENVE	Max	0.58	9.09	2.90	8.56	2.70	5.8%	6.9%
Parter	B15	51	ENVE	Max	1.02	10.17	2.00	9.65	1.90	5.1%	5.0%
Parter	B15	51	ENVE	Max	1.45	11.25	5.90	10.73	5.60	4.6%	5.1%
Parter	B16	52	ENVE	Max	0.15	8.34	7.80	7.83	7.40	6.1%	5.1%
Parter	B16	52	ENVE	Max	0.54	9.32	4.40	8.80	4.10	5.5%	6.8%
Parter	B16	52	ENVE	Max	0.93	10.29	0.50	9.78	0.50	5.0%	0.0%
Parter	B16	52	ENVE	Max	1.32	11.26	3.00	10.75	2.80	4.5%	6.7%
Parter	B16	52	ENVE	Max	1.71	12.24	5.90	11.73	5.50	4.2%	6.8%
Parter	B19	55	ENVE	Max	0.15	-49.98	-40.30	-50.19	-40.70	0.4%	1.0%
Parter	B19	55	ENVE	Max	0.62	-46.79	-17.30	-47.00	-17.60	0.5%	1.7%
Parter	B19	55	ENVE	Max	1.10	-40.66	3.50	-40.87	3.20	0.5%	8.6%
Parter	B19	55	ENVE	Max	1.57	-31.58	32.50	-31.80	32.50	0.7%	0.0%
Parter	B19	55	ENVE	Max	2.04	-19.57	57.20	-19.78	57.20	1.1%	0.0%
Parter	B19	55	ENVE	Max	2.51	-6.03	70.90	-6.24	70.90	3.5%	0.0%
Parter	B19	55	ENVE	Max	2.99	7.52	73.20	7.31	73.20	2.8%	0.0%
Parter	B19	55	ENVE	Max	3.46	31.56	64.00	31.52	64.00	0.1%	0.0%
Parter	B19	55	ENVE	Max	3.93	53.01	43.80	52.97	43.80	0.1%	0.0%
Parter	B19	55	ENVE	Max	4.40	69.12	15.80	69.09	15.40	0.0%	2.5%
Parter	B19	55	ENVE	Max	4.88	79.89	-2.40	79.85	-2.90	0.0%	20.8%
Parter	B19	55	ENVE	Max	5.35	85.31	-22.80	85.28	-23.40	0.0%	2.6%
Parter	B20	56	ENVE	Max	0.15	-22.68	-7.90	-22.89	-8.30	0.9%	5.1%
Parter	B20	56	ENVE	Max	0.64	-18.17	2.10	-18.38	1.80	1.1%	14.3%
Parter	B20	56	ENVE	Max	1.13	-12.10	9.60	-12.31	9.40	1.7%	2.1%

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Parter	B20	56	ENVE	Max	1.61	-4.46	19.40	-4.67	19.40	4.6%	0.0%
Parter	B20	56	ENVE	Max	2.10	4.74	22.90	4.53	22.90	4.4%	0.0%
Parter	B20	56	ENVE	Max	2.59	15.83	18.80	15.84	18.80	0.1%	0.0%
Parter	B20	56	ENVE	Max	3.08	28.19	9.40	28.20	9.20	0.1%	2.1%
Parter	B20	56	ENVE	Max	3.56	37.70	1.60	37.72	1.30	0.0%	18.8%
Parter	B20	56	ENVE	Max	4.05	44.38	-8.80	44.39	-9.20	0.0%	4.5%
Parter	B21	57	ENVE	Max	0.15	15.05	13.50	14.38	12.90	4.5%	4.4%
Parter	B21	57	ENVE	Max	0.58	17.76	6.60	17.09	6.30	3.8%	4.5%
Parter	B21	57	ENVE	Max	1.00	22.07	-1.90	21.40	-1.90	3.0%	0.0%
Parter	B21	57	ENVE	Max	1.43	26.38	-1.40	25.71	-1.80	2.5%	28.6%
Parter	B21	57	ENVE	Max	1.85	29.09	-1.90	28.42	-2.50	2.3%	31.6%
Parter	B22	136	ENVE	Max	0.15	-35.19	-25.70	-35.40	-26.10	0.6%	1.6%
Parter	B22	136	ENVE	Max	0.58	-32.49	-11.20	-32.71	-11.60	0.7%	3.6%
Parter	B22	136	ENVE	Max	1.00	-28.99	1.90	-29.21	1.60	0.7%	15.8%
Parter	B22	136	ENVE	Max	1.00	-25.00	1.80	-25.22	1.50	0.9%	16.7%
Parter	B22	136	ENVE	Max	1.50	-20.06	17.00	-20.27	17.00	1.1%	0.0%
Parter	B22	136	ENVE	Max	2.00	-13.47	35.10	-13.68	35.10	1.6%	0.0%
Parter	B22	136	ENVE	Max	2.50	-5.76	46.70	-5.97	46.70	3.7%	0.0%
Parter	B22	136	ENVE	Max	3.00	1.98	51.50	1.77	51.50	10.8%	0.0%
Parter	B22	136	ENVE	Max	3.00	6.55	51.60	6.33	51.60	3.4%	0.0%
Parter	B22	136	ENVE	Max	3.47	18.42	46.40	18.40	46.40	0.1%	0.0%
Parter	B22	136	ENVE	Max	3.94	33.52	34.20	33.50	34.20	0.1%	0.0%
Parter	B22	136	ENVE	Max	4.41	47.61	16.50	47.60	16.10	0.0%	2.4%
Parter	B22	136	ENVE	Max	4.88	58.23	4.00	58.21	3.50	0.0%	12.5%
Parter	B22	136	ENVE	Max	5.35	63.60	-10.60	63.58	-11.20	0.0%	5.7%
Parter	B23	59	ENVE	Max	0.15	-26.62	-10.70	-26.77	-11.00	0.5%	2.8%
Parter	B23	59	ENVE	Max	0.64	-23.29	1.60	-23.44	1.40	0.6%	12.5%
Parter	B23	59	ENVE	Max	1.13	-16.82	14.70	-16.97	14.70	0.9%	0.0%
Parter	B23	59	ENVE	Max	1.61	-7.23	28.90	-7.37	28.90	2.0%	0.0%
Parter	B23	59	ENVE	Max	2.10	4.68	33.50	4.53	33.50	3.1%	0.0%
Parter	B23	59	ENVE	Max	2.59	22.51	27.60	22.50	27.60	0.0%	0.0%
Parter	B23	59	ENVE	Max	3.08	39.55	12.30	39.55	12.30	0.0%	0.0%
Parter	B23	59	ENVE	Max	3.56	50.92	0.70	50.91	0.50	0.0%	28.6%
Parter	B23	59	ENVE	Max	4.05	56.59	-12.20	56.59	-12.60	0.0%	3.3%
Parter	B24	60	ENVE	Max	0.15	-3.50	9.70	-3.95	9.00	12.9%	7.2%
Parter	B24	60	ENVE	Max	0.63	-0.21	10.80	-0.66	10.20	218.0%	5.6%
Parter	B24	60	ENVE	Max	1.12	6.12	9.40	5.67	9.10	7.4%	3.2%
Parter	B24	60	ENVE	Max	1.60	14.43	5.50	13.97	5.50	3.1%	0.0%
Parter	B24	60	ENVE	Max	2.08	24.35	1.00	24.39	0.80	0.2%	20.0%
Parter	B24	60	ENVE	Max	2.57	35.46	-2.90	35.50	-3.40	0.1%	17.2%
Parter	B24	60	ENVE	Max	3.05	41.07	-9.20	41.11	-9.90	0.1%	7.6%
Parter	B25	61	ENVE	Max	0.15	-2.82	1.00	-2.90	0.80	3.1%	20.0%
Parter	B25	61	ENVE	Max	0.61	-1.66	2.00	-1.75	1.90	5.2%	5.0%
Parter	B25	61	ENVE	Max	1.08	-0.50	2.50	-0.59	2.40	17.0%	4.0%
Parter	B25	61	ENVE	Max	1.54	0.65	2.50	0.57	2.50	13.2%	0.0%
Parter	B25	61	ENVE	Max	2.00	1.81	2.50	1.72	2.50	4.8%	0.0%
Parter	B25	61	ENVE	Max	2.46	2.96	2.30	2.88	2.20	2.9%	4.3%
Parter	B25	61	ENVE	Max	2.93	4.12	2.30	4.03	2.20	2.1%	4.3%
Parter	B25	61	ENVE	Max	3.39	5.27	1.70	5.19	1.60	1.6%	5.9%
Parter	B25	61	ENVE	Max	3.85	6.43	0.60	6.34	0.40	1.3%	33.3%
Parter	B27	63	ENVE	Max	0.15	-32.18	-24.30	-32.35	-24.70	0.5%	1.6%
Parter	B27	63	ENVE	Max	0.63	-28.70	-9.60	-28.87	-9.90	0.6%	3.1%
Parter	B27	63	ENVE	Max	1.11	-23.69	3.10	-23.86	2.80	0.7%	9.7%
Parter	B27	63	ENVE	Max	1.60	-17.15	17.40	-17.31	17.40	1.0%	0.0%
Parter	B27	63	ENVE	Max	2.08	-9.83	30.40	-9.99	30.40	1.7%	0.0%
Parter	B27	63	ENVE	Max	2.56	-2.51	37.50	-2.68	37.50	6.5%	0.0%
Parter	B27	63	ENVE	Max	3.04	4.81	38.70	4.64	38.70	3.4%	0.0%
Parter	B27	63	ENVE	Max	3.52	15.83	34.00	15.83	34.00	0.0%	0.0%
Parter	B27	63	ENVE	Max	4.00	28.08	23.50	28.07	23.50	0.0%	0.0%
Parter	B27	63	ENVE	Max	4.49	38.91	9.40	38.90	9.20	0.0%	2.1%
Parter	B27	63	ENVE	Max	4.97	46.96	-1.80	46.96	-2.20	0.0%	22.2%

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Parter	B27	63	ENVE	Max	5.45	52.24	-15.10	52.23	-15.50	0.0%	2.6%
Parter	B29	65	ENVE	Max	0.15	3.63	4.30	3.30	4.00	9.1%	7.0%
Parter	B29	65	ENVE	Max	0.54	4.60	2.70	4.27	2.50	7.2%	7.4%
Parter	B29	65	ENVE	Max	0.93	5.58	0.70	5.25	0.70	5.9%	0.0%
Parter	B29	65	ENVE	Max	1.32	6.55	1.90	6.22	1.80	5.0%	5.3%
Parter	B29	65	ENVE	Max	1.71	7.52	3.60	7.20	3.40	4.4%	5.6%
Parter	B30	66	ENVE	Max	0.15	2.42	3.00	2.18	2.90	10.2%	3.3%
Parter	B30	66	ENVE	Max	0.55	3.41	1.90	3.16	1.80	7.2%	5.3%
Parter	B30	66	ENVE	Max	0.94	4.40	0.40	4.15	0.40	5.6%	0.0%
Parter	B30	66	ENVE	Max	1.34	5.39	1.90	5.14	1.80	4.6%	5.3%
Parter	B30	66	ENVE	Max	1.73	6.37	3.00	6.13	2.90	3.9%	3.3%
Parter	B31	67	ENVE	Max	0.15	3.53	3.40	3.27	3.20	7.4%	5.9%
Parter	B31	67	ENVE	Max	0.54	4.50	1.80	4.24	1.80	5.8%	0.0%
Parter	B31	67	ENVE	Max	0.93	5.48	0.70	5.22	0.70	4.8%	0.0%
Parter	B31	67	ENVE	Max	1.32	6.45	2.70	6.19	2.60	4.0%	3.7%
Parter	B31	67	ENVE	Max	1.71	7.43	4.40	7.17	4.10	3.5%	6.8%
Parter	B32	68	ENVE	Max	0.15	4.54	11.90	3.48	11.10	23.4%	6.7%
Parter	B32	68	ENVE	Max	0.58	12.12	8.40	11.05	8.00	8.8%	4.8%
Parter	B32	68	ENVE	Max	1.02	21.86	4.20	20.79	4.20	4.9%	0.0%
Parter	B32	68	ENVE	Max	1.45	31.91	8.90	30.84	8.40	3.3%	5.6%
Parter	B33	69	ENVE	Max	0.15	7.59	6.20	6.88	5.70	9.3%	8.1%
Parter	B33	69	ENVE	Max	0.58	12.87	1.80	12.17	1.70	5.5%	5.6%
Parter	B33	69	ENVE	Max	1.02	17.84	3.50	17.14	3.30	3.9%	5.7%
Parter	B33	69	ENVE	Max	1.45	20.65	8.40	19.95	7.90	3.4%	6.0%
Parter	B34	70	ENVE	Max	0.15	-16.53	-5.30	-16.82	-5.80	1.8%	9.4%
Parter	B34	70	ENVE	Max	0.61	-13.45	1.80	-13.74	1.30	2.2%	27.8%
Parter	B34	70	ENVE	Max	1.08	-7.79	6.70	-8.08	6.50	3.7%	3.0%
Parter	B34	70	ENVE	Max	1.54	-0.61	10.90	-0.90	10.90	48.1%	0.0%
Parter	B34	70	ENVE	Max	2.00	7.98	12.40	7.69	12.40	3.7%	0.0%
Parter	B34	70	ENVE	Max	2.46	19.88	6.60	19.86	6.60	0.1%	0.0%
Parter	B34	70	ENVE	Max	2.93	32.56	1.80	32.55	1.50	0.0%	16.7%
Parter	B34	70	ENVE	Max	3.39	42.47	-5.70	42.46	-6.10	0.0%	7.0%
Parter	B34	70	ENVE	Max	3.85	47.72	-15.20	47.71	-15.70	0.0%	3.3%
Parter	B35	71	ENVE	Max	0.15	-20.33	-5.80	-20.58	-6.20	1.2%	6.9%
Parter	B35	71	ENVE	Max	0.61	-15.40	2.50	-15.64	2.20	1.6%	12.0%
Parter	B35	71	ENVE	Max	1.08	-9.06	8.20	-9.30	8.00	2.7%	2.4%
Parter	B35	71	ENVE	Max	1.54	-1.31	13.30	-1.55	13.30	18.7%	0.0%
Parter	B35	71	ENVE	Max	2.00	7.85	15.20	7.61	15.20	3.1%	0.0%
Parter	B35	71	ENVE	Max	2.46	18.45	10.00	18.44	10.00	0.0%	0.0%
Parter	B35	71	ENVE	Max	2.93	30.76	4.60	30.76	4.40	0.0%	4.3%
Parter	B35	71	ENVE	Max	3.39	40.52	-3.20	40.51	-3.50	0.0%	9.4%
Parter	B35	71	ENVE	Max	3.85	47.71	-13.60	47.71	-14.00	0.0%	2.9%
Parter	B36	72	ENVE	Max	0.15	-5.80	4.20	-6.18	3.80	6.6%	9.5%
Parter	B36	72	ENVE	Max	0.54	-3.36	6.00	-3.74	5.80	11.4%	3.3%
Parter	B36	72	ENVE	Max	0.94	0.64	7.90	0.26	7.90	59.4%	0.0%
Parter	B36	72	ENVE	Max	1.33	4.74	11.20	4.36	11.10	8.1%	0.9%
Parter	B36	72	ENVE	Max	1.33	17.28	11.50	17.12	11.50	1.0%	0.0%
Parter	B36	72	ENVE	Max	1.67	23.49	6.40	23.52	6.20	0.2%	3.1%
Parter	B36	72	ENVE	Max	2.01	31.73	3.60	31.76	3.30	0.1%	8.3%
Parter	B36	72	ENVE	Max	2.35	40.62	-0.90	40.65	-1.30	0.1%	44.4%
Parter	B37	73	ENVE	Max	0.15	-18.46	-0.40	-18.85	-0.80	2.1%	100.0%
Parter	B37	73	ENVE	Max	0.60	-10.68	6.30	-11.07	6.00	3.6%	4.8%
Parter	B37	73	ENVE	Max	1.05	-1.57	11.90	-1.96	11.80	24.8%	0.8%
Parter	B37	73	ENVE	Max	1.50	8.07	16.40	7.68	16.50	4.8%	0.6%
Parter	B37	73	ENVE	Max	1.95	16.37	13.70	15.99	13.70	2.4%	0.0%
Parter	B37	73	ENVE	Max	2.40	23.01	12.80	22.95	12.50	0.3%	2.3%
Parter	B37	73	ENVE	Max	2.85	28.05	10.30	27.99	9.80	0.2%	4.9%
Parter	B38	74	ENVE	Max	0.15	-38.88	-26.90	-39.02	-27.20	0.4%	1.1%
Parter	B38	74	ENVE	Max	0.63	-33.72	-9.30	-33.85	-9.60	0.4%	3.2%
Parter	B38	74	ENVE	Max	1.11	-27.02	5.40	-27.16	5.10	0.5%	5.6%
Parter	B38	74	ENVE	Max	1.60	-18.82	20.40	-18.96	20.40	0.7%	0.0%

