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IZJAVA O AVTORSTVU

Podpisani **MILAN OGNJANOVIĆ** izjavljam, da sem avtor diplomske naloge z naslovom: »**PROJEKT VEČNAMENSKE STAVBE V JEKLENI IZVEDBI**«.

Izjavljam, da se odpovedujem vsem materialnim pravicam iz dela za potrebe elektronske separatoteke FGG.

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BIBLIOGRAFSKO – DOKUMENTACIJSKA STRAN IN IZVLEČEK

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Mentor:	**prof. dr. Jože Korelc**
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Izvleček

Za delovni objekt smo si izbrali že obstoječo jekleno konstrukcijo štirinadstropne večnamenske stavbe, katere statični izračun je bil opravljen še po standardih JUS. V okviru diplomske naloge smo izdelali statični izračun jeklene konstrukcije po evropskih standardih, ki so uradno veljavni predpisi v Sloveniji.

Na osnovi predpisane arhitekture smo z računalniškim programom za risanje inženirskih načrtov AutoCAD narisali načrte glavnih prerezov in detajlov nosilne konstrukcije ter opravili statični izračun jeklene konstrukcije. Slednji obsega statično in dinamično analizo, temeljenje ter seznam materialov uporabljenih v konstrukciji. Za statični sistem smo si izbrali togi prostorski okvir, ki smo ga obravnavali kot ravninskega ločeno v dveh pravokotnih smereh (X in Y), z upoštevanjem medsebojnega vpliva. Obtežbe smo določili v skladu s predstandardom ENV 1991. Medetažno konstrukcijo smo projektirali v skladu s predstandardom ENV 1994. Nosilnost temeljnih tal smo izračunali po predstandardu ENV 1997. Statično analizo smo naredili s pomočjo programskega orodja ESA Prima-Win. Upoštevali smo začetno nepopolnost konstrukcije ter preverili pomike in reakcije, ki so bili rezultat programa. S pomočjo programskega orodja ESA Prima-Win smo opravili tudi dinamično analizo po teoriji II. reda.

BIBLIOGRAPHIC – DOCUMENTALISTIC INFORMATION

UDC: **006(4):624.014.2(043.2)**

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Abstract

Our object of treatment was the existing steel frame construction of four-storey multipurpose building, for which static calculation was carried out according to the JUS standards. In the framework of the thesis we carried out a static calculation of steel frame construction according to the European standards, officially in force in the Republic of Slovenia.

On the basis of the prescribed architecture and with the help of the computer programme for drawing of engineering designs AutoCAD we drew the designs of the main profiles and details of the support frame and carried out a static calculation of the steel frame construction. The latter encompasses static and dynamic analysis, foundation and a list of used material in the structure. A rigid spatial frame was chosen for the static system, which was handled as plane and separately in two right-angled directions (X and Y), by taking into account reciprocal influence. Load was determined in accordance with the pre-standard ENV 1991. Structure between storeys was designed in accordance with the pre-standard ENV 1994. The carrying capacity of the ground was calculated according to the pre-standard ENV 1997. Static analysis was carried out with the help of software ESA Prima-Win. The initial imperfection of the construction was taken into account and we also reviewed the movements and reactions resulting from the programme. Through the software ESA Prima-Win we also carried out a dynamic analysis according to the 2nd order theory.

ZAHVALA

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KAZALO VSEBINE

KAZALO PREGLEDNIC

KAZALO SLIK

1 UVOD

1.1 Namen naloge

Celeiapark Celje je že obstoječ nakupovalno poslovni objekt, katerega jeklena konstrukcija je bila izračunana po standardih JUS. Namen diplomske naloge je bil statični izračun jeklene konstrukcije po evropskih standardih EVROKOD, ki upoštevajo večje varnostne faktorje, zaradi česar je konstrukcija iz statičnega vidika varnejša. Analiza konstrukcije je bila opravljena po elastični analizi II. reda z upoštevanjem začetnih geometrijskih nepopolnosti konstrukcije. Za izračun notranjih statičnih količin in dimenzioniranje elementov konstrukcije smo uporabili programsko orodje ESA-Prima Win.

1.2 Opis obstoječega stanja

Statični sistem konstrukcije je tog prostorski okvir, ki je obravnavan kot ravninski v obeh glavnih smereh (X in Y) z upoštevanjem medsebojnega vpliva. V smeri X so momentni, neojačani in nepomični glavni okvirji. Razmak med njimi je 6.8m, priključki v okvir so togi, na začetnem in končnem delu konstrukcije pa sta AB steni debeline 30cm. Ker objekt ni simetrične oblike, so momentni okvirji različnih oblik. Pravokotno na glavne okvirje so priključene grede v betonski izvedbi, ki skupaj s stebri predstavljajo štiri sekundarne okvirje. Le-ti se med montažo povežejo z nateznimi diagonalami, ki se jih odstrani, ko beton doseže zahtevano trdnost. Nosilni sistem objekta je mešana konstrukcija, grajena iz jekla in betona. Objekt ima 30 cm debelo betonsko jedro trapezoidne oblike.

Strop je sovprežen, sestavljen iz valjanih prečk H prereza in armirane betonske plošče. V vzdolžni smeri prevzemajo upogibne momente betonski nosilci. V prečni smeri je strop kontinuiran. Priključek jeklene prečke na steber je v togi izvedbi. Mozniki, ki zagotavljajo sovprežnost, so razporejeni po celotni dolžini prečk. Stebri so priključeni na temelje preko sidrnih vijakov in podložne jeklene pločevine. Priključek preprečuje pomike in rotacijo okoli močne osi.

Izbrani material stebrov in prečk je jeklo kvalitete S235 JR, oziroma za posamezne elemente S355 J0. Medetažna plošča je armirana z rebrasto in mrežno armaturo RA400/500 in MA500/560. Betoni uporabljeni v konstrukciji so kvalitete MB20 – MB40. Vsi priključki so vijačeni. Kvaliteta vijakov je 10.9, zvari pa so prve kategorije. Račun priključkov je izvedlo podjetje TRIMO Trebnje.

Obtežba je sestavljena iz lastne in stalne obtežbe ter spremenljive obtežbe. Slednja je razdeljena na horizontalno in vertikalno koristno obtežbo po veljavnih standardih in predpisih, oziroma posamezne večje vertikalne koristne obtežbe podane s strani investitorja.

Statična analiza je narejena po standardih JUS, ki so v Sloveniji še veljavni. Za stebre so izbrani valjani H profili HEB450 in HEA450 po celotni konstrukciji, razen pri podpiranju mansarde, kjer so uporabljeni stebri HEA200. Za prečke so izbrani valjani nosilci H prereza HEA450, z izjemo strešnih leg pri mansardi, kjer so profili HEA200. Računska obremenitev za statično analizo je opravljena z računalniškim programom Okvir.

Dinamična analiza nosilne konstrukcije je narejena v skladu s predpisi JUS. Objekt stoji v VII. potresnem območju, prav tako pa je objekt preverjen na horizontalno obtežbo z vetrom I. območja in temperaturno razliko ±20°C.

Montažna fasada je viseča, neprezračevana in toplotno izolirana ter s sidri priključena na nosilno konstrukcijo. Zunanja površina je steklena, razen na delih, kjer je betonska stena. Streha je toplotno izolirana in vodotesna. Nad tretjim nadstropjem je streha ravna in pohodna, nad mansardo pa nepohodna. Stopnice so troramne v betonski izvedbi. Podest je betonska plošča, ki je vpeta v betonsko steno. Stavba ima dve dvigali, eno za obiskovalce, drugo pa za potrebe oskrbe objekta. Na zunanji strani objekta je še požarno stopnišče v jekleni izvedbi, ki je od stavbe ločeno z dilatacijo.

Stavba stoji na srednje trdnih tleh. Stebri so togo priključeni na temelje. Za pogoje temeljenja in dopustno obremenitev temeljnih tal je upoštevano geotehnično poročilo o pogojih temeljenja, ki ga je pod številko 1273/2001 izdelalo podjetje INI Ljubljana.

Nosilni elementi (stebri, prečke, povezje in strop) so požarno zaščiteni. Za vertikalne inštalacijske vode so izvedeni jaški. Horizontalni vodi pa potekajo pod stropnimi nosilci in so skriti pod visečim stropom. Po potrebi lahko potekajo napeljave skozi ojačane odprtine v stojini nosilcev. Prezračevanje poteka preko prezračevalnih kanalov, ki so speljani po zgoraj omenjenih poteh. Zvočna izolacija med etažami je debelina betonske plošče in 2.5cm trdega Tervola. Zvočna izolacija stopnišča je v enaki izvedbi. Zaščita jeklenih elementov pred rjavenjem je dosežena s protikorozijskim premazom. Nobeden od jeklenih delov konstrukcije ni neposredno izpostavljen vremenskim vplivom.

1.3 Opis konstrukcije obravnavane v diplomski nalogi

Statični sistem konstrukcije predstavlja tog prostorski okvir, ki smo ga obravnavali kot ravninskega v obeh glavnih smereh (X in Y) z upoštevanjem medsebojnega vpliva. V smeri X so momentni, neojačani in nepomični glavni okvirji. Objekt smo sestavili iz trinajstih momentnih okvirjev, ki smo jih razporedili na vsakih 6m, razen na mestu, kjer objekt spremeni smer. Tam smo ločili objekt na dva dela z dilatacijo. Objekt A je simetričen, dolžine 48m v vzdolžni smeri in 15.5m v prečni smeri. Objekt B je nesimetrične oblike, potek okvirjev pa je razviden iz zasnove pod točko 3.1. Pri obeh objektih smo uporabili toge priključke v okvir. Pravokotno na glavne okvirje smo priključili prostovrtljive prečke, ki skupaj s stebri predstavljajo štiri pomične sekundarne okvirje, ki smo jih povezali z nateznimi diagonalami različnih prerezov.

Sovprežen strop smo sestavili iz valjanih prečk I prereza in armirane betonske plošče. V vzdolžni smeri so sovprežne prečke prostoležeči nosilci. Strop v smeri y je dilatiran, da smo zagotovili prosto vrtljivost priključkov prečk na valjane stebre H prereza. Horizontalno togost prereza smo dosegli z vodenjem armature nad podporo. V prečni smeri v oseh 1 – 4 je strop kontinuiran. Priključek jeklene prečke na steber je v togi izvedbi. Mozniki, ki zagotavljajo sovprežnost, so razporejeni po celotni dolžini prečk. Stebre smo priključili na temelje preko sidrnih vijakov in podložne jeklene pločevine. Priključek preprečuje pomike in rotacijo okoli močne osi. Vsi priključki morajo imeti po standardu 20% večjo nosilnost od priključenih elementov, sicer lahko pride do porušitve v območju priključkov.

Izbrani material stebrov in prečk je jeklo kvalitete S275, oziroma za posamezne elemente S355. Medetažne stropove in pohodno streho smo armirali z rebrasto armaturo RA400/500. V stropovih smo uporabili betone kvalitete C25/30, v temeljih pa C30/37. Vsi priključki so vijačeni. Kvaliteta vijakov je 10.9, razen pri stopnišču, kjer smo uporabili vijake 5.8, zvari pa so prve kategorije.

Obtežba je sestavljena iz lastne in stalne obtežbe ter spremenljive obtežbe. Lastno in stalno obtežbo predstavljajo beton, jeklena konstrukcija, fasada in izolacije. Spremenljiva obtežba je razdeljena na koristno obtežbo, obtežbo vetra in snega (1.24 kN/m^2), ki ga odčitamo iz snežne karte. Koristna obtežba in obtežba z vetrom sta določeni v skladu s predstandardom ENV 1991 (EC 1). Velikost pritiska vetra na določeni višini narašča linearno. Vertikalno ploskovno obtežbo smo razdelili na linijsko obtežbo, tako da na vsak okvir pripada vsota širine levega in desnega polja pravokotno na smer okvirja. Pri tem smo upoštevali začetno nepopolnost konstrukcije v vsaki etaži.

Računsko obremenitev za statično analizo smo opravili s pomočjo programskega orodja ESA Prima-Win. Pri globalni analizi smo obravnavali glavne okvirje v oseh A – N in sekundarne okvirje v oseh 1 – 4. Za stebre smo si izbrali valjane H profile HEA tako, da so notranji stebri večjih prerezov kot zunanji. Za prečke smo uporabili valjane nosilce I prereza IPE, pri čemer imajo daljše prečke večji prerez kot krajše. Pri obnašanju konstrukcije med potresom je pomembno, da dimenzioniramo prečke na plastično nosilnost ter da so stebri ves čas v elastičnem območju, zato smo pri globalni analizi upoštevali teorijo II. reda. Obtežne kombinacije za mejno stanje nosilnosti in mejno stanje uporabnosti so v skladu z ENV 1993–1–1 (EC 3). Tako smo določili šest obtežnih kombinacij za mejno stanje nosilnosti in dve za mejno stanje uporabnosti z upoštevanjem začetnih geometrijskih nepopolnosti konstrukcije.

Dinamično analizo nosilne konstrukcije smo naredili v skladu z ENV 1998 (EC 8). V prvem delu dinamične analize smo izračunali potresne sile z upoštevanjem računskega pospeška tal ($0.15a_g$), ki pripada VII. potresnemu območju, v katerem se nahaja naš objekt. Velikost potresnih sil je odvisna od mase objekta, lastnega nihajnega časa konstrukcije in jo določimo s pomočjo projektnega spektra odziva. Za zmanjšanje potresnih sil smo pri momentnih okvirjih upoštevali faktor obnašanja $q = 6$, pri povezju pa $q = 4$. S tem faktorjem se upošteva sposobnost sipanja energije. V drugem delu dinamične analize smo izvedli kontrole posameznih nosilnih elementov, ki morajo zadoščati potresno varnemu projektiranju. V primeru, da ne moremo zanemariti povečanja upogibnih momentov zaradi horizontalnih pomikov vozlišč, okvir razvrstimo med pomične okvirje. Za nepomične štejemo okvirje, pri katerih velja $\theta \leq 0.1$. V našem primeru imamo pomičen okvir, ki ga moramo dimenzionirati po teoriji drugega reda ob upoštevanju začetnih geometrijskih nepopolnosti. Potresne sile so izračunane po teoriji prvega reda. Vpliv teorije drugega reda upoštevamo tako, da notranje sile povečamo s faktorjem $k_\delta = (1 - \theta)$. Metodo lahko uporabljamo vse dokler velja razmerje $\theta \leq 0.25$.

Sovprežen strop smo izračunali v skladu s predstandardom za sovprežne konstrukcije ENV 1994 (EC 4). Račun smo razdelili na dva dela. Prvi del predstavlja fazo montaže, pri kateri sta dve obtežni kombinaciji, ena za mejno stanje nosilnosti, druga pa za mejno stanje uporabnosti. Pri fazi montaže smo opravili kontrole bočne zvrnitve, kompaktnosti in kontrolo pomikov. Drugi del računa je sovprežno stanje, kjer imamo za vsako mejno stanje po eno obtežno kombinacijo. Potrebne kontrole pri sovprežnem stanju so kontrola upogibne nosilnosti, izkoriščenosti, vertikalni strig in kontrola pomikov. Pri izračunu moznikov smo predpostavili polno sovprežnost in si izbrali moznike Nelson. Izračunali smo še strižno armaturo, pri kateri je pomembno preveriti tudi nosilnost armature proti vzdolžnemu strigu.

Montažna fasada je viseča, neprezračevana in toplotno izolirana ter s sidri priključena na nosilno konstrukcijo. Zunanja površina fasade je v celoti steklena. Streha je toplotno izolirana in vodotesna. Nad tretjim nadstropjem je streha ravna in pohodna, nad mansardo pa nepohodna in sestavljena iz profilirane pločevine. Stopnice so dvoramne, narejene iz jeklenih nosilcev [profila, ki so z vijaki prostovrtljivo priključeni na nosilno konstrukcijo. Pri stopnicah smo uporabili jeklo kvalitete S235.

Izračunali smo štiri značilne priključke: členkasti spoj sekundarnega nosilca na primarni nosilec, priključek stebra na temelj, momentni spoj primarnega nosilca in stebra prečnega okvirja ter stik diagonale s stebrom.

Stavba stoji na srednje trdnih tleh. Stebri so togo priključeni na točkovne temelje tlorisne površine 2.5m × 2.5m in debeline 70cm. Izračun nosilnosti temeljnih tal smo naredili po predstandardu za temeljenje ENV 1997–1 ANNEX B (EC 7) po poenostavljeni analitični metodi.

Nosilni elementi (stebri, prečke, povezje in strop) so požarno zaščiteni. Stopniščni prostor je ločen od okolice s požarno odpornimi zidovi in požarno varnimi vrati. Material za požarno zaščito je požarno varni obrizg. Za vertikalne inštalacijske vode so izvedeni jaški. Horizontalni vodi pa potekajo pod stropnimi nosilci in so skriti pod visečim stropom. Po potrebi lahko potekajo napeljave skozi ojačane odprtine v stojini nosilcev. Prezračevanje poteka preko prezračevalnih kanalov, ki so speljani po zgoraj omenjenih poteh. Zvočna izolacija med etažami je debelina betonske plošče in 2 cm trdega Tervola. Zvočna izolacija stopnišča je narejena iz plastične mase, ki prekriva stopnice. Zaščita jeklenih elementov pred rjavenjem je dosežena s protikorozijskim premazom. Nobeden od jeklenih delov konstrukcije ni neposredno izpostavljen vremenskim vplivom.

1.4 Primerjava diplomskega dela z obstoječim stanjem

Glavna razlika med izvedbama je v tem, da je pri diplomski nalogi nosilna konstrukcija v celoti iz jekla izračunana po evropskih standardih, pri obstoječem stanju pa je nosilna konstrukcija v mešani izvedbi (60% beton, 40% jeklo) izračunana še po standardih JUS.

Prednosti v celoti jeklene konstrukcije so:

- enostavnejša in cenejša izvedba
- lažja konstrukcija. Teža nosilne jeklene konstrukcije v diplomski nalogi je 289478kg, jekleni del obstoječega objekta tehta približno 160000kg, preostali del nosilne konstrukcije, brez betonskih plošč pa približno 140000kg.
- statični izračun je bil narejen po standardih EVROKOD, ki veljajo po vsej Evropi in z upoštevanjem večjih varnostnih faktorjev prispevajo k varnejši konstrukciji
- za gradnjo je potreben manjši gradbeni prostor in manj dela se izvaja na gradbišču
- ker je izvedba hitrejša, je objekt prej predan uporabi.

Slabost take konstrukcije je večja občutljivost na potresno obtežbo, ker objekt nima armiranih betonskih sten in betonskega jedra.

Primerjava porabe materialov:

	obstoječi objekt	objekt v diplomski nalogi
beton	2893949kg	1921470kg
armatura	363451kg	241667kg
konstrukcijsko jeklo	145303kg	289478kg
SKUPAJ	3402703kg	2452615kg

2 TEHNIČNO POROČILO

2.1 Zasnova

Objekt je poslovna stavba, njegova nosilna konstrukcija je izvedena iz jekla. Objekt je nepodkleten in ima prtličje, tri nadstropja ter mansardo. Višina prtličja je 4.3m, višina nadstropij in mansarde pa 3.3m. Projekt je narejen v skladu z zahtevami Evrokoda.

2.2 Statični sistem

Konstrukcija je prostorski okvir, ki je obravnavan kot ravninski za vsako glavno smer X in Y posebej z upoštevanjem medsebojnega vpliva. V smeri X imamo glavne okvirje, ki so momentni, so neojačani ter nepomični. Razmak med njimi je 6m in priključki v okvir so togi. V smeri Y pa so na glavni okvir prostovrtljivo priključene prečke, ki s stebri predstavljajo štiri pomične sekundarne okvirje, ki so povezani z diagonalnimi poveznimi diagonalami. Sovprežni strop ne sodeluje pri globalni analizi. Medetažna konstrukcija in ravna streha nad tretjim nadstropjem sta iz AB plošče, ki leži na sovprežnih nosilcih. Streha in sovprežni strop predstavljajo togo šipo in zagotavljajo horizontalno togost. Streha nad četrtim nadstropjem pa je nepohodna, proizvajalca Trimo.

2.3 Obtežba

Obtežba je sestavljena iz:-lastna obtežba (streha 5.14kN/m^2; medetažna konstrukcija 4.51kN/m^2; fasada 0.5kN/m^2; predelne stene 0.8kN/m^2)
- koristna obtežba (pisarne 3.0kN/m^2; stopnice 3.0kN/m^2)
- sneg (S = 1.52kN/m^2)
- veter – hitrost vetra je 25m/s
- potres – računski pospešek pri potresu je 0.15g (g = pospešek prostega pada)

2.4 Material

Nosilna konstrukcija objekta (stebri in prečke) se izvede v jeklu kvalitete S275. Armatura v sovprežnem stropu je kvalitete S500. Medetažna plošča in temelji so iz armiranega betona, kvalitete C25/30. Mozniki NELSON f_y/f_u=350/450kN/mm^2.

2.5 Izbrani prerezi

Nosilna konstrukcija objekta A je sestavljena iz dveh zunanjih in sedmih notranjih momentnih okvirjev. Pri zunanjemu okvirju so zunanji stebri iz profilov HEA 260, notranji pa iz profilov HEA 320. Notranji momenti okvir, ki je bolj obremenjen, pa je sestavljen iz zunanjih stebrov HEA 360 in notranjih stebrov HEA 450. Prečke v zunanjih poljih, dolžine 6m, so iz profilov IPE 360, prečke v notranjem polju, razpona 3.5m, pa iz profilov IPE 300. Nosilna konstrukcija objekta B pa je sestavljena iz dveh zunanjih in dveh notranjih momentnih okvirjev. V vzdolžni smeri so momentni okvirji med seboj povezani s prečkami profila IPE 330. Natezne diagonale, za prevzem horizontalne obtežbe v vzdolžni smeri, se z višino zmanjšujejo in so iz votlih cevi različnih debelin. Sekundarni nosilci sovprežnega stropa so iz profilov IPE 220.

2.6 Priključki

Členkasti spoj sekundarnega nosilca na primarni nosilec je vijačen z visokovrednimi vijaki M12 10.9 preko vezne pločevine. Vezna pločevina je z dvostranskim kotnim zvarom privarjena na stojino primarnega nosilca.

Momentni spoj primarnega nosilca in stebra prečnega okvirja je vijačen z visokovrednimi vijaki M20 10.9 preko čelne pločevine. Čelna pločevina je s čelnimi zvari pritrjena na prečko. Stebri so na mestu priključkov ojačani.

Priključek stebra na temelj je vijačen s sidri M30 preko čelne pločevine. Čelna pločevina je pritrjena z dvostranskim kotnim zvarom na stojino stebra in z enostranskim kotnim zvarom na vezno pločevino, ki sta z enostranskimi kotnimi zvari pritrjeni na pasnici stebra.

Priključek nateznih diagonal na nosilno konstrukcijo je vijačen z visokovrednimi vijaki M33 10.9 preko vezne pločevine. Zvar med vezno pločevino in diagonalo je kotni.

Priključki primarnega nosilca na steber, povezja na steber in stebra na temelj so polnonosilni.

2.7 Dinamična analiza

Stavba stoji v VII. potresni coni. Potresne sile so določene s projektnim spektrom odziva za elastično analizo, ki upošteva disipacijo potresne energije. Konstrukcija je potresnovarno projektirana v skladu s posebnimi pravili, ki veljajo za gradnjo jeklenih konstrukcij na potresnih območjih OSIST ENV 1998. Za momentne okvirje se upošteva faktor obnašanja $q = 6$, za povezje pa $q = 4$. S tem faktorjem se upošteva sposobnost sipanja energije.

2.8 Streha

Konstrukcijski sklop ravne, pohodne toplotno izolirane in vodotesne strehe je: drenažni sloj [10cm], hidroizolacija, vlaknina, TI [10cm], parna zapora, izenačevalni sloj, AB plošča [12cm], jeklen nosilec.

Nad mansardo pa imamo ravno, nepohodno streho proizvajalca Trimo.

2.9 Fasada

Objekt ima stekleno montažno fasado, ki je s pomočjo mreže aluminijastih stebričkov in nosilčkov pritrjena na glavno nosilno konstrukcijo. Fasada je tipska, proizvajalca IMPOL-MONTAL.

2.10 Inštalacije

Vertikalne inštalacije potekajo preko inštalacijskih odprtin (jaški). Horizontalne inštalacije potekajo pod visečim stropom. Na zahtevo inštalaterja pa se horizontalni vodi lahko vodijo preko stojin prečk, katere pa je potrebno primerno ojačati.

2.11 Izdelava in montaža konstrukcijskih elementov

Pri izdelavi in montaži konstrukcijskih elementov je potrebno upoštevati določila ENV 1090-1. S pravilnim vrstnim redom montaže je potrebno zagotoviti stabilnost konstrukcije v času montaže. Posebno pozornost je potrebno posvetiti geometrijskim tolerancam ter izdelavi in kontroli kvalitete zvarov. Mere v načrtih so nominalne in jih je potrebno natančno določiti glede na dejansko geometrijo konstrukcije. Spremembe na nosilni konstrukciji so dovoljene samo v soglasju z odgovornim projektantom. Zagotoviti je potrebno strokovni nadzor nad izvajanjem jeklene konstrukcije. Nadzor mora opraviti strokovnjak za jeklene konstrukcije.