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Parter	B38	74	ENVE	Max	2.08	-10.13	33.90	-10.27	33.90	1.4%	0.0%
Parter	B38	74	ENVE	Max	2.56	-1.45	40.70	-1.58	40.70	9.5%	0.0%
Parter	B38	74	ENVE	Max	3.04	7.24	40.80	7.11	40.80	1.9%	0.0%
Parter	B38	74	ENVE	Max	3.52	20.70	34.20	20.70	34.20	0.0%	0.0%
Parter	B38	74	ENVE	Max	4.00	34.65	20.90	34.65	20.90	0.0%	0.0%
Parter	B38	74	ENVE	Max	4.49	47.70	5.70	47.70	5.40	0.0%	5.3%
Parter	B38	74	ENVE	Max	4.97	58.03	-8.90	58.03	-9.20	0.0%	3.4%
Parter	B38	74	ENVE	Max	5.45	65.59	-26.30	65.59	-26.70	0.0%	1.5%
Parter	B39	75	ENVE	Max	0.15	-26.25	-15.70	-26.53	-16.20	1.1%	3.2%
Parter	B39	75	ENVE	Max	0.61	-21.32	-4.70	-21.60	-5.00	1.3%	6.4%
Parter	B39	75	ENVE	Max	1.08	-14.98	3.80	-15.26	3.60	1.9%	5.3%
Parter	B39	75	ENVE	Max	1.54	-7.23	11.10	-7.51	11.10	3.9%	0.0%
Parter	B39	75	ENVE	Max	2.00	1.11	18.10	0.83	18.10	25.2%	0.0%
Parter	B39	75	ENVE	Max	2.46	9.45	18.90	9.17	18.90	2.9%	0.0%
Parter	B39	75	ENVE	Max	2.93	17.25	15.60	17.24	15.40	0.1%	1.3%
Parter	B39	75	ENVE	Max	3.39	27.01	12.10	27.00	11.70	0.0%	3.3%
Parter	B39	75	ENVE	Max	3.85	34.20	5.90	34.19	5.40	0.0%	8.5%
Parter	B40	76	ENVE	Max	0.15	-45.75	-24.40	-45.86	-24.80	0.2%	1.6%
Parter	B40	76	ENVE	Max	0.63	-38.88	-3.90	-38.99	-4.20	0.3%	7.7%
Parter	B40	76	ENVE	Max	1.12	-30.48	12.90	-30.59	12.70	0.4%	1.6%
Parter	B40	76	ENVE	Max	1.60	-20.56	32.70	-20.68	32.70	0.5%	0.0%
Parter	B40	76	ENVE	Max	2.08	-10.17	46.30	-10.28	46.30	1.1%	0.0%
Parter	B40	76	ENVE	Max	2.57	0.23	52.20	0.12	52.20	48.9%	0.0%
Parter	B40	76	ENVE	Max	3.05	12.32	50.20	12.32	50.10	0.1%	0.2%
Parter	B40	76	ENVE	Max	3.53	28.57	40.30	28.58	40.30	0.0%	0.0%
Parter	B40	76	ENVE	Max	4.02	44.83	22.50	44.84	22.50	0.0%	0.0%
Parter	B40	76	ENVE	Max	4.50	60.13	1.80	60.14	1.70	0.0%	5.6%
Parter	B40	76	ENVE	Max	4.50	60.62	3.50	60.63	3.40	0.0%	2.9%
Parter	B40	76	ENVE	Max	4.98	74.33	-15.40	74.34	-15.60	0.0%	1.3%
Parter	B40	76	ENVE	Max	5.45	86.12	-38.40	86.13	-38.70	0.0%	0.8%
Parter	B41	77	ENVE	Max	0.15	-22.99	-20.40	-23.30	-20.90	1.4%	2.5%
Parter	B41	77	ENVE	Max	0.61	-19.91	-10.40	-20.22	-10.70	1.6%	2.9%
Parter	B41	77	ENVE	Max	1.08	-14.79	-2.30	-15.10	-2.50	2.1%	8.7%
Parter	B41	77	ENVE	Max	1.54	-8.27	4.20	-8.58	4.10	3.8%	2.4%
Parter	B41	77	ENVE	Max	2.00	-1.15	12.80	-1.46	12.70	27.2%	0.8%
Parter	B41	77	ENVE	Max	2.46	5.97	15.50	5.65	15.50	5.2%	0.0%
Parter	B41	77	ENVE	Max	2.93	12.49	14.30	12.17	14.00	2.5%	2.1%
Parter	B41	77	ENVE	Max	3.39	20.68	13.40	20.65	13.00	0.1%	3.0%
Parter	B41	77	ENVE	Max	3.85	25.92	10.60	25.90	10.00	0.1%	5.7%
Parter	B42	78	ENVE	Max	0.15	-9.81	1.10	-9.72	1.20	0.9%	8.3%
Parter	B42	78	ENVE	Max	0.60	-6.84	4.90	-6.75	5.00	1.3%	2.0%
Parter	B42	78	ENVE	Max	1.05	-1.21	8.10	-1.12	8.00	7.7%	1.2%
Parter	B42	78	ENVE	Max	1.50	7.10	13.00	7.18	13.00	1.2%	0.0%
Parter	B42	78	ENVE	Max	1.95	15.40	11.70	15.49	11.80	0.6%	0.8%
Parter	B42	78	ENVE	Max	2.40	21.63	11.30	21.47	11.70	0.8%	3.4%
Parter	B42	78	ENVE	Max	2.85	26.67	9.10	26.51	9.50	0.6%	4.2%
Parter	B43	79	ENVE	Max	0.15	-15.10	-1.30	-14.54	-0.60	3.9%	116.7%
Parter	B43	79	ENVE	Max	0.60	-9.42	4.30	-8.86	4.80	6.3%	10.4%
Parter	B43	79	ENVE	Max	1.05	-2.41	7.00	-1.85	7.20	30.3%	2.8%
Parter	B43	79	ENVE	Max	1.50	5.94	11.40	6.50	11.40	8.6%	0.0%
Parter	B43	79	ENVE	Max	1.95	14.29	11.50	14.85	11.80	3.8%	2.5%
Parter	B43	79	ENVE	Max	2.40	21.30	11.40	21.86	12.10	2.6%	5.8%
Parter	B43	79	ENVE	Max	2.85	27.75	8.50	27.68	9.40	0.2%	9.6%
Parter	B44	80	ENVE	Max	0.15	-35.10	-26.30	-35.28	-26.70	0.5%	1.5%
Parter	B44	80	ENVE	Max	0.63	-31.82	-10.10	-32.00	-10.40	0.6%	3.0%
Parter	B44	80	ENVE	Max	1.11	-26.15	3.90	-26.33	3.70	0.7%	5.1%
Parter	B44	80	ENVE	Max	1.60	-18.94	20.90	-19.12	20.90	1.0%	0.0%
Parter	B44	80	ENVE	Max	2.08	-10.96	36.60	-11.14	36.60	1.6%	0.0%
Parter	B44	80	ENVE	Max	2.56	-2.97	45.40	-3.15	45.40	6.1%	0.0%
Parter	B44	80	ENVE	Max	3.04	5.02	47.50	4.84	47.50	3.6%	0.0%
Parter	B44	80	ENVE	Max	3.52	16.89	42.80	16.89	42.80	0.0%	0.0%

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Parter	B44	80	ENVE	Max	4.00	31.02	31.20	31.02	31.20	0.0%	0.0%
Parter	B44	80	ENVE	Max	4.49	43.73	14.40	43.73	14.10	0.0%	2.1%
Parter	B44	80	ENVE	Max	4.97	53.66	2.70	53.66	2.30	0.0%	14.8%
Parter	B44	80	ENVE	Max	5.45	59.24	-11.20	59.24	-11.70	0.0%	4.5%
Parter	B45	81	ENVE	Max	0.15	-12.60	0.50	-12.36	0.70	1.9%	28.6%
Parter	B45	81	ENVE	Max	0.54	-11.05	5.20	-10.82	5.30	2.2%	1.9%
Parter	B45	81	ENVE	Max	0.94	-8.97	11.50	-8.74	11.60	2.7%	0.9%
Parter	B45	81	ENVE	Max	1.33	-7.81	22.30	-7.58	22.30	3.1%	0.0%
Parter	B45	81	ENVE	Max	1.33	33.83	23.40	34.03	23.40	0.6%	0.0%
Parter	B45	81	ENVE	Max	1.67	35.97	11.60	36.17	11.50	0.5%	0.9%
Parter	B45	81	ENVE	Max	2.01	40.64	5.40	40.84	5.40	0.5%	0.0%
Parter	B45	81	ENVE	Max	2.35	44.00	-0.60	44.20	-0.60	0.5%	0.0%
Parter	B46	82	ENVE	Max	0.15	10.93	12.30	11.07	12.50	1.2%	1.6%
Parter	B46	82	ENVE	Max	0.58	14.43	6.90	14.56	7.00	0.9%	1.4%
Parter	B46	82	ENVE	Max	1.02	19.16	3.20	19.29	3.20	0.7%	0.0%
Parter	B46	82	ENVE	Max	1.45	25.13	9.00	25.26	9.00	0.5%	0.0%
Parter	B47	83	ENVE	Max	0.15	11.82	7.40	12.33	7.70	4.1%	3.9%
Parter	B47	83	ENVE	Max	0.58	16.06	1.30	16.56	1.40	3.1%	7.1%
Parter	B47	83	ENVE	Max	1.02	19.06	1.20	19.56	1.30	2.6%	7.7%
Parter	B47	83	ENVE	Max	1.45	20.82	4.80	21.32	5.20	2.4%	7.7%
Parter	B48	84	ENVE	Max	0.15	-9.47	1.70	-9.77	1.20	3.2%	29.4%
Parter	B48	84	ENVE	Max	0.61	-5.94	5.30	-6.25	4.90	5.2%	7.5%
Parter	B48	84	ENVE	Max	1.08	-2.42	7.20	-2.72	7.00	12.7%	2.8%
Parter	B48	84	ENVE	Max	1.54	1.11	7.50	0.80	7.40	27.6%	1.3%
Parter	B48	84	ENVE	Max	2.00	4.64	8.30	4.33	8.30	6.6%	0.0%
Parter	B48	84	ENVE	Max	2.46	8.16	8.70	7.86	8.50	3.8%	2.3%
Parter	B48	84	ENVE	Max	2.93	11.69	9.20	11.38	8.90	2.6%	3.3%
Parter	B48	84	ENVE	Max	3.39	15.22	8.10	14.91	7.70	2.0%	4.9%
Parter	B48	84	ENVE	Max	3.85	18.74	5.40	18.44	4.80	1.6%	11.1%
Parter	B49	85	ENVE	Max	0.15	-17.77	-3.50	-17.45	-2.90	1.8%	20.7%
Parter	B49	85	ENVE	Max	0.61	-12.62	3.50	-12.30	4.00	2.6%	12.5%
Parter	B49	85	ENVE	Max	1.08	-7.46	8.20	-7.15	8.50	4.4%	3.5%
Parter	B49	85	ENVE	Max	1.54	-2.31	11.00	-1.99	11.00	15.8%	0.0%
Parter	B49	85	ENVE	Max	2.00	2.85	13.20	3.16	13.20	10.0%	0.0%
Parter	B49	85	ENVE	Max	2.47	8.00	12.30	8.32	12.30	3.8%	0.0%
Parter	B49	85	ENVE	Max	2.93	13.16	8.30	13.47	8.50	2.3%	2.4%
Parter	B49	85	ENVE	Max	2.93	19.58	8.50	19.60	8.70	0.1%	2.3%
Parter	B49	85	ENVE	Max	3.27	25.38	4.50	25.40	4.70	0.1%	4.3%
Parter	B49	85	ENVE	Max	3.61	32.45	-1.10	32.47	-0.80	0.1%	37.5%
Parter	B49	85	ENVE	Max	3.95	38.86	-8.30	38.88	-8.00	0.1%	3.8%
Parter	B50	86	ENVE	Max	0.15	-2.56	0.90	-2.69	0.70	5.1%	22.2%
Parter	B50	86	ENVE	Max	0.61	-1.40	1.80	-1.53	1.70	9.4%	5.6%
Parter	B50	86	ENVE	Max	1.08	-0.25	2.20	-0.38	2.10	53.1%	4.5%
Parter	B50	86	ENVE	Max	1.54	0.91	2.10	0.78	2.10	14.5%	0.0%
Parter	B50	86	ENVE	Max	2.00	2.06	2.50	1.93	2.50	6.4%	0.0%
Parter	B50	86	ENVE	Max	2.46	3.22	3.30	3.09	3.20	4.1%	3.0%
Parter	B50	86	ENVE	Max	2.93	4.38	3.70	4.24	3.50	3.0%	5.4%
Parter	B50	86	ENVE	Max	3.39	5.53	3.50	5.40	3.30	2.4%	5.7%
Parter	B50	86	ENVE	Max	3.85	6.69	2.80	6.56	2.50	2.0%	10.7%
Parter	B51	87	ENVE	Max	0.15	-3.28	4.10	-3.07	4.40	7.1%	6.8%
Parter	B51	87	ENVE	Max	0.63	-0.62	5.00	-0.41	5.30	53.4%	5.7%
Parter	B51	87	ENVE	Max	1.12	2.03	4.70	2.25	4.80	9.7%	2.1%
Parter	B51	87	ENVE	Max	1.60	4.69	3.20	4.91	3.20	4.4%	0.0%
Parter	B51	87	ENVE	Max	2.08	7.35	2.10	7.57	2.20	2.9%	4.5%
Parter	B51	87	ENVE	Max	2.57	10.01	1.30	10.22	1.50	2.1%	13.3%
Parter	B51	87	ENVE	Max	3.05	12.67	-0.70	12.88	-0.50	1.7%	40.0%
Parter	B52	88	ENVE	Max	0.15	-4.28	3.90	-4.50	3.50	5.2%	10.3%
Parter	B52	88	ENVE	Max	0.61	-2.36	5.40	-2.58	5.20	9.4%	3.7%
Parter	B52	88	ENVE	Max	1.08	0.73	5.80	0.51	5.70	30.4%	1.7%
Parter	B52	88	ENVE	Max	1.54	3.93	6.10	3.71	6.10	5.6%	0.0%
Parter	B52	88	ENVE	Max	2.00	7.13	4.70	6.91	4.70	3.1%	0.0%

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Parter	B52	88	ENVE	Max	2.46	11.18	2.50	11.16	2.40	0.2%	4.0%
Parter	B52	88	ENVE	Max	2.93	16.64	0.40	16.62	0.20	0.1%	50.0%
Parter	B52	88	ENVE	Max	3.39	21.88	-3.10	21.86	-3.40	0.1%	9.7%
Parter	B52	88	ENVE	Max	3.85	25.02	-7.90	25.00	-8.30	0.1%	5.1%
Parter	B53	89	ENVE	Max	0.00	-4.46	-0.20	-4.47	-0.20	0.3%	0.0%
Parter	B53	89	ENVE	Max	0.50	-3.00	2.60	-3.01	2.60	0.4%	0.0%
Parter	B53	89	ENVE	Max	1.00	0.11	4.40	0.10	4.40	10.6%	0.0%
Parter	B53	89	ENVE	Max	1.50	4.66	3.30	4.65	3.30	0.1%	0.0%
Parter	B53	89	ENVE	Max	2.00	7.01	0.20	7.01	0.20	0.0%	0.0%
Parter	B54	90	ENVE	Max	0.00	-3.22	0.10	-3.20	0.10	0.4%	0.0%
Parter	B54	90	ENVE	Max	0.50	-1.76	1.90	-1.74	1.90	0.8%	0.0%
Parter	B54	90	ENVE	Max	1.00	0.53	2.80	0.54	2.80	2.6%	0.0%
Parter	B54	90	ENVE	Max	1.50	4.07	1.70	4.08	1.70	0.2%	0.0%
Parter	B54	90	ENVE	Max	2.00	6.43	-0.30	6.43	-0.30	0.1%	0.0%
Parter	B58	95	ENVE	Max	0.00	-3.64	-1.20	-3.65	-1.10	0.4%	9.1%
Parter	B58	95	ENVE	Max	0.39	-2.64	0.20	-2.65	0.30	0.5%	33.3%
Parter	B58	95	ENVE	Max	0.78	-0.90	1.20	-0.91	1.20	1.5%	0.0%
Parter	B58	95	ENVE	Max	1.17	0.49	1.40	0.49	1.40	0.7%	0.0%
Parter	B59	96	ENVE	Max	0.00	-12.24	-1.80	-12.26	-1.80	0.1%	0.0%
Parter	B59	96	ENVE	Max	0.50	-10.78	4.80	-10.80	4.80	0.2%	0.0%
Parter	B59	96	ENVE	Max	1.00	-8.04	13.20	-8.06	13.20	0.2%	0.0%
Parter	B59	96	ENVE	Max	1.50	-5.22	19.10	-5.23	19.10	0.3%	0.0%
Parter	B59	96	ENVE	Max	2.00	-2.39	22.70	-2.41	22.70	0.7%	0.0%
Parter	B59	96	ENVE	Max	2.50	0.44	23.80	0.42	23.80	3.9%	0.0%
Parter	B59	96	ENVE	Max	3.00	4.98	22.50	4.98	22.50	0.0%	0.0%
Parter	B59	96	ENVE	Max	3.50	9.82	18.80	9.82	18.80	0.0%	0.0%
Parter	B59	96	ENVE	Max	4.00	14.66	12.70	14.66	12.70	0.0%	0.0%
Parter	B59	96	ENVE	Max	4.50	19.49	4.20	19.49	4.20	0.0%	0.0%
Parter	B60	97	ENVE	Max	0.00	25.09	1.60	25.09	1.60	0.0%	0.0%
Parter	B60	97	ENVE	Max	0.37	29.45	-4.30	29.44	-4.40	0.0%	2.3%
Parter	B60	97	ENVE	Max	0.73	34.47	-11.40	34.47	-11.40	0.0%	0.0%
Parter	B60	97	ENVE	Max	1.10	36.71	-19.20	36.71	-19.20	0.0%	0.0%
Parter	B61	98	ENVE	Max	0.00	-13.77	-19.00	-13.79	-19.00	0.2%	0.0%
Parter	B61	98	ENVE	Max	0.50	-12.31	-12.40	-12.33	-12.40	0.2%	0.0%
Parter	B61	98	ENVE	Max	1.00	-9.77	-6.90	-9.79	-6.90	0.2%	0.0%
Parter	B61	98	ENVE	Max	1.50	-7.20	-2.60	-7.23	-2.60	0.3%	0.0%
Parter	B61	98	ENVE	Max	2.00	-4.64	1.10	-4.66	1.10	0.5%	0.0%
Parter	B61	98	ENVE	Max	2.50	-2.08	4.10	-2.10	4.10	1.1%	0.0%
Parter	B61	98	ENVE	Max	3.00	0.49	5.00	0.47	5.00	4.6%	0.0%
Parter	B61	98	ENVE	Max	3.50	4.70	3.80	4.70	3.80	0.0%	0.0%
Parter	B61	98	ENVE	Max	4.00	7.06	1.40	7.06	1.30	0.0%	7.1%
Parter	B70	176	ENVE	Max	0.15	-6.50	4.50	-6.59	4.40	1.3%	2.2%
Parter	B70	176	ENVE	Max	0.56	-1.61	6.20	-1.70	6.10	5.2%	1.6%
Parter	B70	176	ENVE	Max	0.97	4.37	6.40	4.29	6.40	1.9%	0.0%
Parter	B70	176	ENVE	Max	1.37	11.46	6.30	11.37	6.30	0.7%	0.0%
Parter	B70	176	ENVE	Max	1.78	19.53	5.30	19.44	5.40	0.4%	1.9%
Parter	B70	176	ENVE	Max	2.19	31.95	1.80	31.88	1.90	0.2%	5.3%
Parter	B71	177	ENVE	Max	0.15	-2.35	5.30	-2.95	4.80	25.9%	9.4%
Parter	B71	177	ENVE	Max	0.54	5.27	4.70	4.66	4.40	11.5%	6.4%
Parter	B71	177	ENVE	Max	0.93	11.92	2.20	11.32	2.20	5.1%	0.0%
Parter	B71	177	ENVE	Max	1.32	17.58	5.40	16.97	5.10	3.5%	5.6%
Parter	B71	177	ENVE	Max	1.71	22.23	7.00	21.62	6.40	2.7%	8.6%
Parter	B14	58	ENVE	Max	0.15	-36.82	-7.80	-37.11	-8.30	0.8%	6.4%
Parter	B14	58	ENVE	Max	0.61	-27.90	7.30	-28.18	6.90	1.0%	5.5%
Parter	B14	58	ENVE	Max	1.08	-16.65	19.30	-16.93	19.30	1.7%	0.0%
Parter	B14	58	ENVE	Max	1.54	-5.17	30.80	-5.46	30.80	5.5%	0.0%
Parter	B14	58	ENVE	Max	2.00	6.31	34.20	6.02	34.20	4.5%	0.0%
Parter	B14	58	ENVE	Max	2.46	19.39	29.30	19.38	29.30	0.0%	0.0%
Parter	B14	58	ENVE	Max	2.93	37.15	16.30	37.15	16.30	0.0%	0.0%
Parter	B14	58	ENVE	Max	3.39	54.49	3.90	54.49	3.50	0.0%	10.3%
Parter	B14	58	ENVE	Max	3.85	67.63	-12.10	67.62	-12.60	0.0%	4.1%