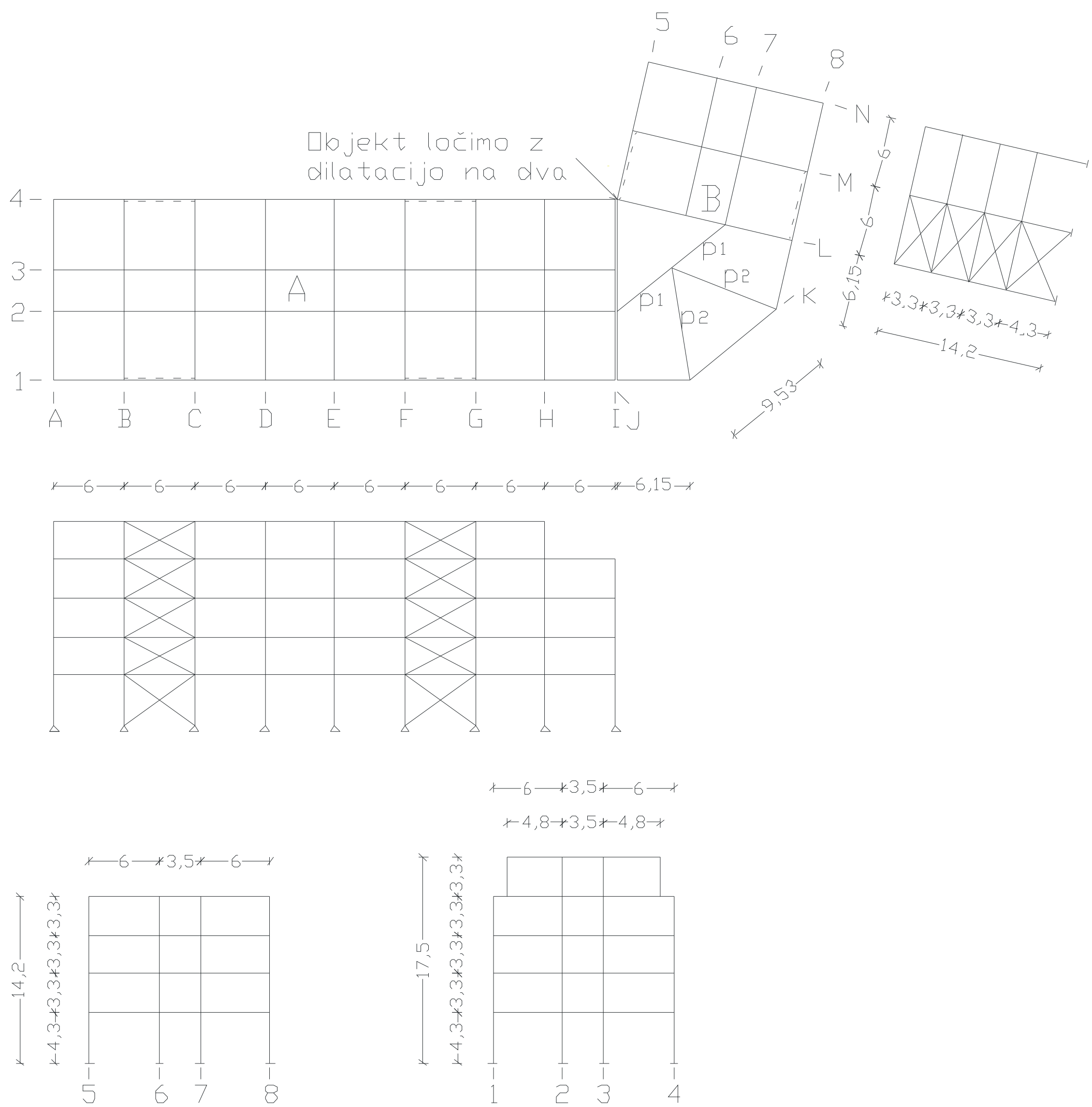
2.12 Protikorozijska zaščita stavbe

Protikorozijska zaščita jeklenih elementov je izvedena s protikorozijskim premazom. Noben jekleni del konstrukcije ni neposredno izpostavljen zunanjim vplivom vremena. Kvaliteta premazov mora zagotavljati zadosten oprijem, kar mora biti izkazano z ustreznimi meritvami.

3 GLOBALNA ANALIZA

3.1 Zasnova

Nosilno konstrukcijo predstavljajo jekleni okvirji, ki so razvrščeni v prečni in vzdolžni smeri kot nam kaže skica spodaj. Stavba je ločena z dilatacijo na dva objekta. Objektu A ima v vzdolžni smeri devet okvirjev, razporejenih na vsakih šest metrov. Pri objektu B pa je razvidno iz slike spodaj. V prečni smeri pa imamo štiri okvirje, ki pa potekajo na razdalji 6m, 3.5m, 6m, ter okvir K. Priključki momentnih okvirjev na AB stebre so togi, priključki sekundarnih okvirjev z diagonalnim centričnim povezjem pa so členkasti. Strop je sovprežen, sestavljen iz valjanih prečk I prereza in AB plošče. Sovprežnost je zagotovljena z mozniki.



3.2 Obtežba

3.2.1 Lastna in stalna obtežba

3.2.1.1 Streha (ravna)

drenažni sloj.................10cm	$1.80kN/m^2$
hidroizolacija	$0.07kN/m^2$
vlaknina	
TI.................................10cm	$0.02kN/m^2$
parna zapora	$0.05kN/m^2$
izenačevalni sloj	
AB plošča.....................12cm	$3.00kN/m^2$
jeklen nosilec	$0.20kN/m^2$
	$G_S = 5.14kN/m^2$

3.2.1.2 Streha nad mansardo (ravna)

strešna plošča TRIMO	$0.30kN/m^2$
strešna lega	$0.20kN/m^2$
	$G_S = 0.5kN/m^2$

3.2.1.3 Medetažna konstrukcija

zaključni sloj.................1cm	$0.01m \cdot 25kN/m^3 = 0.25kN/m^2$
cementni estrih..............4cm	$0.04m \cdot 24kN/m^3 = 0.96kN/m^2$
TI + spuščeni strop	$0.10kN/m^2$
AB plošča....................12cm	$0.16m \cdot 25kN/m^3 = 3.00kN/m^2$
jeklen nosilec	$0.20kN/m^2$
	$G_{MK} = 4.51kN/m^2$

3.2.1.4 Fasada

fasadna plošča	$0.30kN/m^2$
fasadna podkonstrukcija	$0.20kN/m^2$
	$G_F = 0.50kN/m^2$

3.2.1.5 Predelne stene

$G_{PS} = 0.8 kN/m^2$

3.2.2 Spremenljiva obtežba

3.2.2.1 Koristna obtežba

ENV 2 - 1

pisarne (kategorija B)..$q_P = 3.0 kN/m^2$

stopnišče..$q_S = 3.0 kN/m^2$

streha (če je pohodna)...$q_{ST} = 0.75 kN/m^2$

α....redukcijski koeficient ≥ 0.6

α_n....redukcija glede na višino objekta, če je več kot dva nadstropja

$$\alpha_n = \frac{2 + (n-2)\psi_0}{n}$$ ENV 2 – 1

α_A.... redukcijski faktor

$\alpha_A = 5/7 \cdot \Psi_0 + A_0/A \leq 1.0$

$A_0 = 10 m^2$

$\Psi_0 = 0.7$, razen pri kategoriji E ($\Psi_0 = 1.0$) ENV 1 - 1

n	α_n	A (m^2)	α_A	q_P (kN/m^2)	q_S (kN/m^2)
1	/	36	0.78	2.34	3.0
2	/	36	0.78	2.34	3.0
3	0,90	36	0.78	2.11	3.0
4	0,85	36	0.78	1.99	3.0

3.2.2.2 Sneg

ENV 2 – 3

cona B....jo razberemo iz snežne karte

$S_K = 1.55 kN/m^2$

$S = S_K \cdot \mu_i \cdot C_e \cdot C_t$

μ_i....naklon kritine (ravna streha oz. enokapnica imata 0.8)

$C_e = C_t = 1.0$

$\underline{S = 1.55 \cdot 0.8 \cdot 1.0 \cdot 1.0 = 1.24 kN/m^2}$

3.2.2.3 Veter

SIST ENV 1991 – 2 – 4

$q_{ref} = \rho/2 \cdot V_{ref}^2$

V_{ref} = 25m/s....cona A ⇒ razberemo iz karte za veter

$\rho = 1.25 kg/m^3$....gostota zraka

$$q_{ref} = \frac{1.25 kg/m^3}{2}(25 m/s)^2 = 0.39\, kN/m^2$$

3.2.2.3.1 Zunanji vpliv vetra

$W_e = q_{ref} \cdot C_e(Z_e) \cdot C_{pe}$

W_e....zunanji pritisk vetra na stavbo kN/m^2

Z_e....kote etaž od tal navzgor

Koeficient C_e

C_e...ENV 1991 – 2 – 4, slika 8.3

d...višina stavbe

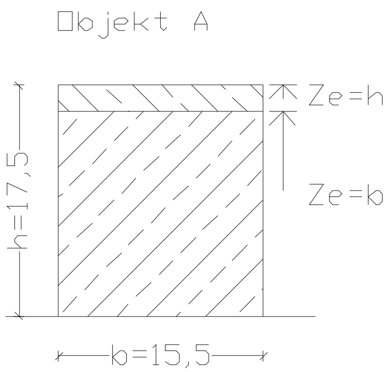
b...širina stavbe

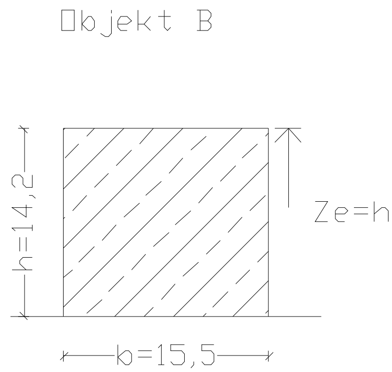
h_P…višina parapeta ($h_P = 0.9 m$)

$C_{pe} = C_{pe10}$....dejanska površina večja od $10 m^2$

$C_{pe} = C_{pe1}$....dejanska površina je med $1 m^2$ in $10 m^2$

Prečna smer:

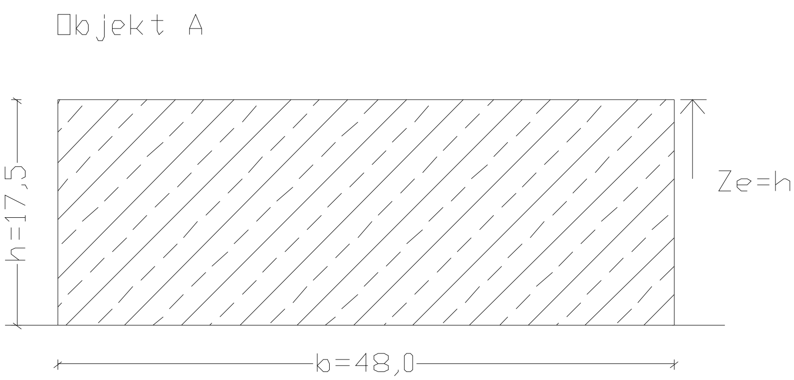


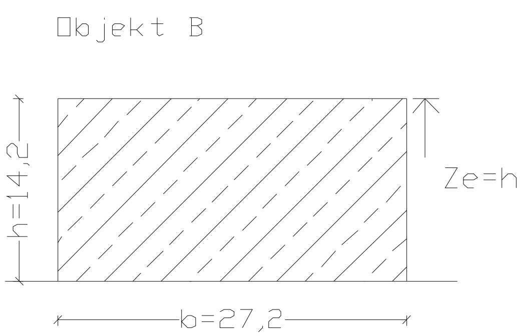


$C_e(Z_e = h) = 1.65$ $C_e(Z_e = h) = 1.55$

$C_e(Z_e = b) = 1.55$

Vzdolžna smer:





Objekt A

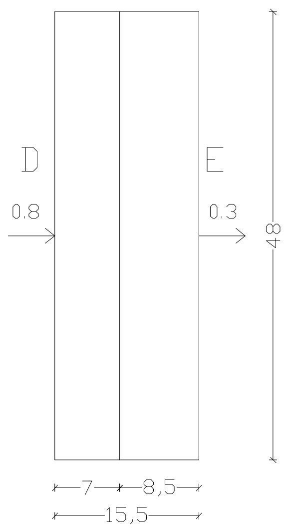
$C_e(Z_e = h) = 1.55$

Objekt B

$C_e(Z_e = h) = 1.55$

3.2.2.3.1.1 Veter v prečni smeri

Objekt A



$Z_e \leq 15.5\text{m}$

$$\frac{d}{h} = \frac{15.5}{17.5} = 0.9 \leq 1.0$$

e = 2h = 35m

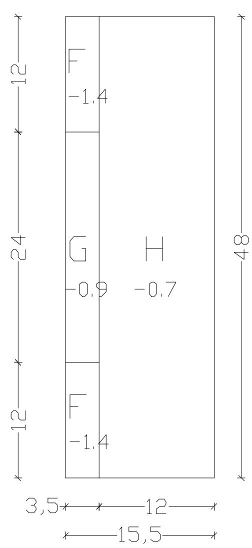
ENV 1991 – 2 – 4, stran 47 D = 0.8

E = 0.3

$$W_E^D = 0.39\text{kN/m}^2 \cdot 1.55 \cdot 0.8 = 0.48\text{kN/m}^2$$

$$W_E^E = 0.39\text{kN/m}^2 \cdot 1.55 \cdot 0.3 = 0.18\text{kN/m}^2$$

- ravna streha



$15.5\text{m} \leq Z_e \leq 17.5\text{m}$

e = 2h = 35m

ENV 1991 – 2 – 4, stran 47 F = –1.4

G = –0.9

H = –0.7

$$W_E^D = 0.39\text{kN/m}^2 \cdot 1.65 \cdot 0.8 = 0.51\text{kN/m}^2$$

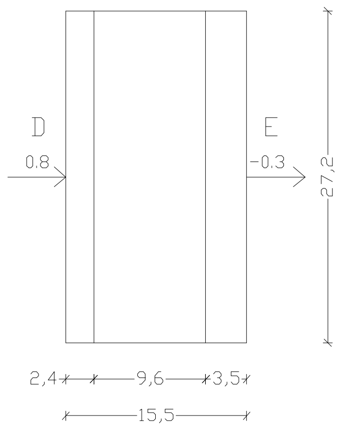
$$W_E^E = 0.39\text{kN/m}^2 \cdot 1.65 \cdot 0.3 = 0.19\text{kN/m}^2$$

$$W_E^F = 0.39\text{kN/m}^2 \cdot 1.65 \cdot (-1.4) = -0.90\text{kN/m}^2$$

$$W_E^G = 0.39\text{kN/m}^2 \cdot 1.65 \cdot (-0.9) = -0.58\text{kN/m}^2$$

$$W_E^H = 0.39\text{kN/m}^2 \cdot 1.65 \cdot (-0.7) = -0.45\text{kN/m}^2$$

Objekt B



$Z_e \leq 14.2\text{m}$

$$\frac{d}{h} = \frac{15.5}{14.2} = 1.1 \geq 1.0$$

e = b = 27.2m

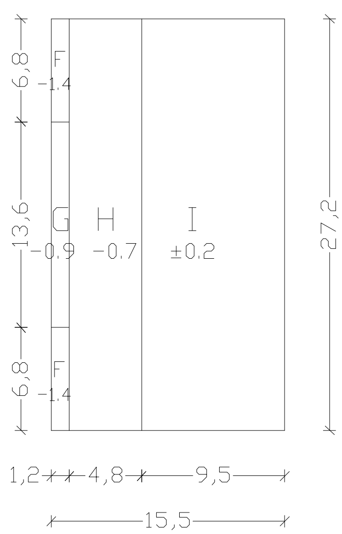
ENV 1991 – 2 – 4, stran 47 D = 0.8

E = 0.3

$W_E^D = 0.39\text{kN/m}^2 \cdot 1.55 \cdot 0.8 = 0.48\text{kN/m}^2$

$W_E^E = 0.39\text{kN/m}^2 \cdot 1.55 \cdot 0.3 = 0.18\text{kN/m}^2$

- ravna streha



$Z_e \leq 14.2\text{m}$

e = b = 27.2m

ENV 1991 – 2 – 4, stran 47 F = –1.4

G = –0.9

H = –0.7

I = ±0.2

$W_E^D = 0.39\text{kN/m}^2 \cdot 1.55 \cdot 0.8 = 0.48\text{kN/m}^2$

$W_E^E = 0.39\text{kN/m}^2 \cdot 1.55 \cdot 0.3 = 0.18\text{kN/m}^2$

$W_E^F = 0.39\text{kN/m}^2 \cdot 1.55 \cdot (-1.4) = -0.85\text{kN/m}^2$

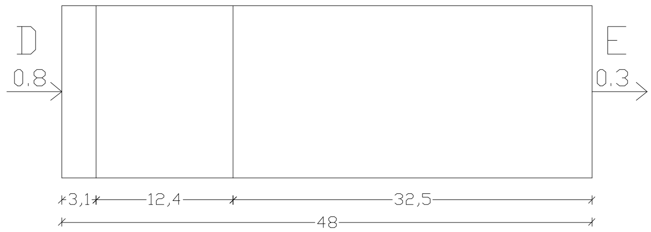
$W_E^G = 0.39\text{kN/m}^2 \cdot 1.55 \cdot (-0.9) = -0.54\text{kN/m}^2$

$W_E^H = 0.39\text{kN/m}^2 \cdot 1.55 \cdot (-0.7) = -0.42\text{kN/m}^2$

$W_E^I = 0.39\text{kN/m}^2 \cdot 1.55 \cdot (\pm 0.2) = \pm 0.12\text{kN/m}^2$

3.2.2.3.1.2 Veter v vzdolžni smeri

Objekt A



$Z_e \leq 17.5m$

$\frac{d}{h} = \frac{48}{17.5} = 2.7 \leq 4.0$

$e = b = 15.5m$

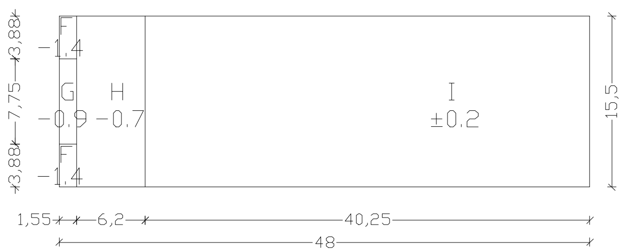
ENV 1991 – 2 – 4, stran 47 D = 0.69

E = 0.3

$W_E^D = 0.39kN/m^2 \cdot 1.55 \cdot 0.69 = 0.42kN/m^2$

$W_E^E = 0.39kN/m^2 \cdot 1.55 \cdot 0.3 = 0.18kN/m^2$

- ravna streha



$Z_e \leq 17.5m$

$e = b = 15.5m$

ENV 1991 – 2 – 4, stran 47 F = –1.4

G = –0.9

H = –0.7

I = ±0.2

$W_E^D = 0.39kN/m^2 \cdot 1.55 \cdot 0.69 = 0.42kN/m^2$

$W_E^E = 0.39kN/m^2 \cdot 1.55 \cdot 0.3 = 0.18kN/m^2$

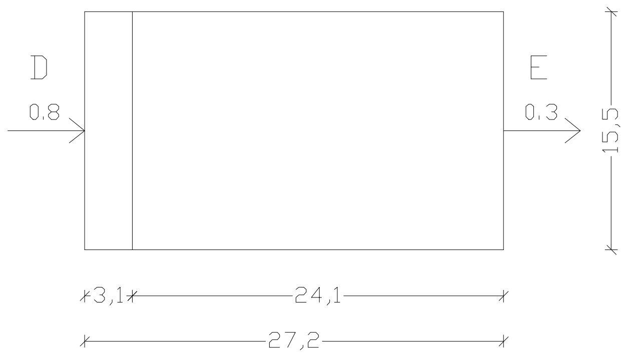
$W_E^F = 0.39kN/m^2 \cdot 1.55 \cdot (-1.4) = -0.85kN/m^2$

$W_E^G = 0.39kN/m^2 \cdot 1.55 \cdot (-0.9) = -0.54kN/m^2$

$W_E^H = 0.39kN/m^2 \cdot 1.55 \cdot (-0.7) = -0.42kN/m^2$

$W_E^I = 0.39kN/m^2 \cdot 1.55 \cdot (\pm0.2) = \pm0.12kN/m^2$

Objekt B



$Z_e \leq 14.2m$

$\frac{d}{h} = \frac{27.2}{14.2} = 1.9 \leq 4.0$

$e = b = 15.5m$

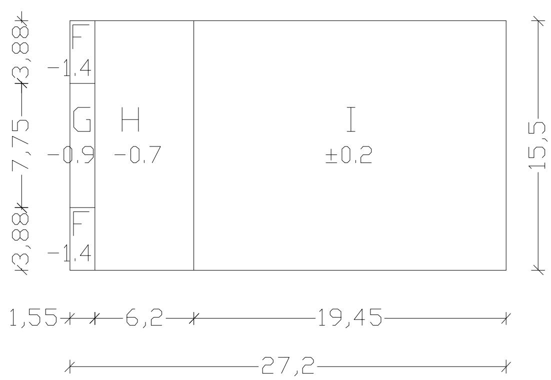
ENV 1991 – 2 – 4, stran 47 D = 0.75

E = 0.3

$W_E^D = 0.39kN/m^2 \cdot 1.55 \cdot 0.75 = 0.45kN/m^2$

$W_E^E = 0.39kN/m^2 \cdot 1.55 \cdot 0.3 = 0.18kN/m^2$

- ravna streha



$Z_e \leq 17.5m$

$e = b = 15.5m$

ENV 1991 – 2 – 4, stran 47

F = −1.4

G = −0.9

H = −0.7

I = ±0.2

$W_E^D = 0.39kN/m^2 \cdot 1.55 \cdot 0.69 = 0.45kN/m^2$

$W_E^E = 0.39kN/m^2 \cdot 1.55 \cdot 0.3 = 0.18kN/m^2$

$W_E^F = 0.39kN/m^2 \cdot 1.55 \cdot (-1.4) = -0.85kN/m^2$

$W_E^G = 0.39kN/m^2 \cdot 1.55 \cdot (-0.9) = -0.54kN/m^2$

$W_E^H = 0.39kN/m^2 \cdot 1.55 \cdot (-0.7) = -0.42kN/m^2$

$W_E^I = 0.39kN/m^2 \cdot 1.55 \cdot (\pm 0.2) = \pm 0.12kN/m^2$

3.2.2.3.2 Notranji vpliv vetra

$W_i = q_{ref} \cdot C_e(Z_i) \cdot C_{pi}$

$Z_i = Z_e \Rightarrow C_e(Z_i) = C_e(Z_e) = 1.55$

$C_{pi} = -0.5$… notranji srk

$C_{pi} = 0.8$… notranji pritisk

Prečna smer:

$Z_e \leq 17.5m$

$W_i = 0.39kN/m^2 \cdot 1.55 \cdot (-0.5) = -0.30kN/m^2$ (srk)

$W_i = 0.39kN/m^2 \cdot 1.55 \cdot 0.8 = 0.48kN/m^2$ (pritisk)

$15.5m \leq Z_e \leq 17.5m$

$W_i = 0.39kN/m^2 \cdot 1.65 \cdot (-0.5) = -0.32kN/m^2$ (srk)

$W_i = 0.39kN/m^2 \cdot 1.65 \cdot 0.8 = 0.51kN/m^2$ (pritisk)

Vzdolžna smer:

$Z_e \leq 17.5m$

$W_i = 0.39kN/m^2 \cdot 1.55 \cdot (-0.5) = -0.30kN/m^2$ (srk)

$W_i = 0.39kN/m^2 \cdot 1.55 \cdot 0.8 = 0.48kN/m^2$ (pritisk)

3.2.2.3.3 Notranji + zunanji vpliv vetra

3.2.2.3.3.1 Veter v prečni smeri

Objekt A in B:

Srk:

$W_E^D = 0.48kN/m^2 + 0.3kN/m^2\ (0.32kN/m^2) = 0.78kN/m^2\ (0.80kN/m^2)$

$W_E^E = 0.18kN/m^2 - 0.3kN/m^2\ (0.32kN/m^2) = -0.12kN/m^2\ (-0.14kN/m^2)$

$W_E^F = 0.85kN/m^2 - 0.3kN/m^2\ (0.32kN/m^2) = 0.55kN/m^2\ (0.53kN/m^2)$

$W_E^G = 0.54kN/m^2 - 0.3kN/m^2\ (0.32kN/m^2) = 0.24kN/m^2\ (0.22kN/m^2)$

$W_E^H = 0.42kN/m^2 - 0.3kN/m^2\ (0.32kN/m^2) = 0.12kN/m^2\ (0.10kN/m^2)$

$W_E^I = 0.12kN/m^2 - 0.3kN/m^2\ (0.32kN/m^2) = -0.42kN/m^2\ (-0.44kN/m^2)$

Pritisk:

$W_E^D = 0.48kN/m^2 - 0.48kN/m^2\ (0.51kN/m^2) = 0kN/m^2\ (-\ 0.03kN/m^2)$

$W_E^E = 0.18kN/m^2 + 0.48kN/m^2\ (0.51kN/m^2) = 0.66kN/m^2\ (0.69kN/m^2)$

$W_E^F = 0.85kN/m^2 + 0.48kN/m^2\ (0.51kN/m^2) = 1.33kN/m^2\ (1.36kN/m^2)$

$W_E^G = 0.54kN/m^2 + 0.48kN/m^2\ (0.51kN/m^2) = 1.02kN/m^2\ (1.05kN/m^2)$

$W_E^H = 0.42kN/m^2 + 0.48kN/m^2\ (0.51kN/m^2) = 0.90kN/m^2\ (0.93kN/m^2)$

$W_E^I = 0.12kN/m^2 + 0.48kN/m^2\ (0.51kN/m^2) = 0.60kN/m^2\ (0.63kN/m^2)$

3.2.2.3.3.2 Veter v vzdolžni smeri [kN/m^2]

Objekt A:

Srk:

$W_E^D = 0.42kN/m^2 + 0.3kN/m^2 = 0.72kN/m^2$

$W_E^E = 0.18kN/m^2 - 0.3kN/m^2 = -0.12kN/m^2$

$W_E^F = 0.85kN/m^2 - 0.3kN/m^2 = 0.55kN/m^2$

$W_E^G = 0.54kN/m^2 - 0.3kN/m^2 = 0.24kN/m^2$

$W_E^H = 0.42kN/m^2 - 0.3kN/m^2 = 0.12kN/m^2$

$W_E^I = 0.12kN/m^2 - 0.3kN/m^2 = -0.42kN/m^2$

Pritisk:

$W_E^D = 0.42kN/m^2 - 0.48kN/m^2 = -\ 0.06kN/m^2$

$W_E^E = 0.18kN/m^2 + 0.48kN/m^2 = 0.66kN/m^2$

$W_E^F = 0.85kN/m^2 + 0.48kN/m^2 = 1.33kN/m^2$

$W_E^G = 0.54kN/m^2 + 0.48kN/m^2 = 1.02kN/m^2$

$W_E^H = 0.42kN/m^2 + 0.48kN/m^2 = 0.90kN/m^2$

$W_E^I = 0.12kN/m^2 + 0.48kN/m^2 = 0.60kN/m^2$

Objekt B:

Srk:

$W_E^D = 0.45kN/m^2 + 0.3kN/m^2 = 0.75kN/m^2$

$W_E^E = 0.18kN/m^2 - 0.3kN/m^2 = -0.12kN/m^2$

$W_E^F = 0.85kN/m^2 - 0.3kN/m^2 = 0.55kN/m^2$

$W_E^G = 0.54kN/m^2 - 0.3kN/m^2 = 0.24kN/m^2$

$W_E^H = 0.42kN/m^2 - 0.3kN/m^2 = 0.12kN/m^2$

$W_E^I = 0.12kN/m^2 - 0.3kN/m^2 = -0.42kN/m^2$

Pritisk:

$W_E^D = 0.45kN/m^2 - 0.48kN/m^2 = - 0.03kN/m^2$

$W_E^E = 0.18kN/m^2 + 0.48kN/m^2 = 0.66kN/m^2$

$W_E^F = 0.85kN/m^2 + 0.48kN/m^2 = 1.33kN/m^2$

$W_E^G = 0.54kN/m^2 + 0.48kN/m^2 = 1.02kN/m^2$

$W_E^H = 0.42kN/m^2 + 0.48kN/m^2 = 0.90kN/m^2$

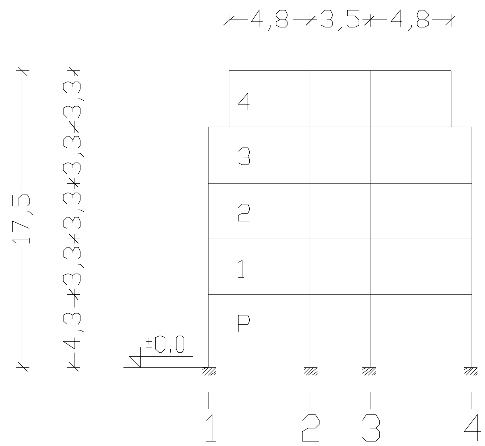
$W_E^I = 0.12kN/m^2 + 0.48kN/m^2 = 0.60kN/m^2$

3.3 Statična analiza

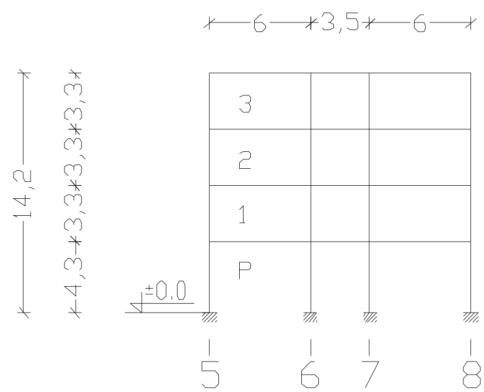
3.3.1 Zunanji prečni okvir

3.3.1.1 Računski model

Okvir A

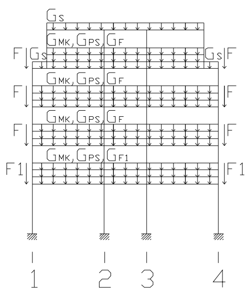


Okvir N



3.3.1.2 Obtežne sheme

Okvir A



Lastna in stalna obtežba:

$G_S = 0.5kN/m^2 \cdot 3m = 1.5kN/m$ $G_S = 5.14kN/m^2 \cdot 3m = 15.42kN/m$

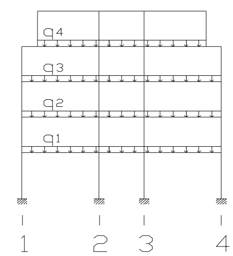
$G_{MK} = 4.51kN/m^2 \cdot 3m = 13.53kN/m$

$G_{PS} = 0.8kN/m^2 \cdot 3m = 2.4kN/m$

$G_F = 0.5kN/m^2 \cdot 3.3m = 1.65kN/m$

$F = 0.5kN/m^2 \cdot 3m \cdot 3.3m = 4.95kN$

$F_1 = 0.5kN/m^2 \cdot 3m \cdot 3.8m = 5.7kN$



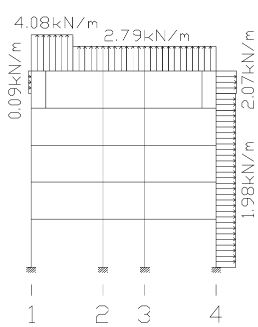
Koristna obtežba:

$q_4 = 1.99kN/m^2 \cdot 3m = 5.97kN/m$

$q_3 = 2.11kN/m^2 \cdot 3m = 6.33kN/m$

$q_2 = 2.34kN/m^2 \cdot 3m = 7.02kN/m$

$q_1 = 2.34kN/m^2 \cdot 3m = 7.02kN/m$



Veter (pritisk):

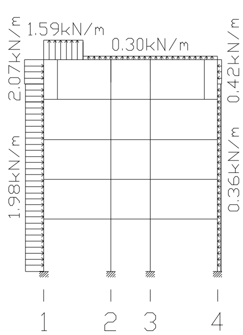
$W_{Dsp} = 0 \cdot 3m = 0$ $W_{Dzg} = 0.03kN/m^2 \cdot 3m = 0.09kN/m$

$W_F = 1.36kN/m^2 \cdot 3m = 4.08kN/m$

$W_H = 0.93kN/m^2 \cdot 3m = 2.79kN/m$

$W_{Esp} = 0.66kN/m^2 \cdot 3m = 1.98kN/m$

$W_{Ezg} = 0.69kN/m^2 \cdot 3m = 2.07kN/m$



Veter (srk):

$W_{Dsp} = 0.78kN/m^2 \cdot 3m = 2.34kN/m$

$W_{Dzg} = 0.80kN/m^2 \cdot 3m = 2.4kN/m$

$W_F = 0.53kN/m^2 \cdot 3m = 1.59kN/m$

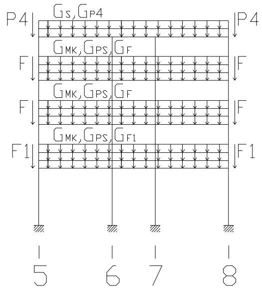
$W_H = 0.10kN/m^2 \cdot 3m = 0.30kN/m$

$W_{Esp} = -0.12kN/m^2 \cdot 3m = -0.36kN/m$

$W_{Ezg} = -0.14kN/m^2 \cdot 3m = -0.42kN/m$

Sneg: $q_{sneg} = 1.24kN/m^2 \cdot 3m = 3.72kN/m$

Okvir N



Lastna in stalna obtežba:

$G_S = 5.14kN/m^2 \cdot 3m = 15.42kN/m$

$G_{MK} = 4.51kN/m^2 \cdot 3m = 13.53kN/m$

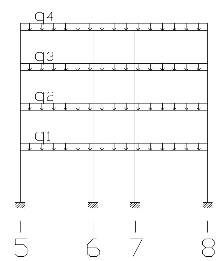
$G_{PS} = 0.8kN/m^2 \cdot 3m = 2.4kN/m$

$G_F = 0.5kN/m^2 \cdot 3.3m = 1.65kN/m$

$G_{P4} = 25kN/m^3 \cdot 0.9m \cdot 0.2m = 4.5kN/m$

$P_4 = 25kN/m^3 \cdot 3m \cdot 0.9m \cdot 0.2m = 13.5kN$

$F = 0.5kN/m^2 \cdot 3m \cdot 3.3m = 4.95kN$ $F_1 = 0.5kN/m^2 \cdot 3m \cdot 3.8m = 5.7kN$



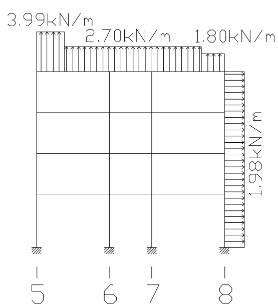
Koristna obtežba:

$q_4 = 0.75kN/m^2 \cdot 3m = 2.25kN/m$

$q_3 = 2.11kN/m^2 \cdot 3m = 6.33kN/m$

$q_2 = 2.34kN/m^2 \cdot 3m = 7.02kN/m$

$q_1 = 2.34kN/m^2 \cdot 3m = 7.02kN/m$



Veter (pritisk):

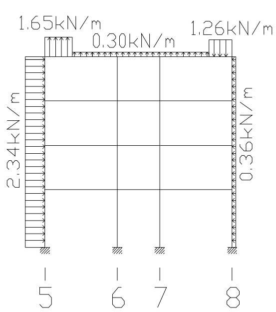
$W_D = 0 \cdot 3m = 0$

$W_F = 1.33kN/m^2 \cdot 3m = 3.99kN/m$

$W_H = 0.90kN/m^2 \cdot 3m = 2.70kN/m$

$W_I = 0.60kN/m^2 \cdot 3m = 1.80kN/m$

$W_E = 0.66kN/m^2 \cdot 3m = 1.98kN/m$



Veter (srk):

$W_D = 0.78kN/m^2 \cdot 3m = 2.34kN/m$

$W_F = 0.55kN/m^2 \cdot 3m = 1.65kN/m$

$W_H = 0.10kN/m^2 \cdot 3m = 0.3kN/m$

$W_I = – 0.42kN/m^2 \cdot 3m = – 1.26kN/m$

$W_E = – 0.12kN/m^2 \cdot 3m = – 0.36kN/m$

Sneg: $q_{sneg} = 1.24kN/m^2 \cdot 3m = 3.72kN/m$

3.3.1.3 Obtežne kombinacije

3.3.1.3.1 MSN

$$\sum_j \gamma_{G,j} G_{K,j} + \gamma_{Q,1} Q_{K,1} + \sum_{i \geq 1} \gamma_{Q,i} \psi_{0,i} Q_{K,i}$$

C1. $1.35G + 1.5Q + 1.5 \cdot 0.6S + 1.5 \cdot 0.6W$

C2. $1.35G + 1.5W + 1.5 \cdot 0.7Q + 1.5 \cdot 0.6S$

C3. $1.35G + 1.5S + 1.5 \cdot 0.7Q + 1.5 \cdot 0.6W$

C4. $1.0G + 1.5W$

C5. $1.35G + 1.5Q$(šahovnica1) $+ 1.5 \cdot 0.6S + 1.5 \cdot 0.6W$

C6. $1.35G + 1.5Q$(šahovnica2) $+ 1.5 \cdot 0.6S + 1.5 \cdot 0.6W$

3.3.1.3.2 MSU

$$\sum_j G_{K,j} + Q_{K,1} + \sum_{i \geq 1} \psi_{0,i} Q_{K,i}$$

C7. $G + 0.9(Q + S + W)$

C8. $G + W$

3.3.1.3.2.1 Kontrola horizontalnih pomikov

Večetažna zgradba: -posamezna etaža: $\delta_i \leq \delta_{max\ i} = \dfrac{h_i}{300}$

-celotna višina zgradbe: $\delta \leq \delta_{max} = \dfrac{H}{500}$

Okvir A	Okvir N
$\delta_1 = 0.0032m \leq \delta_{max\ 1} = 0.014m$	$\delta_1 = 0.0024m \leq \delta_{max\ 1} = 0.014m$
$\delta_2 = 0.0053m \leq \delta_{max\ 2} = 0.025m$	$\delta_2 = 0.0036m \leq \delta_{max\ 2} = 0.025m$
$\delta_3 = 0.0070m \leq \delta_{max\ 3} = 0.036m$	$\delta_3 = 0.0045m \leq \delta_{max\ 3} = 0.036m$
$\delta_4 = 0.0081m \leq \delta_{max\ 4} = 0.047m$	$\delta_4 = 0.0051m \leq \delta_{max} = 0.0235m$
$\delta_5 = 0.0088m \leq \delta_{max} = 0.029m$	

3.3.1.3.2.2 Kontrola vertikalnih pomikov

$\delta_{max} \leq \frac{L}{250}$

Zunanja prečka: Notranja prečka:

Okvir A

$\delta_{max} = 0.0055m \leq \frac{L}{250} = 0.024m$ $\delta_{max} = 0.0022m \leq \frac{L}{250} = 0.014m$

Okvir N

$\delta_{max} = 0.0063m \leq \frac{L}{250} = 0.024m$ $\delta_{max} = 0.0021m \leq \frac{L}{250} = 0.014m$

3.3.1.4 Začetna nepopolnost

Okvir A

$\Phi = k_C k_S \Phi_0$ $\Phi = 0.00278$

$\Phi_0 = \frac{1}{200}$

$k_C = \sqrt{\left(0.5 + \frac{1}{n_C}\right)} = \sqrt{\left(0.5 + \frac{1}{4}\right)} = 0.87 \leq 1.0$

$k_S = \sqrt{\left(0.2 + \frac{1}{n_S}\right)} = \sqrt{\left(0.2 + \frac{1}{5}\right)} = 0.64 \leq 1.0$

n_c...število stebrov etaže $n_c = 4$

n_s...število etaž $n_s = 5$

Okvir N

$\Phi = k_C k_S \Phi_0$ $\Phi = 0.00291$

$$\Phi_0 = \frac{1}{200}$$

$$k_C = \sqrt{\left(0.5 + \frac{1}{n_C}\right)} = \sqrt{\left(0.5 + \frac{1}{4}\right)} = 0.87 \leq 1.0$$

$$k_S = \sqrt{\left(0.2 + \frac{1}{n_S}\right)} = \sqrt{\left(0.2 + \frac{1}{4}\right)} = 0.67 \leq 1.0$$

n_c...število stebrov etaže $n_c = 4$

n_s...število etaž $n_s = 4$

3.3.1.5 Dimenzioniranje

Kontrola reakcij:

Σq_{Vi} ... račun reakcij glede na podane vertikalne obtežbe.

ΣV_i ... reakcije so dobljene s programom ESA Prima Win.

Okvir A

$\Sigma q_{Vi} = \Sigma V_i$ (ESA)

$\Sigma q_{Vi} = 1.35G + 1.5Q = 1.35 \cdot (41.1kN + 1104.4kN) + 1.5 \cdot (393.9kN)$

$\Sigma q_{Vi} = 2137.3kN$

$\Sigma V_i = 405.5kN + 659.8kN + 661.8kN + 410.3kN = 2137.4kN$

Okvir N

$\Sigma q_{Vi} = \Sigma V_i$ (ESA)

$\Sigma q_{Vi} = 1.35G + 1.5Q = 1.35 \cdot (58.2kN + 1130.11kN) + 1.5 \cdot (350.6kN)$

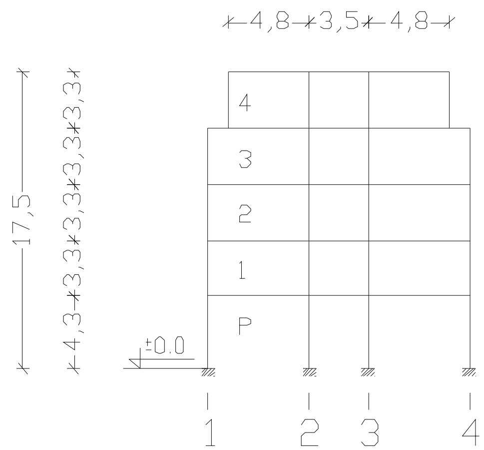
$\Sigma q_{Vi} = 2130.1kN$

$\Sigma V_i = 419.1kN + 646.6kN + 646.2kN + 418.3kN = 2130.2kN$

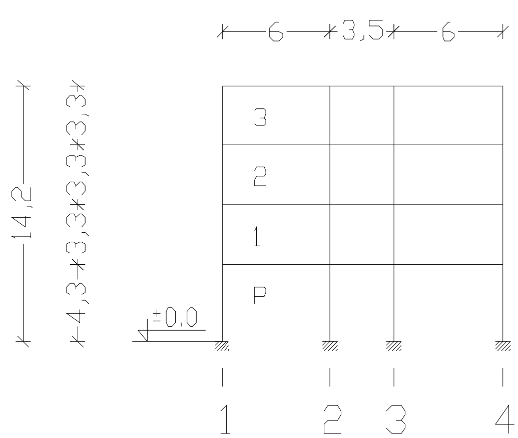
3.3.2 Notranji prečni okvir

3.3.2.1 Računski model

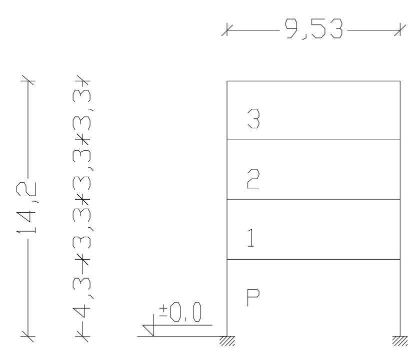
Okvir B, C, D, E, F, G, H



Okvir J, L, M

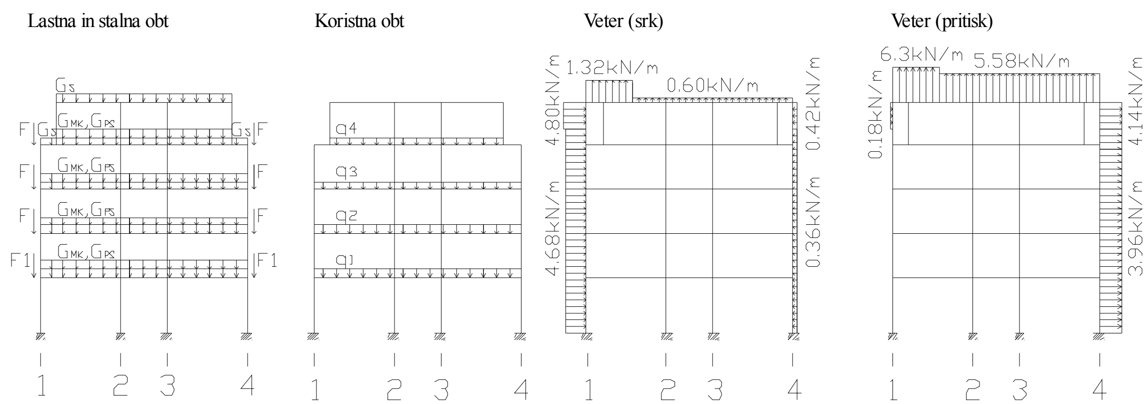


Okvir K



3.3.2.2 Obtežne sheme

Okvir B, C, D, E, F, G, H



Lastna in stalna obtežba:

$G_S = 0.5kN/m^2 \cdot 6m = 3.0kN/m$ $G_S = 5.14kN/m^2 \cdot 6m = 30.84kN/m$

$G_{MK} = 4.51kN/m^2 \cdot 6m = 27.06kN/m$

$G_{PS} = 0.8kN/m^2 \cdot 6m = 4.8kN/m$

$F = 0.5kN/m^2 \cdot 6m \cdot 3.3m = 9.9kN$ $F_1 = 0.5kN/m^2 \cdot 6m \cdot 3.8m = 11.4kN$

Koristna obtežba:

$q_4 = 1.99kN/m^2 \cdot 6m = 11.94kN/m$

$q_3 = 2.11kN/m^2 \cdot 6m = 12.66kN/m$

$q_2 = 2.34kN/m^2 \cdot 6m = 14.04kN/m$

$q_1 = 2.34kN/m^2 \cdot 6m = 14.04kN/m$

Sneg:

$q_{sneg} = 1.24kN/m^2 \cdot 6m = 7.44kN/m$

Veter (srk):

$W_{Dsp} = 0.78kN/m^2 \cdot 6m = 4.68kN/m$

$W_{Dzg} = 0.80kN/m^2 \cdot 6m = 4.80kN/m$

$W_G = 0.22kN/m^2 \cdot 6m = 1.32kN/m$

$W_H = 0.10kN/m^2 \cdot 6m = 0.60kN/m$

$W_{Esp} = -\,0.12kN/m^2 \cdot 6m = -\,0.72kN/m$

$W_{Ezg} = -\,0.14kN/m^2 \cdot 6m = -\,0.84kN/m$

Veter (pritisk):

$W_{Dsp} = 0 \cdot 6m = 0$

$W_{Dzg} = 0.03kN/m^2 \cdot 6m = 0.18kN/m$

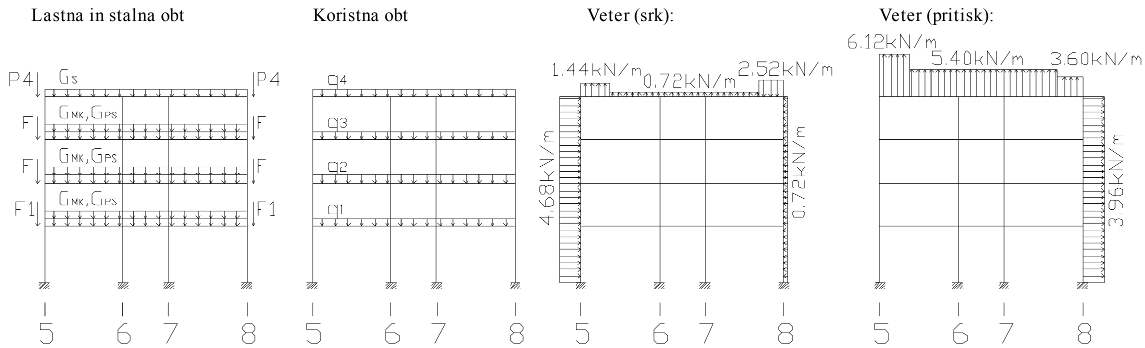
$W_G = 1.05kN/m^2 \cdot 6m = 6.30kN/m$

$W_H = 0.93kN/m^2 \cdot 6m = 5.58kN/m$

$W_{Esp} = 0.66kN/m^2 \cdot 6m = 3.96kN/m$

$W_{Ezg} = 0.69kN/m^2 \cdot 6m = 4.14kN/m$

Okvir M



Lastna in stalna obtežba:

$G_S = 5.14kN/m^2 \cdot 6m = 30.84kN/m$

$G_{MK} = 4.51kN/m^2 \cdot 6m = 27.06kN/m$

$G_{PS} = 0.8kN/m^2 \cdot 6m = 4.8kN/m$

$F = 0.5kN/m^2 \cdot 6m \cdot 3.3m = 9.9kN$ $F_1 = 0.5kN/m^2 \cdot 6m \cdot 3.8m = 11.4kN$

$P_4 = 25kN/m^3 \cdot 6m \cdot 0.9m \cdot 0.2m = 27.0kN$

Koristna obtežba:

$q_4 = 0.75kN/m^2 \cdot 6m = 4.5kN/m$

$q_3 = 2.11kN/m^2 \cdot 6m = 12.66kN/m$

$q_2 = 2.34kN/m^2 \cdot 6m = 14.04kN/m$

$q_1 = 2.34kN/m^2 \cdot 6m = 14.04kN/m$

Sneg:

$q_{sneg} = 1.24kN/m^2 \cdot 6m = 7.44kN/m$

Veter (srk):

$W_D = 0.78kN/m^2 \cdot 6m = 4.68kN/m$

$W_G = 0.24kN/m^2 \cdot 6m = 1.44kN/m$

$W_H = 0.12kN/m^2 \cdot 6m = 0.72kN/m$

$W_I = -0.42kN/m^2 \cdot 6m = -2.52kN/m$

$W_E = -0.12kN/m^2 \cdot 6m = -0.72kN/m$

Veter (pritisk):

$W_D = 0 \cdot 6m = 0$

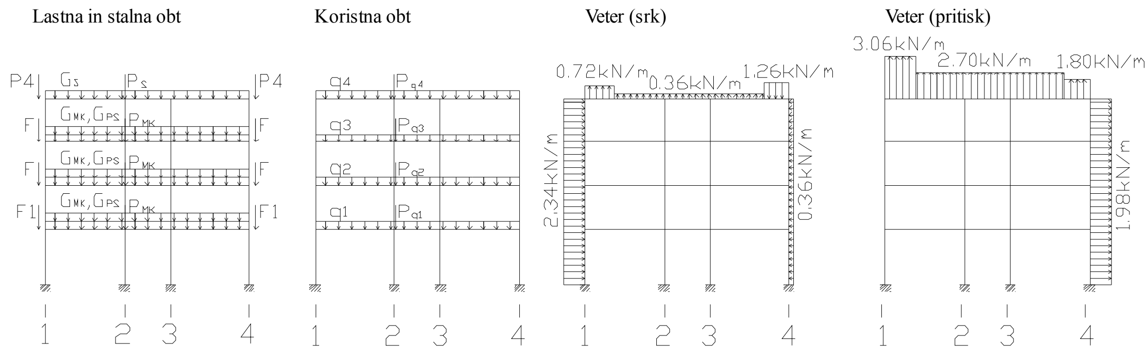
$W_G = 1.02kN/m^2 \cdot 6m = 6.12kN/m$

$W_H = 0.90kN/m^2 \cdot 6m = 5.40kN/m$

$W_I = 0.60kN/m^2 \cdot 6m = 3.60kN/m$

$W_E = 0.66kN/m^2 \cdot 6m = 3.96kN/m$

Okvir J



Lastna in stalna obtežba:

$G_S = 5.14kN/m^2 \cdot 3m = 15.42kN/m$ $\quad$ $P_S = G_{Z(S)} = 45.5kN$

$G_{MK} = 4.51kN/m^2 \cdot 3m = 13.53kN/m$ $\quad$ $P_{MK} = G_{Z(MK)} = 39.9kN$

$G_{PS} = 0.8kN/m^2 \cdot 3m = 2.4kN/m$

$G_{P4} = 25kN/m^3 \cdot 0.9m \cdot 0.2m = 4.5kN/m$ $\quad$ $P_4 = 25kN/m^3 \cdot 3m \cdot 0.9m \cdot 0.2m = 13.5kN$

$G_F = 0.5kN/m^2 \cdot 3.3m = 1.65kN/m$

$F = 0.5kN/m^2 \cdot 3m \cdot 3.3m = 4.95kN$ $\quad$ $F_1 = 0.5kN/m^2 \cdot 3m \cdot 3.8m = 5.7kN$

Koristna obtežba:

$q_4 = 0.75kN/m^2 \cdot 3m = 2.25kN/m$ $\quad$ $P_{q4} = Q_{Z4} = 6.6kN$

$q_3 = 2.11kN/m^2 \cdot 3m = 6.33kN/m$ $\quad$ $P_{q3} = Q_{Z3} = 18.7kN$

$q_2 = 2.34kN/m^2 \cdot 3m = 7.02kN/m$ $\quad$ $P_{q2} = Q_{Z2} = 20.7kN$

$q_1 = 2.34kN/m^2 \cdot 3m = 7.02kN/m$ $\quad$ $P_{q1} = Q_{Z1} = 20.7kN$

Sneg:

$q_{sneg} = 1.24kN/m^2 \cdot 3m = 3.72kN/m$ $\quad$ $S_Z = 10.9kN$

Veter (srk):

$W_D = 0.78kN/m^2 \cdot 3m = 2.34kN/m$

$W_G = 0.24kN/m^2 \cdot 3m = 0.72kN/m$

$W_H = 0.12kN/m^2 \cdot 3m = 0.36kN/m$

$W_I = -0.42kN/m^2 \cdot 3m = -1.26kN/m$

$W_E = -0.12kN/m^2 \cdot 3m = -0.36kN/m$

Veter (pritisk):

$W_D = 0 \cdot 3m = 0$

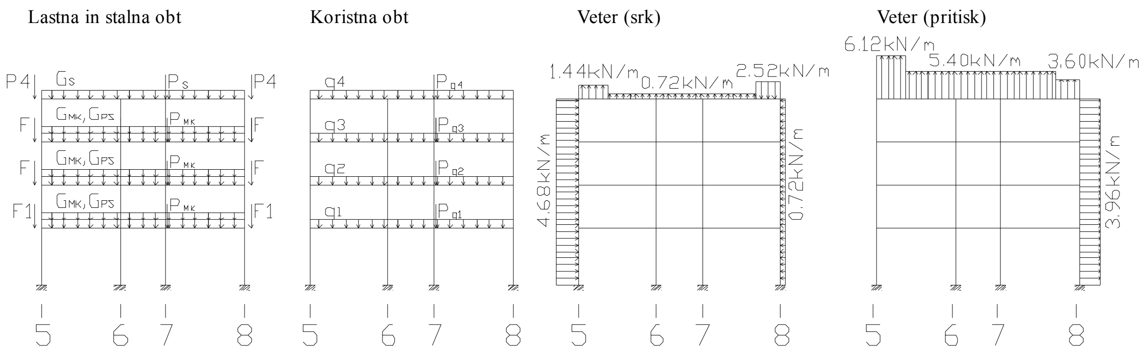
$W_G = 1.02kN/m^2 \cdot 3m = 3.06kN/m$

$W_H = 0.90kN/m^2 \cdot 3m = 2.70kN/m$

$W_I = 0.60kN/m^2 \cdot 3m = 1.80kN/m$

$W_E = 0.66kN/m^2 \cdot 3m = 1.98kN/m$

Okvir L



Lastna in stalna obtežba:

$G_S = 5.14kN/m^2 \cdot 6m = 30.84kN/m$ $P_S = G_{Z(S)} = 45.5kN$

$G_{MK} = 4.51kN/m^2 \cdot 6m = 27.06kN/m$ $P_{MK} = G_{Z(MK)} = 39.9kN$

$G_{PS} = 0.8kN/m^2 \cdot 6m = 4.8kN/m$

$F = 0.5kN/m^2 \cdot 6m \cdot 3.3m = 9.9kN$ $F_1 = 0.5kN/m^2 \cdot 6m \cdot 3.8m = 11.4kN$

$P_4 = 25kN/m^3 \cdot 6m \cdot 0.9m \cdot 0.2m = 27.0kN$

Koristna obtežba:

$q_4 = 0.75kN/m^2 \cdot 6m = 4.5kN/m$ $P_{q4} = Q_{Z4} = 6.6kN$

$q_3 = 2.11kN/m^2 \cdot 6m = 12.66kN/m$ $P_{q3} = Q_{Z3} = 18.7kN$

$q_2 = 2.34kN/m^2 \cdot 6m = 14.04kN/m$ $P_{q2} = Q_{Z2} = 20.7kN$

$q_1 = 2.34kN/m^2 \cdot 6m = 14.04kN/m$ $P_{q1} = Q_{Z1} = 20.7kN$

Sneg:

$q_{sneg} = 1.24kN/m^2 \cdot 6m = 7.44kN/m$ $S_Z = 10.9kN$

Veter (srk):

$W_D = 0.78kN/m^2 \cdot 6m = 4.68kN/m$

$W_G = 0.24kN/m^2 \cdot 6m = 1.44kN/m$

$W_H = 0.12kN/m^2 \cdot 6m = 0.72kN/m$

$W_I = -0.42kN/m^2 \cdot 6m = -2.52kN/m$

$W_E = -0.12kN/m^2 \cdot 6m = -0.72kN/m$

Veter (pritisk):

$W_D = 0 \cdot 6m = 0$

$W_G = 1.02kN/m^2 \cdot 6m = 6.12kN/m$

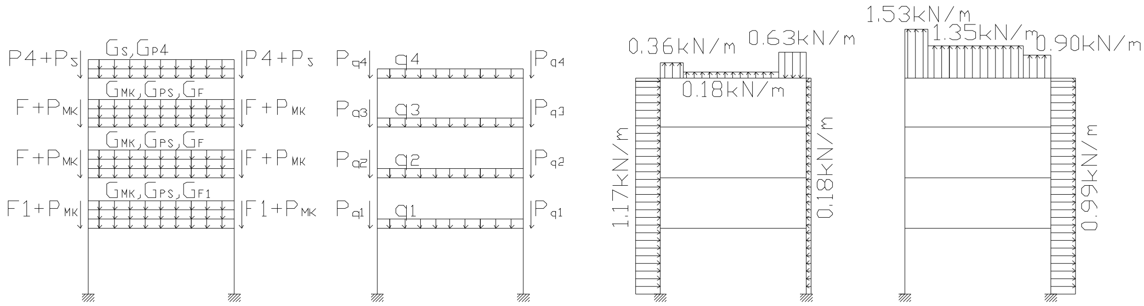
$W_H = 0.90kN/m^2 \cdot 6m = 5.40kN/m$

$W_I = 0.60kN/m^2 \cdot 6m = 3.60kN/m$

$W_E = 0.66kN/m^2 \cdot 6m = 3.96kN/m$

Okvir K

Lastna in stalna obt | Koristna obt | Veter (srk) | Veter (pritisk)



Lastna in stalna obtežba:

$G_S = 5.14kN/m^2 \cdot 1.5m = 7.71kN/m$ $P_S = G_{Z(S)} = 151.1kN$

$G_{MK} = 4.51kN/m^2 \cdot 1.5m = 6.77kN/m$ $P_{MK} = G_{Z(MK)} = 136.1kN$

$G_{PS} = 0.8kN/m^2 \cdot 1.5m = 1.2kN/m$

$G_{P4} = 25kN/m^3 \cdot 0.9m \cdot 0.2m = 4.5kN/m$ $P_4 = 25kN/m^3 \cdot 1.5m \cdot 0.9m \cdot 0.2m = 6.75kN$

$G_F = 0.5kN/m^2 \cdot 3.3m = 1.65kN/m$

$F = 0.5kN/m^2 \cdot 1.5m \cdot 3.3m = 2.48kN$ $F_1 = 0.5kN/m^2 \cdot 1.5m \cdot 3.8m = 2.85kN$

Koristna obtežba:

$q_4 = 0.75kN/m^2 \cdot 1.5m = 1.30kN/m$ $P_{q4} = Q_{Z4D} = 22.1kN$

$q_3 = 2.11kN/m^2 \cdot 1.5m = 3.17kN/m$ $P_{q3} = Q_{Z3D} = 62.0kN$

$q_2 = 2.34kN/m^2 \cdot 1.5m = 3.51kN/m$ $P_{q2} = Q_{Z2D} = 68.8kN$

$q_1 = 2.34kN/m^2 \cdot 1.5m = 3.51kN/m$ $P_{q1} = Q_{Z1D} = 68.8kN$

Sneg:

$q_{sneg} = 1.24kN/m^2 \cdot 1.5m = 1.86kN/m$ $S_Z = 37.2kN$

Veter (srk):

$W_D = 0.78kN/m^2 \cdot 1.5m = 1.17kN/m$

$W_G = 0.24kN/m^2 \cdot 1.5m = 0.36kN/m$

$W_H = 0.12kN/m^2 \cdot 1.5m = 0.18kN/m$

$W_I = -0.42kN/m^2 \cdot 1.5m = -0.63kN/m$

$W_E = -0.12kN/m^2 \cdot 1.5m = -0.18kN/m$

Veter (pritisk):

$W_D = 0 \cdot 3m = 0$

$W_G = 1.02kN/m^2 \cdot 1.5m = 1.53kN/m$

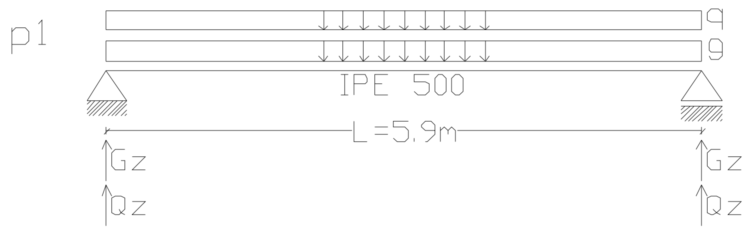
$W_H = 0.90kN/m^2 \cdot 1.5m = 1.35kN/m$

$W_I = 0.60kN/m^2 \cdot 1.5m = 0.90kN/m$

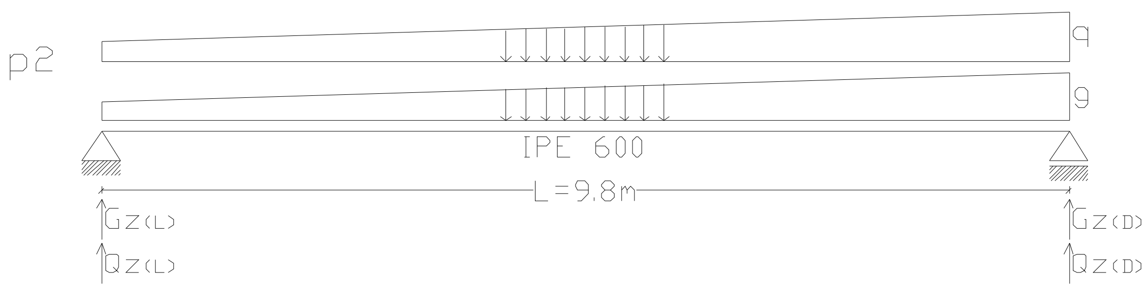
$W_E = 0.66kN/m^2 \cdot 1.5m = 0.99kN/m$

Prečki p1 in p2

Reakcije smo dobili s pomočjo programa ESA-Prima Win.



Stalna obtežba:	Koristna obtežba:	Sneg:
$G_{Z(S)} = 45.5kN$	$Q_{Z1} = Q_{Z2} = 20.7kN$	$S = 10.9kN$
$G_{Z(MK)} = 39.9kN$	$Q_{Z3} = 18.7kN$	
	$Q_{Z4} = 6.6kN$	



Stalna obtežba:

$G_{Z(S)L} = 113.3kN$ $G_{Z(S)D} = 151.1kN$

$G_{Z(MK)L} = 99.5kN$ $G_{Z(MK)D} = 136.1kN$

Koristna obtežba:

$Q_{Z1L} = Q_{Z2L} = 51.6kN$ $Q_{Z1D} = Q_{Z2D} = 68.8kN$

$Q_{Z3L} = 46.5kN$ $Q_{Z3D} = 62.0kN$

$Q_{Z4L} = 16.5kN$ $Q_{Z4D} = 22.1kN$

Sneg:

$S_L = 27.7kN$ $S_D = 37.2kN$

3.3.2.3 Obtežne kombinacije

3.3.2.3.1 MSN

$$\sum_{j}\gamma_{G,j}G_{K,j}+\gamma_{Q,1}Q_{K,1}+\sum_{i\geq 1}\gamma_{Q,i}\psi_{0,i}Q_{K,i}$$

C1. $1.35G + 1.5Q + 1.5 \cdot 0.6S + 1.5 \cdot 0.6W$

C2. $1.35G + 1.5W + 1.5 \cdot 0.7Q + 1.5 \cdot 0.6S$

C3. $1.35G + 1.5S + 1.5 \cdot 0.7Q + 1.5 \cdot 0.6W$

C4. $1.0G + 1.5W$

C5. $1.35G + 1.5Q$(šahovnica1) $+ 1.5 \cdot 0.6S + 1.5 \cdot 0.6W$

C6. $1.35G + 1.5Q$(šahovnica2) $+ 1.5 \cdot 0.6S + 1.5 \cdot 0.6W$

3.3.2.3.2 MSU

$$\sum_{j}G_{K,j}+Q_{K,1}+\sum_{i\geq 1}\psi_{0,i}Q_{K,i}$$

C7. $G + 0.9(Q + S + W)$

C8. $G + W$

3.3.2.3.2.1 Kontrola horizontalnih pomikov

Večetažna zgradba: -posamezna etaža: $\delta \leq \delta_{max\ i} = \frac{h}{300}$

-celotna višina zgradbe: $\delta \leq \delta_{max} = \frac{H}{500}$

Okvir B, C, D, E, F, G, H

$\delta_1 = 0.0032m \leq \delta_{max\ 1} = 0.014m$

$\delta_2 = 0.0062m \leq \delta_{max\ 2} = 0.025m$

$\delta_3 = 0.0086m \leq \delta_{max\ 3} = 0.036m$

$\delta_4 = 0.0102m \leq \delta_{max\ 4} = 0.047m$

$\delta_5 = 0.0112m \leq \delta_{max} = 0.029m$

Okvir M

$\delta_1 = 0.0025m \leq \delta_{max\ 1} = 0.014m$

$\delta_2 = 0.0046m \leq \delta_{max\ 2} = 0.025m$

$\delta_3 = 0.0062m \leq \delta_{max\ 3} = 0.036m$

$\delta_4 = 0.0071m \leq \delta_{max} = 0.0235m$

Okvir J

$\delta_1 = 0.0013m \leq \delta_{max\ 1} = 0.014m$

$\delta_2 = 0.0023m \leq \delta_{max\ 2} = 0.025m$

$\delta_3 = 0.0031m \leq \delta_{max\ 3} = 0.036m$

$\delta_4 = 0.0035m \leq \delta_{max} = 0.0235m$

Okvir K

$\delta_1 = 0.0009m \leq \delta_{max\ 1} = 0.014m$

$\delta_2 = 0.0016m \leq \delta_{max\ 2} = 0.025m$

$\delta_3 = 0.0023m \leq \delta_{max\ 3} = 0.036m$

$\delta_4 = 0.0028m \leq \delta_{max} = 0.0235m$

Okvir L

$\delta_1 = 0.0025m \leq \delta_{max\ 1} = 0.014m$

$\delta_2 = 0.0047m \leq \delta_{max\ 2} = 0.025m$

$\delta_3 = 0.0063m \leq \delta_{max\ 3} = 0.036m$

$\delta_4 = 0.0073m \leq \delta_{max} = 0.0235m$

3.3.2.3.2.2 Kontrola vertikalnih pomikov

Zunanja prečka:

Okvir B, C, D, E, F, G, H

$$\delta_{max} = 0.0109m \leq \frac{L}{250} = 0.024m$$

Okvir M

$$\delta_{max} = 0.0079m \leq \frac{L}{250} = 0.024m$$

Okvir J

$$\delta_{max} = 0.0042m \leq \frac{L}{250} = 0.024m$$

Okvir L

$$\delta_{max} = 0.0080m \leq \frac{L}{250} = 0.024m$$

Okvir K

$$\delta_{max} = 0.0111m \leq \frac{L}{250} = 0.024m$$

Notranja prečka:

Okvir B, C, D, E, F, G, H

$$\delta_{max} = 0.0048m \leq \frac{L}{250} = 0.014m$$

Okvir M

$$\delta_{max} = 0.0031m \leq \frac{L}{250} = 0.014m$$

Okvir J

$$\delta_{max} = 0.0019m \leq \frac{L}{250} = 0.014m$$

Okvir L

$$\delta_{max} = 0.0034m \leq \frac{L}{250} = 0.014m$$

3.3.2.4 Začetna nepopolnost

Okvir B, C, D, E, F, G, H

$$\Phi = k_C k_S \Phi_0 \qquad \Phi = 0.00278$$

$$\Phi_0 = \frac{1}{200}$$

$$k_C = \sqrt{\left(0.5 + \frac{1}{n_C}\right)} = \sqrt{\left(0.5 + \frac{1}{4}\right)} = 0.87 \leq 1.0$$

$$k_S = \sqrt{\left(0.2 + \frac{1}{n_S}\right)} = \sqrt{\left(0.2 + \frac{1}{5}\right)} = 0.64 \leq 1.0$$

n_c...število stebrov etaže $n_c = 4$

n_s...število etaž $n_s = 5$

Okvir J, L, M

$\Phi = k_C k_S \varphi_0$ $\Phi = 0.00291$

$$\Phi_0 = \frac{1}{200}$$

$$k_C = \sqrt{\left(0.5 + \frac{1}{n_C}\right)} = \sqrt{\left(0.5 + \frac{1}{4}\right)} = 0.87 \leq 1.0$$

$$k_S = \sqrt{\left(0.2 + \frac{1}{n_S}\right)} = \sqrt{\left(0.2 + \frac{1}{4}\right)} = 0.67 \leq 1.0$$

n_c...število stebrov etaže $n_c = 4$

n_s...število etaž $n_s = 4$

Okvir K

$\Phi = k_C k_S \varphi_0$ $\Phi = 0.00335$

$$\Phi_0 = \frac{1}{200}$$

$$k_C = \sqrt{\left(0.5 + \frac{1}{n_C}\right)} = \sqrt{\left(0.5 + \frac{1}{2}\right)} = 1.0 \leq 1.0$$

$$k_S = \sqrt{\left(0.2 + \frac{1}{n_S}\right)} = \sqrt{\left(0.2 + \frac{1}{4}\right)} = 0.67 \leq 1.0$$

n_c...število stebrov etaže $n_c = 2$

n_s...število etaž $n_s = 4$

3.3.2.5 Dimenzioniranje

Kontrola reakcij:

Okvir B, C, D, E, F, G, H

$\Sigma q_{Vi} = \Sigma V_i$ (ESA)

$\Sigma q_{Vi} = 1.35G + 1.5Q = 1.35 \cdot (82.2kN + 2012.17kN) + 1.5 \cdot (787.88kN)$

$\Sigma q_{Vi} = 4009.2kN$

$\Sigma V_i = 793.4kN + 1205.5kN + 1208.6kN + 801.7kN = 4009.2kN$

Okvir M

$\Sigma q_{Vi} = \Sigma V_i$ (ESA)

$\Sigma q_{Vi} = 1.35G + 1.5Q = 1.35 \cdot (116.4kN + 1959.51kN) + 1.5 \cdot (701.22kN)$

$\Sigma q_{Vi} = 3854.4kN$

$\Sigma V_i = 777.6kN + 1143.9kN + 1147.2kN + 785.6kN = 3854.3kN$

Okvir J

$\Sigma q_{Vi} = \Sigma V_i$ (ESA)

$\Sigma q_{Vi} = 1.35G + 1.5Q = 1.35 \cdot (258.9kN + 979.76kN) + 1.5 \cdot (350.61kN + 66.7kN)$

$\Sigma q_{Vi} = 2298.16kN$

$\Sigma V_i = 393.4kN + 927.8kN + 584.6kN + 392.3kN = 2298.1kN$

Okvir L

$\Sigma q_{Vi} = \Sigma V_i$ (ESA)

$\Sigma q_{Vi} = 1.35G + 1.5Q = 1.35 \cdot (317.1kN + 1959.51kN) + 1.5 \cdot (701.22kN + 66.7kN)$

$\Sigma q_{Vi} = 4225.3kN$

$\Sigma V_i = 776.4kN + 1154.5kN + 1503.4kN + 790.9kN = 4225.2kN$

Okvir K

$\Sigma q_{Vi} = \Sigma V_i$ (ESA)

$\Sigma q_{Vi} = 1.35G + 1.5Q = 1.35 \cdot (377.1kN + 1387.9kN) + 1.5 \cdot (109.5kN + 443.4kN)$

$\Sigma q_{Vi} = 3212.1kN$

$\Sigma V_i = 1607.1kN + 1605.0kN = 3212.1kN$

4 DINAMIČNA ANALIZA (OSIST ENV 1998-1-1)

Objekt stoji v VII. potresni coni. Temeljna tla so tipa B ($T_C = 0.5$, $T_D = 2.0$). Pri nelinearnemu izračunu dinamične analize smo uporabili metodo Newton-Raphson. Pri določevanju notranjih sil smo upoštevali vpliv teorije drugega reda.

4.1 Dinamična analiza v prečni smeri (Okvir A)

4.1.1 Izračun nihajnega časa

$$T_1 = c_t H^{\frac{3}{4}}$$

$$c_t = 0.085$$

$$T_1 = 0.085 \cdot 17.5^{\frac{3}{4}} = 0.73\text{s}$$

$$T_1(\text{ESA}) = \frac{1}{\nu} = \frac{1}{1.390\text{s}^{-1}} = 0.72\text{s}$$

4.1.2 Določitev potresnih sil

$T_C \leq T \leq T_D$: $$S_d(T) = a_g S \frac{2.5}{q}\left[\frac{T_C}{T}\right] \geq 0.20 a_g$$

S_d … ordinata računskega spectra odziva, normirana s pospeškom prostega pada

$$S_d(T) = 0.15 \cdot 9.81 \cdot 1.0 \cdot \frac{2.5}{6}\left[\frac{0.5}{0.72}\right] = 0.426\text{m/s}^2 \geq 0.245\text{m/s}^2$$

Določitev mas po posameznih etažah:

$\sum_j G_{k,j} + \sum_i \psi_{E,i} Q_{k,i}$ $\varphi = 1.0$...za zadnjo etažo

$\psi_{E,i} = \varphi \cdot \psi_{2,i}$ $\varphi = 0.5$...za ostale etaže

$\psi_{2,i} = 0.3$...za pisarne

$m_1 = G_{jek.\ nosilci} + G_{beton} + 0.15Q = 2742.7\text{kg} + 27776.7\text{kg} + 0.15 \cdot 8532.1\text{kg} = 32183.2\text{kg}$

$m_2 = G_{jek.\ nosilci} + G_{beton} + 0.15Q = 2534.8\text{kg} + 27776.7\text{kg} + 0.15 \cdot 8532.1\text{kg} = 31975.3\text{kg}$

$m_3 = G_{jek.\ nosilci} + G_{beton} + 0.15Q = 2534.8\text{kg} + 27776.7\text{kg} + 0.15 \cdot 7678.9\text{kg} = 31811.7\text{kg}$

$m_4 = G_{jek.\ nosilci} + G_{beton} + 0.15Q = 2534.8\text{kg} + 27248.3\text{kg} + 0.15 \cdot 6129.4\text{kg} = 30978.9\text{kg}$

$m_5 = G_{jek.\ nosilci} + G_{beton} + 0.3Q = 1554.5\text{kg} + 2003\text{kg} + 0 = 3557.5\text{kg}$

$m_{skupaj} = 130506.6kg$

$F_b = S_d(T) \cdot m \cdot \lambda = 0.426m/s^2 \cdot 130506.6kg \cdot 1.0 = 55.61kN$

$$F_1^{'} = F_b \cdot \frac{s_1 m_1}{\sum\limits_{i=1-5} s_i m_i} = 55.61kN \cdot \frac{4.3m \cdot 32183.2kg}{4.3m \cdot 32183.2kg + ... + 3.3m \cdot 3557.5kg} = 16.63kN$$

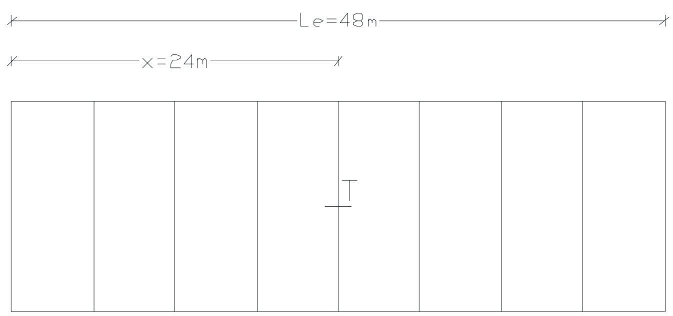
$$F_2^{'} = F_b \cdot \frac{s_2 m_2}{\sum\limits_{i=1-5} s_i m_i} = 55.61kN \cdot \frac{3.3m \cdot 31975.3kg}{4.3m \cdot 32183.2kg + ... + 3.3m \cdot 3557.5kg} = 12.68kN$$

$$F_3^{'} = F_b \cdot \frac{s_3 m_3}{\sum\limits_{i=1-5} s_i m_i} = 55.61kN \cdot \frac{3.3m \cdot 31811.7kg}{4.3m \cdot 32183.2kg + ... + 3.3m \cdot 3557.5kg} = 12.61kN$$

$$F_4^{'} = F_b \cdot \frac{s_4 m_4}{\sum\limits_{i=1-5} s_i m_i} = 55.61kN \cdot \frac{3.3m \cdot 30978.9kg}{4.3m \cdot 32183.2kg + ... + 3.3m \cdot 3557.5kg} = 12.28kN$$

$$F_5^{'} = F_b \cdot \frac{s_5 m_5}{\sum\limits_{i=1-5} s_i m_i} = 53.08kN \cdot \frac{3.3m \cdot 3557.5kg}{4.3m \cdot 32183.2kg + ... + 3.3m \cdot 3557.5kg} = 1.41kN$$

Torzijski učinek:



$\delta = 1 + 0.6 \cdot x / L_e = 1 + 0.6 \cdot 24m / 48m = 1.3$

$$F_1 = \delta \cdot F_1^{'} = 1.3 \cdot 16.63kN = 21.62kN$$

$$F_2 = \delta \cdot F_2^{'} = 1.3 \cdot 12.68kN = 16.48kN$$

$$F_3 = \delta \cdot F_3^{'} = 1.3 \cdot 12.61kN = 16.40kN$$

$$F_4 = \delta \cdot F_4^{'} = 1.3 \cdot 12.28kN = 15.97kN$$

$$F_5 = \delta \cdot F_5^{'} = 1.3 \cdot 1.41kN = 1.83kN$$

4.1.3 Potresna obtežna kombinacija

$$\sum G_{k,j} + \gamma_I A_{Ed} + \sum \psi_{2,i} Q_{k,i} = 1.0G + 1.0A_{Ed} + 0.15Q$$

4.1.4 Kontrola pomikov

$d_r \cdot \nu \leq 0.0075 \cdot h$

$\nu = 0.5$

$d_r = (u_i - u_{i-1}) \cdot q$ i…število etaž

$q = 6$ q...redukcijski faktor disipacije energije

$d_{r1} = (u_1 - 0) \cdot q = (6.2mm) \cdot 6 = 37.2mm$

$d_{r2} = (u_2 - u_1) \cdot q = (10.6mm - 6.2mm) \cdot 6 = 26.4mm$

$d_{r3} = (u_3 - u_2) \cdot q = (13.5mm - 10.6mm) \cdot 6 = 17.4mm$

$d_{r4} = (u_4 - u_3) \cdot q = (15.1mm - 13.5mm) \cdot 6 = 9.6mm$

$d_{r5} = (u_5 - u_4) \cdot q = (15.6mm - 15.1mm) \cdot 6 = 3.2mm$

$d_{r1} \cdot \nu = 37.2mm \cdot 0.5 = 18.6mm \leq 0.0075 \cdot h = 0.0075 \cdot 4300mm = 32.25mm$

$d_{r2} \cdot \nu = 26.4mm \cdot 0.5 = 13.2mm \leq 0.0075 \cdot h = 0.0075 \cdot 3300mm = 24.75mm$

$d_{r3} \cdot \nu = 17.4mm \cdot 0.5 = 8.7mm \leq 0.0075 \cdot h = 0.0075 \cdot 3300mm = 24.75mm$

$d_{r4} \cdot \nu = 9.6mm \cdot 0.5 = 4.8mm \leq 0.0075 \cdot h = 0.0075 \cdot 3300mm = 24.75mm$

$d_{r5} \cdot \nu = 3.0mm \cdot 0.5 = 1.5mm \leq 0.0075 \cdot h = 0.0075 \cdot 3300mm = 24.75mm$

4.1.5 Vpliv teorije II. reda

$$\boxed{\theta_i = \frac{P_{TOTi} \cdot d_{ri}}{V_{TOTi} \cdot h_i} \leq 0.1}$$

V primeru, da ne moremo zanemariti povečanja upogibnih momentov zaradi horizontalnih pomikov vozlišč, okvir razvrstimo med pomične okvirje. Za nepomične štejemo okvirje, pri katerih velja $\theta \leq 0.1$. V našem primeru imamo pomičen okvir, ki ga moramo dimenzionirati po teoriji drugega reda ob upoštevanju začetnih geometrijskih nepopolnosti.