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Parter	B69	92	ENVE	Max	0.15	0.79	11.40	-0.26	10.70	133.3%	6.1%
Parter	B69	92	ENVE	Max	0.58	8.37	9.50	7.31	9.20	12.6%	3.2%
Parter	B69	92	ENVE	Max	1.02	18.11	9.30	17.05	9.40	5.8%	1.1%
Parter	B69	92	ENVE	Max	1.45	28.16	13.30	27.10	12.90	3.7%	3.0%
Parter	B72	103	ENVE	Max	0.15	32.62	8.70	31.93	8.40	2.1%	3.4%
Parter	B72	103	ENVE	Max	0.58	38.35	-6.50	38.60	-6.60	0.7%	1.5%
Parter	B72	103	ENVE	Max	1.02	47.05	-14.30	47.30	-14.60	0.5%	2.1%
Parter	B72	103	ENVE	Max	1.45	51.81	-19.20	52.07	-19.90	0.5%	3.6%
Parter	B1	37	ENVE	Min	0.15	-10.38	-12.20	-10.36	-11.80	0.3%	3.4%
Parter	B1	37	ENVE	Min	0.62	-9.06	-7.60	-8.89	-7.30	2.0%	4.1%
Parter	B1	37	ENVE	Min	1.10	-7.82	-3.60	-7.65	-3.40	2.3%	5.9%
Parter	B1	37	ENVE	Min	1.57	-6.58	-0.20	-6.41	-0.10	2.7%	100.0%
Parter	B1	37	ENVE	Min	2.04	-5.34	2.60	-5.16	2.60	3.4%	0.0%
Parter	B1	37	ENVE	Min	2.51	-4.10	3.80	-3.92	3.80	4.5%	0.0%
Parter	B1	37	ENVE	Min	2.99	-2.86	2.90	-2.68	3.00	6.5%	3.3%
Parter	B1	37	ENVE	Min	3.46	-1.62	1.40	-1.44	1.50	12.2%	6.7%
Parter	B1	37	ENVE	Min	3.93	-0.38	-0.70	-0.20	-0.50	86.8%	40.0%
Parter	B1	37	ENVE	Min	4.40	0.86	-3.30	1.04	-3.00	16.9%	10.0%
Parter	B1	37	ENVE	Min	4.88	2.10	-6.60	2.28	-6.20	7.7%	6.5%
Parter	B1	37	ENVE	Min	5.35	3.34	-10.40	3.52	-10.00	5.0%	4.0%
Parter	B2	38	ENVE	Min	0.15	-12.59	-14.50	-12.06	-13.70	4.4%	5.8%
Parter	B2	38	ENVE	Min	0.65	-11.28	-8.50	-10.75	-8.00	4.9%	6.3%
Parter	B2	38	ENVE	Min	1.15	-9.97	-3.20	-9.44	-3.00	5.6%	6.7%
Parter	B2	38	ENVE	Min	1.65	-8.66	0.05	-8.13	0.10	6.5%	50.7%
Parter	B2	38	ENVE	Min	2.15	-7.35	-5.90	-6.82	-5.60	7.8%	5.4%
Parter	B2	38	ENVE	Min	2.65	-6.03	-12.50	-5.50	-12.00	9.6%	4.2%
Parter	B3	39	ENVE	Min	0.15	-9.36	-9.20	-9.12	-8.90	2.6%	3.4%
Parter	B3	39	ENVE	Min	0.65	-8.05	-4.90	-7.81	-4.70	3.0%	4.3%
Parter	B3	39	ENVE	Min	1.15	-6.73	-1.20	-6.50	-1.10	3.6%	9.1%
Parter	B3	39	ENVE	Min	1.65	-5.42	0.20	-5.19	0.20	4.5%	0.0%
Parter	B3	39	ENVE	Min	2.15	-4.11	-2.80	-3.87	-2.60	6.1%	7.7%
Parter	B3	39	ENVE	Min	2.65	-2.80	-6.40	-2.56	-6.10	9.2%	4.9%
Parter	B4	50	ENVE	Min	0.15	-63.46	-52.10	-63.40	-51.90	0.1%	0.4%
Parter	B4	50	ENVE	Min	0.58	-54.42	-26.90	-54.37	-26.80	0.1%	0.4%
Parter	B4	50	ENVE	Min	1.00	-46.08	-7.50	-46.03	-7.20	0.1%	4.2%
Parter	B4	50	ENVE	Min	1.00	-40.10	-7.40	-40.05	-7.20	0.1%	2.8%
Parter	B4	50	ENVE	Min	1.50	-31.56	6.70	-31.51	6.90	0.1%	2.9%
Parter	B4	50	ENVE	Min	2.00	-23.02	17.70	-22.97	17.70	0.2%	0.0%
Parter	B4	50	ENVE	Min	2.50	-14.48	23.80	-14.44	23.80	0.3%	0.0%
Parter	B4	50	ENVE	Min	3.00	-6.18	25.10	-5.97	25.30	3.5%	0.8%
Parter	B4	50	ENVE	Min	3.00	-1.49	25.10	-1.28	25.20	16.4%	0.4%
Parter	B4	50	ENVE	Min	3.47	5.19	21.20	5.40	21.40	3.9%	0.9%
Parter	B4	50	ENVE	Min	3.94	13.32	13.90	13.53	14.20	1.5%	2.1%
Parter	B4	50	ENVE	Min	4.41	22.35	2.50	22.56	2.80	0.9%	10.7%
Parter	B4	50	ENVE	Min	4.88	30.91	-13.10	31.12	-12.70	0.7%	3.1%
Parter	B4	50	ENVE	Min	5.35	38.05	-32.40	38.26	-32.00	0.5%	1.3%
Parter	B5	41	ENVE	Min	0.15	-12.28	-14.10	-12.09	-13.80	1.5%	2.2%
Parter	B5	41	ENVE	Min	0.65	-10.96	-8.30	-10.78	-8.10	1.7%	2.5%
Parter	B5	41	ENVE	Min	1.15	-9.65	-3.10	-9.47	-3.00	2.0%	3.3%
Parter	B5	41	ENVE	Min	1.65	-8.34	-0.02	-8.15	0.04	2.3%	154.3%
Parter	B5	41	ENVE	Min	2.15	-7.03	-5.80	-6.84	-5.60	2.7%	3.6%
Parter	B5	41	ENVE	Min	2.65	-5.71	-12.20	-5.53	-11.90	3.4%	2.5%
Parter	B6	42	ENVE	Min	0.15	-9.79	-9.60	-9.47	-9.20	3.4%	4.3%
Parter	B6	42	ENVE	Min	0.65	-8.48	-5.00	-8.15	-4.80	4.0%	4.2%
Parter	B6	42	ENVE	Min	1.15	-7.17	-1.10	-6.84	-1.10	4.7%	0.0%
Parter	B6	42	ENVE	Min	1.65	-5.85	0.10	-5.53	0.10	5.9%	0.0%
Parter	B6	42	ENVE	Min	2.15	-4.54	-2.90	-4.22	-2.70	7.7%	7.4%
Parter	B6	42	ENVE	Min	2.65	-3.23	-6.50	-2.91	-6.20	11.2%	4.8%
Parter	B7	43	ENVE	Min	0.15	-18.51	-12.00	-17.80	-11.40	4.0%	5.3%
Parter	B7	43	ENVE	Min	0.58	-14.67	-4.90	-13.96	-4.70	5.1%	4.3%
Parter	B7	43	ENVE	Min	1.00	-9.64	-0.60	-8.93	-0.70	7.9%	16.7%



Parter	B7	43	ENVE	Min	1.43	-4.60	-9.70	-3.90	-9.40	18.1%	3.2%
Parter	B7	43	ENVE	Min	1.85	-0.76	-20.60	-0.06	-19.90	1228.6%	3.5%
Parter	B8	44	ENVE	Min	0.15	-15.57	-11.40	-14.66	-10.80	6.2%	5.6%
Parter	B8	44	ENVE	Min	0.58	-14.44	-4.90	-13.52	-4.60	6.8%	6.5%
Parter	B8	44	ENVE	Min	1.02	-13.30	-4.30	-12.39	-4.20	7.4%	2.4%
Parter	B8	44	ENVE	Min	1.45	-12.16	-14.40	-11.25	-13.80	8.1%	4.3%
Parter	B9	45	ENVE	Min	0.15	-11.10	-12.60	-10.68	-11.90	3.9%	5.9%
Parter	B9	45	ENVE	Min	0.65	-9.78	-7.30	-9.37	-6.90	4.5%	5.8%
Parter	B9	45	ENVE	Min	1.15	-8.47	-2.80	-8.05	-2.60	5.2%	7.7%
Parter	B9	45	ENVE	Min	1.65	-7.16	0.40	-6.74	0.50	6.2%	20.0%
Parter	B9	45	ENVE	Min	2.15	-5.85	-4.60	-5.43	-4.40	7.7%	4.5%
Parter	B9	45	ENVE	Min	2.65	-4.54	-10.40	-4.12	-9.90	10.1%	5.1%
Parter	B10	46	ENVE	Min	0.15	-10.07	-8.90	-9.92	-8.60	1.6%	3.5%
Parter	B10	46	ENVE	Min	0.65	-8.76	-4.20	-8.60	-4.00	1.8%	5.0%
Parter	B10	46	ENVE	Min	1.15	-7.45	-0.20	-7.29	-0.10	2.2%	100.0%
Parter	B10	46	ENVE	Min	1.65	-6.14	-1.60	-5.98	-1.70	2.6%	6.2%
Parter	B10	46	ENVE	Min	2.15	-4.83	-5.30	-4.67	-5.40	3.4%	1.9%
Parter	B10	46	ENVE	Min	2.65	-3.51	-9.70	-3.35	-9.70	4.7%	0.0%
Parter	B11	47	ENVE	Min	0.15	-34.98	-20.40	-33.82	-19.50	3.4%	4.6%
Parter	B11	47	ENVE	Min	0.58	-28.45	-6.60	-27.30	-6.20	4.2%	6.5%
Parter	B11	47	ENVE	Min	1.02	-20.68	1.40	-19.53	1.40	5.9%	0.0%
Parter	B11	47	ENVE	Min	1.45	-12.35	-8.60	-11.19	-8.10	10.3%	6.2%
Parter	B12	48	ENVE	Min	0.15	-13.14	-8.60	-12.34	-8.20	6.4%	4.9%
Parter	B12	48	ENVE	Min	0.58	-4.80	-4.70	-4.01	-4.60	19.8%	2.2%
Parter	B12	48	ENVE	Min	1.02	2.96	-10.80	3.76	-10.90	21.2%	0.9%
Parter	B12	48	ENVE	Min	1.45	9.49	-25.10	10.29	-24.70	7.7%	1.6%
Parter	B13	49	ENVE	Min	0.15	-21.91	-12.80	-21.29	-12.20	2.9%	4.9%
Parter	B13	49	ENVE	Min	0.58	-16.79	-4.50	-16.18	-4.20	3.8%	7.1%
Parter	B13	49	ENVE	Min	1.00	-10.49	1.30	-9.87	1.40	6.2%	7.1%
Parter	B13	49	ENVE	Min	1.43	-4.18	-3.30	-3.57	-3.10	17.3%	6.5%
Parter	B13	49	ENVE	Min	1.85	0.93	-14.00	1.55	-13.60	39.7%	2.9%
Parter	B15	51	ENVE	Min	0.15	-11.77	-7.30	-11.24	-6.90	4.7%	5.8%
Parter	B15	51	ENVE	Min	0.58	-10.69	-2.40	-10.16	-2.30	5.2%	4.3%
Parter	B15	51	ENVE	Min	1.02	-9.60	-1.30	-9.08	-1.20	5.8%	8.3%
Parter	B15	51	ENVE	Min	1.45	-8.52	-5.90	-8.00	-5.60	6.6%	5.4%
Parter	B16	52	ENVE	Min	0.15	-10.74	-7.80	-10.23	-7.40	5.0%	5.4%
Parter	B16	52	ENVE	Min	0.54	-9.76	-3.90	-9.25	-3.60	5.5%	8.3%
Parter	B16	52	ENVE	Min	0.93	-8.79	-0.20	-8.28	-0.20	6.2%	0.0%
Parter	B16	52	ENVE	Min	1.32	-7.81	-3.70	-7.30	-3.50	7.0%	5.7%
Parter	B16	52	ENVE	Min	1.71	-6.84	-8.30	-6.33	-7.90	8.1%	5.1%
Parter	B19	55	ENVE	Min	0.15	-94.86	-84.80	-94.90	-84.90	0.0%	0.1%
Parter	B19	55	ENVE	Min	0.62	-89.44	-41.00	-89.47	-41.10	0.0%	0.2%
Parter	B19	55	ENVE	Min	1.10	-78.67	-4.80	-78.71	-4.60	0.0%	4.3%
Parter	B19	55	ENVE	Min	1.57	-62.56	15.70	-62.59	15.80	0.1%	0.6%
Parter	B19	55	ENVE	Min	2.04	-41.11	31.20	-41.14	31.20	0.1%	0.0%
Parter	B19	55	ENVE	Min	2.51	-16.89	39.00	-16.93	39.00	0.2%	0.0%
Parter	B19	55	ENVE	Min	2.99	0.56	38.60	0.72	38.70	22.3%	0.3%
Parter	B19	55	ENVE	Min	3.46	14.10	31.90	14.26	32.10	1.1%	0.6%
Parter	B19	55	ENVE	Min	3.93	26.12	18.90	26.28	19.30	0.6%	2.1%
Parter	B19	55	ENVE	Min	4.40	35.19	1.00	35.36	1.50	0.5%	33.3%
Parter	B19	55	ENVE	Min	4.88	41.33	-20.70	41.49	-20.60	0.4%	0.5%
Parter	B19	55	ENVE	Min	5.35	44.51	-60.00	44.67	-59.90	0.4%	0.2%
Parter	B20	56	ENVE	Min	0.15	-43.11	-25.90	-43.10	-25.90	0.0%	0.0%
Parter	B20	56	ENVE	Min	0.64	-36.44	-10.00	-36.43	-9.70	0.0%	3.1%
Parter	B20	56	ENVE	Min	1.13	-26.93	1.70	-26.91	1.90	0.1%	10.5%
Parter	B20	56	ENVE	Min	1.61	-14.57	10.00	-14.56	10.10	0.1%	1.0%
Parter	B20	56	ENVE	Min	2.10	-3.98	13.70	-3.76	13.70	6.1%	0.0%
Parter	B20	56	ENVE	Min	2.59	5.22	9.00	5.45	9.10	4.2%	1.1%
Parter	B20	56	ENVE	Min	3.08	12.86	0.30	13.09	0.50	1.7%	40.0%
Parter	B20	56	ENVE	Min	3.56	18.93	-11.70	19.16	-11.40	1.2%	2.6%
Parter	B20	56	ENVE	Min	4.05	23.44	-28.40	23.67	-28.40	1.0%	0.0%

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Parter	B21	57	ENVE	Min	0.15	-11.86	-10.10	-11.11	-9.50	6.7%	6.3%
Parter	B21	57	ENVE	Min	0.58	-9.15	-5.60	-8.40	-5.20	8.9%	7.7%
Parter	B21	57	ENVE	Min	1.00	-4.84	-4.10	-4.09	-4.10	18.3%	0.0%
Parter	B21	57	ENVE	Min	1.43	-0.54	-12.20	0.21	-12.20	353.9%	0.0%
Parter	B21	57	ENVE	Min	1.85	2.18	-24.10	2.92	-23.50	25.6%	2.6%
Parter	B22	136	ENVE	Min	0.15	-67.21	-58.60	-67.24	-58.70	0.0%	0.2%
Parter	B22	136	ENVE	Min	0.58	-62.65	-30.90	-62.67	-30.90	0.0%	0.0%
Parter	B22	136	ENVE	Min	1.00	-56.62	-8.40	-56.64	-8.10	0.0%	3.7%
Parter	B22	136	ENVE	Min	1.00	-50.19	-8.40	-50.21	-8.20	0.0%	2.4%
Parter	B22	136	ENVE	Min	1.50	-41.60	6.70	-41.62	6.80	0.0%	1.5%
Parter	B22	136	ENVE	Min	2.00	-30.03	18.90	-30.04	19.00	0.1%	0.5%
Parter	B22	136	ENVE	Min	2.50	-16.41	26.40	-16.43	26.40	0.1%	0.0%
Parter	B22	136	ENVE	Min	3.00	-5.56	27.30	-5.37	27.50	3.6%	0.7%
Parter	B22	136	ENVE	Min	3.00	-1.12	27.40	-0.93	27.50	20.7%	0.4%
Parter	B22	136	ENVE	Min	3.47	6.87	22.50	7.06	22.70	2.7%	0.9%
Parter	B22	136	ENVE	Min	3.94	15.39	13.60	15.58	14.00	1.2%	2.9%
Parter	B22	136	ENVE	Min	4.41	23.35	0.90	23.54	1.30	0.8%	30.8%
Parter	B22	136	ENVE	Min	4.88	29.40	-15.20	29.59	-14.70	0.6%	3.4%
Parter	B22	136	ENVE	Min	5.35	32.56	-38.90	32.75	-38.90	0.6%	0.0%
Parter	B23	59	ENVE	Min	0.15	-54.06	-31.50	-54.06	-31.50	0.0%	0.0%
Parter	B23	59	ENVE	Min	0.64	-48.38	-8.80	-48.39	-8.70	0.0%	1.1%
Parter	B23	59	ENVE	Min	1.13	-37.02	5.00	-37.02	5.00	0.0%	0.0%
Parter	B23	59	ENVE	Min	1.61	-19.97	14.80	-19.98	14.80	0.0%	0.0%
Parter	B23	59	ENVE	Min	2.10	-3.27	18.10	-3.13	18.20	4.4%	0.5%
Parter	B23	59	ENVE	Min	2.59	8.64	12.90	8.78	13.00	1.6%	0.8%
Parter	B23	59	ENVE	Min	3.08	18.23	2.30	18.37	2.50	0.8%	8.0%
Parter	B23	59	ENVE	Min	3.56	24.70	-12.10	24.84	-11.90	0.6%	1.7%
Parter	B23	59	ENVE	Min	4.05	28.03	-36.40	28.17	-36.50	0.5%	0.3%
Parter	B24	60	ENVE	Min	0.15	-21.79	-19.50	-21.75	-18.70	0.2%	4.3%
Parter	B24	60	ENVE	Min	0.63	-18.19	-9.80	-17.68	-9.20	2.9%	6.5%
Parter	B24	60	ENVE	Min	1.12	-11.87	-2.40	-11.36	-2.10	4.5%	14.3%
Parter	B24	60	ENVE	Min	1.60	-3.56	1.30	-3.05	1.40	16.7%	7.1%
Parter	B24	60	ENVE	Min	2.08	4.75	-4.50	5.26	-4.40	9.7%	2.3%
Parter	B24	60	ENVE	Min	2.57	11.07	-17.50	11.58	-17.50	4.4%	0.0%
Parter	B24	60	ENVE	Min	3.05	14.37	-36.20	14.88	-36.30	3.4%	0.3%
Parter	B25	61	ENVE	Min	0.15	-6.32	-5.70	-6.23	-5.50	1.6%	3.6%
Parter	B25	61	ENVE	Min	0.61	-5.17	-3.00	-5.07	-2.90	1.9%	3.4%
Parter	B25	61	ENVE	Min	1.08	-4.01	-0.90	-3.91	-0.80	2.5%	12.5%
Parter	B25	61	ENVE	Min	1.54	-2.85	0.70	-2.76	0.70	3.5%	0.0%
Parter	B25	61	ENVE	Min	2.00	-1.70	1.80	-1.60	1.80	6.0%	0.0%
Parter	B25	61	ENVE	Min	2.46	-0.54	0.80	-0.45	0.90	21.7%	11.1%
Parter	B25	61	ENVE	Min	2.93	0.61	-0.80	0.71	-0.70	13.6%	14.3%
Parter	B25	61	ENVE	Min	3.39	1.77	-3.00	1.87	-2.90	5.2%	3.4%
Parter	B25	61	ENVE	Min	3.85	2.92	-5.70	3.02	-5.50	3.2%	3.6%
Parter	B27	63	ENVE	Min	0.15	-57.31	-51.00	-57.32	-51.00	0.0%	0.0%
Parter	B27	63	ENVE	Min	0.63	-52.03	-24.60	-52.04	-24.60	0.0%	0.0%
Parter	B27	63	ENVE	Min	1.11	-43.98	-4.50	-43.99	-4.20	0.0%	7.1%
Parter	B27	63	ENVE	Min	1.60	-33.15	8.00	-33.15	8.10	0.0%	1.2%
Parter	B27	63	ENVE	Min	2.08	-20.90	17.00	-20.91	17.10	0.0%	0.6%
Parter	B27	63	ENVE	Min	2.56	-8.66	22.40	-8.66	22.40	0.1%	0.0%
Parter	B27	63	ENVE	Min	3.04	-0.46	21.90	-0.30	21.90	51.3%	0.0%
Parter	B27	63	ENVE	Min	3.52	6.86	17.80	7.01	17.90	2.2%	0.6%
Parter	B27	63	ENVE	Min	4.00	14.18	10.20	14.33	10.40	1.1%	1.9%
Parter	B27	63	ENVE	Min	4.49	20.72	-0.80	20.88	-0.50	0.7%	60.0%
Parter	B27	63	ENVE	Min	4.97	25.73	-14.60	25.89	-14.20	0.6%	2.8%
Parter	B27	63	ENVE	Min	5.45	29.21	-37.60	29.37	-37.60	0.5%	0.0%
Parter	B29	65	ENVE	Min	0.15	-7.79	-5.50	-7.51	-5.30	3.6%	3.8%
Parter	B29	65	ENVE	Min	0.54	-6.81	-2.70	-6.54	-2.60	4.2%	3.8%
Parter	B29	65	ENVE	Min	0.93	-5.84	-0.20	-5.56	-0.20	4.9%	0.0%
Parter	B29	65	ENVE	Min	1.32	-4.86	-1.70	-4.59	-1.60	6.0%	6.2%
Parter	B29	65	ENVE	Min	1.71	-3.89	-4.40	-3.61	-4.20	7.6%	4.8%

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Parter	B30	66	ENVE	Min	0.15	-6.37	-3.90	-6.13	-3.70	3.8%	5.4%
Parter	B30	66	ENVE	Min	0.55	-5.38	-1.60	-5.14	-1.50	4.6%	6.7%
Parter	B30	66	ENVE	Min	0.94	-4.39	0.30	-4.16	0.30	5.7%	0.0%
Parter	B30	66	ENVE	Min	1.34	-3.40	-1.60	-3.17	-1.50	7.4%	6.7%
Parter	B30	66	ENVE	Min	1.73	-2.42	-3.90	-2.18	-3.70	10.8%	5.4%
Parter	B31	67	ENVE	Min	0.15	-7.67	-4.60	-7.33	-4.30	4.6%	7.0%
Parter	B31	67	ENVE	Min	0.54	-6.69	-1.80	-6.36	-1.60	5.3%	12.5%
Parter	B31	67	ENVE	Min	0.93	-5.72	-0.10	-5.38	-0.10	6.3%	0.0%
Parter	B31	67	ENVE	Min	1.32	-4.74	-2.40	-4.41	-2.30	7.6%	4.3%
Parter	B31	67	ENVE	Min	1.71	-3.77	-5.10	-3.43	-4.90	9.8%	4.1%
Parter	B32	68	ENVE	Min	0.15	-33.16	-17.60	-32.09	-16.80	3.3%	4.8%
Parter	B32	68	ENVE	Min	0.58	-25.58	-4.80	-24.51	-4.40	4.4%	9.1%
Parter	B32	68	ENVE	Min	1.02	-15.84	1.10	-14.77	1.10	7.2%	0.0%
Parter	B32	68	ENVE	Min	1.45	-5.79	-10.60	-4.72	-10.10	22.6%	5.0%
Parter	B33	69	ENVE	Min	0.15	-23.14	-12.00	-22.35	-11.50	3.6%	4.3%
Parter	B33	69	ENVE	Min	0.58	-17.86	-3.10	-17.06	-3.00	4.7%	3.3%
Parter	B33	69	ENVE	Min	1.02	-12.89	-4.90	-12.09	-4.80	6.6%	2.1%
Parter	B33	69	ENVE	Min	1.45	-10.08	-13.40	-9.28	-12.90	8.6%	3.9%
Parter	B34	70	ENVE	Min	0.15	-38.44	-27.00	-38.46	-27.00	0.0%	0.0%
Parter	B34	70	ENVE	Min	0.61	-33.20	-13.00	-33.21	-12.60	0.0%	3.2%
Parter	B34	70	ENVE	Min	1.08	-23.28	-3.10	-23.30	-2.80	0.1%	10.7%
Parter	B34	70	ENVE	Min	1.54	-11.21	3.80	-10.94	3.90	2.5%	2.6%
Parter	B34	70	ENVE	Min	2.00	-2.62	7.10	-2.35	7.10	11.5%	0.0%
Parter	B34	70	ENVE	Min	2.46	5.97	1.30	6.24	1.50	4.3%	13.3%
Parter	B34	70	ENVE	Min	2.93	13.15	-8.00	13.42	-7.80	2.0%	2.6%
Parter	B34	70	ENVE	Min	3.39	18.81	-23.10	19.08	-23.10	1.4%	0.0%
Parter	B34	70	ENVE	Min	3.85	21.90	-44.10	22.17	-44.10	1.2%	0.0%
Parter	B35	71	ENVE	Min	0.15	-40.57	-25.90	-40.57	-25.50	0.0%	1.6%
Parter	B35	71	ENVE	Min	0.61	-33.37	-12.50	-33.38	-12.10	0.0%	3.3%
Parter	B35	71	ENVE	Min	1.08	-23.62	-1.60	-23.62	-1.40	0.0%	14.3%
Parter	B35	71	ENVE	Min	1.54	-12.50	6.10	-12.26	6.20	1.9%	1.6%
Parter	B35	71	ENVE	Min	2.00	-3.34	9.20	-3.10	9.20	7.7%	0.0%
Parter	B35	71	ENVE	Min	2.46	5.82	3.40	6.06	3.60	3.9%	5.6%
Parter	B35	71	ENVE	Min	2.93	13.57	-6.30	13.81	-6.00	1.7%	5.0%
Parter	B35	71	ENVE	Min	3.39	19.91	-19.30	20.15	-18.90	1.2%	2.1%
Parter	B35	71	ENVE	Min	3.85	24.84	-38.50	25.08	-38.50	0.9%	0.0%
Parter	B36	72	ENVE	Min	0.15	-23.00	-12.10	-22.96	-11.70	0.2%	3.4%
Parter	B36	72	ENVE	Min	0.54	-18.86	-4.10	-18.82	-3.90	0.2%	5.1%
Parter	B36	72	ENVE	Min	0.94	-14.80	2.50	-14.36	2.50	3.0%	0.0%
Parter	B36	72	ENVE	Min	1.33	-10.70	5.50	-10.27	5.60	4.3%	1.8%
Parter	B36	72	ENVE	Min	1.33	2.08	5.80	2.29	5.80	9.5%	0.0%
Parter	B36	72	ENVE	Min	1.67	6.00	-0.70	6.22	-0.60	3.5%	16.7%
Parter	B36	72	ENVE	Min	2.01	10.68	-8.70	10.90	-8.50	2.0%	2.4%
Parter	B36	72	ENVE	Min	2.35	15.72	-18.40	15.94	-18.10	1.4%	1.7%
Parter	B37	73	ENVE	Min	0.15	-48.73	-21.50	-48.79	-21.10	0.1%	1.9%
Parter	B37	73	ENVE	Min	0.60	-34.94	-6.70	-35.01	-6.50	0.2%	3.1%
Parter	B37	73	ENVE	Min	1.05	-19.66	4.20	-19.36	4.30	1.5%	2.3%
Parter	B37	73	ENVE	Min	1.50	-10.02	7.60	-9.73	7.70	3.0%	1.3%
Parter	B37	73	ENVE	Min	1.95	-1.72	2.00	-1.42	2.30	20.8%	13.0%
Parter	B37	73	ENVE	Min	2.40	3.92	-6.70	4.21	-6.30	7.0%	6.3%
Parter	B37	73	ENVE	Min	2.85	6.88	-17.40	7.18	-16.80	4.1%	3.6%
Parter	B38	74	ENVE	Min	0.15	-66.02	-55.70	-66.02	-55.70	0.0%	0.0%
Parter	B38	74	ENVE	Min	0.63	-58.46	-25.60	-58.46	-25.60	0.0%	0.0%
Parter	B38	74	ENVE	Min	1.11	-48.13	-5.00	-48.13	-4.70	0.0%	6.4%
Parter	B38	74	ENVE	Min	1.60	-35.08	9.00	-35.08	9.20	0.0%	2.2%
Parter	B38	74	ENVE	Min	2.08	-21.13	18.90	-21.13	19.00	0.0%	0.5%
Parter	B38	74	ENVE	Min	2.56	-7.50	24.60	-7.36	24.70	1.8%	0.4%
Parter	B38	74	ENVE	Min	3.04	1.19	24.80	1.33	24.90	10.2%	0.4%
Parter	B38	74	ENVE	Min	3.52	9.88	19.30	10.02	19.40	1.4%	0.5%
Parter	B38	74	ENVE	Min	4.00	18.57	9.50	18.71	9.70	0.7%	2.1%
Parter	B38	74	ENVE	Min	4.49	26.77	-4.40	26.90	-4.20	0.5%	4.8%

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TEHNIC

Parter	B38	74	ENVE	Min	4.97	33.46	-24.60	33.60	-24.60	0.4%	0.0%
Parter	B38	74	ENVE	Min	5.45	38.63	-54.50	38.77	-54.50	0.4%	0.0%
Parter	B39	75	ENVE	Min	0.15	-51.09	-42.10	-51.10	-42.10	0.0%	0.0%
Parter	B39	75	ENVE	Min	0.61	-43.89	-20.40	-43.90	-20.10	0.0%	1.5%
Parter	B39	75	ENVE	Min	1.08	-34.13	-6.00	-34.14	-5.80	0.0%	3.4%
Parter	B39	75	ENVE	Min	1.54	-21.83	5.10	-21.84	5.20	0.0%	1.9%
Parter	B39	75	ENVE	Min	2.00	-11.70	10.40	-11.43	10.40	2.3%	0.0%
Parter	B39	75	ENVE	Min	2.46	-3.36	7.90	-3.09	8.10	8.5%	2.5%
Parter	B39	75	ENVE	Min	2.93	4.39	1.70	4.65	2.00	5.7%	15.0%
Parter	B39	75	ENVE	Min	3.39	10.73	-7.70	10.99	-7.30	2.4%	5.5%
Parter	B39	75	ENVE	Min	3.85	15.66	-19.80	15.92	-19.30	1.7%	2.6%
Parter	B40	76	ENVE	Min	0.15	-74.32	-50.70	-74.32	-50.60	0.0%	0.2%
Parter	B40	76	ENVE	Min	0.63	-64.47	-17.80	-64.47	-17.50	0.0%	1.7%
Parter	B40	76	ENVE	Min	1.12	-51.83	1.70	-51.82	1.90	0.0%	10.5%
Parter	B40	76	ENVE	Min	1.60	-36.45	16.70	-36.45	16.90	0.0%	1.2%
Parter	B40	76	ENVE	Min	2.08	-20.20	26.80	-20.19	26.90	0.0%	0.4%
Parter	B40	76	ENVE	Min	2.57	-5.25	31.80	-5.13	31.90	2.4%	0.3%
Parter	B40	76	ENVE	Min	3.05	5.15	31.80	5.27	31.80	2.3%	0.0%
Parter	B40	76	ENVE	Min	3.53	15.54	24.90	15.66	24.90	0.8%	0.0%
Parter	B40	76	ENVE	Min	4.02	25.94	12.20	26.06	12.30	0.5%	0.8%
Parter	B40	76	ENVE	Min	4.50	35.81	-5.40	35.93	-5.30	0.3%	1.9%
Parter	B40	76	ENVE	Min	4.50	35.31	-3.50	35.48	-3.40	0.5%	2.9%
Parter	B40	76	ENVE	Min	4.98	44.27	-32.40	44.44	-32.40	0.4%	0.0%
Parter	B40	76	ENVE	Min	5.45	52.18	-70.70	52.35	-70.70	0.3%	0.0%
Parter	B41	77	ENVE	Min	0.15	-50.53	-51.40	-50.55	-51.50	0.0%	0.2%
Parter	B41	77	ENVE	Min	0.61	-45.29	-29.10	-45.31	-29.10	0.1%	0.0%
Parter	B41	77	ENVE	Min	1.08	-36.35	-12.30	-36.38	-12.10	0.1%	1.7%
Parter	B41	77	ENVE	Min	1.54	-24.87	-0.80	-24.89	-0.70	0.1%	14.3%
Parter	B41	77	ENVE	Min	2.00	-14.41	5.30	-14.13	5.30	2.0%	0.0%
Parter	B41	77	ENVE	Min	2.46	-7.29	4.20	-7.01	4.40	4.0%	4.5%
Parter	B41	77	ENVE	Min	2.93	-0.77	-0.20	-0.49	0.20	56.9%	200.0%
Parter	B41	77	ENVE	Min	3.39	4.35	-7.20	4.63	-6.70	6.0%	7.5%
Parter	B41	77	ENVE	Min	3.85	7.43	-16.10	7.71	-15.50	3.6%	3.9%
Parter	B42	78	ENVE	Min	0.15	-32.63	-19.60	-32.79	-20.00	0.5%	2.0%
Parter	B42	78	ENVE	Min	0.60	-27.59	-7.80	-27.75	-8.00	0.6%	2.6%
Parter	B42	78	ENVE	Min	1.05	-18.91	2.10	-19.24	2.00	1.7%	4.8%
Parter	B42	78	ENVE	Min	1.50	-10.61	5.60	-10.94	5.60	3.1%	0.0%
Parter	B42	78	ENVE	Min	1.95	-2.31	0.40	-2.64	0.40	14.2%	0.0%
Parter	B42	78	ENVE	Min	2.40	3.33	-7.80	3.00	-8.00	9.8%	2.6%
Parter	B42	78	ENVE	Min	2.85	6.29	-18.10	5.96	-18.20	5.2%	0.6%
Parter	B43	79	ENVE	Min	0.15	-35.89	-23.40	-35.96	-24.20	0.2%	3.4%
Parter	B43	79	ENVE	Min	0.60	-27.71	-9.80	-27.81	-10.30	0.4%	5.1%
Parter	B43	79	ENVE	Min	1.05	-20.14	0.90	-20.79	0.60	3.2%	33.3%
Parter	B43	79	ENVE	Min	1.50	-11.79	6.30	-12.44	6.20	5.5%	1.6%
Parter	B43	79	ENVE	Min	1.95	-3.44	1.70	-4.10	1.40	19.0%	17.6%
Parter	B43	79	ENVE	Min	2.40	3.57	-6.40	2.92	-6.90	18.3%	7.8%
Parter	B43	79	ENVE	Min	2.85	9.25	-17.30	8.60	-18.10	7.1%	4.6%
Parter	B44	80	ENVE	Min	0.15	-67.83	-60.70	-67.83	-60.70	0.0%	0.0%
Parter	B44	80	ENVE	Min	0.63	-62.25	-29.10	-62.25	-29.10	0.0%	0.0%
Parter	B44	80	ENVE	Min	1.11	-52.32	-5.50	-52.33	-5.30	0.0%	3.8%
Parter	B44	80	ENVE	Min	1.60	-39.61	8.70	-39.61	8.90	0.0%	2.2%
Parter	B44	80	ENVE	Min	2.08	-25.49	19.30	-25.49	19.40	0.0%	0.5%
Parter	B44	80	ENVE	Min	2.56	-11.36	25.40	-11.36	25.40	0.0%	0.0%
Parter	B44	80	ENVE	Min	3.04	-1.92	24.90	-1.74	25.00	10.1%	0.4%
Parter	B44	80	ENVE	Min	3.52	6.07	20.60	6.24	20.80	2.8%	1.0%
Parter	B44	80	ENVE	Min	4.00	14.05	12.40	14.23	12.70	1.2%	2.4%
Parter	B44	80	ENVE	Min	4.49	21.26	0.50	21.44	0.90	0.8%	44.4%
Parter	B44	80	ENVE	Min	4.97	26.93	-14.50	27.11	-14.10	0.7%	2.8%
Parter	B44	80	ENVE	Min	5.45	30.21	-37.90	30.39	-37.90	0.6%	0.0%
Parter	B45	81	ENVE	Min	0.15	-34.39	-16.50	-34.19	-16.40	0.6%	0.6%
Parter	B45	81	ENVE	Min	0.54	-31.88	-5.50	-31.68	-5.50	0.6%	0.0%