Potresne sile so izračunane po teoriji prvega reda. Vpliv teorije drugega reda upoštevamo tako, da notranje sile povečamo s faktorjem $k_\delta = (1 - \theta)$. Metodo lahko uporabljamo vse dokler velja razmerje $\theta \leq 0.25$.

$$\theta_1 = \frac{P_{TOT1} \cdot d_{r1}}{V_{TOT1} \cdot h_1} = \frac{1377kN \cdot 37.2mm}{72.3kN \cdot 4300mm} = 0.164 > 0.1 \qquad k_\delta = \frac{1}{1-\theta} = \frac{1}{1-0.164} = 1.196$$

$$\theta_2 = \frac{P_{TOT2} \cdot d_{r2}}{V_{TOT2} \cdot h_2} = \frac{1034kN \cdot 26.4mm}{50.7kN \cdot 3300mm} = 0.163 > 0.1 \qquad k_\delta = \frac{1}{1-\theta} = \frac{1}{1-0.163} = 1.195$$

$$\theta_3 = \frac{P_{TOT3} \cdot d_{r3}}{V_{TOT3} \cdot h_3} = \frac{692.6kN \cdot 17.4mm}{34.3kN \cdot 3300mm} = 0.107 > 0.1 \qquad k_\delta = \frac{1}{1-\theta} = \frac{1}{1-0.107} = 1.120$$

$$\theta_4 = \frac{P_{TOT4} \cdot d_{r4}}{V_{TOT4} \cdot h_4} = \frac{352.4kN \cdot 9.6mm}{17.9kN \cdot 3300mm} = 0.0573 \leq 0.1$$

$$\theta_5 = \frac{P_{TOT5} \cdot d_{r5}}{V_{TOT5} \cdot h_5} = \frac{19.8kN \cdot 3.0mm}{1.83kN \cdot 3300mm} = 0.0098 \leq 0.1$$

4.2 Dinamična analiza v prečni smeri (Okvir N)

4.2.1 Izračun nihajnega časa

$$T_1 = c_t H^{\frac{3}{4}}$$

$$T_1 = 0.085 \cdot 14.2^{\frac{3}{4}} = 0.62s$$

$$T_1(ESA) = \frac{1}{\nu} = \frac{1}{1.447s^{-1}} = 0.69s$$

4.2.2 Določitev potresnih sil

$T_C \leq T \leq T_D$: $$S_d(T) = a_g S \frac{2.5}{q}\left[\frac{T_C}{T}\right] \geq 0.20 a_g$$

$$S_d(T) = 0.15 \cdot 9.81 \cdot 1.0 \cdot \frac{2.5}{6}\left[\frac{0.5}{0.69}\right] = 0.444 m/s^2 \geq 0.245 m/s^2$$

Določitev mas po posameznih etažah:

$m_1 = G_{jek.\ nosilci} + G_{beton} + 0.15Q = 2742.7kg + 27776.7kg + 0.15 \cdot 8532.1kg = 32183.2kg$

$m_2 = G_{jek.\ nosilci} + G_{beton} + 0.15Q = 2534.8kg + 27776.7kg + 0.15 \cdot 8532.1kg = 31975.3kg$

$m_3 = G_{jek.\ nosilci} + G_{beton} + 0.15Q = 2534.8kg + 27776.7kg + 0.15 \cdot 7678.9kg = 31811.7kg$

$m_4 = G_{jek.\ nosilci} + G_{beton} + 0.3Q = 1848.9kg + 27248.3kg + 0.3 \cdot 6129.4kg = 27626.9kg$

$m_{skupaj} = 123597.1kg$

$F_b = S_d(T) \cdot m \cdot \lambda = 0.444 m/s^2 \cdot 123597.1 kg \cdot 1.0 = 54.83 kN$

$$F_1' = F_b \cdot \frac{s_1 m_1}{\sum\limits_{i=1-4} s_i m_i} = 54.83kN \cdot \frac{4.3m \cdot 32183.2kg}{4.3m \cdot 32183.2kg + ... + 3.3m \cdot 27626.9kg} = 17.24kN$$

$$F_2' = F_b \cdot \frac{s_2 m_2}{\sum\limits_{i=1-4} s_i m_i} = 54.83kN \cdot \frac{3.3m \cdot 31975.3kg}{4.3m \cdot 32183.2kg + ... + 3.3m \cdot 27626.9kg} = 13.15kN$$

$$F_3' = F_b \cdot \frac{s_3 m_3}{\sum\limits_{i=1-4} s_i m_i} = 54.83kN \cdot \frac{3.3m \cdot 31811.7kg}{4.3m \cdot 32183.2kg + ... + 3.3m \cdot 27626.9kg} = 13.08kN$$

$$F_4' = F_b \cdot \frac{s_4 m_4}{\sum\limits_{i=1-4} s_i m_i} = 52.70kN \cdot \frac{3.3m \cdot 27626.9kg}{4.3m \cdot 32183.2kg + ... + 3.3m \cdot 27626.9kg} = 11.36kN$$

Torzijski učinek:

$\delta = 1 + 0.6 \cdot x / L_e = 1 + 0.6 \cdot 12m / 24m = 1.3$

$$F_1 = \delta \cdot F_1' = 1.3 \cdot 17.24kN = 22.41kN$$

$$F_2 = \delta \cdot F_2' = 1.3 \cdot 13.15kN = 17.09kN$$

$$F_3 = \delta \cdot F_3' = 1.3 \cdot 13.08kN = 17.00kN$$

$$F_4 = \delta \cdot F_4' = 1.3 \cdot 11.36kN = 14.77kN$$

4.2.3 Potresna obtežna kombinacija

$$\sum G_{k,j} + \gamma_I A_{Ed} + \sum \psi_{2,i} Q_{k,i} = 1.0G + 1.0A_{Ed} + 0.15Q$$

4.2.4 Kontrola pomikov

$d_r \cdot \nu \leq 0.0075 \cdot h$

$\nu = 0.5$

$d_r = (u_i - u_{i-1}) \cdot q$

$q = 6$

$d_{r1} = (u_1 - 0) \cdot q = (6.1mm) \cdot 6 = 36.6mm$

$d_{r2} = (u_2 - u_1) \cdot q = (10.3mm - 6.1mm) \cdot 6 = 25.2mm$

$d_{r3} = (u_3 - u_2) \cdot q = (13.1mm - 10.3mm) \cdot 6 = 16.8mm$

$d_{r4} = (u_4 - u_3) \cdot q = (14.5mm - 13.1mm) \cdot 6 = 8.4mm$

$d_{r1} \cdot \nu = 36.6mm \cdot 0.5 = 18.3mm \leq 0.0075 \cdot h = 0.0075 \cdot 4300mm = 32.25mm$

$d_{r2} \cdot \nu = 25.2mm \cdot 0.5 = 12.6mm \leq 0.0075 \cdot h = 0.0075 \cdot 3300mm = 24.75mm$

$d_{r3} \cdot \nu = 16.8mm \cdot 0.5 = 8.4mm \leq 0.0075 \cdot h = 0.0075 \cdot 3300mm = 24.75mm$

$d_{r4} \cdot \nu = 8.4mm \cdot 0.5 = 4.2mm \leq 0.0075 \cdot h = 0.0075 \cdot 3300mm = 24.75mm$

4.2.5 Vpliv teorije II. reda

$$\theta_1 = \frac{P_{TOT1} \cdot d_{r1}}{V_{TOT1} \cdot h_1} = \frac{1416kN \cdot 36.6mm}{71.27kN \cdot 4300mm} = 0.169 > 0.1 \qquad k_\delta = \frac{1}{1-\theta} = \frac{1}{1-0.169} = 1.203$$

$$\theta_2 = \frac{P_{TOT2} \cdot d_{r2}}{V_{TOT2} \cdot h_2} = \frac{1069kN \cdot 25.2mm}{48.86kN \cdot 3300mm} = 0.167 > 0.1 \qquad k_\delta = \frac{1}{1-\theta} = \frac{1}{1-0.167} = 1.201$$

$$\theta_3 = \frac{P_{TOT3} \cdot d_{r3}}{V_{TOT3} \cdot h_3} = \frac{727.6kN \cdot 16.8mm}{31.77kN \cdot 3300mm} = 0.116 > 0.1 \qquad k_\delta = \frac{1}{1-\theta} = \frac{1}{1-0.116} = 1.131$$

$$\theta_4 = \frac{P_{TOT4} \cdot d_{r4}}{V_{TOT4} \cdot h_4} = \frac{387.4kN \cdot 8.4mm}{14.77kN \cdot 3300mm} = 0.0668 \leq 0.1$$

4.3 Dinamična analiza v prečni smeri (Okvir B – H)

4.3.1 Izračun nihajnega časa

$$T_1 = c_t H^{\frac{3}{4}}$$

$$T_1 = 0.085 \cdot 17.5^{\frac{3}{4}} = 0.73s$$

$$T_1(ESA) = \frac{1}{\nu} = \frac{1}{1.302s^{-1}} = 0.77s$$

4.3.2 Določitev potresnih sil

$T_C \leq T \leq T_D$: $\quad S_d(T) = a_g S \frac{2.5}{q}\left[\frac{T_C}{T}\right] \geq 0.20 a_g$

$$S_d(T) = 0.15 \cdot 9.81 \cdot 1.0 \cdot \frac{2.5}{6}\left[\frac{0.5}{0.77}\right] = 0.399 m/s^2 \geq 0.245 m/s^2$$

Določitev mas po posameznih etažah:

$m_1 = G_{jek.\ nosilci} + G_{beton} + 0.15Q = 3564.9kg + 55553.4kg + 0.15 \cdot 22183.4kg = 62445.8kg$

$m_2 = G_{jek.\ nosilci} + G_{beton} + 0.15Q = 3248.9kg + 55553.4kg + 0.15 \cdot 22183.4kg = 62129.8kg$

$m_3 = G_{jek.\ nosilci} + G_{beton} + 0.15Q = 3248.9kg + 55553.4kg + 0.15 \cdot 20003.0kg = 61802.7kg$

$m_4 = G_{jek.\ nosilci} + G_{beton} + 0.15Q = 3248.9kg + 54496.6kg + 0.15 \cdot 15944.4kg = 60137.2kg$

$m_5 = G_{jek.\ nosilci} + G_{beton} + 0.3Q = 1911.3kg + 4006kg + 0 = 5917.3kg$

$m_{skupaj} = 252432.8kg$

$F_b = S_d(T) \cdot m \cdot \lambda = 0.399m/s^2 \cdot 252432.8kg \cdot 1.0 = 100.76kN$

$$F_1' = F_b \cdot \frac{s_1 m_1}{\sum\limits_{i=1-5} s_i m_i} = 100.76kN \cdot \frac{4.3m \cdot 62445.8kg}{4.3m \cdot 62445.8kg + ... + 3.3m \cdot 5917.3kg} = 30.21kN$$

$$F_2' = F_b \cdot \frac{s_2 m_2}{\sum\limits_{i=1-5} s_i m_i} = 100.76kN \cdot \frac{3.3m \cdot 62129.8kg}{4.3m \cdot 62445.8kg + ... + 3.3m \cdot 5917.3kg} = 23.07kN$$

$$F_3' = F_b \cdot \frac{s_3 m_3}{\sum\limits_{i=1-5} s_i m_i} = 100.76kN \cdot \frac{3.3m \cdot 62129.8kg}{4.3m \cdot 62445.8kg + ... + 3.3m \cdot 5917.3kg} = 22.95kN$$

$$F_4' = F_b \cdot \frac{s_4 m_4}{\sum\limits_{i=1-5} s_i m_i} = 100.76kN \cdot \frac{3.3m \cdot 60137.2kg}{4.3m \cdot 62445.8kg + ... + 3.3m \cdot 5917.3kg} = 22.33kN$$

$$F_5' = F_b \cdot \frac{s_5 m_5}{\sum\limits_{i=1-5} s_i m_i} = 100.76kN \cdot \frac{3.3m \cdot 5917.3kg}{4.3m \cdot 62445.8kg + ... + 3.3m \cdot 5917.3kg} = 2.20kN$$

Torzijski učinek:

$\delta = 1 + 0.6 \cdot x / L_e = 1 + 0.6 \cdot 18m / 48m = 1.225$

$$F_1 = \delta \cdot F_1' = 1.225 \cdot 30.21kN = 37.01kN$$

$$F_2 = \delta \cdot F_2' = 1.225 \cdot 23.07kN = 28.26kN$$

$$F_3 = \delta \cdot F_3' = 1.225 \cdot 22.95kN = 28.11kN$$

$$F_4 = \delta \cdot F_4' = 1.225 \cdot 22.33kN = 27.35kN$$

$$F_5 = \delta \cdot F_5' = 1.225 \cdot 2.20kN = 2.69kN$$

4.3.3 Potresna obtežna kombinacija

$$\sum G_{k,j} + \gamma_I A_{Ed} + \sum \psi_{2,i} Q_{k,i} = 1.0G + 1.0A_{Ed} + 0.15Q$$

4.3.4 Kontrola pomikov

$d_r \cdot \nu \leq 0.0075 \cdot h$

$\nu = 0.5$

$d_r = (u_i - u_{i-1}) \cdot q$

$q = 6$

$d_{r1} = (u_1 - 0) \cdot q = (5.5mm) \cdot 6 = 33.0mm$

$d_{r2} = (u_2 - u_1) \cdot q = (10.6mm - 5.5mm) \cdot 6 = 30.6mm$

$d_{r3} = (u_3 - u_2) \cdot q = (14.5mm - 10.6mm) \cdot 6 = 23.4mm$

$d_{r4} = (u_4 - u_3) \cdot q = (16.8mm - 14.5mm) \cdot 6 = 13.8mm$

$d_{r5} = (u_5 - u_4) \cdot q = (17.6mm - 16.8mm) \cdot 6 = 4.8mm$

$d_{r1} \cdot \nu = 33.0mm \cdot 0.5 = 16.5mm \leq 0.0075 \cdot h = 0.0075 \cdot 4300mm = 32.25mm$

$d_{r2} \cdot \nu = 30.6mm \cdot 0.5 = 15.3mm \leq 0.0075 \cdot h = 0.0075 \cdot 3300mm = 24.75mm$

$d_{r3} \cdot \nu = 23.4mm \cdot 0.5 = 11.7mm \leq 0.0075 \cdot h = 0.0075 \cdot 3300mm = 24.75mm$

$d_{r4} \cdot \nu = 13.8mm \cdot 0.5 = 6.9mm \leq 0.0075 \cdot h = 0.0075 \cdot 3300mm = 24.75mm$

$d_{r5} \cdot \nu = 4.8mm \cdot 0.5 = 2.4mm \leq 0.0075 \cdot h = 0.0075 \cdot 3300mm = 24.75mm$

4.3.5 Vpliv teorije II. reda

$$\theta_1 = \frac{P_{TOT1} \cdot d_{r1}}{V_{TOT1} \cdot h_1} = \frac{2584.6kN \cdot 33.0mm}{123.42kN \cdot 4300mm} = 0.162 > 0.1 \qquad k_\delta = \frac{1}{1-\theta} = \frac{1}{1-0.162} = 1.193$$

$$\theta_2 = \frac{P_{TOT2} \cdot d_{r2}}{V_{TOT2} \cdot h_2} = \frac{1942.4kN \cdot 30.6mm}{86.41kN \cdot 3300mm} = 0.209 > 0.1 \qquad k_\delta = \frac{1}{1-\theta} = \frac{1}{1-0.209} = 1.264$$

$$\theta_3 = \frac{P_{TOT3} \cdot d_{r3}}{V_{TOT3} \cdot h_3} = \frac{1303.0kN \cdot 23.4mm}{58.15kN \cdot 3300mm} = 0.159 > 0.1 \qquad k_\delta = \frac{1}{1-\theta} = \frac{1}{1-0.159} = 1.189$$

$$\theta_4 = \frac{P_{TOT4} \cdot d_{r4}}{V_{TOT4} \cdot h_4} = \frac{667.0kN \cdot 13.8mm}{30.04kN \cdot 3300mm} = 0.0929 \leq 0.1$$

$$\theta_5 = \frac{P_{TOT5} \cdot d_{r5}}{V_{TOT5} \cdot h_5} = \frac{39.4kN \cdot 4.8mm}{2.69kN \cdot 3300mm} = 0.0213 \leq 0.1$$

4.4 Dinamična analiza v prečni smeri (Okvir M)

4.4.1 Izračun nihajnega časa

$$T_1 = c_t H^{\frac{3}{4}}$$

$$T_1 = 0.085 \cdot 14.2^{\frac{3}{4}} = 0.62s$$

$$T_1(ESA) = \frac{1}{\nu} = \frac{1}{1.345s^{-1}} = 0.74s$$

4.4.2 Določitev potresnih sil

$T_C \leq T \leq T_D$: $$S_d(T) = a_g S \frac{2.5}{q}\left[\frac{T_C}{T}\right] \geq 0.20 a_g$$

$$S_d(T) = 0.15 \cdot 9.81 \cdot 1.0 \cdot \frac{2.5}{6}\left[\frac{0.5}{0.74}\right] = 0.412 m/s^2 \geq 0.245 m/s^2$$

Določitev mas po posameznih etažah:

$m_1 = G_{jek.\ nosilci} + G_{beton} + 0.15Q = 3564.9kg + 55553.4kg + 0.15 \cdot 22183.4kg = 62445.8kg$

$m_2 = G_{jek.\ nosilci} + G_{beton} + 0.15Q = 3248.9kg + 55553.4kg + 0.15 \cdot 22183.4kg = 62129.8kg$

$m_3 = G_{jek.\ nosilci} + G_{beton} + 0.15Q = 3248.9kg + 55553.4kg + 0.15 \cdot 20003.0kg = 60137.2kg$

$m_4 = G_{jek.\ nosilci} + G_{beton} + 0.15Q = 2206.1kg + 49423.0kg + 0.3 \cdot 7110kg = 53762.1kg$

$m_{skupaj} = 240140.4kg$

$F_b = S_d(T) \cdot m \cdot \lambda = 0.412m/s^2 \cdot 240140.4kg \cdot 1.0 = 99.02kN$

$$F_1' = F_b \cdot \frac{s_1 m_1}{\sum_{i=1-4} s_i m_i} = 99.02kN \cdot \frac{4.3m \cdot 62445.8kg}{4.3m \cdot 62445.8kg + ... + 3.3m \cdot 53762.1kg} = 31.10kN$$

$$F_2' = F_b \cdot \frac{s_2 m_2}{\sum_{i=1-4} s_i m_i} = 99.02kN \cdot \frac{3.3m \cdot 62129.8kg}{4.3m \cdot 62445.8kg + ... + 3.3m \cdot 53762.1kg} = 23.75kN$$

$$F_3' = F_b \cdot \frac{s_3 m_3}{\sum_{i=1-4} s_i m_i} = 99.02kN \cdot \frac{3.3m \cdot 60137.2kg}{4.3m \cdot 62445.8kg + ... + 3.3m \cdot 53762.1kg} = 23.62kN$$

$$F_4' = F_b \cdot \frac{s_4 m_4}{\sum_{i=1-4} s_i m_i} = 99.02kN \cdot \frac{3.3m \cdot 53762.1kg}{4.3m \cdot 62445.8kg + ... + 3.3m \cdot 53762.1kg} = 20.55kN$$

Torzijski učinek:

$\delta = 1 + 0.6 \cdot x / L_e = 1 + 0.6 \cdot 6m / 24m = 1.15$

$$F_1 = \delta \cdot F_1' = 1.15 \cdot 31.10kN = 35.76kN$$

$$F_2 = \delta \cdot F_2' = 1.15 \cdot 23.75kN = 27.31kN$$

$$F_3 = \delta \cdot F_3' = 1.15 \cdot 23.62kN = 27.16kN$$

$$F_4 = \delta \cdot F_4' = 1.15 \cdot 20.55kN = 23.63kN$$

4.4.3 Potresna obtežna kombinacija

$$\sum G_{k,j} + \gamma_1 A_{Ed} + \sum \psi_{2,i} Q_{k,i} = 1.0G + 1.0A_{Ed} + 0.15Q$$

4.4.4 Kontrola pomikov

$d_r \cdot \nu \leq 0.0075 \cdot h$

$\nu = 0.5$

$d_r = (u_i - u_{i-1}) \cdot q$

$q = 6$

$d_{r1} = (u_1 - 0) \cdot q = (5.1mm) \cdot 6 = 30.6mm$

$d_{r2} = (u_2 - u_1) \cdot q = (9.7mm - 5.1mm) \cdot 6 = 27.6mm$

$d_{r3} = (u_3 - u_2) \cdot q = (13.1mm - 9.7mm) \cdot 6 = 20.4mm$

$d_{r4} = (u_4 - u_3) \cdot q = (15.2mm - 13.1mm) \cdot 6 = 12.6mm$

$d_{r1} \cdot \nu = 30.6mm \cdot 0.5 = 15.3mm \leq 0.0075 \cdot h = 0.0075 \cdot 4300mm = 32.25mm$

$d_{r2} \cdot \nu = 27.6mm \cdot 0.5 = 13.8mm \leq 0.0075 \cdot h = 0.0075 \cdot 3300mm = 24.75mm$

$d_{r3} \cdot \nu = 20.4mm \cdot 0.5 = 10.2mm \leq 0.0075 \cdot h = 0.0075 \cdot 3300mm = 24.75mm$

$d_{r4} \cdot \nu = 12.6mm \cdot 0.5 = 6.3mm \leq 0.0075 \cdot h = 0.0075 \cdot 3300mm = 24.75mm$

4.4.5 Vpliv teorije II. reda

$$\theta_1 = \frac{P_{TOT1} \cdot d_{r1}}{V_{TOT1} \cdot h_1} = \frac{2553.1kN \cdot 30.6mm}{113.86kN \cdot 4300mm} = 0.159 > 0.1 \qquad k_\delta = \frac{1}{1-\theta} = \frac{1}{1-0.159} = 1.189$$

$$\theta_2 = \frac{P_{TOT2} \cdot d_{r2}}{V_{TOT2} \cdot h_2} = \frac{1910.9kN \cdot 27.6mm}{78.1kN \cdot 3300mm} = 0.205 > 0.1 \qquad k_\delta = \frac{1}{1-\theta} = \frac{1}{1-0.205} = 1.258$$

$$\theta_3 = \frac{P_{TOT3} \cdot d_{r3}}{V_{TOT3} \cdot h_3} = \frac{1217.6kN \cdot 20.4mm}{50.94kN \cdot 3300mm} = 0.148 > 0.1 \qquad k_\delta = \frac{1}{1-\theta} = \frac{1}{1-0.148} = 1.188$$

$$\theta_4 = \frac{P_{TOT4} \cdot d_{r4}}{V_{TOT4} \cdot h_4} = \frac{635.5kN \cdot 12.6mm}{23.63kN \cdot 3300mm} = 0.103 \leq 0.1 \qquad k_\delta = \frac{1}{1-\theta} = \frac{1}{1-0.103} = 1.115$$

4.5 Dinamična analiza v prečni smeri (Okvir J)

4.5.1 Izračun nihajnega časa

$$T_1 = c_t H^{\frac{3}{4}}$$

$$T_1 = 0.085 \cdot 14.2^{\frac{3}{4}} = 0.62s$$

$$T_1(ESA) = \frac{1}{\nu} = \frac{1}{1.739s^{-1}} = 0.58s$$

4.5.2 Določitev potresnih sil

$T_C \leq T \leq T_D$: $$S_d(T) = a_g S \frac{2.5}{q}\left[\frac{T_C}{T}\right] \geq 0.20 a_g$$

$$S_d(T) = 0.15 \cdot 9.81 \cdot 1.0 \cdot \frac{2.5}{6}\left[\frac{0.5}{0.58}\right] = 0.533m/s^2 \geq 0.245m/s^2$$

$m_1 = G_{jek.\ nosilci} + G_{beton} + 0.15Q = 2742.7kg + 28011.1kg + 0.15 \cdot 11091.7kg = 32417.6kg$

$m_2 = G_{jek.\ nosilci} + G_{beton} + 0.15Q = 2534.8kg + 28011.1kg + 0.15 \cdot 11091.7kg = 32209.7kg$

$m_3 = G_{jek.\ nosilci} + G_{beton} + 0.15Q = 2534.8kg + 28011.1kg + 0.15 \cdot 10001.5kg = 32046.1kg$

$m_4 = G_{jek.\ nosilci} + G_{beton} + 0.15Q = 1848.9kg + 25509.6kg + 0.3 \cdot 3550kg = 28422.0kg$

$m_{skupaj} = 125095.4kg$

$F_b = S_d(T) \cdot m \cdot \lambda = 0.533m/s^2 \cdot 125095.4kg \cdot 1.0 = 66.69kN$

$$F_1' = F_b \cdot \frac{s_1 m_1}{\sum\limits_{i=1-4} s_i m_i} = 66.69kN \cdot \frac{4.3m \cdot 32417.6kg}{4.3m \cdot 32417.6kg + ... + 3.3m \cdot 28422.0kg} = 20.88kN$$

$$F_2' = F_b \cdot \frac{s_2 m_2}{\sum\limits_{i=1-4} s_i m_i} = 66.69kN \cdot \frac{3.3m \cdot 32209.7kg}{4.3m \cdot 32417.6kg + ... + 3.3m \cdot 28422.0kg} = 15.92kN$$

$$F_3' = F_b \cdot \frac{s_3 m_3}{\sum\limits_{i=1-4} s_i m_i} = 66.69\text{kN} \cdot \frac{3.3\text{m} \cdot 32046.1\text{kg}}{4.3\text{m} \cdot 32417.6\text{kg} + ... + 3.3\text{m} \cdot 28422.0\text{kg}} = 15.84\text{kN}$$

$$F_4' = F_b \cdot \frac{s_4 m_4}{\sum\limits_{i=1-4} s_i m_i} = 66.69\text{kN} \cdot \frac{3.3\text{m} \cdot 28422.0\text{kg}}{4.3\text{m} \cdot 32417.6\text{kg} + ... + 3.3\text{m} \cdot 28422.0\text{kg}} = 14.05\text{kN}$$

Torzijski učinek:

$\delta = 1 + 0.6 \cdot x / L_e = 1 + 0.6 \cdot 6\text{m} / 24\text{m} = 1.15$

$$F_1 = \delta \cdot F_1' = 1.15 \cdot 20.88\text{kN} = 24.01\text{kN}$$

$$F_2 = \delta \cdot F_2' = 1.15 \cdot 15.92\text{kN} = 18.31\text{kN}$$

$$F_3 = \delta \cdot F_3' = 1.15 \cdot 15.84\text{kN} = 18.22\text{kN}$$

$$F_4 = \delta \cdot F_4' = 1.15 \cdot 14.05\text{kN} = 16.16\text{kN}$$

4.5.3 Potresna obtežna kombinacija

$$\sum G_{k,j} + \gamma_I A_{Ed} + \sum \psi_{2,i} Q_{k,i} = 1.0G + 1.0A_{Ed} + 0.15Q$$