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Parter	B45	81	ENVE	Min	0.94	-28.40	4.70	-28.20	4.70	0.7%	0.0%
Parter	B45	81	ENVE	Min	1.33	-26.60	12.40	-26.40	12.30	0.8%	0.8%
Parter	B45	81	ENVE	Min	1.33	12.57	13.40	12.48	13.40	0.7%	0.0%
Parter	B45	81	ENVE	Min	1.67	13.89	3.60	13.80	3.60	0.6%	0.0%
Parter	B45	81	ENVE	Min	2.01	16.61	-6.80	16.52	-7.00	0.5%	2.9%
Parter	B45	81	ENVE	Min	2.35	18.60	-18.20	18.52	-18.50	0.5%	1.6%
Parter	B46	82	ENVE	Min	0.15	-24.44	-14.70	-24.42	-14.70	0.1%	0.0%
Parter	B46	82	ENVE	Min	0.58	-20.94	-4.90	-20.93	-4.90	0.1%	0.0%
Parter	B46	82	ENVE	Min	1.02	-16.21	-0.30	-16.19	-0.30	0.1%	0.0%
Parter	B46	82	ENVE	Min	1.45	-10.24	-9.90	-10.23	-9.90	0.1%	0.0%
Parter	B47	83	ENVE	Min	0.15	-16.63	-9.80	-17.19	-10.10	3.3%	3.1%
Parter	B47	83	ENVE	Min	0.58	-12.40	-3.50	-12.95	-3.60	4.5%	2.9%
Parter	B47	83	ENVE	Min	1.02	-9.40	-6.40	-9.95	-6.40	5.9%	0.0%
Parter	B47	83	ENVE	Min	1.45	-7.64	-15.00	-8.19	-15.30	7.3%	2.0%
Parter	B48	84	ENVE	Min	0.15	-20.55	-18.50	-20.53	-17.90	0.1%	3.4%
Parter	B48	84	ENVE	Min	0.61	-17.03	-9.80	-16.72	-9.40	1.8%	4.3%
Parter	B48	84	ENVE	Min	1.08	-13.50	-2.70	-13.20	-2.50	2.3%	8.0%
Parter	B48	84	ENVE	Min	1.54	-9.98	2.70	-9.67	2.80	3.2%	3.6%
Parter	B48	84	ENVE	Min	2.00	-6.45	6.20	-6.14	6.20	5.0%	0.0%
Parter	B48	84	ENVE	Min	2.46	-2.92	3.20	-2.62	3.40	11.7%	5.9%
Parter	B48	84	ENVE	Min	2.93	0.60	-1.40	0.91	-1.10	33.6%	27.3%
Parter	B48	84	ENVE	Min	3.39	4.13	-7.60	4.43	-7.10	6.9%	7.0%
Parter	B48	84	ENVE	Min	3.85	7.65	-15.40	7.96	-14.90	3.8%	3.4%
Parter	B49	85	ENVE	Min	0.15	-29.23	-18.40	-29.21	-18.90	0.1%	2.7%
Parter	B49	85	ENVE	Min	0.61	-22.27	-8.00	-22.25	-8.40	0.1%	5.0%
Parter	B49	85	ENVE	Min	1.08	-15.31	0.02	-15.29	-0.20	0.1%	902.9%
Parter	B49	85	ENVE	Min	1.54	-9.59	5.70	-9.88	5.50	3.0%	3.5%
Parter	B49	85	ENVE	Min	2.00	-4.44	8.90	-4.72	8.90	6.4%	0.0%
Parter	B49	85	ENVE	Min	2.47	0.72	7.80	0.43	7.70	39.6%	1.3%
Parter	B49	85	ENVE	Min	2.93	5.87	2.90	5.59	2.60	4.8%	10.3%
Parter	B49	85	ENVE	Min	2.93	9.81	3.20	9.75	2.90	0.6%	9.4%
Parter	B49	85	ENVE	Min	3.27	13.97	-3.40	13.92	-3.70	0.4%	8.8%
Parter	B49	85	ENVE	Min	3.61	18.84	-11.60	18.78	-11.90	0.3%	2.6%
Parter	B49	85	ENVE	Min	3.95	23.34	-21.30	23.28	-21.70	0.2%	1.9%
Parter	B50	86	ENVE	Min	0.15	-7.12	-6.50	-7.00	-6.30	1.6%	3.2%
Parter	B50	86	ENVE	Min	0.61	-5.96	-3.40	-5.85	-3.30	2.0%	3.0%
Parter	B50	86	ENVE	Min	1.08	-4.81	-1.00	-4.69	-0.90	2.5%	11.1%
Parter	B50	86	ENVE	Min	1.54	-3.65	1.00	-3.53	1.00	3.3%	0.0%
Parter	B50	86	ENVE	Min	2.00	-2.49	1.40	-2.38	1.40	4.9%	0.0%
Parter	B50	86	ENVE	Min	2.46	-1.34	0.20	-1.22	0.20	9.4%	0.0%
Parter	B50	86	ENVE	Min	2.93	-0.18	-1.60	-0.07	-1.40	173.8%	14.3%
Parter	B50	86	ENVE	Min	3.39	0.97	-3.90	1.09	-3.70	10.6%	5.4%
Parter	B50	86	ENVE	Min	3.85	2.13	-6.70	2.25	-6.40	5.1%	4.7%
Parter	B51	87	ENVE	Min	0.15	-10.30	-7.50	-10.53	-7.90	2.2%	5.3%
Parter	B51	87	ENVE	Min	0.63	-7.64	-3.20	-7.87	-3.40	3.0%	6.2%
Parter	B51	87	ENVE	Min	1.12	-4.98	-0.10	-5.21	-0.30	4.5%	200.0%
Parter	B51	87	ENVE	Min	1.60	-2.33	1.70	-2.55	1.60	9.7%	5.9%
Parter	B51	87	ENVE	Min	2.08	0.33	0.10	0.11	0.10	68.2%	0.0%
Parter	B51	87	ENVE	Min	2.57	2.99	-4.10	2.76	-4.20	7.6%	2.4%
Parter	B51	87	ENVE	Min	3.05	5.65	-9.50	5.42	-9.80	4.0%	3.2%
Parter	B52	88	ENVE	Min	0.15	-13.57	-8.90	-13.59	-8.60	0.2%	3.5%
Parter	B52	88	ENVE	Min	0.61	-10.43	-3.90	-10.45	-3.70	0.2%	5.4%
Parter	B52	88	ENVE	Min	1.08	-6.66	-0.10	-6.48	0.01	2.9%	905.2%
Parter	B52	88	ENVE	Min	1.54	-3.46	2.30	-3.28	2.30	5.7%	0.0%
Parter	B52	88	ENVE	Min	2.00	-0.26	2.20	-0.08	2.20	250.0%	0.0%
Parter	B52	88	ENVE	Min	2.46	2.94	-1.80	3.13	-1.70	6.0%	5.9%
Parter	B52	88	ENVE	Min	2.93	6.14	-7.30	6.33	-7.10	3.0%	2.8%
Parter	B52	88	ENVE	Min	3.39	9.22	-14.60	9.41	-14.60	2.0%	0.0%
Parter	B52	88	ENVE	Min	3.85	11.15	-25.50	11.34	-25.50	1.7%	0.0%
Parter	B53	89	ENVE	Min	0.00	-8.39	-1.10	-8.39	-1.10	0.0%	0.0%
Parter	B53	89	ENVE	Min	0.50	-6.03	1.60	-6.04	1.60	0.1%	0.0%

Parter	B53	89	ENVE	Min	1.00	-0.69	2.60	-0.69	2.60	0.5%	0.0%
Parter	B53	89	ENVE	Min	1.50	2.87	1.70	2.88	1.70	0.2%	0.0%
Parter	B53	89	ENVE	Min	2.00	4.33	-0.40	4.34	-0.40	0.2%	0.0%
Parter	B54	90	ENVE	Min	0.00	-5.99	-0.60	-5.98	-0.60	0.1%	0.0%
Parter	B54	90	ENVE	Min	0.50	-3.63	1.00	-3.62	1.00	0.2%	0.0%
Parter	B54	90	ENVE	Min	1.00	-0.16	1.70	-0.17	1.70	1.7%	0.0%
Parter	B54	90	ENVE	Min	1.50	2.12	0.90	2.12	0.90	0.1%	0.0%
Parter	B54	90	ENVE	Min	2.00	3.58	-1.00	3.58	-1.00	0.1%	0.0%
Parter	B58	95	ENVE	Min	0.00	-5.60	-1.70	-5.60	-1.70	0.1%	0.0%
Parter	B58	95	ENVE	Min	0.39	-4.02	-0.30	-4.02	-0.30	0.1%	0.0%
Parter	B58	95	ENVE	Min	0.78	-1.50	0.50	-1.48	0.50	1.3%	0.0%
Parter	B58	95	ENVE	Min	1.17	-0.50	0.60	-0.48	0.70	3.9%	14.3%
Parter	B59	96	ENVE	Min	0.00	-21.40	-5.50	-21.40	-5.50	0.0%	0.0%
Parter	B59	96	ENVE	Min	0.50	-19.04	1.80	-19.04	1.80	0.0%	0.0%
Parter	B59	96	ENVE	Min	1.00	-14.37	6.90	-14.37	7.00	0.0%	1.4%
Parter	B59	96	ENVE	Min	1.50	-9.53	10.70	-9.53	10.70	0.0%	0.0%
Parter	B59	96	ENVE	Min	2.00	-4.69	13.00	-4.69	13.00	0.0%	0.0%
Parter	B59	96	ENVE	Min	2.50	-0.39	13.90	-0.37	13.90	5.2%	0.0%
Parter	B59	96	ENVE	Min	3.00	2.43	13.40	2.45	13.40	0.8%	0.0%
Parter	B59	96	ENVE	Min	3.50	5.26	11.20	5.28	11.20	0.4%	0.0%
Parter	B59	96	ENVE	Min	4.00	8.09	7.50	8.11	7.50	0.2%	0.0%
Parter	B59	96	ENVE	Min	4.50	10.92	2.30	10.94	2.30	0.2%	0.0%
Parter	B60	97	ENVE	Min	0.00	15.15	0.40	15.10	0.40	0.3%	0.0%
Parter	B60	97	ENVE	Min	0.37	17.67	-8.30	17.62	-8.30	0.3%	0.0%
Parter	B60	97	ENVE	Min	0.73	20.56	-20.10	20.51	-20.10	0.2%	0.0%
Parter	B60	97	ENVE	Min	1.10	21.91	-33.20	21.86	-33.20	0.2%	0.0%
Parter	B61	98	ENVE	Min	0.00	-23.72	-32.60	-23.72	-32.60	0.0%	0.0%
Parter	B61	98	ENVE	Min	0.50	-21.36	-21.20	-21.37	-21.20	0.0%	0.0%
Parter	B61	98	ENVE	Min	1.00	-17.05	-11.60	-17.05	-11.60	0.0%	0.0%
Parter	B61	98	ENVE	Min	1.50	-12.69	-4.20	-12.69	-4.20	0.0%	0.0%
Parter	B61	98	ENVE	Min	2.00	-8.33	0.30	-8.33	0.30	0.0%	0.0%
Parter	B61	98	ENVE	Min	2.50	-3.97	2.00	-3.97	2.00	0.0%	0.0%
Parter	B61	98	ENVE	Min	3.00	-0.31	2.40	-0.29	2.40	7.2%	0.0%
Parter	B61	98	ENVE	Min	3.50	2.23	1.50	2.25	1.50	0.9%	0.0%
Parter	B61	98	ENVE	Min	4.00	3.69	-0.40	3.71	-0.40	0.6%	0.0%
Parter	B70	176	ENVE	Min	0.15	-21.58	-11.00	-21.60	-10.90	0.1%	0.9%
Parter	B70	176	ENVE	Min	0.56	-16.69	-3.10	-16.71	-3.10	0.1%	0.0%
Parter	B70	176	ENVE	Min	0.97	-10.70	2.50	-10.72	2.60	0.2%	3.8%
Parter	B70	176	ENVE	Min	1.37	-3.62	2.50	-3.64	2.40	0.5%	4.0%
Parter	B70	176	ENVE	Min	1.78	4.45	-3.80	4.43	-3.80	0.4%	0.0%
Parter	B70	176	ENVE	Min	2.19	12.69	-13.40	12.67	-13.40	0.2%	0.0%
Parter	B71	177	ENVE	Min	0.15	-26.36	-12.90	-25.60	-12.40	3.0%	4.0%
Parter	B71	177	ENVE	Min	0.54	-18.74	-4.20	-17.99	-3.90	4.2%	7.7%
Parter	B71	177	ENVE	Min	0.93	-12.09	1.30	-11.33	1.20	6.7%	7.7%
Parter	B71	177	ENVE	Min	1.32	-6.44	-4.50	-5.68	-4.30	13.3%	4.7%
Parter	B71	177	ENVE	Min	1.71	-1.79	-12.30	-1.03	-11.80	73.4%	4.2%
Parter	B14	58	ENVE	Min	0.15	-64.38	-27.80	-64.38	-27.40	0.0%	1.5%
Parter	B14	58	ENVE	Min	0.61	-51.25	-7.80	-51.25	-7.40	0.0%	5.4%
Parter	B14	58	ENVE	Min	1.08	-33.91	7.40	-33.91	7.60	0.0%	2.6%
Parter	B14	58	ENVE	Min	1.54	-16.14	17.30	-16.15	17.40	0.0%	0.6%
Parter	B14	58	ENVE	Min	2.00	-4.24	21.90	-3.96	21.90	7.0%	0.0%
Parter	B14	58	ENVE	Min	2.46	7.24	16.90	7.52	17.00	3.7%	0.6%
Parter	B14	58	ENVE	Min	2.93	18.72	6.00	19.00	6.20	1.5%	3.2%
Parter	B14	58	ENVE	Min	3.39	29.97	-10.20	30.24	-9.80	0.9%	4.1%
Parter	B14	58	ENVE	Min	3.85	38.89	-33.40	39.17	-33.40	0.7%	0.0%
Parter	B69	92	ENVE	Min	0.15	-35.47	-16.20	-34.57	-15.50	2.6%	4.5%
Parter	B69	92	ENVE	Min	0.58	-27.89	-2.40	-27.00	-2.00	3.3%	20.0%
Parter	B69	92	ENVE	Min	1.02	-18.15	3.90	-17.26	4.00	5.2%	2.5%
Parter	B69	92	ENVE	Min	1.45	-8.10	-6.20	-7.21	-5.60	12.4%	10.7%
Parter	B72	103	ENVE	Min	0.15	-0.56	-10.20	0.51	-9.60	208.6%	6.3%
Parter	B72	103	ENVE	Min	0.58	4.73	-15.60	5.79	-15.50	18.4%	0.6%

**GADO CONS CONSTRUCT S.R.L.**

STUDIU TEHNIC PRIVIND EFICIENȚA ECONOMICĂ A UTILIZĂRII ÎNVELITORILOR DE TIP BRAMAC PRIN  
ANALIZA INFLUENȚELOR STRUCTURALE GENERATE DE TIPUL DE ÎNVELITOARE ASUPRA SISTEMULUI  
STRUCTURAL AL UNEI CLĂDIRI CU REGIM DE ÎNĂLȚIME P+M

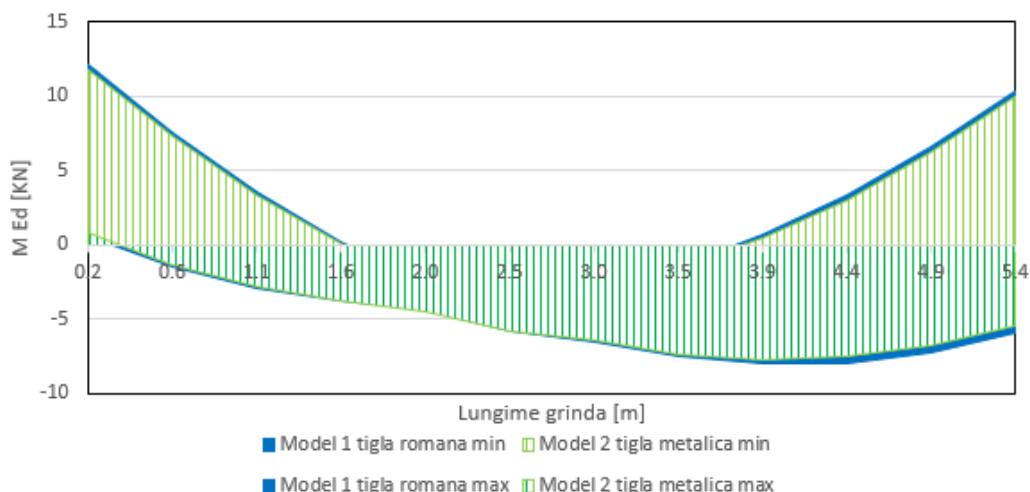
**STUDIU  
TEHNIC**

Parter	B72	103	ENVE	Min	1.02	9.70	-34.10	10.77	-34.20	9.9%	0.3%
Parter	B72	103	ENVE	Min	1.45	12.51	-55.70	13.58	-55.90	7.9%	0.4%

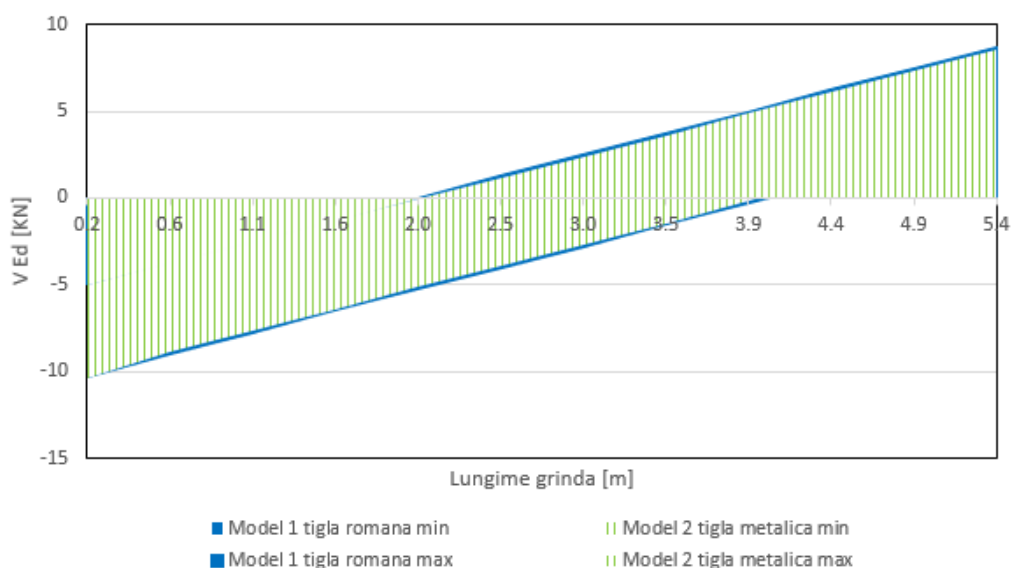
Pentru exemplificare grafică, se prezintă comparativ diagrame de momente încovoietoare și forțe tăietoare pentru câteva grinzi selectate:

TABLE: Element Forces - Beams										
Story	Beam	Unique Name	Output Case	Case Type	Step Type	Station m	Model 1 tigla romana		Model 2 tigla metalica	
							V2 kN	M3 kN-m	V2 kN	M3 kN-m
Parter	B1	37	ENVE	Combination	Min	0.2	-10.384	-12.200	-10.356	-11.800
Parter	B1	37	ENVE	Combination	Mn	0.6	-9.062	-7.600	-8.886	-7.300
Parter	B1	37	ENVE	Combination	Mn	1.1	-7.821	-3.600	-7.646	-3.400
Parter	B1	37	ENVE	Combination	Mn	1.6	-6.581	-0.200	-6.405	-0.100
Parter	B1	37	ENVE	Combination	Mn	2.0	-5.340	2.600	-5.165	2.600
Parter	B1	37	ENVE	Combination	Mn	2.5	-4.100	3.800	-3.924	3.800
Parter	B1	37	ENVE	Combination	Mn	3.0	-2.859	2.900	-2.684	3.000
Parter	B1	37	ENVE	Combination	Mn	3.5	-1.619	1.400	-1.443	1.500
Parter	B1	37	ENVE	Combination	Mn	3.9	-0.378	-0.700	-0.202	-0.500
Parter	B1	37	ENVE	Combination	Mn	4.4	0.863	-3.300	1.038	-3.000
Parter	B1	37	ENVE	Combination	Mn	4.9	2.103	-6.600	2.279	-6.200
Parter	B1	37	ENVE	Combination	Mn	5.4	3.344	-10.400	3.519	-10.000
Parter	B1	37	ENVE	Combination	Max	0.2	-4.933	-0.600	-5.066	-0.800
Parter	B1	37	ENVE	Combination	Max	0.6	-3.692	1.500	-3.826	1.300
Parter	B1	37	ENVE	Combination	Max	1.1	-2.452	2.900	-2.585	2.800
Parter	B1	37	ENVE	Combination	Max	1.6	-1.211	3.800	-1.345	3.700
Parter	B1	37	ENVE	Combination	Max	2.0	0.029	4.400	-0.104	4.500
Parter	B1	37	ENVE	Combination	Max	2.5	1.270	5.800	1.136	5.800
Parter	B1	37	ENVE	Combination	Max	3.0	2.511	6.500	2.377	6.400
Parter	B1	37	ENVE	Combination	Max	3.5	3.751	7.500	3.617	7.300
Parter	B1	37	ENVE	Combination	Max	3.9	4.992	8.000	4.858	7.700
Parter	B1	37	ENVE	Combination	Max	4.4	6.232	7.900	6.099	7.500
Parter	B1	37	ENVE	Combination	Max	4.9	7.473	7.200	7.339	6.700
Parter	B1	37	ENVE	Combination	Max	5.4	8.713	5.900	8.580	5.400

Comparatie diagrama infasuratoare de momente incovoietoare grinda B1



Comparatie diagrama infasuratoare de forte taietoare grinda B1



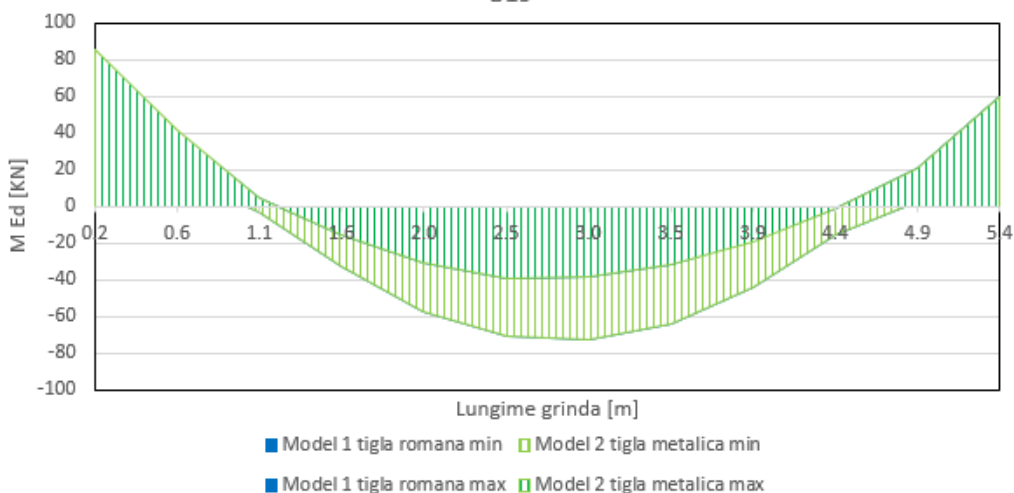


**TABLE: Element Forces - Beams**

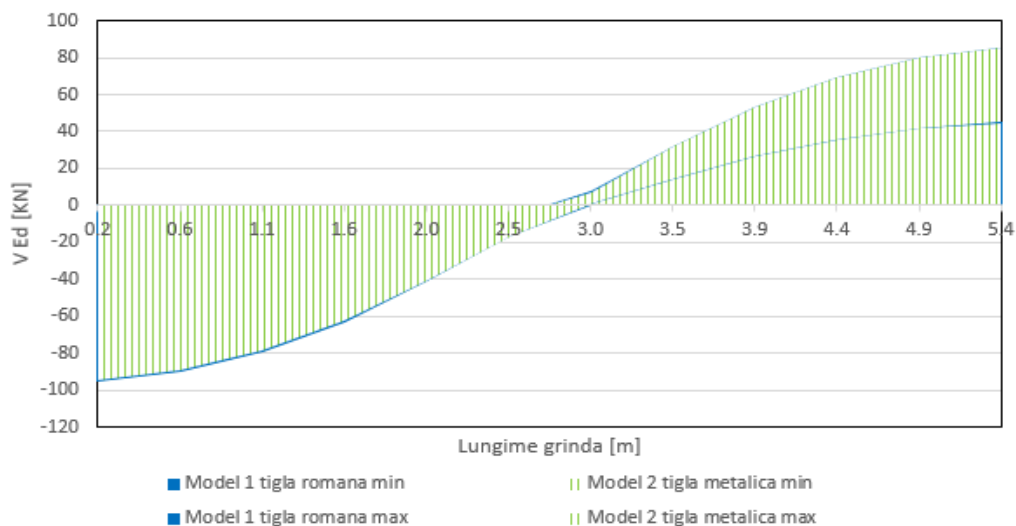
Story	Beam	Unique Name	Output Case	Case Type	Step Type	Model 1 tigla romana		Model 2 tigla metalica		
						Station	V2	M3	V2	M3
						m	kN	kN-m	kN	kN-m
Parter	B19	55	ENVE	Combination	Max	0.2	-49.979	-40.300	-50.190	-40.700
Parter	B19	55	ENVE	Combination	Max	0.6	-46.792	-17.300	-47.004	-17.600
Parter	B19	55	ENVE	Combination	Max	1.1	-40.661	3.500	-40.872	3.200
Parter	B19	55	ENVE	Combination	Max	1.6	-31.584	32.500	-31.795	32.500
Parter	B19	55	ENVE	Combination	Max	2.0	-19.568	57.200	-19.779	57.200
Parter	B19	55	ENVE	Combination	Max	2.5	-6.029	70.900	-6.240	70.900
Parter	B19	55	ENVE	Combination	Max	3.0	7.521	73.200	7.310	73.200
Parter	B19	55	ENVE	Combination	Max	3.5	31.556	64.000	31.523	64.000
Parter	B19	55	ENVE	Combination	Max	3.9	53.006	43.800	52.973	43.800
Parter	B19	55	ENVE	Combination	Max	4.4	69.120	15.800	69.086	15.400
Parter	B19	55	ENVE	Combination	Max	4.9	79.888	-2.400	79.854	-2.900
Parter	B19	55	ENVE	Combination	Max	5.4	85.310	-22.800	85.276	-23.400
Parter	B19	55	ENVE	Combination	Min	0.2	-94.863	-84.800	-94.896	-84.900
Parter	B19	55	ENVE	Combination	Min	0.6	-89.441	-41.000	-89.474	-41.100
Parter	B19	55	ENVE	Combination	Min	1.1	-78.673	-4.800	-78.706	-4.600
Parter	B19	55	ENVE	Combination	Min	1.6	-62.559	15.700	-62.593	15.800
Parter	B19	55	ENVE	Combination	Min	2.0	-41.109	31.200	-41.143	31.200
Parter	B19	55	ENVE	Combination	Min	2.5	-16.894	39.000	-16.928	39.000
Parter	B19	55	ENVE	Combination	Min	3.0	0.562	38.600	0.724	38.700
Parter	B19	55	ENVE	Combination	Min	3.5	14.101	31.900	14.263	32.100
Parter	B19	55	ENVE	Combination	Min	3.9	26.117	18.900	26.279	19.300
Parter	B19	55	ENVE	Combination	Min	4.4	35.194	1.000	35.355	1.500
Parter	B19	55	ENVE	Combination	Min	4.9	41.326	-20.700	41.487	-20.600
Parter	B19	55	ENVE	Combination	Min	5.4	44.512	-60.000	44.674	-59.900

Comparatie diagrama infasuratoare de momente incovoietoare grinda

B19



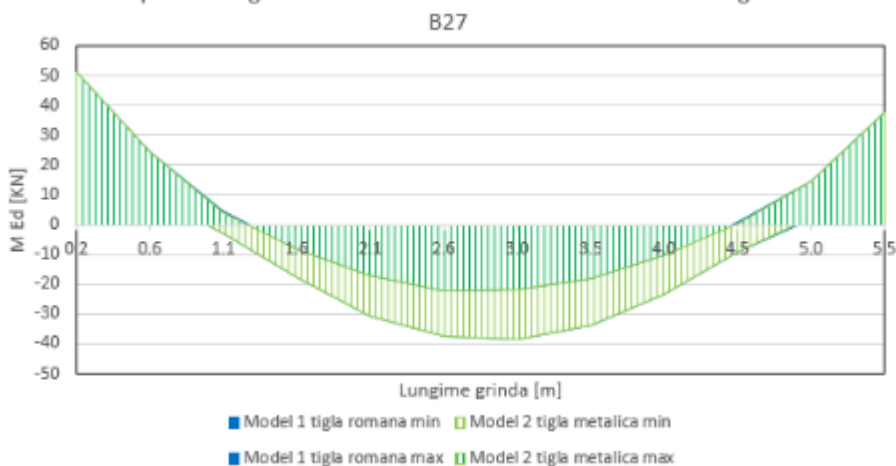
Comparatie diagrama infasuratoare de forte taietoare grinda B19



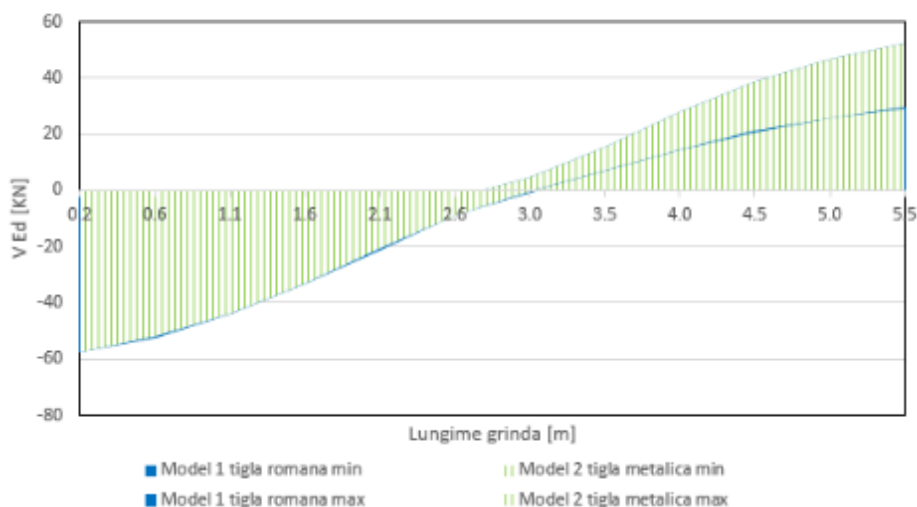
**TABLE: Element Forces - Beams**

Story	Beam	Unique Name	Output Case	Case Type	Step Type	Station m	Model 1 tigla romana		Model 2 tigla metalica	
							V2 kN	M3 kN-m	V2 kN	M3 kN-m
Parter	B27	63	ENVE	Combination	Max	0.2	-32.184	-24.300	-32.347	-24.700
Parter	B27	63	ENVE	Combination	Max	0.6	-28.702	-9.600	-28.866	-9.900
Parter	B27	63	ENVE	Combination	Max	1.1	-23.691	3.100	-23.855	2.800
Parter	B27	63	ENVE	Combination	Max	1.6	-17.151	17.400	-17.315	17.400
Parter	B27	63	ENVE	Combination	Max	2.1	-9.831	30.400	-9.995	30.400
Parter	B27	63	ENVE	Combination	Max	2.6	-2.511	37.500	-2.675	37.500
Parter	B27	63	ENVE	Combination	Max	3.0	4.808	38.700	4.645	38.700
Parter	B27	63	ENVE	Combination	Max	3.5	15.831	34.000	15.826	34.000
Parter	B27	63	ENVE	Combination	Max	4.0	28.077	23.500	28.072	23.500
Parter	B27	63	ENVE	Combination	Max	4.5	38.907	9.400	38.902	9.200
Parter	B27	63	ENVE	Combination	Max	5.0	46.961	-1.800	46.956	-2.200
Parter	B27	63	ENVE	Combination	Max	5.5	52.238	-15.100	52.233	-15.500
Parter	B27	63	ENVE	Combination	Min	0.2	-57.312	-51.000	-57.317	-51.000
Parter	B27	63	ENVE	Combination	Min	0.6	-52.034	-24.600	-52.039	-24.600
Parter	B27	63	ENVE	Combination	Min	1.1	-43.981	-4.500	-43.985	-4.200
Parter	B27	63	ENVE	Combination	Min	1.6	-33.150	8.000	-33.155	8.100
Parter	B27	63	ENVE	Combination	Min	2.1	-20.905	17.000	-20.910	17.100
Parter	B27	63	ENVE	Combination	Min	2.6	-8.659	22.400	-8.664	22.400
Parter	B27	63	ENVE	Combination	Min	3.0	-0.461	21.900	-0.305	21.900
Parter	B27	63	ENVE	Combination	Min	3.5	6.859	17.800	7.015	17.900
Parter	B27	63	ENVE	Combination	Min	4.0	14.178	10.200	14.335	10.400
Parter	B27	63	ENVE	Combination	Min	4.5	20.719	-0.800	20.875	-0.500
Parter	B27	63	ENVE	Combination	Min	5.0	25.730	-14.600	25.886	-14.200
Parter	B27	63	ENVE	Combination	Min	5.5	29.211	-37.600	29.367	-37.600