4.5.4 Kontrola pomikov

$d_r \cdot \nu \leq 0.0075 \cdot h$

$\nu = 0.5$

$d_r = (u_i - u_{i-1}) \cdot q$

$q = 6$

$d_{r1} = (u_1 - 0) \cdot q = (3.4\text{mm}) \cdot 6 = 20.4\text{mm}$

$d_{r2} = (u_2 - u_1) \cdot q = (6.5\text{mm} - 3.4\text{mm}) \cdot 6 = 18.6\text{mm}$

$d_{r3} = (u_3 - u_2) \cdot q = (8.8\text{mm} - 6.5\text{mm}) \cdot 6 = 13.8\text{mm}$

$d_{r4} = (u_4 - u_3) \cdot q = (10.3\text{mm} - 8.8\text{mm}) \cdot 6 = 9.0\text{mm}$

$d_{r1} \cdot \nu = 20.4\text{mm} \cdot 0.5 = 10.2\text{mm} \leq 0.0075 \cdot h = 0.0075 \cdot 4300\text{mm} = 32.25\text{mm}$

$d_{r2} \cdot \nu = 18.6\text{mm} \cdot 0.5 = 9.3\text{mm} \leq 0.0075 \cdot h = 0.0075 \cdot 3300\text{mm} = 24.75\text{mm}$

$d_{r3} \cdot \nu = 13.8\text{mm} \cdot 0.5 = 6.9\text{mm} \leq 0.0075 \cdot h = 0.0075 \cdot 3300\text{mm} = 24.75\text{mm}$

$d_{r4} \cdot \nu = 9.0\text{mm} \cdot 0.5 = 4.4\text{mm} \leq 0.0075 \cdot h = 0.0075 \cdot 3300\text{mm} = 24.75\text{mm}$

4.5.5 Vpliv teorije II. reda

$$\theta_1 = \frac{P_{TOT1} \cdot d_{r1}}{V_{TOT1} \cdot h_1} = \frac{1487.3kN \cdot 20.4mm}{76.7kN \cdot 4300mm} = 0.0920 \leq 0.1$$

$$\theta_2 = \frac{P_{TOT2} \cdot d_{r2}}{V_{TOT2} \cdot h_2} = \frac{1114.3kN \cdot 18.6mm}{52.69kN \cdot 3300mm} = 0.119 > 0.1 \qquad k_\delta = \frac{1}{1-\theta} = \frac{1}{1-0.119} = 1.135$$

$$\theta_3 = \frac{P_{TOT3} \cdot d_{r3}}{V_{TOT3} \cdot h_3} = \frac{742.7kN \cdot 13.8mm}{34.47kN \cdot 3300mm} = 0.0901 \leq 0.1$$

$$\theta_4 = \frac{P_{TOT4} \cdot d_{r4}}{V_{TOT4} \cdot h_4} = \frac{372.9kN \cdot 9.0mm}{16.16kN \cdot 3300mm} = 0.0629 \leq 0.1$$

4.6 Dinamična analiza v prečni smeri (Okvir L)

4.6.1 Izračun nihajnega časa

$$T_1 = c_t H^{\frac{3}{4}}$$

$$T_1 = 0.085 \cdot 14.2^{\frac{3}{4}} = 0.62s$$

$$T_1(ESA) = \frac{1}{\nu} = \frac{1}{1.296s^{-1}} = 0.77s$$

4.6.2 Določitev potresnih sil

$$T_C \leq T \leq T_D: \qquad S_d(T) = a_g S \frac{2.5}{q}\left[\frac{T_C}{T}\right] \geq 0.20 a_g$$

$$S_d(T) = 0.15 \cdot 9.81 \cdot 1.0 \cdot \frac{2.5}{6}\left[\frac{0.5}{0.77}\right] = 0.397m/s^2 \geq 0.245m/s^2$$

$m_1 = G_{jek.\ nosilci} + G_{beton} + 0.15Q = 3564.9kg + 60527.9kg + 0.15 \cdot 22183.4kg = 67420.3kg$

$m_2 = G_{jek.\ nosilci} + G_{beton} + 0.15Q = 3248.9kg + 60527.9kg + 0.15 \cdot 22183.4kg = 67104.3kg$

$m_3 = G_{jek.\ nosilci} + G_{beton} + 0.15Q = 3248.9kg + 60527.9kg + 0.15 \cdot 20003.0kg = 66777.3kg$

$m_4 = G_{jek.\ nosilci} + G_{beton} + 0.15Q = 2206.1kg + 54958.2kg + 0.3 \cdot 7110kg = 59297.3kg$

$m_{skupaj} = 260599.2kg$

$F_b = S_d(T) \cdot m \cdot \lambda = 0.397m/s^2 \cdot 260599.2kg \cdot 1.0 = 103.54kN$

$$F_1' = F_b \cdot \frac{s_1 m_1}{\sum\limits_{i=1-4} s_i m_i} = 103.54kN \cdot \frac{4.3m \cdot 67420.3kg}{4.3m \cdot 67420.3kg + ... + 3.3m \cdot 59297.3kg} = 32.37kN$$

$$F_2' = F_b \cdot \frac{s_2 m_2}{\sum\limits_{i=1-4} s_i m_i} = 103.54kN \cdot \frac{3.3m \cdot 67104.3kg}{4.3m \cdot 67420.3kg + ... + 3.3m \cdot 59297.3kg} = 24.72kN$$

$$F_3' = F_b \cdot \frac{s_3 m_3}{\sum\limits_{i=1-4} s_i m_i} = 103.54kN \cdot \frac{3.3m \cdot 66777.3kg}{4.3m \cdot 67420.3kg + ... + 3.3m \cdot 59297.3kg} = 24.60kN$$

$$F_4' = F_b \cdot \frac{s_4 m_4}{\sum\limits_{i=1-4} s_i m_i} = 103.54kN \cdot \frac{3.3m \cdot 59297.3kg}{4.3m \cdot 67420.3kg + ... + 3.3m \cdot 59297.3kg} = 21.85kN$$

Torzijski učinek:

$\delta = 1 + 0.6 \cdot x / L_e = 1 + 0.6 \cdot 1m / 24m = 1.025$

$$F_1 = \delta \cdot F_1' = 1.025 \cdot 32.37kN = 33.18kN$$

$$F_2 = \delta \cdot F_2' = 1.025 \cdot 24.72kN = 25.34kN$$

$$F_3 = \delta \cdot F_3' = 1.025 \cdot 24.60kN = 25.22kN$$

$$F_4 = \delta \cdot F_4' = 1.025 \cdot 21.85kN = 22.39kN$$

4.6.3 Potresna obtežna kombinacija

$$\sum G_{k,j} + \gamma_I A_{Ed} + \sum \psi_{2,i} Q_{k,i} = 1.0G + 1.0A_{Ed} + 0.15Q$$

4.6.4 Kontrola pomikov

$d_r \cdot \nu \leq 0.0075 \cdot h$

$\nu = 0.5$

$d_r = (u_i - u_{i-1}) \cdot q$

$q = 6$

$d_{r1} = (u_1 - 0) \cdot q = (4.7mm) \cdot 6 = 28.2mm$

$d_{r2} = (u_2 - u_1) \cdot q = (9.0mm - 4.7mm) \cdot 6 = 25.8mm$

$d_{r3} = (u_3 - u_2) \cdot q = (12.2mm - 9.0mm) \cdot 6 = 19.2mm$

$d_{r4} = (u_4 - u_3) \cdot q = (14.2mm - 12.2mm) \cdot 6 = 12.0mm$

$d_{r1} \cdot \nu = 28.2\text{mm} \cdot 0.5 = 14.1\text{mm} \leq 0.0075 \cdot h = 0.0075 \cdot 4300\text{mm} = 32.25\text{mm}$

$d_{r2} \cdot \nu = 25.8\text{mm} \cdot 0.5 = 12.9\text{mm} \leq 0.0075 \cdot h = 0.0075 \cdot 3300\text{mm} = 24.75\text{mm}$

$d_{r3} \cdot \nu = 19.2\text{mm} \cdot 0.5 = 9.6\text{mm} \leq 0.0075 \cdot h = 0.0075 \cdot 3300\text{mm} = 24.75\text{mm}$

$d_{r4} \cdot \nu = 12.0\text{mm} \cdot 0.5 = 6.0\text{mm} \leq 0.0075 \cdot h = 0.0075 \cdot 3300\text{mm} = 24.75\text{mm}$

4.6.5 Vpliv teorije II. reda

$$\theta_1 = \frac{P_{TOT1} \cdot d_{r1}}{V_{TOT1} \cdot h_1} = \frac{2763.7\text{kN} \cdot 28.2\text{mm}}{106.13\text{kN} \cdot 4300\text{mm}} = 0.171 > 0.1 \qquad k_\delta = \frac{1}{1-\theta} = \frac{1}{1-0.171} = 1.206$$

$$\theta_2 = \frac{P_{TOT2} \cdot d_{r2}}{V_{TOT2} \cdot h_2} = \frac{1926.3\text{kN} \cdot 25.8\text{mm}}{72.95\text{kN} \cdot 3300\text{mm}} = 0.206 > 0.1 \qquad k_\delta = \frac{1}{1-\theta} = \frac{1}{1-0.206} = 1.259$$

$$\theta_3 = \frac{P_{TOT3} \cdot d_{r3}}{V_{TOT3} \cdot h_3} = \frac{1378.4\text{kN} \cdot 19.2\text{mm}}{47.61\text{kN} \cdot 3300\text{mm}} = 0.168 > 0.1 \qquad k_\delta = \frac{1}{1-\theta} = \frac{1}{1-0.168} = 1.202$$

$$\theta_4 = \frac{P_{TOT4} \cdot d_{r4}}{V_{TOT4} \cdot h_4} = \frac{690.8\text{kN} \cdot 12.0\text{mm}}{22.39\text{kN} \cdot 3300\text{mm}} = 0.112 > 0.1 \qquad k_\delta = \frac{1}{1-\theta} = \frac{1}{1-0.112} = 1.126$$

4.7 Dinamična analiza v prečni smeri (Okvir K)

4.7.1 Izračun nihajnega časa

$$T_1 = c_t H^{\frac{3}{4}}$$

$$T_1 = 0.085 \cdot 14.2^{\frac{3}{4}} = 0.62\text{s}$$

$$T_1(ESA) = \frac{1}{\nu} = \frac{1}{1.172\text{s}^{-1}} = 0.85\text{s}$$

4.7.2 Določitev potresnih sil

$T_C \leq T \leq T_D$: $\qquad S_d(T) = a_g S \frac{2.5}{q}\left[\frac{T_C}{T}\right] \geq 0.20 a_g$

$$S_d(T) = 0.15 \cdot 9.81 \cdot 1.0 \cdot \frac{2.5}{6}\left[\frac{0.5}{0.85}\right] = 0.359\text{m/s}^2 \geq 0.245\text{m/s}^2$$

$m_1 = G_{jek.\ nosilci} + G_{beton} + 0.15Q = 2289.6\text{kg} + 26588.0\text{kg} + 0.15 \cdot 17436.3\text{kg} = 31493.0\text{kg}$

$m_2 = G_{jek.\ nosilci} + G_{beton} + 0.15Q = 2085.6\text{kg} + 26588.0\text{kg} + 0.15 \cdot 17436.3\text{kg} = 31251.3\text{kg}$

$m_3 = G_{jek.\ nosilci} + G_{beton} + 0.15Q = 2085.6kg + 26588.0kg + 0.15 \cdot 15719.7kg = 30993.9kg$

$m_4 = G_{jek.\ nosilci} + G_{beton} + 0.15Q = 1412.4kg + 30949.2kg + 0.3 \cdot 5768.5kg = 34092.2kg$

$m_{skupaj} = 127830.4kg$

$F_b = S_d(T) \cdot m \cdot \lambda = 0.359m/s^2 \cdot 127830.4kg \cdot 1.0 = 45.93kN$

$$F_1' = F_b \cdot \frac{s_1 m_1}{\sum\limits_{i=1-4} s_i m_i} = 45.93kN \cdot \frac{4.3m \cdot 31493.0kg}{4.3m \cdot 31493.0kg + ... + 3.3m \cdot 34092.2kg} = 13.72kN$$

$$F_2' = F_b \cdot \frac{s_2 m_2}{\sum\limits_{i=1-4} s_i m_i} = 45.93kN \cdot \frac{3.3m \cdot 31251.3kg}{4.3m \cdot 31493.0kg + ... + 3.3m \cdot 34092.2kg} = 10.45kN$$

$$F_3' = F_b \cdot \frac{s_3 m_3}{\sum\limits_{i=1-4} s_i m_i} = 45.93kN \cdot \frac{3.3m \cdot 30993.9kg}{4.3m \cdot 31493.0kg + ... + 3.3m \cdot 34092.2kg} = 10.36kN$$

$$F_4' = F_b \cdot \frac{s_4 m_4}{\sum\limits_{i=1-4} s_i m_i} = 45.93kN \cdot \frac{3.3m \cdot 34092.2kg}{4.3m \cdot 31493.0kg + ... + 3.3m \cdot 34092.2kg} = 11.40kN$$

Torzijski učinek:

$\delta = 1 + 0.6 \cdot x / L_e = 1 + 0.6 \cdot 7m / 24m = 1.175$

$$F_1 = \delta \cdot F_1' = 1.175 \cdot 13.72kN = 16.12kN$$

$$F_2 = \delta \cdot F_2' = 1.175 \cdot 10.45kN = 12.28kN$$

$$F_3 = \delta \cdot F_3' = 1.175 \cdot 10.36kN = 12.18kN$$

$$F_4 = \delta \cdot F_4' = 1.175 \cdot 11.40kN = 13.39kN$$

4.7.3 Potresna obtežna kombinacija

$$\sum G_{k,j} + \gamma_I A_{Ed} + \sum \psi_{2,i} Q_{k,i} = 1.0G + 1.0A_{Ed} + 0.15Q$$

4.7.4 Kontrola pomikov

$d_r \cdot \nu \leq 0.0075 \cdot h$

$\nu = 0.5$

$d_r = (u_i - u_{i-1}) \cdot q$

$q = 6$

$d_{r1} = (u_1 - 0) \cdot q = (4.1mm) \cdot 6 = 24.6mm$

$d_{r2} = (u_2 - u_1) \cdot q = (6.9mm - 4.1mm) \cdot 6 = 16.8mm$

$d_{r3} = (u_3 - u_2) \cdot q = (10.0mm - 6.9mm) \cdot 6 = 18.6mm$

$d_{r4} = (u_4 - u_3) \cdot q = (12.8mm - 10.0mm) \cdot 6 = 16.8mm$

$d_{r1} \cdot \nu = 24.6mm \cdot 0.5 = 12.3mm \leq 0.0075 \cdot h = 0.0075 \cdot 4300mm = 32.25mm$

$d_{r2} \cdot \nu = 16.8mm \cdot 0.5 = 8.4mm \leq 0.0075 \cdot h = 0.0075 \cdot 3300mm = 24.75mm$

$d_{r3} \cdot \nu = 18.6mm \cdot 0.5 = 9.3mm \leq 0.0075 \cdot h = 0.0075 \cdot 3300mm = 24.75mm$

$d_{r4} \cdot \nu = 16.8mm \cdot 0.5 = 8.4mm \leq 0.0075 \cdot h = 0.0075 \cdot 3300mm = 24.75mm$

4.7.5 Vpliv teorije II. reda

$$\theta_1 = \frac{P_{TOT1} \cdot d_{r1}}{V_{TOT1} \cdot h_1} = \frac{1919.5kN \cdot 24.6mm}{53.97kN \cdot 4300mm} = 0.203 > 0.1 \qquad k_\delta = \frac{1}{1-\theta} = \frac{1}{1-0.203} = 1.255$$

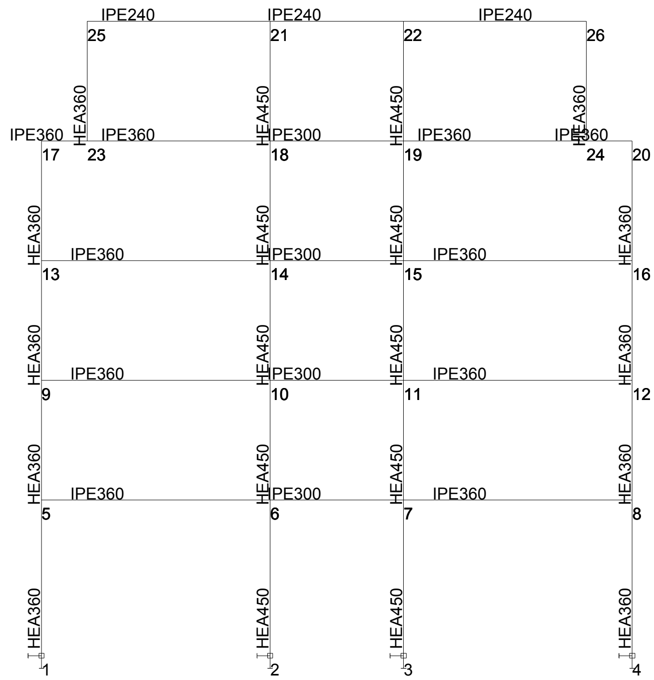
$$\theta_2 = \frac{P_{TOT2} \cdot d_{r2}}{V_{TOT2} \cdot h_2} = \frac{1449.5kN \cdot 16.8mm}{37.85kN \cdot 3300mm} = 0.195 > 0.1 \qquad k_\delta = \frac{1}{1-\theta} = \frac{1}{1-0.195} = 1.242$$

$$\theta_3 = \frac{P_{TOT3} \cdot d_{r3}}{V_{TOT3} \cdot h_3} = \frac{980.3kN \cdot 18.6mm}{25.57kN \cdot 3300mm} = 0.216 > 0.1 \qquad k_\delta = \frac{1}{1-\theta} = \frac{1}{1-0.216} = 1.276$$

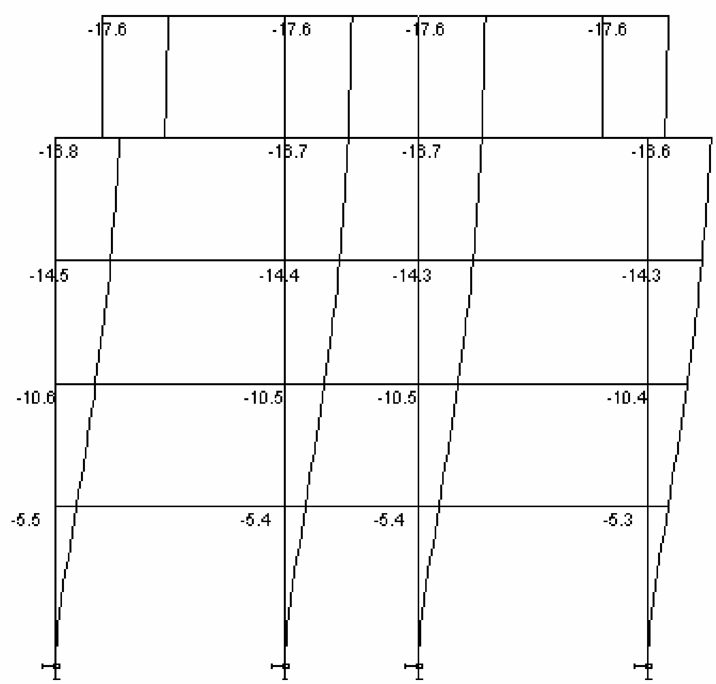
$$\theta_4 = \frac{P_{TOT4} \cdot d_{r4}}{V_{TOT4} \cdot h_4} = \frac{513.7kN \cdot 16.8mm}{13.39kN \cdot 3300mm} = 0.195 > 0.1 \qquad k_\delta = \frac{1}{1-\theta} = \frac{1}{1-0.195} = 1.242$$

4.8 Rezultati dobljeni s programom ESA – Prima Win (prečni okvirji)

Notranji prečni okvir (okvir B – H):



Geometrija



Pomiki - potres

HEA 450 - K9

Notranje sile pri K9: 1.0G+0.15Q+1.0A
Group of member(s) :1/37
Group of nonlinear combination(s) :9
Cross-section : 3 - HEA450

memb	non. c.	dx [m]	N [kN]	V [kN]	M [kNm]
21	9	0.000	**-672.23**	33.18	-126.76
17		1.650	-481.14	**53.09**	6.00
25		2.933	-13.66	**-10.16**	3.39
17		3.300	-481.15	52.70	**93.39**
16		0.000	-637.68	50.80	**-149.69**

HEA 360 - K9

Notranje sile pri K9: 1.0G+0.15Q+1.0A
Group of member(s) :1/37
Group of nonlinear combination(s) :9
Cross-section : 4 - HEA360

memb	non. c.	dx [m]	N [kN]	V [kN]	M [kNm]
26	9	0.000	**-497.29**	34.76	**-90.15**
27		1.650	-369.75	**47.67**	1.17
15		1.650	-112.03	**-32.77**	-3.28
29		3.300	-126.09	41.02	**85.15**

IPE 360 - K9

Notranje sile pri K9: 1.0G+0.15Q+1.0A
Group of member(s) :1/37
Group of nonlinear combination(s) :9
Cross-section : 1 - IPE360

memb	non. c.	dx [m]	N [kN]	V [kN]	M [kNm]
3	9	0.375	**12.69**	74.98	-24.05
30		1.200	**-74.05**	74.96	54.93
		0.000	-74.01	**111.98**	-57.30
33		1.200	-40.68	**-126.20**	-85.15
1		2.625	-29.50	-5.30	**60.54**
		6.000	-29.62	-119.89	**-150.92**

IPE 300 - K9

Notranje sile pri K9: 1.0G+0.15Q+1.0A
Group of member(s) :1/37
Group of nonlinear combination(s) :9
Cross-section : 2 - IPE300

memb	non. c.	dx [m]	N [kN]	V [kN]	M [kNm]
10	9	3.500	**-17.15**	-65.10	-47.03
		0.000	-17.10	**52.67**	-25.26
2		3.500	-12.91	**-82.32**	**-77.16**
		1.167	-12.80	-3.09	**22.52**

IPE 240 - K9

Notranje sile pri K9: 1.0G+0.15Q+1.0A
Group of member(s) :1/37
Group of nonlinear combination(s) :9
Cross-section : 5 - IPE240

memb	non. c.	dx [m]	N [kN]	V [kN]	M [kNm]
37	9	0.000	**-25.21**	**7.48**	-7.24
35		4.800	-23.08	**-9.40**	**-11.64**
		1.846	-23.08	-0.55	**3.09**

HEA 450 - K10

Notranje sile pri K10: 1.0G+0.15Q
Group of member(s) :1/37
Group of nonlinear combination(s) :10
Cross-section : 3 - HEA450

memb	non. c.	dx [m]	N [kN]	V [kN]	M [kNm]
21	10	4.300	**-656.04**	-6.25	-23.57
17		1.650	-491.39	**24.15**	-2.21
22		1.833	-492.54	**-21.04**	-0.92
		0.000	-492.54	-20.88	**37.57**
17		0.000	-491.39	23.97	**-41.96**

HEA 360 - K10

Notranje sile pri K10: 1.0G+0.15Q
Group of member(s) :1/37
Group of nonlinear combination(s) :10
Cross-section : 4 - HEA360

memb	non. c.	dx [m]	N [kN]	V [kN]	M [kNm]
26	10	4.300	**-453.37**	13.49	38.49
29		1.467	-119.17	**37.21**	3.84
15		1.467	-118.66	**-36.79**	-3.22
29		3.300	-119.19	37.07	**71.98**
15		3.300	-118.68	-36.65	**-70.58**

IPE 360 - K10

Notranje sile pri K10: 1.0G+0.15Q
Group of member(s) :1/37
Group of nonlinear combination(s) :10
Cross-section : 1 - IPE360

memb	non. c.	dx [m]	N [kN]	V [kN]	M [kNm]
3	10	5.250	**18.36**	-75.31	-27.68
30		0.000	**-36.98**	**118.58**	-70.58
33		1.200	-36.74	**-119.29**	-71.98
1		3.000	18.13	-2.66	**55.81**
		6.000	18.15	-104.55	**-104.94**

IPE 300 - K10

Notranje sile pri K10: 1.0G+0.15Q
Group of member(s) :1/37
Group of nonlinear combination(s) :10
Cross-section : 2 - IPE300

memb	non. c.	dx [m]	N [kN]	V [kN]	M [kNm]
8	10	0.389	**8.52**	45.28	-14.99
10		3.500	**-3.90**	-59.20	-36.66
		0.000	-3.89	**58.58**	-35.59
2		3.500	4.07	**-60.57**	**-39.07**
5		1.750	0.41	-0.98	**15.54**

IPE 240 - K10

Notranje sile pri K10: 1.0G+0.15Q
Group of member(s) :1/37
Group of nonlinear combination(s) :10
Cross-section : 5 - IPE240

memb	non. c.	dx [m]	N [kN]	V [kN]	M [kNm]
37	10	0.000	**-22.07**	**6.25**	-4.15
35		4.800	-21.80	**-8.26**	**-8.99**
		2.215	-21.80	-0.52	**2.38**

HEA 450 - K11

Notranje sile pri K11: 1.0A
Group of member(s) :1/37
Group of nonlinear combination(s) :11
Cross-section : 3 - HEA450

memb	non. c.	dx [m]	N [kN]	V [kN]	M [kNm]
16	11	4.300	**16.27**	40.23	43.64
21		0.000	**-15.79**	39.54	-127.75
16		0.000	16.21	**40.25**	**-129.37**
20		0.000	0.25	**-1.71**	10.63
22		3.300	-9.41	28.39	**54.51**

HEA 360 - K11

Notranje sile pri K11: 1.0A
Group of member(s) :1/37
Group of nonlinear combination(s) :11
Cross-section : 4 - HEA360

memb	non. c.	dx [m]	N [kN]	V [kN]	M [kNm]
12	11	4.300	**42.82**	22.46	25.63
26		0.000	**-42.87**	21.11	-67.82
12		0.000	42.79	**22.52**	**-70.96**
27		3.300	-28.03	15.39	**29.43**

IPE 360 - K11

Notranje sile pri K11: 1.0A
Group of member(s) :1/37
Group of nonlinear combination(s) :11
Cross-section : 1 - IPE360

memb	non. c.	dx [m]	N [kN]	V [kN]	M [kNm]
1	11	0.000	**-47.61**	-14.91	**45.05**
		3.000	-47.60	**-15.01**	0.14
		6.000	-47.61	-14.91	**-44.78**