Comparatie diagrama infasuratoare de momente incovoietoare grinda



Comparatie diagrama infasuratoare de forte taietoare grinda B27



### **4.3. COMPARAȚII GLOBALE ELEMENTE DE BETON ARMAT**

Așa cum se poate observa din comparațiile realizate anterior, eforturile dezvoltate în stâlpi în cadrul celor două modele de calcul sunt aproximativ similare. În cazul diferențelor procentuale mari se observă că acestea corespund unor valori extrem de reduse ale forțelor sau momentelor, astfel acestea trebuie neglijate. Diferențele constatate la bază sunt în medie de aprox. 5%, respectiv în cazul momentelor încovoietoare cea mai mare diferență este de 1.3 kNm, iar a forțelor tăietoare este de 0,9 kN. Aceste diferențe nu influențează și nu modifică în niciun fel armarea elementelor verticale. Armările rezultate pe stâlpi în ambele modele de calcul sunt armări minime și au fost dispuse din condițiile constructive prevăzute în normativul P100/1-2013 (procent minim de armare).

În cazul grinzilor din beton armat, diferențele de eforturi sunt în medie de cca. 4%, acestea fiind armate preponderent din procente minime, respectând condițiile constructive impuse de cod. Grinzile lungi din cadrul planșeului de peste parter sunt dimensionate din gruparea fundamentală de încărcări în ambele modele de calcul, armările rezultate fiind similare. La nivelul centurilor și grinzilor de la mansardă, modificarea greutateii învelitorii nu influențează semnificativ starea de eforturi din elementele orizontale și înclinate din beton armat, armarea rezultată fiind similară în ambele modele. În mod concret, la grinzile peste parter cea mai mare diferență de momente încovoietoare este de 0,9 kNm, iar de forță tăietoare este de 1,2 kN.

La nivelul planșeului de beton armat de peste parter nu sunt diferențe în ceea ce privește armarea plăcii întrucât modificarea greutateii învelitorii nu influențează în niciun fel starea de eforturi din placă (elementele șarpantei reazemă direct pe grinzi și centuri).

În concluzie, în ceea ce privește elementele din beton armat, dimensiunile secționale ale acestora și armările în ambele modele sunt identice.

Este important de menționat faptul că practica de proiectare curentă are în vedere pe de o parte acoperirea condițiilor constructive impuse de codurile de proiectare și pe de altă parte dimensionarea la eforturi provenite din combinațiile de încărcări. Studiul realizat a pus în evidență faptul că elementele sunt armate preponderent din procente minime de armare, respectiv din condiții constructive. În cazurile unde s-au efectuat dimensionări din eforturi rezultate ca urmare a efectelor combinațiilor de încărcări, valorile eforturilor rezultate în cele două modele sunt extrem de apropiate, iar armarea selectată pe baza dimensionării de efort acoperă o plajă mult mai mare de valori.

În mod concret, dacă ne raportăm la grinzi, acolo unde s-au observat cele mai mari diferențe de eforturi și privim din prisma valorilor absolute trebuie precizat

că diferențele au rezultat ca urmare a momentului din modelul 1 – „țiglă romană” cu valoarea 20.4 kNm și a momentului din modelul 2 – „țiglă metalică” cu valoarea de 19,50 kNm. Similar, în cazul forței tăietoarea, în modelul 1 valoarea acesteia este de 34,98 kN, iar în cel de al doilea model este de 33,82 kN. În consecință, armarea longitudinală și transversală dispusă pe baza verificărilor de rezistență nu poate să fie aleasă diferit pentru o diferență atât de mică de eforturi. De exemplu armarea minimă dispusă din condiții constructive conduce la o capacitate la moment încovoietor de cca. 40 kNm.

În cazul grinzilor cu valori ale momentelor de proiectare mai mari decât capacitatea obținută din procente minime, diferențe de până în 1 kNm se păstrează între cele două modele analizate. De exemplu cel mai mare moment de proiectare obținut pe o grindă în modelul 1 – „țiglă romană” este 84,90 kNm, iar în cazul aceeași grindă în modelul 2 – „țiglă metalică”, momentul de proiectare este 84,80 kNm. În consecință, armarea dispusă este identică în ambele cazuri.

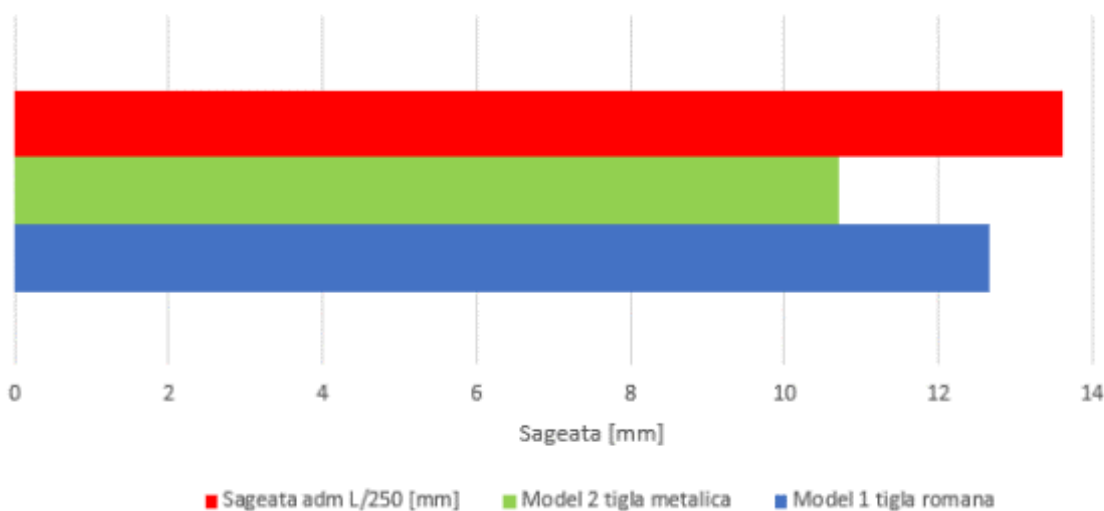
#### 4.4. COMPARAȚII ELEMENTE ȘARPANTĂ

Prezentarea comparativă a săgeții și momentul de calcul pentru un căprior curent și pentru o pana intermediară în cele două cazuri dimensionate.

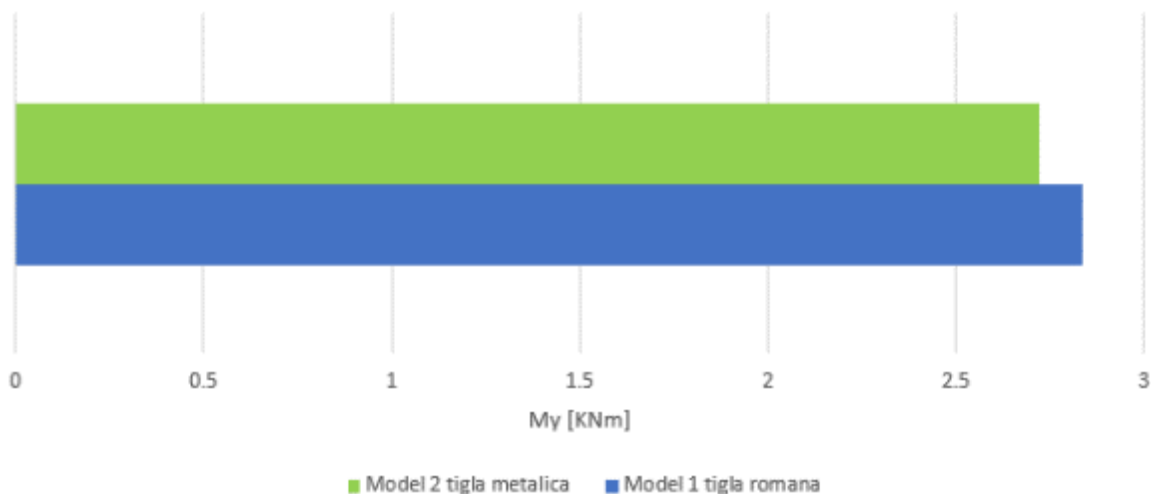
Căpriorii au secțiunea de 5x20 cm în ambele modele, iar distanța la care sunt dispuși este de 60 cm interax în cazul modelului 1 cu învelitoare din țiglă romană, respectiv 70 cm interax în cazul modelului 2 cu învelitoare din țiglă metalică.

Capriori 5x20cm	Model 1 tigla romana	Model 2 tigla metalica	Sageata adm L/250 [mm]
	d=60cm interax	d=70cm interax	
	Sageata [mm]	Sageata [mm]	Sageata adm L/250 [mm]
	12.672	10.713	13.622
	My[KNm]	My[KNm]	
	2.837	2.72	

Comparatie sageata capriori



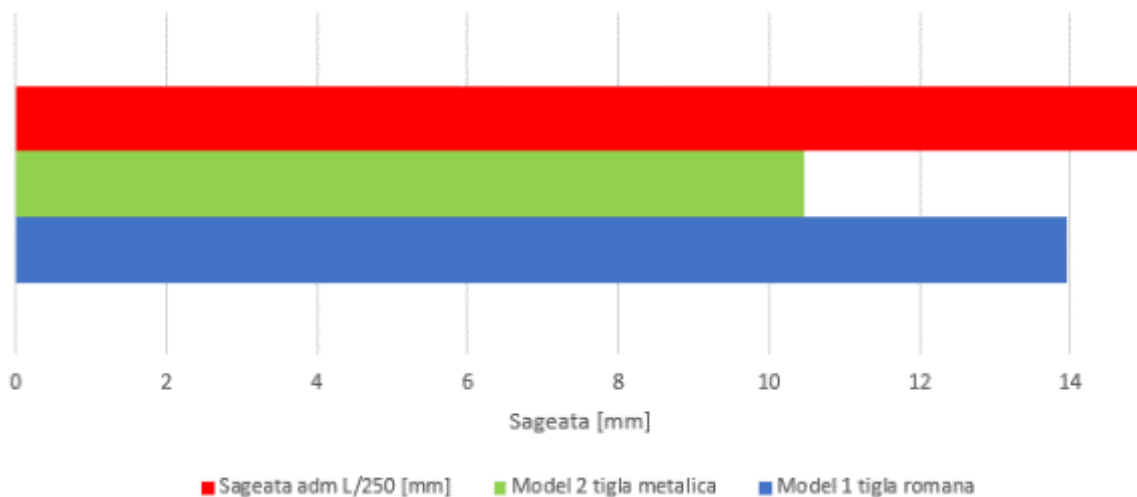
Comparatie moment incovoiator capriori



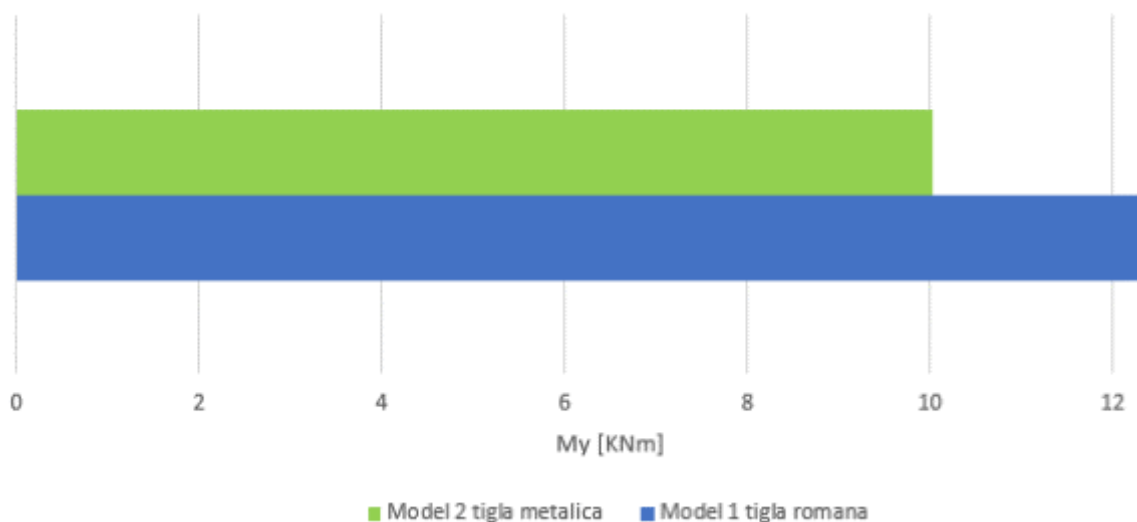
Panele intermediare au secțiunea de 10x30 cm în ambele modele.

Pana 10x30cm	Model 1 tigla romana	Model 2 tigla metalica	
	Sageata [mm]	Sageata [mm]	Sageata adm L/250 [mm]
	13.949	10.474	16
	My[KNm]	My[KNm]	
	12.296	10.028	

Comparatie sageata pana



Comparatie moment incovoietor pana



## 5. CONSUMURI DE MATERIAL

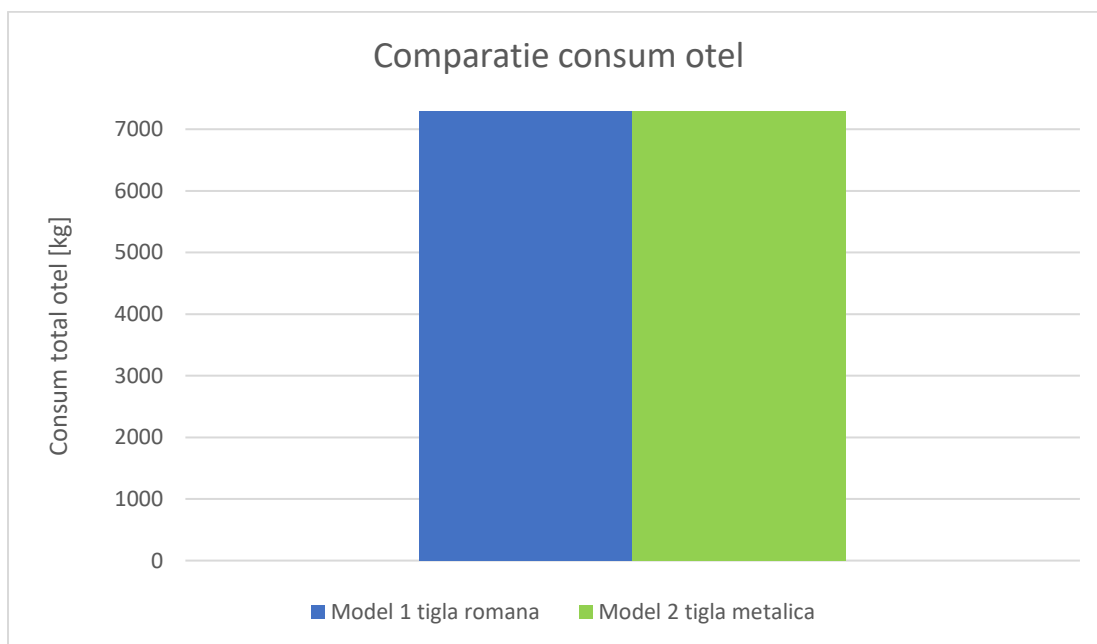
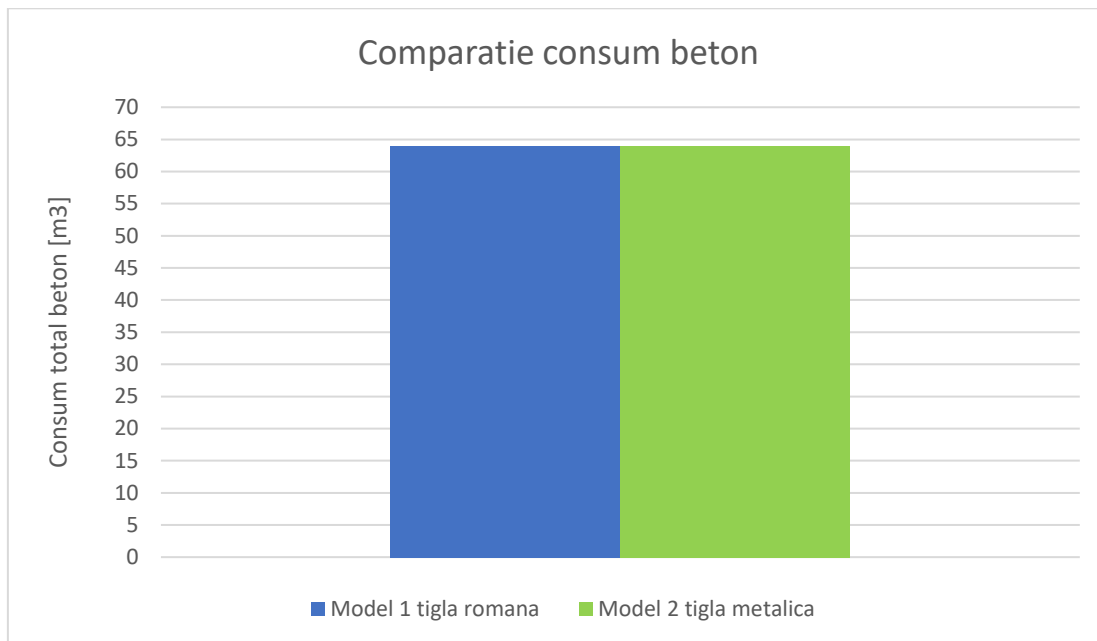
Consumurile de materiale, respectiv beton, oțel și material lemnos sunt prezentate comparativ sub formă tabelară și grafică. Astfel, așa cum se poate observa, în ceea ce privește consumul de beton și de oțel (armături în elementele structurale de beton armat) nu există diferențe între cele două modele. În

consecință, tipul diferit de învelitoare utilizat (învelitoare din țiglă de beton – model 1 țiglă romană vs. învelitoare din țiglă metalică – model 2) nu modifică secțiunile elementelor și armarea acestora.

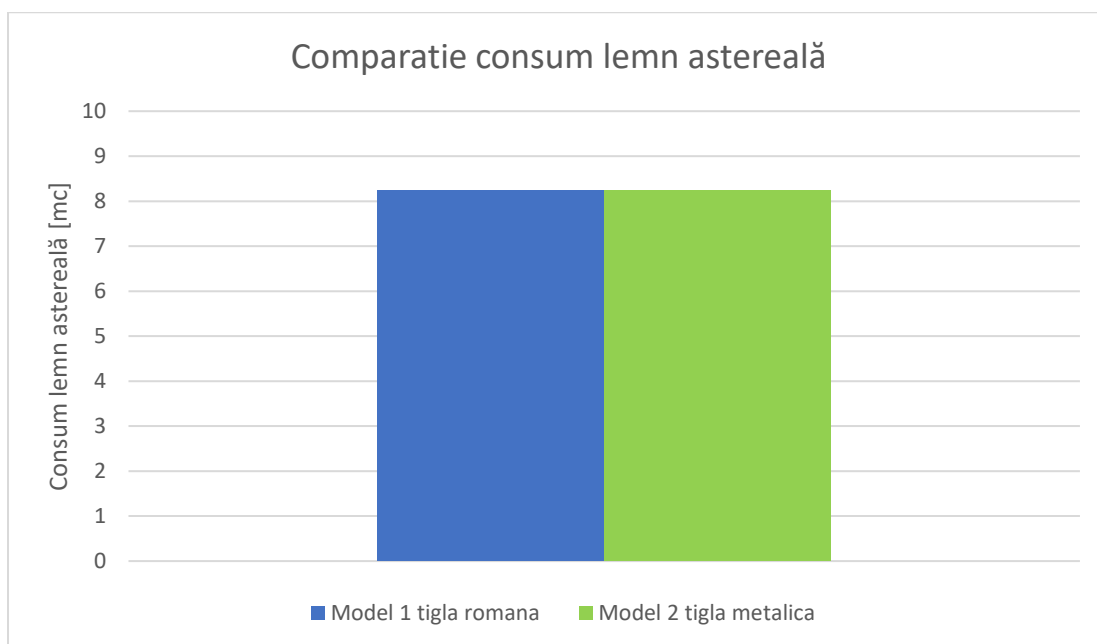
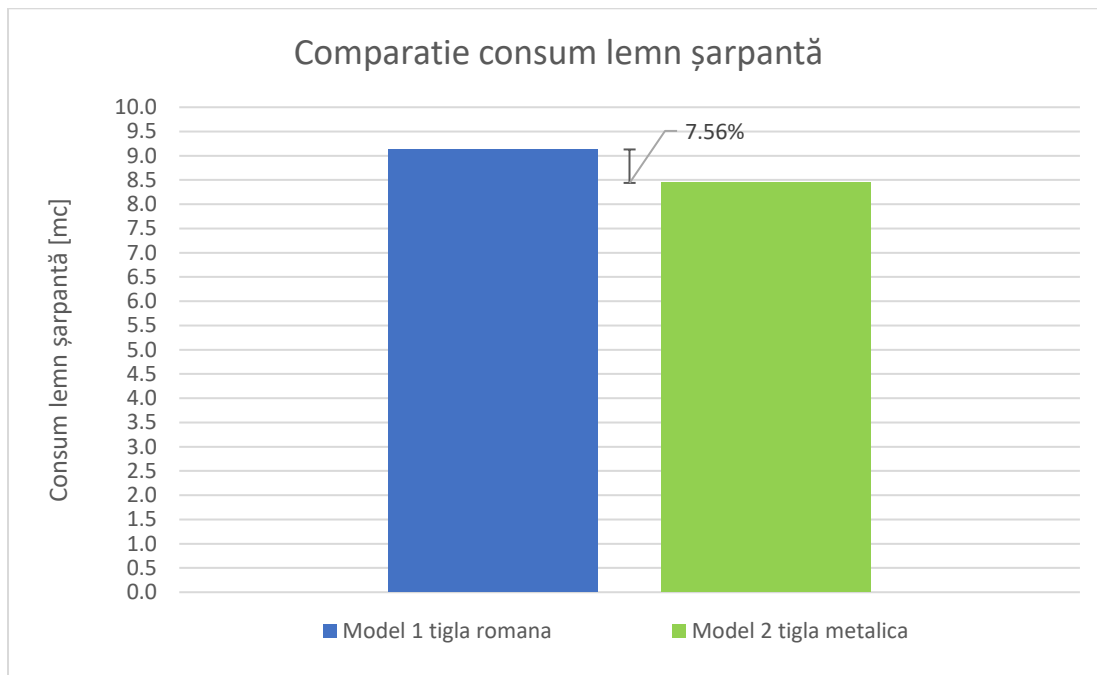
Se înregistrează o scădere a consumului de material lemnos utilizat la șarpantă cu cca. 7.56% în cazul modelului 2 cu învelitoare din țiglă metalică față de modelul 1 cu învelitoare din țiglă romană (8.44 m<sup>3</sup> lemn în modelul 2 cu învelitoare din țiglă metalică vs. 9.13 m<sup>3</sup> lemn în cazul modelului 1 cu învelitoare din țiglă romană). Acest consum de materiale cuprinde elementele care intră în alcătuirea șarpantei, respectiv căpriori, pane, clești și popi. În ceea ce privește consumul de astereală, acesta este identic întrucât pentru acest element s-a utilizat scândură de brad uzuală (material folosit în mod curent pe plan local).

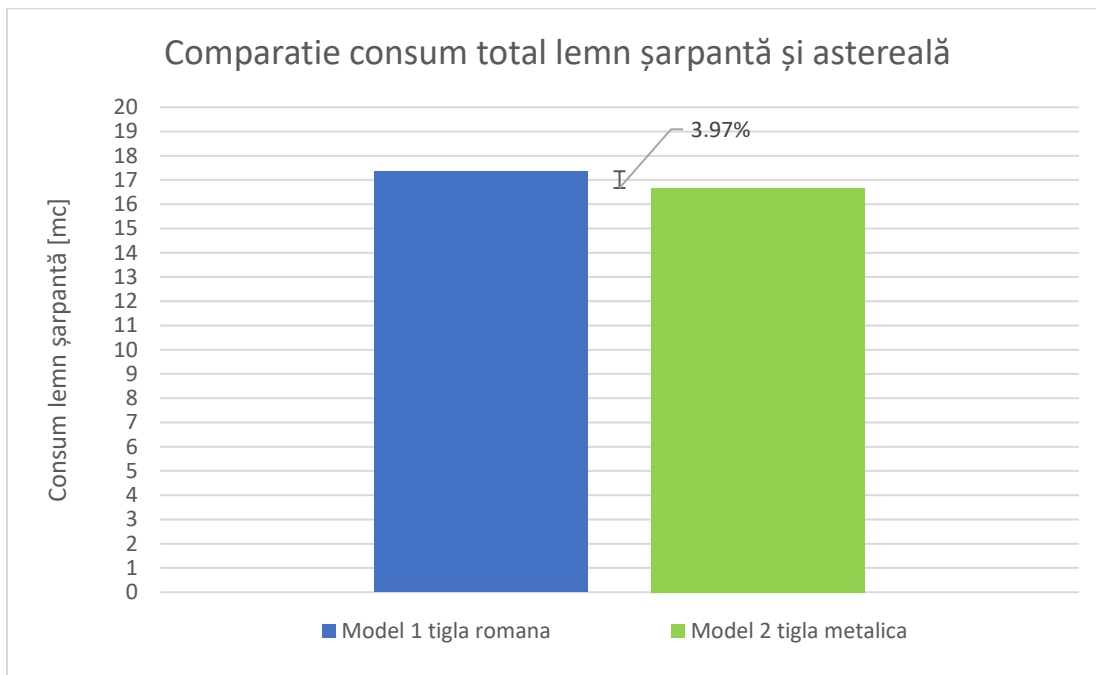
Așa cum se poate observa în tabelul de mai jos consumul de material lemnos ce intră în alcătuirea structurii șarpantei în cele două modele este aproximativ similar cu consumul de material lemnos necesar pentru astereală. În consecință, dacă ne raportăm la consumul total de material lemnos se înregistrează o diferență procentuală de cca. 4% în cazul învelitorii cu țiglă metalică față de țigla romană.

Descriere articol comasat	Unitate măsură	Cantitate		Diferențe procentuale
		Model 1 țiglă romana	Model 2 țigla metalica	
Armatura BST500C stalpi supra	kg	2775.82	2775.82	0%
Beton C20/25 stalpi supra	m3	15.10	15.10	0%
Armatura BST500C grinzi Parter	kg	1636.32	1636.32	0%
Beton C20/25 grinzi Parter	m3	17.38	17.38	0%
Armatura BST500C planseu peste parter	kg	1489.99	1489.99	0%
Beton C20/25 planseu peste parter	m3	16.23	16.23	0%
Armatura BST500C grinzi si centuri Mansarda	kg	1191.99	1191.99	0%
Beton C20/25 grinzi si centuri Mansarda	m3	13.07	13.07	0%
Armatura BST500C scari	kg	199.92	199.92	0%
Beton C20/25 scari	m3	2.00	2.00	0%
Elemente sarpanta lemn	mc	9.13	8.44	7.56%
Astereala	mc	8.23	8.23	0%
<b>Total otel BST 500S</b>	<b>kg</b>	<b>7294</b>	<b>7294</b>	<b>0%</b>
<b>Total beton C20/25</b>	<b>m3</b>	<b>64</b>	<b>64</b>	<b>0%</b>
<b>Total elemente lemn astereala + sarpantă</b>	<b>mc</b>	<b>17.36</b>	<b>16.67</b>	<b>3.97%</b>









		Model 1 țiglă romană		Model 2 țiglă metalică	
Sectiuni transversale		Lungime [m]	Volume_ construite [m³]	Lungime [m]	Volume_ construite [m³]
100/100	Elemente lemn, otel	104.10	1.04	104	1.04
	Popi	5.54	0.06	6	0.06
	<b>Total</b>	109.64	1.10	110	1.10
100/150	Elemente lemn, otel	21.27	0.32	21	0.32
	<b>Total</b>	21.27	0.32	21	0.32
100/400	Elemente lemn, otel	20.61	0.83	21	0.83
	<b>Total</b>	20.61	0.83	21	0.83
50/150	Căpriori	74.18	0.56	65	0.49
	<b>Total</b>	74.18	0.56	65	0.49
25/150	Clește	39.54	0.15	35	0.13
	<b>Total</b>	39.54	0.15	35	0.13
50/200	Căpriori	496.15	4.96	436	4.36
	<b>Total</b>	496.15	4.96	436	4.36
100/300	Elemente lemn, otel	40.60	1.22	41	1.22
	<b>Total</b>	40.60	1.22	41	1.22
<b>Total</b>		801.96	9.12	728	8.44

## 6. CONCLUZII

Prezentul studiu tehnic a fost întocmit la solicitarea beneficiarului BMI ROMANIA SISTEME DE INVELITORI S.R.L. în scopul determinării eficienței economice în cazul utilizării învelitorilor de tip „Bramac”.

În cadrul studiului tehnic s-au analizat influențele generate de tipul învelitorii asupra sistemului structural al unei clădiri, respectiv cuantificarea acestora sub formă de consumuri de material. Astfel, studiul a analizat prin calcul structural o construcție cu regim de înălțime P+M și funcțiune de locuință situată într-un amplasament cu hazard seismic moderat ( $a_g^{225} = 0,20g$ ) și cu o valoare caracteristică de încărcare din zăpadă  $S_k=2.00 \text{ kN/m}^2$ , valoare care acoperă majoritatea zonelor din România. În ceea ce privește învelitoarea, studiul tehnic a analizat comparativ construcția precizată anterior atât într-o soluție cu învelitoare din țiglă romană, cât și o soluție de învelitoare din țiglă metalică.

Proiectarea elementelor structurale și modelarea acțiunii seismice s-a făcut în acord cu prevederile normativului de proiectare seismică a clădirilor în vigoare P100-1/2013. Având în vedere tendința codurilor de proiectare la nivel global, la solicitarea beneficiarului s-a considerat o cerință de performanță superioară care să aibă în vedere un interval mediu de recurență IMR de 475 de ani. Astfel, pentru obținerea valorilor de proiectare ale forțelor seismice s-au utilizat factorii de scalare pentru accelerația terenului conform normativului pentru evaluarea seismică a construcțiilor existente în vigoare P100-3/2019. În consecință, accelerația de proiectare a terenului considerată în amplasamentul studiat este de  $a_g^{475} = 0,27g$ .

Așa cum a fost prezentat în capitolele anterioare, tipul învelitorii utilizate la o construcție cu regim de înălțime redus, amplasată într-un amplasament cu hazard seismic moderat nu influențează dimensionarea elementelor din beton armat. În consecință, utilizarea unei învelitori din beton de tip țiglă romană nu a condus la consumuri suplimentare de oțel și beton față de modelul cu țiglă metalică. Acest aspect s-a datorat faptului că majoritatea elementelor de beton au fost dimensionate din condiții constructive, respectiv din procente minime de armare. În ceea ce privește dimensiunile secționale ale elementelor acestea au fost stabilite prin predimensionare pe condiții minime de rigiditate. Eforturile înregistrate ca efect al combinațiilor de încărcări în cele două modele analizate au fost în mare măsură similare, obținându-se diferențe nesemnificative. Privind prin prisma valorilor absolute de eforturi, diferențe de 1...2 kNm în cazul unui moment încovoietor nu pot modifica armarea longitudinală a unui element de beton armat.

Din perspectiva elementelor de lemn care alcătuiesc șarpanta, studiul tehnic a pus în evidență faptul că diferențele de greutate dintre cele două tipuri de învelitori dispuse în modelele analizate nu conduc la creșteri însemnate de material lemnos. Elementele principale care au cel mai mare aport în consumul de material lemnos, respectiv căpriorii, sunt solicitați preponderent la încovoiere. Astfel, aportul cel mai

însemnat în dimensionarea secțiunilor acestora îl are încărcarea provenită din zăpadă, valoarea acesteia fiind net superioară greutateii învelitorii. În mod similar, încărcarea din zăpadă dimensionează secțiunile panelor. Disponerea la un pas optim al elementelor de tip căprior (60...70 cm) în cadrul învelitorilor din țiglă romană nu conduce la majorări de secțiune pentru astereala folosită în mod curent în România, respectiv scândură de brad.

Totodată, studiul tehnic a pus în evidență faptul că dimensionarea elementelor supuse preponderent la încovoiere este de cele mai multe ori rezultată din condiții de limitare a deformațiilor. În acest sens, conceptul arhitectural – structural pentru limitarea deschiderilor și alcătuirea spațială a acoperișului (volumetria acestuia) reprezintă un aspect definitoriu în dimensionarea secțiunilor de lemn.

Analizele realizate pe modelele supuse studiului au pus în evidență un consum suplimentar de material lemnos de cca. 8% în cazul utilizării învelitorii de tip țiglă romană față de utilizarea învelitorii din țiglă metalică. Este important de precizat că acest procent a fost obținut prin raportarea diferențelor obținute numai la elementele principale care alcătuiesc structura șarpantei, fără a include astereala care are un aport de cca. 50% din consumul total de material lemnos. Astfel, dacă ne referim la o diferență globală de material care să includă și astereala diferența de consum dintre cele două modele în care s-au utilizat cele două tipuri de învelitori este de cca. 4%. În ceea ce privește astereala, trebuie menționat că în practica curentă de proiectare utilizarea scândurii de brad este cea mai comună soluție și nu se dispun dimensiuni diferite pentru acest tip de element întrucât costurile generate de propunerea unor secțiuni diferite conduc la creșteri de preț însemnate.

În concluzie, influențele generate de utilizarea unei învelitori de tip țiglă romană față de utilizarea unei învelitori de tip țiglă metalică în termeni de consumuri de material a pus în evidență numai consumuri suplimentare de material lemnos. Diferențele obținute în consumul global de lemn se situează sub 5% pentru modelele analizate ceea ce conduce la concluzia că în economia investiției generale costul suplimentar generat de aceste consumuri este neglijabil. Astfel, decizia privind utilizarea unui anumit tip de învelitoare trebuie să aibă în vedere în primul rând durabilitatea materialului și costurile de întreținere în condiții de exploatare normală pe termen lung.

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