IPE 300 - K11

Notranje sile pri K11: 1.0A
Group of member(s) :1/37
Group of nonlinear combination(s) :11
Cross-section : 2 - IPE300

memb	non. c.	dx [m]	N [kN]	V [kN]	M [kNm]
2	11	0.000	**-16.88**	-21.19	**37.15**
		1.750	-16.87	**-21.22**	0.03
		3.500	-16.88	-21.19	**-37.09**

IPE 240 - K11

Notranje sile pri K11: 1.0A
Group of member(s) :1/37
Group of nonlinear combination(s) :11
Cross-section : 5 - IPE240

memb	non. c.	dx [m]	N [kN]	V [kN]	M [kNm]
37	11	0.000	**-3.09**	1.21	**-3.03**
		2.585	-3.09	**1.21**	0.10
11		1.750	-1.69	**-1.38**	-0.02
37		4.800	-3.09	1.21	**2.79**

Kontrola nosilnosti in stabilnosti

EC3 Code Check
Cross-section : 1 - IPE360

Macro 1	Member 1	IPE360	S 275	Non-Lin. Comb. 1	1.00

NSd| [kN]	Vy.Sd| [kN]	Vz.Sd| [kN]	Mt.Sd| [kNm]	My.Sd| [kNm]	Mz.Sd | [kNm]
36.88	0.00	-206.85	0.00	-221.99	0.00

The critical check is on position 6.00 m

LTB		
LTB length	3.00	m
k	1.00	
kw	1.00	
C1	1.35	
C2	1.25	
C3	1.73	

load in center of gravity

SECTION CHECK	
N	0.02 < 1
Vz	0.41 < 1
M	0.87 < 1

STABILITY CHECK	
LTB	1.00 < 1
Compression + Moment	0.87 < 1
Compression + LTB	1.00 < 1

Cross-section : 2 - IPE300

Macro 1	Member 2	IPE300	S 275	Non-Lin. Comb. 2	0.66

NSd| [kN]	Vy.Sd| [kN]	Vz.Sd| [kN]	Mt.Sd| [kNm]	My.Sd| [kNm]	Mz.Sd | [kNm]
17.44	-0.00	-121.33	-0.00	-97.42	-0.00

The critical check is on position 3.50 m

LTB		
LTB length	1.75	m
k	1.00	
kw	1.00	
C1	1.47	
C2	0.69	
C3	2.64	

load in center of gravity

SECTION CHECK	
N	0.01 < 1
Vz	0.33 < 1
M	0.62 < 1

STABILITY CHECK	
LTB	0.66 < 1
Compression + Moment	0.62 < 1
Compression + LTB	0.66 < 1

Cross-section : 3 - HEA450

Macro 7	Member 16	HEA450	S 275	Non-Lin. Comb. 2	0.48

NSd| [kN]	Vy.Sd| [kN]	Vz.Sd| [kN]	Mt.Sd| [kNm]	My.Sd| [kNm]	Mz.Sd | [kNm]
-1120.14	0.00	47.64	0.00	-130.66	-0.00

The critical check is on position 0.00 m

Buckling parameters	yy	zz	
type	non-sway	sway	
Slenderness	15.25	58.95	
Reduced slenderness	0.18	0.68	
Buckling curve	a	b	

Buckling parameters	yy	zz	
Imperfection	0.21	0.34	
Reduction factor	1.00	0.80	
Length	4.30	4.30	m
Buckling factor	1.00	0.67	
Buckling length	4.30	2.89	m
Critical Euler load	158532.68	10615.30	kN

LTB		
LTB length	2.15	m
k	1.00	
kw	1.00	
C1	2.69	
C2	0.00	
C3	0.68	

load in center of gravity

SECTION CHECK	
Vz	0.05 < 1
M	0.20 < 1

STABILITY CHECK	
Buckling	0.32 < 1
LTB	0.16 < 1
Compression + Moment	0.41 < 1
Compression + LTB	0.48 < 1

Cross-section : 4 - HEA360

Macro 9	Member 26	HEA360	S 275	Non-Lin. Comb. 2	0.49

NSd| [kN]	Vy.Sd| [kN]	Vz.Sd| [kN]	Mt.Sd| [kNm]	My.Sd| [kNm]	Mz.Sd | [kNm]
-806.42	0.00	53.36	0.00	-101.06	-0.00

The critical check is on position 0.00 m

Buckling parameters	yy	zz	
type	non-sway	sway	
Slenderness	18.96	57.89	
Reduced slenderness	0.22	0.67	
Buckling curve	b	c	
Imperfection	0.34	0.49	
Reduction factor	1.00	0.75	
Length	4.30	4.30	m
Buckling factor	1.00	0.67	
Buckling length	4.30	2.88	m
Critical Euler load	82476.82	8844.21	kN

LTB		
LTB length	2.15	m
k	1.00	
kw	1.00	
C1	2.48	
C2	0.05	
C3	0.85	

load in center of gravity

SECTION CHECK	
Vz	0.08 < 1
M	0.23 < 1

STABILITY CHECK	
Buckling	0.30 < 1
LTB	0.19 < 1
Compression + Moment	0.41 < 1
Compression + LTB	0.49 < 1

Cross-section : 5 - IPE240

Macro 12	Member 35	IPE240	S 275	Non-Lin. Comb. 3	0.54

NSd| [kN]	Vy.Sd| [kN]	Vz.Sd| [kN]	Mt.Sd| [kNm]	My.Sd| [kNm]	Mz.Sd | [kNm]
-38.81	0.00	-28.09	-0.00	-27.82	0.00

The critical check is on position 4.80 m

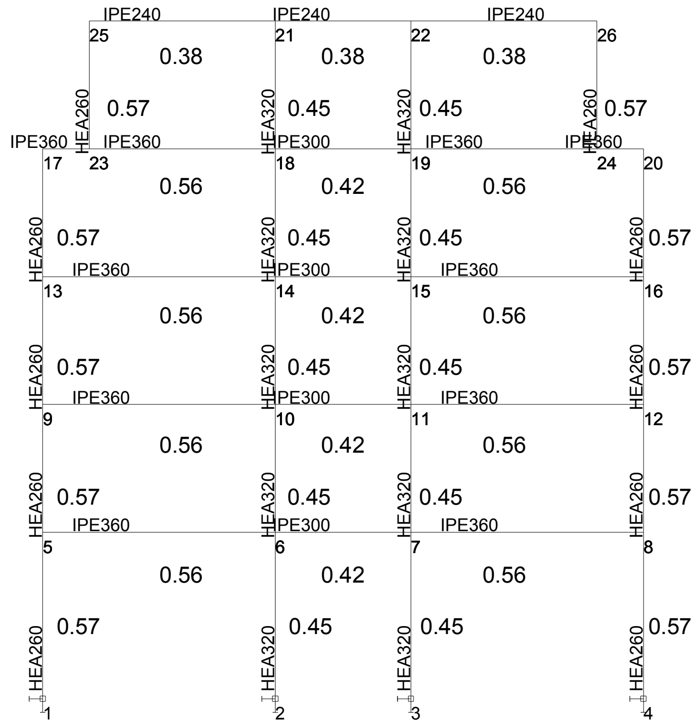
LTB		
LTB length	2.40	m
k	1.00	
kw	1.00	
C1	1.40	
C2	0.93	
C3	1.73	

load in center of gravity

SECTION CHECK	
Vz	0.10 < 1
M	0.30 < 1

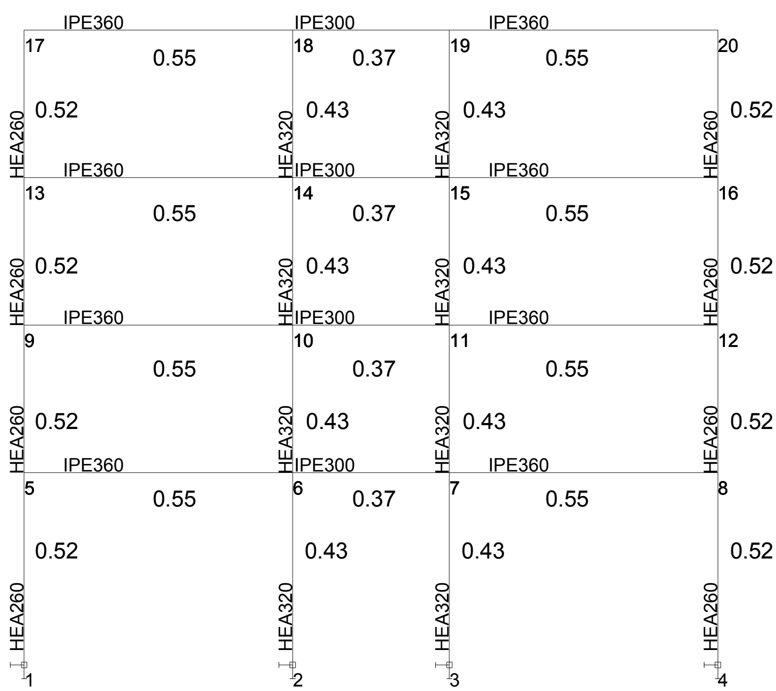
STABILITY CHECK	
Buckling	0.20 < 1
LTB	0.35 < 1
Compression + Moment	0.51 < 1
Compression + LTB	0.54 < 1

Zunanji prečni okvir (okvir A):



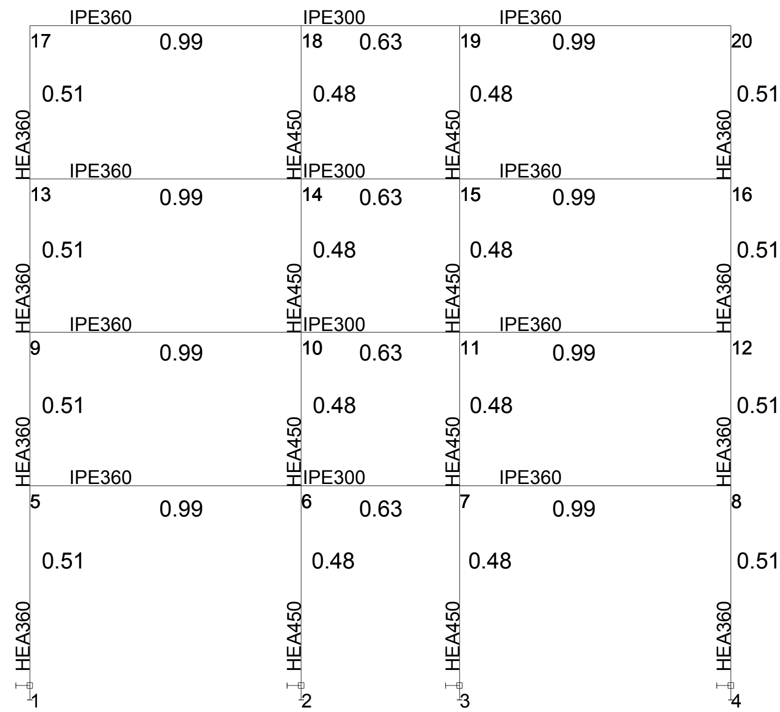
Izkoriščenost prerezov

Zunanji prečni okvir (okvir N):



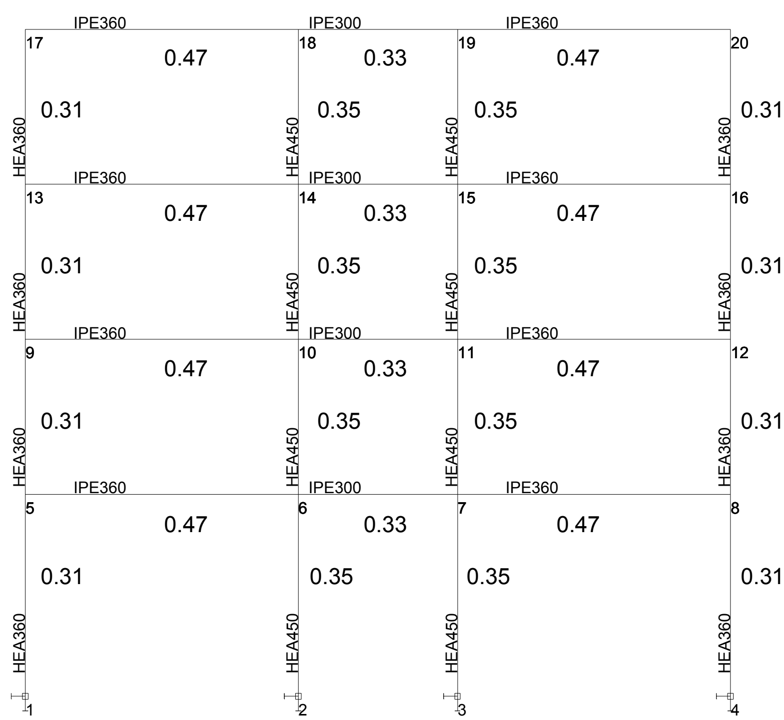
Izkoriščenost prerezov

Notranji prečni okvir (okvir M):



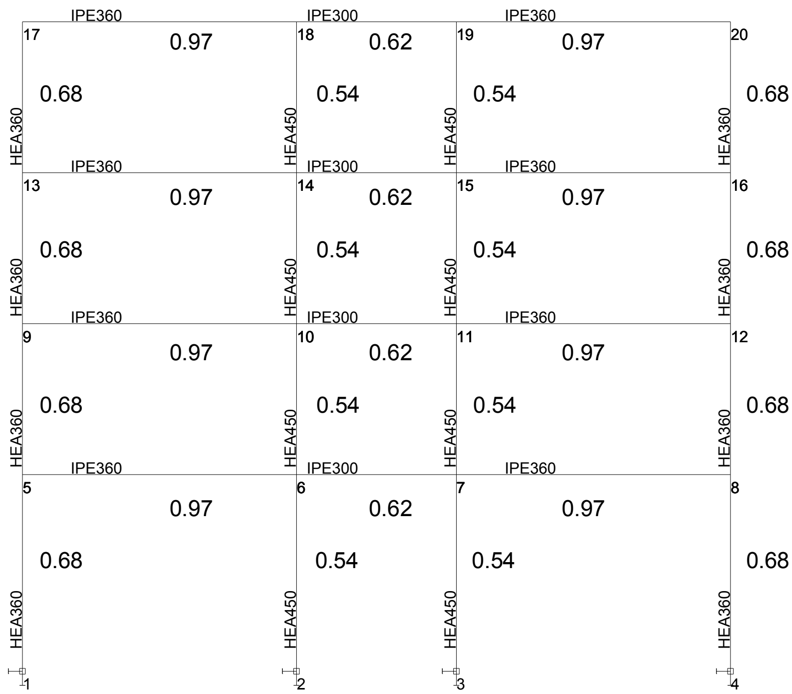
Izkoriščenost prerezov

Notranji prečni okvir (okvir J):



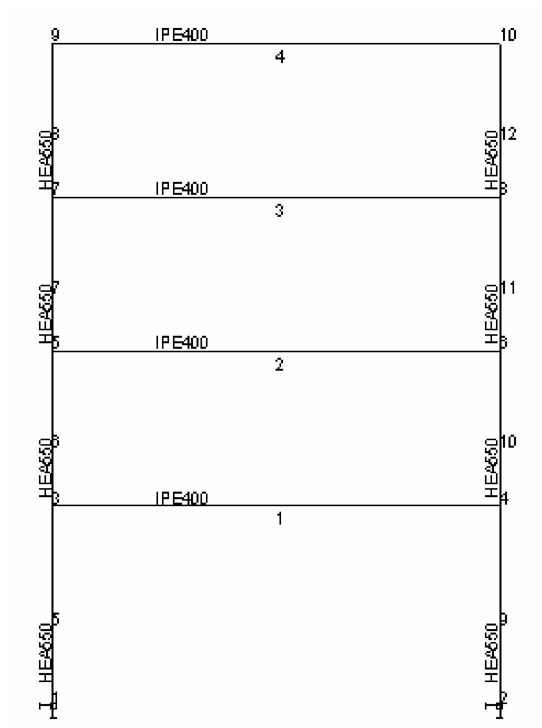
Izkoriščenost prerezov

Notranji prečni okvir (okvir L):

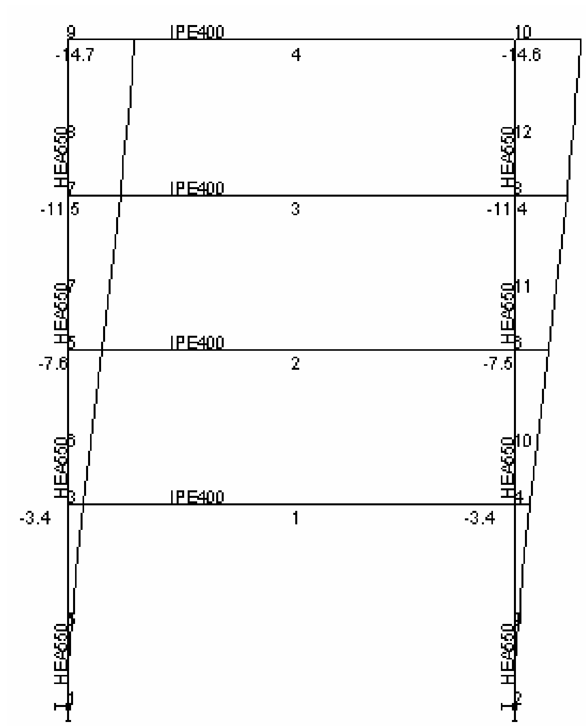


Izkoriščenost prerezov

Zunanji prečni okvir (okvir K):



Geometrija



Pomiki - potres[mm]

HEA 550 - K7

Notranje sile pri K7: 1.0G+0.15Q+1.0A
Group of member(s) :1/12
Group of nonlinear combination(s) :7
Cross-section : 1 - HEA550

memb	non. c.	dx [m]	N [kN]	V [kN]	M [kNm]
9	7	0.000	**-950.18**	40.04	**-141.58**
12		1.320	-254.89	**45.73**	23.94
8		1.320	-244.46	**-31.85**	-1.26
12		3.300	-254.91	45.55	**114.35**

IPE 400 - K7

Notranje sile pri K7: 1.0G+0.15Q+1.0A
Group of member(s) :1/12
Group of nonlinear combination(s) :7
Cross-section : 2 - IPE400

memb	non. c.	dx [m]	N [kN]	V [kN]	M [kNm]
3	7	0.635	**5.44**	33.16	-17.88
4		9.530	**-52.15**	**-64.34**	**-114.35**
		0.000	-52.05	**53.92**	-64.28
		4.447	-52.13	-1.32	**52.94**

HEA 550 - K8

Notranje sile pri K8: 1.0G+0.15Q
Group of member(s) :1/12
Group of nonlinear combination(s) :8
Cross-section : 1 - HEA550

memb	non. c.	dx [m]	N [kN]	V [kN]	M [kNm]
5	8	4.300	**-924.64**	-7.18	-24.00
12		1.320	-249.57	**38.80**	12.02
8		1.320	-249.80	**-38.81**	-13.11
12		3.300	-249.58	38.67	**88.76**
8		3.300	-249.81	-38.68	**-89.87**

IPE 400 - K8

Notranje sile pri K8: 1.0G+0.15Q
Group of member(s) :1/12
Group of nonlinear combination(s) :8
Cross-section : 2 - IPE400

memb	non. c.	dx [m]	N [kN]	V [kN]	M [kNm]
3	8	8.259	**17.56**	-33.34	-20.76
4		5.083	**-38.79**	-3.84	**51.20**
		0.000	-38.76	**59.24**	**-89.87**
		9.530	-38.76	**-59.01**	-88.76

HEA 550 - K9

Notranje sile pri K9: 1.0A
Group of member(s) :1/12
Group of nonlinear combination(s) :9
Cross-section : 1 - HEA550

memb	non. c.	dx [m]	N [kN]	V [kN]	M [kNm]
5	9	4.300	**26.00**	27.30	-2.49
9		0.000	**-25.79**	26.53	-118.00
5		0.000	25.97	**27.33**	**-119.92**
11		3.300	-11.50	12.73	**32.86**

IPE 400 - K9

Notranje sile pri K9: 1.0A
Group of member(s) :1/12
Group of nonlinear combination(s) :9
Cross-section : 2 - IPE400

memb	non. c.	dx [m]	N [kN]	V [kN]	M [kNm]
1	9	0.000	**-15.31**	-6.95	33.21
2		4.447	-12.62	**-7.41**	2.34
		0.000	-12.62	-7.39	**35.25**
		9.530	-12.62	-7.39	**-35.27**

Kontrola nosilnosti in stabilnosti

EC3 Code Check
Cross-section : 1 - HEA550

Macro 6	Member 9	HEA550	S 275	Non-Lin. Comb. 1	0.46

NSd| [kN]	Vy.Sd| [kN]	Vz.Sd| [kN]	Mt.Sd| [kNm]	My.Sd| [kNm]	Mz.Sd | [kNm]
-1685.23	0.00	28.95	-0.00	71.92	0.00

The critical check is on position 4.30 m

Buckling parameters	yy	zz	
type	sway	non-sway	
Slenderness	13.63	60.25	
Reduced slenderness	0.16	0.69	
Buckling curve	a	b	
Imperfection	0.21	0.34	
Reduction factor	1.00	0.79	
Length	4.30	4.30	m
Buckling factor	1.00	0.73	
Buckling length	4.30	3.13	m
Critical Euler load	236657.63	12106.15	kN

LTB		
LTB length	2.15	m
k	1.00	
kw	1.00	
C1	2.65	
C2	0.01	
C3	0.68	

load in center of gravity

SECTION CHECK	
Vz	0.02 < 1
M	0.08 < 1

STABILITY CHECK	
Buckling	0.40 < 1
LTB	0.06 < 1
Compression + Moment	0.38 < 1
Compression + LTB	0.46 < 1

Cross-section : 2 - IPE400

Macro 4	Member 4	IPE400	S 275	Non-Lin. Comb. 3	0.89

NSd| [kN]	Vy.Sd| [kN]	Vz.Sd| [kN]	Mt.Sd| [kNm]	My.Sd| [kNm]	Mz.Sd | [kNm]
-63.66	0.00	-98.15	-0.00	-149.65	0.00

The critical check is on position 9.53 m

Buckling parameters	yy	zz	
type	sway	non-sway	
Slenderness	36.20	191.25	
Reduced slenderness	0.42	2.78	
Buckling curve	a	b	
Imperfection	0.21	0.34	
Reduction factor	0.95	0.11	
Length	9.53	9.53	m
Buckling factor	1.00	0.63	
Buckling length	9.53	5.99	m
Critical Euler load	13358.46	300.78	kN

LTB		
LTB length	4.76	m
k	1.00	
kw	1.00	
C1	1.30	
C2	1.54	
C3	0.75	

load in center of gravity

SECTION CHECK	
Vz	0.16 < 1
M	0.46 < 1

STABILITY CHECK	
Buckling	0.26 < 1
LTB	0.69 < 1
Compression + Moment	0.56 < 1
Compression + LTB	0.89 < 1

4.9 Dinamična analiza v vzdolžni smeri (Objekt A)

4.9.1 Izračun mase in nihajnega časa

$$m = \frac{1}{n_{povezij}} \left(n_{mom.\,okvirjev} - 1 \right) \cdot m^{mom.\,okvirjev}$$

$n_{povezij} = 2 \cdot 2 = 4$

$n_{mom.okvirjev} = 9$

$$m = \frac{1}{4} (9 - 1) \cdot m^{mom.\,okvirjev} = 2 \cdot m^{mom.okvirjev}$$

$m_1 = 124891.6kg$

$m_2 = 124259.6kg$

$m_3 = 123605.4kg$

$m_4 = 120274.4kg$

$m_5 = 11834.6kg$

$$T = \frac{1}{\nu} = \frac{1}{1.578s^{-1}} = 0.63s$$

$\nu = 1.578s^{-1}$

4.9.2 Začetna nepopolnost

$\Phi = k_C k_S \Phi_0$ $\Phi = 0.0032$

$$\Phi_0 = \frac{1}{200}$$

$$k_C = \sqrt{\left(0.5 + \frac{1}{n_C}\right)} = \sqrt{\left(0.5 + \frac{1}{2}\right)} = 1.0 \leq 1.0$$

$$k_S = \sqrt{\left(0.2 + \frac{1}{n_S}\right)} = \sqrt{\left(0.2 + \frac{1}{5}\right)} = 0.64 \leq 1.0$$

n_c...število stebrov etaže $n_c = 2$

n_s...število etaž $n_s = 5$

4.9.3 Določitev potresnih sil

$T_C \leq T \leq T_D$: $S_d(T) = a_g S \frac{2.5}{q}\left[\frac{T_C}{T}\right] \geq 0.20a_g$

$$S_d(T) = 0.15 \cdot 9.81 \cdot 1.0 \cdot \frac{2.5}{6}\left[\frac{0.5}{0.63}\right] = 0.484m/s^2 \geq 0.245m/s^2$$

$F_b = S_d(T) \cdot m \cdot \lambda = 0.484m/s^2 \cdot 504865.6kg \cdot 1.0 = 244.23kN$

$$F_1' = F_b \cdot \frac{s_1 m_1}{\sum_{i=1-5} s_i m_i} = 244.23kN \cdot \frac{4.3m \cdot 124891.6kg}{4.3m \cdot 124891.6kg + ... + 3.3m \cdot 11834.6kg} = 73.24kN$$

$$F_2' = F_b \cdot \frac{s_2 m_2}{\sum_{i=1-5} s_i m_i} = 244.23kN \cdot \frac{3.3m \cdot 124259.6kg}{4.3m \cdot 124891.6kg + ... + 3.3m \cdot 11824.6kg} = 55.92kN$$

$$F_3' = F_b \cdot \frac{s_3 m_3}{\sum_{i=1-5} s_i m_i} = 244.23kN \cdot \frac{3.3m \cdot 123605.4.kg}{4.3m \cdot 124891.6kg + ... + 3.3m \cdot 11824.6kg} = 55.63kN$$

$$F_4' = F_b \cdot \frac{s_4 m_4}{\sum_{i=1-5} s_i m_i} = 244.23kN \cdot \frac{3.3m \cdot 120274.4kg}{4.3m \cdot 124891.6kg + ... + 3.3m \cdot 11824.6kg} = 54.13kN$$

$$F_5' = F_b \cdot \frac{s_5 m_5}{\sum\limits_{i=1-5} s_i m_i} = 244.23\text{kN} \cdot \frac{3.3\text{m} \cdot 11824.6\text{kg}}{4.3\text{m} \cdot 124891.6\text{kg} + ... + 3.3\text{m} \cdot 11824.6\text{kg}} = 5.33\text{kN}$$

Torzijski učinek:

$\delta = 1 + 0.6 \cdot x / L_e = 1 + 0.6 \cdot 12\text{m} / 48\text{m} = 1.15$

$$F_1 = \delta \cdot F_1' = 1.15 \cdot 73.24\text{kN} = 84.22\text{kN}$$

$$F_2 = \delta \cdot F_2' = 1.15 \cdot 55.92\text{kN} = 64.31\text{kN}$$

$$F_3 = \delta \cdot F_3' = 1.15 \cdot 55.63\text{kN} = 63.97\text{kN}$$

$$F_4 = \delta \cdot F_4' = 1.15 \cdot 54.13\text{kN} = 62.24\text{kN}$$

$$F_5 = \delta \cdot F_5' = 1.15 \cdot 5.33\text{kN} = 6.12\text{kN}$$

4.9.4 Kontrola pomikov

$d_r \cdot \nu \leq 0.0075 \cdot h$

$\nu = 0.5$

$d_r = (u_i - u_{i-1}) \cdot q$

$q = 4$

$d_{r1} = (u_1 - 0) \cdot q = (8.5\text{mm}) \cdot 4 = 34.0\text{mm}$

$d_{r2} = (u_2 - u_1) \cdot q = (15.3\text{mm} - 8.5\text{mm}) \cdot 4 = 27.2\text{mm}$

$d_{r3} = (u_3 - u_2) \cdot q = (21.0\text{mm} - 15.3\text{mm}) \cdot 4 = 22.8\text{mm}$

$d_{r4} = (u_4 - u_3) \cdot q = (26.5\text{mm} - 21.0\text{mm}) \cdot 4 = 22.0\text{mm}$

$d_{r5} = (u_5 - u_4) \cdot q = (30.0\text{mm} - 26.5\text{mm}) \cdot 4 = 14.0\text{mm}$

$d_{r1} \cdot \nu = 34.0\text{mm} \cdot 0.5 = 17.0\text{mm} \leq 0.0075 \cdot h = 0.0075 \cdot 4300\text{mm} = 32.25\text{mm}$

$d_{r2} \cdot \nu = 27.2\text{mm} \cdot 0.5 = 13.6\text{mm} \leq 0.0075 \cdot h = 0.0075 \cdot 3300\text{mm} = 24.75\text{mm}$

$d_{r3} \cdot \nu = 22.8\text{mm} \cdot 0.5 = 11.4\text{mm} \leq 0.0075 \cdot h = 0.0075 \cdot 3300\text{mm} = 24.75\text{mm}$

$d_{r4} \cdot \nu = 22.0\text{mm} \cdot 0.5 = 11.0\text{mm} \leq 0.0075 \cdot h = 0.0075 \cdot 3300\text{mm} = 24.75\text{mm}$

$d_{r5} \cdot \nu = 14.0\text{mm} \cdot 0.5 = 7.0\text{mm} \leq 0.0075 \cdot h = 0.0075 \cdot 3300\text{mm} = 24.75\text{mm}$

4.10 Dinamična analiza v vzdolžni smeri (Objekt B)

4.10.1 Izračun mase in nihajnega časa

$$m = \frac{1}{n_{povezij}} \left(n_{mom.\,okvirjev} - 1\right) \cdot m^{mom.\,okvirjev}$$

$n_{povezij} = 2 \cdot 1 = 2$

$n_{mom.okvirjev} = 4$

$$m = \frac{1}{2}\left(4-1\right) \cdot m^{mom.\,okvirjev} = 1.5 \cdot m^{mom.okvirjev}$$

$m_1 = 126415.0\text{kg}$

$m_2 = 125391.0\text{kg}$

$m_3 = 121417.8\text{kg}$

$m_4 = 106809.8\text{kg}$

$$T = \frac{1}{\nu} = \frac{1}{1.646\text{s}^{-1}} = 0.61\text{s}$$

$\nu = 1.646\text{s}^{-1}$

4.10.2 Začetna nepopolnost

$\Phi = k_C k_S \Phi_0$ $\Phi = 0.00335$

$$\Phi_0 = \frac{1}{200}$$

$$k_C = \sqrt{\left(0.5 + \frac{1}{n_C}\right)} = \sqrt{\left(0.5 + \frac{1}{2}\right)} = 1.0 \le 1.0$$

$$k_S = \sqrt{\left(0.2 + \frac{1}{n_S}\right)} = \sqrt{\left(0.2 + \frac{1}{4}\right)} = 0.67 \le 1.0$$

n_c...število stebrov etaže $n_c = 2$

n_s...število etaž $n_s = 4$

4.10.3 Določitev potresnih sil

$T_C \le T \le T_D$: $S_d(T) = a_g S \frac{2.5}{q}\left[\frac{T_C}{T}\right] \ge 0.20 a_g$

$$S_d(T) = 0.15 \cdot 9.81 \cdot 1.0 \cdot \frac{2.5}{6}\left[\frac{0.5}{0.61}\right] = 0.505 m/s^2 \geq 0.245 m/s^2$$

$F_b = S_d(T) \cdot m \cdot \lambda = 0.505 m/s^2 \cdot 480033.6 kg \cdot 1.0 = 242.23 kN$

$$F_1' = F_b \cdot \frac{s_1 m_1}{\sum\limits_{i=1-4} s_i m_i} = 242.23 kN \cdot \frac{4.3m \cdot 126515.0kg}{4.3m \cdot 126515.0kg + ... + 3.3m \cdot 106809.8kg} = 76.98 kN$$

$$F_2' = F_b \cdot \frac{s_2 m_2}{\sum\limits_{i=1-4} s_i m_i} = 242.23 kN \cdot \frac{3.3m \cdot 125391.0kg}{4.3m \cdot 126515.0kg + ... + 3.3m \cdot 106809.8kg} = 58.60 kN$$

$$F_3' = F_b \cdot \frac{s_3 m_3}{\sum\limits_{i=1-4} s_i m_i} = 242.23 kN \cdot \frac{3.3m \cdot 121417.8kg}{4.3m \cdot 126515.0kg + ... + 3.3m \cdot 106809.8kg} = 56.74 kN$$

$$F_4' = F_b \cdot \frac{s_4 m_4}{\sum\limits_{i=1-4} s_i m_i} = 242.23 kN \cdot \frac{3.3m \cdot 106809.8kg}{4.3m \cdot 126515.0kg + ... + 3.3m \cdot 106809.8kg} = 49.91 kN$$

Torzijski učinek:

$\delta = 1 + 0.6 \cdot x / L_e = 1 + 0.6 \cdot 6m / 24m = 1.15$

$F_1 = \delta \cdot F_1' = 1.15 \cdot 76.98 kN = 88.52 kN$

$F_2 = \delta \cdot F_2' = 1.15 \cdot 58.60 kN = 67.36 kN$

$F_3 = \delta \cdot F_3' = 1.15 \cdot 56.74 kN = 65.25 kN$

$F_4 = \delta \cdot F_4' = 1.15 \cdot 49.91 kN = 57.40 kN$

4.10.4 Kontrola pomikov

$d_r \cdot \nu \leq 0.0075 \cdot h$

$\nu = 0.5$

$d_r = (u_i - u_{i-1}) \cdot q$

$q = 4$

$d_{r1} = (u_1 - 0) \cdot q = (8.1mm) \cdot 4 = 32.4mm$

$d_{r2} = (u_2 - u_1) \cdot q = (14.8mm - 8.1mm) \cdot 4 = 26.8mm$

$d_{r3} = (u_3 - u_2) \cdot q = (20.0mm - 14.8mm) \cdot 4 = 20.8mm$

$d_{r4} = (u_4 - u_3) \cdot q = (26.0mm - 20.0mm) \cdot 4 = 24.0mm$

$d_{r1} \cdot \nu = 32.4mm \cdot 0.5 = 16.2mm \leq 0.0075 \cdot h = 0.0075 \cdot 4300mm = 32.25mm$

$d_{r2} \cdot \nu = 26.8mm \cdot 0.5 = 13.4mm \leq 0.0075 \cdot h = 0.0075 \cdot 3300mm = 24.75mm$

$d_{r3} \cdot \nu = 20.8mm \cdot 0.5 = 10.4mm \leq 0.0075 \cdot h = 0.0075 \cdot 3300mm = 24.75mm$

$d_{r4} \cdot \nu = 24.0mm \cdot 0.5 = 12.0mm \leq 0.0075 \cdot h = 0.0075 \cdot 3300mm = 24.75mm$

4.11 Posebna pravila za momentne okvirje (OSIST ENV 1998-1-3)

notranji:

$\Sigma W_{pl,y}^{steber\ HEA\ 450} \geq \Sigma W_{pl,y}^{nosilec\ IPE\ 360}$ $\Sigma W_{pl,y}^{steber\ HEA\ 450} \geq \Sigma W_{pl,y}^{nosilec\ IPE\ 300}$

$3216.0cm^3 \geq 1019.0cm3$ $3216.0cm^3 \geq 628.0cm^3$

$\Sigma W_{pl,y}^{steber\ HEA\ 320} \geq \Sigma W_{pl,y}^{nosilec\ IPE\ 360}$ $\Sigma W_{pl,y}^{steber\ HEA\ 320} \geq \Sigma W_{pl,y}^{nosilec\ IPE\ 360}$

$1628.0cm^3 \geq 1019.0cm3$ $1628.0cm^3 \geq 628.0cm^3$

zunanji:

$\Sigma W_{pl,y}^{steber\ HEA\ 360} \geq \Sigma W_{pl,y}^{nosilec\ IPE\ 360}$ $\Sigma W_{pl,y}^{steber\ HEA\ 360} \geq \Sigma W_{pl,y}^{nosilec\ IPE\ 300}$

$2 \cdot 2088.0cm^3 = 4176.0cm^3 \geq 1019.0cm3$ $2 \cdot 2088.0cm^3 = 4176.0cm^3 \geq 628.0cm^3$

$\Sigma W_{pl,y}^{steber\ HEA\ 260} \geq \Sigma W_{pl,y}^{nosilec\ IPE\ 360}$ $\Sigma W_{pl,y}^{steber\ HEA\ 260} \geq \Sigma W_{pl,y}^{nosilec\ IPE\ 300}$

$2 \cdot 920.0cm^3 = 1840.0cm^3 \geq 1019.0cm3$ $2 \cdot 920.0cm^3 = 1840.0cm^3 \geq 628.0cm^3$

Prečke IPE 300:

$M_{Sd} = 77.16kNm$ ... glej diplomska naloga, stran 57.

$k_\delta = 1.193$ ... glej diplomska naloga, stran 46.

$M_{Ed} = M_{Sd} \cdot k_\delta = 77.16kNm \cdot 1.193 = 92.05kNm$

$$M_{el,Rd} = \frac{f_y}{\gamma_{M0}} \cdot W_{el} = \frac{27.5kN/cm^2}{1.1} \cdot 557.0cm^3 = 139.25kNm$$

$$\frac{M_{Ed}}{M_{pl,Rd}} = \frac{92.05kNm}{139.25kNm} = 0.66 \leq 1.0$$

$N_{Sd} = 17.15kN$ ... glej diplomska naloga, stran 57.

$N_{Ed} = N_{Sd} = 17.15kNm$

$$N_{pl,Rd} = \frac{f_y}{\gamma_{M0}} \cdot A = \frac{27.5kN/cm^2}{1.1} \cdot 53.8cm^2 = 1345.0kN$$

$$\frac{N_{Ed}}{N_{pl,Rd}} = \frac{17.5kN}{1345.0kN} = 0.013 \leq 0.15$$

$V_{Ed,M}$ ... največja prečna sila, ki se razvije v nosilcu.

$$V_{Ed,M} = \frac{M_{pl,A} + M_{pl,B}}{L} = \frac{172.7kNm + 172.7kNm}{3.5m} = 98.69kN$$

$V_{Ed,G} = 60.6kN$

$V_{Ed} = V_{Ed,M} + V_{Ed,G} = 98.69kN + 60.6kN = 159.29kN$

$$V_{pl,Rd} = \frac{f_y}{\gamma_{M0} \cdot \sqrt{3}} \cdot A_s = \frac{27.5kN/cm^2}{1.1 \cdot \sqrt{3}} \cdot 22.15cm^2 = 319.71kN$$

$$\frac{V_{Ed}}{V_{pl,Rd}} = \frac{159.29kN}{319.71kN} = 0.49 \leq 0.5$$

Prečke IPE 360:

$M_{Sd} = 150.92kNm$ ... glej diplomska naloga, stran 57.

$k_\delta = 1.193$ ... glej diplomska naloga, stran 46.

$M_{Ed} = M_{Sd} \cdot k_\delta = 150.92kNm \cdot 1.193 = 180.05kNm$

$$M_{el,Rd} = \frac{f_y}{\gamma_{M0}} \cdot W_{el} = \frac{27.5kN/cm^2}{1.1} \cdot 904.0cm^3 = 226.0kNm$$

$$\frac{M_{Ed}}{M_{pl,Rd}} = \frac{180.05kNm}{226.0kNm} = 0.80 \leq 1.0$$

$N_{Sd} = 17.15kN$ ... glej diplomska naloga, stran 57.

$N_{Ed} = N_{Sd} = 74.05kNm$

$$N_{pl,Rd} = \frac{f_y}{\gamma_{M0}} \cdot A = \frac{27.5kN/cm^2}{1.1} \cdot 72.7cm^2 = 1817.5kN$$

$$\frac{N_{Ed}}{N_{pl,Rd}} = \frac{74.05kN}{1817.5kN} = 0.04 \leq 0.15$$

$$V_{Ed,M} = \frac{M_{pl,A} + M_{pl,B}}{L} = \frac{280.23kNm + 280.23kNm}{6.0m} = 93.41kN$$

$V_{Ed,G} = 104.6kN$

$V_{Ed} = V_{Ed,M} + V_{Ed,G} = 93.41kN + 104.6kN = 198.01kN$

$$V_{pl,Rd} = \frac{f_y}{\gamma_{M0} \cdot \sqrt{3}} \cdot A_s = \frac{27.5kN/cm^2}{1.1 \cdot \sqrt{3}} \cdot 32.47cm^2 = 468.66kN$$

$$\frac{V_{Ed}}{V_{pl,Rd}} = \frac{198.01kN}{468.66kN} = 0.42 \leq 0.5$$

Stebri HEA 360:

Strižna nosilnost panela stojine stebra v območju spoja prečka – steber mora zadoščati pogoju:

$M_{Ed,spodaj} = M_{Sd,spodaj} \cdot k_\delta = 2317.0kNcm \cdot 1.193 = 2764.18kNm$

$M_{Ed,zgoraj} = M_{Sd,zgoraj} \cdot k_\delta = 2140.0kNcm \cdot 1.193 = 2553.02kNm$

$$V_{wp,Ed} = \frac{M_{Ed}^{spodaj} + M_{Ed}^{zgoraj}}{h_w^{nosilca}} = \frac{2764.18kNcm + 2553.02kNcm}{29.8cm} = 178.43kN$$

$$V_{wp,Rd} = h_w^{nosilca} \cdot t_w^{stebra} \cdot \frac{f_y}{\gamma_{M0} \cdot \sqrt{3}} = 29.8cm \cdot 1.0cm \cdot \frac{27.5kN/cm^2}{1.1 \cdot \sqrt{3}} = 430.13kN$$

$$\frac{V_{wp,Ed}}{V_{wp,Rd}} = \frac{178.43kN}{430.13kN} = 0.42 \leq 1.0$$

Kontrola za prečno silo v stebru V_{Ed}:

$V_{Ed} = 55.44kN$ ... glej diplomska naloga, stran 116.

$$\frac{V_{Ed}}{V_{pl,Rd}} = \frac{55.44kN}{525.39kN} = 0.11 \leq 0.5$$

$$V_{pl,Rd} = \frac{f_y}{\gamma_{M0} \cdot \sqrt{3}} \cdot A_s = \frac{27.5kN/cm^2}{1.1 \cdot \sqrt{3}} \cdot 36.4cm^2 = 525.39kN$$

Stebri HEA 450:

Strižna nosilnost panela stojine stebra v območju spoja prečka – steber mora zadoščati pogoju:

$M_{Ed,spodaj} = M_{Sd,spodaj} \cdot k_\delta = 4364.0kNcm \cdot 1.193 = 5206.25kNcm$

$M_{Ed,zgoraj} = M_{Sd,zgoraj} \cdot k_\delta = 3829.0kNcm \cdot 1.193 = 4567.99kNcm$

$$V_{wp,Ed} = \frac{M_{Ed}^{spodaj} + M_{Ed}^{zgoraj}}{h_w^{nosilca}} = \frac{5206.25kNcm + 4567.99kNcm}{29.8cm} = 327.99kN$$

$$V_{wp,Rd} = h_w^{nosilca} \cdot t_w^{stebra} \cdot \frac{f_y}{\gamma_{M0} \cdot \sqrt{3}} = 29.8cm \cdot 1.15cm \cdot \frac{27.5kN/cm^2}{1.1 \cdot \sqrt{3}} = 494.64kN$$

$$\frac{V_{wp,Ed}}{V_{wp,Rd}} = \frac{327.99kN}{494.64kN} = 0.66 \leq 1.0$$

Kontrola za prečno silo v stebru V_{Ed}:

V_{Ed} = 94.73kN ... glej diplomska naloga, stran 116.

$$\frac{V_{Ed}}{V_{pl,Rd}} = \frac{94.73kN}{759.56kN} = 0.13 \leq 0.5$$

$$V_{pl,Rd} = \frac{f_y}{\gamma_{M0} \cdot \sqrt{3}} \cdot A_s = \frac{27.5kN/cm^2}{1.1 \cdot \sqrt{3}} \cdot 52.62\,cm^2 = 759.56kN$$

Stebri HEA 260:

Strižna nosilnost panela stojine stebra v območju spoja prečka – steber mora zadoščati pogoju:

k_δ = 1.196 ... glej diplomska naloga, stran 42.

$M_{Ed,spodaj} = M_{Sd,spodaj} \cdot k_\delta = 2086.0kNcm \cdot 1.196 = 2494.86kNcm$

$M_{Ed,zgoraj} = M_{Sd,zgoraj} \cdot k_\delta = 1266.0kNcm \cdot 1.196 = 1514.14kNcm$

$$V_{wp,Ed} = \frac{M_{Ed}^{spodaj} + M_{Ed}^{zgoraj}}{h_w^{nosilca}} = \frac{2494.86kNcm + 1514.14kNcm}{29.8cm} = 134.53kN$$

$$V_{wp,Rd} = h_w^{nosilca} \cdot t_w^{stebra} \cdot \frac{f_y}{\gamma_{M0} \cdot \sqrt{3}} = 29.8cm \cdot 0.75cm \cdot \frac{27.5kN/cm^2}{1.1 \cdot \sqrt{3}} = 322.59kN$$

$$\frac{V_{wp,Ed}}{V_{wp,Rd}} = \frac{134.53kN}{322.59kN} = 0.42 \leq 1.0$$

Kontrola za prečno silo v stebru V_{Ed}:

V_{Ed} = 23.95kN ... glej diplomska naloga, stran 115.

$$\frac{V_{Ed}}{V_{pl,Rd}} = \frac{23.95\text{kN}}{281.46\text{kN}} = 0.09 \leq 0.5$$

$$V_{pl,Rd} = \frac{f_y}{\gamma_{M0} \cdot \sqrt{3}} \cdot A_s = \frac{27.5\text{kN/cm}^2}{1.1 \cdot \sqrt{3}} \cdot 19.5\text{cm}^2 = 281.46\text{kN}$$

Stebri HEA 320:

Strižna nosilnost panela stojine stebra v območju spoja prečka – steber mora zadoščati pogoju:

$M_{Ed,spodaj} = M_{Sd,spodaj} \cdot k_{\delta} = 4012.0\text{kNcm} \cdot 1.196 = 4798.35\text{kNcm}$

$M_{Ed,zgoraj} = M_{Sd,zgoraj} \cdot k_{\delta} = 2284.0\text{kNcm} \cdot 1.196 = 2731.66\text{kNcm}$

$$V_{wp,Ed} = \frac{M_{Ed}^{spodaj} + M_{Ed}^{zgoraj}}{h_w^{nosilca}} = \frac{4798.35\text{kNcm} + 2731.66\text{kNcm}}{29.8\text{cm}} = 252.68\text{kN}$$

$$V_{wp,Rd} = h_w^{nosilca} \cdot t_w^{stebra} \cdot \frac{f_y}{\gamma_{M0} \cdot \sqrt{3}} = 29.8\text{cm} \cdot 0.9\text{cm} \cdot \frac{27.5\text{kN/cm}^2}{1.1 \cdot \sqrt{3}} = 387.11\text{kN}$$

$$\frac{V_{wp,Ed}}{V_{wp,Rd}} = \frac{252.68\text{kN}}{387.11\text{kN}} = 0.65 \leq 1.0$$

Kontrola za prečno silo v stebru V_{Ed}:

V_{Ed} = 52.98kN ... glej diplomska naloga, stran 116.

$$\frac{V_{Ed}}{V_{pl,Rd}} = \frac{52.98\text{kN}}{418.81\text{kN}} = 0.13 \leq 0.5$$

$$V_{pl,Rd} = \frac{f_y}{\gamma_{M0} \cdot \sqrt{3}} \cdot A_s = \frac{27.5\text{kN/cm}^2}{1.1 \cdot \sqrt{3}} \cdot 29.02\text{cm}^2 = 418.81\text{kN}$$

Stebri HEA 550:

Strižna nosilnost panela stojine stebra v območju spoja prečka – steber mora zadoščati pogoju:

$k_\delta = 1.255$ ... glej diplomska naloga, stran 55.

$M_{Ed,spodaj} = M_{Sd,spodaj} \cdot k_\delta = 2612.0kNcm \cdot 1.255 = 3278.06kNcm$

$M_{Ed,zgoraj} = M_{Sd,zgoraj} \cdot k_\delta = 915.0kNcm \cdot 1.255 = 1148.33kNcm$

$$V_{wp,Ed} = \frac{M_{Ed}^{spodaj} + M_{Ed}^{zgoraj}}{h_w^{nosilca}} = \frac{3278.06kNcm + 1148.33kNcm}{33.1cm} = 133.73kN$$

$$V_{wp,Rd} = h_w^{nosilca} \cdot t_w^{stebra} \cdot \frac{f_y}{\gamma_{M0} \cdot \sqrt{3}} = 33.1cm \cdot 1.25cm \cdot \frac{27.5kN/cm^2}{1.1 \cdot \sqrt{3}} = 597.20kN$$

$$\frac{V_{wp,Ed}}{V_{wp,Rd}} = \frac{133.73kN}{597.20kN} = 0.22 \leq 1.0$$

Kontrola za prečno silo v stebru V_{Ed}:

$V_{Ed} = 73.53kN$ ... glej diplomska naloga, stran 116.

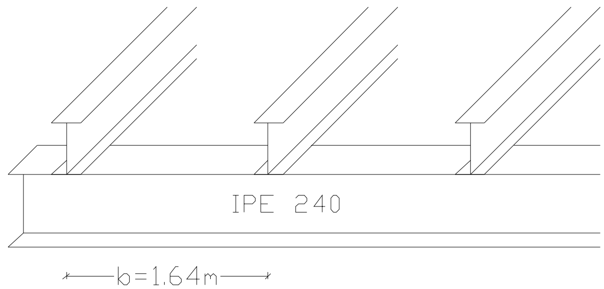
$$\frac{V_{Ed}}{V_{pl,Rd}} = \frac{73.53kN}{1013.25kN} = 0.073 \leq 0.5$$

$$V_{pl,Rd} = \frac{f_y}{\gamma_{M0} \cdot \sqrt{3}} \cdot A_s = \frac{27.5kN/cm^2}{1.1 \cdot \sqrt{3}} \cdot 70.2cm^2 = 1013.25kN$$

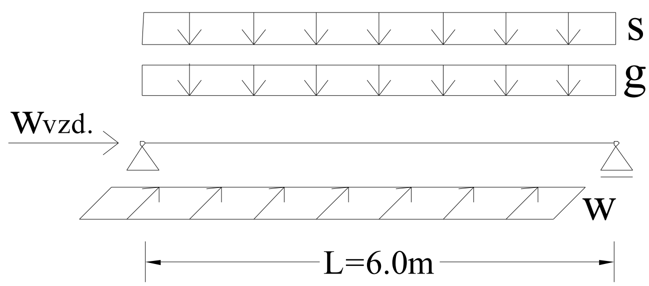
5 SEKUNDARNA KONSTRUKCIJA

5.1 Strešne lege

5.1.1 Zasnova



5.1.1 Računski model



5.1.3 Obtežba

5.1.3.1 Stalna obtežba

$g = G_S \cdot b = 0.5kN/m^2 \cdot 1.64m = 0.82kN/m$

5.1.3.2 Sneg

$s = S \cdot b = 1.24kN/m^2 \cdot 1.64m = 2.04kN/m$

5.1.3.3 Veter

Glej diplomska naloga, stran 19.

$w = W^+ \cdot b = 0.22kN/m^2 \cdot 1.64m = 0.36kN/m$

$w = W^- \cdot b = 0.93kN/m^2 \cdot 1.64m = 1.53kN/m$

$w_{vzd} = W^- \cdot b \cdot h/2 = 0.71kN/m^2 \cdot 1.64m \cdot 3.3m/2 = 1.92kN$

5.1.4 Obtežne kombinacije

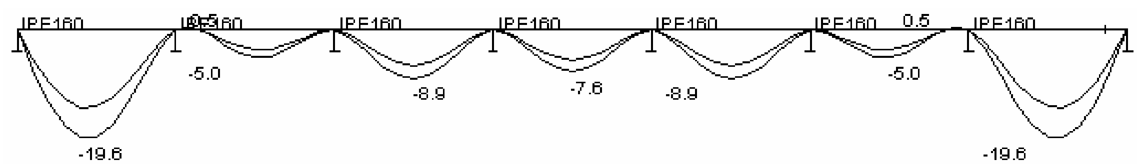
MSN:

1. $1.35g + 1.5s + q_{izb}$
2. $1.35g + 1.5w^{+} + q_{izb}$
3. $1.35(g + s + w^{-}) + q_{izb}$
4. $1.0g + 1.5w^{-} + q_{izb}$
5. $1.35(g + s + w_{vzd}) + q_{izb}$
6. $1.35g + 1.5w_{vzd} + q_{izb}$
7. $1.0g + 1.0A_{Ed} + q_{izb}$

MSU:

8. $1.0g + 1.0s$
9. $1.0g + 0.9(s + w)$

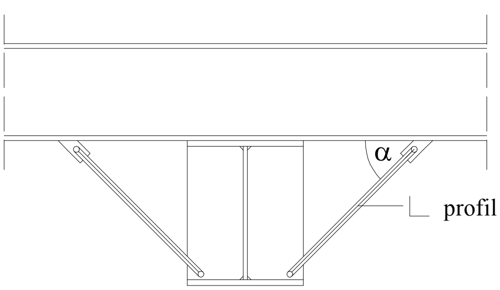
5.1.5 Kontrola pomikov



Pomiki uz MSU[mm]

$$\delta_{max} = 0.0196m \leq \frac{L}{250} = \frac{6m}{250} = 0.024m$$

Bočno podpiranje nosilca prečnega okvirja:



$$Q_{izb.} = q_{izb.} \cdot b = 0.133kN/m \cdot 1.64m = 0.218kN$$

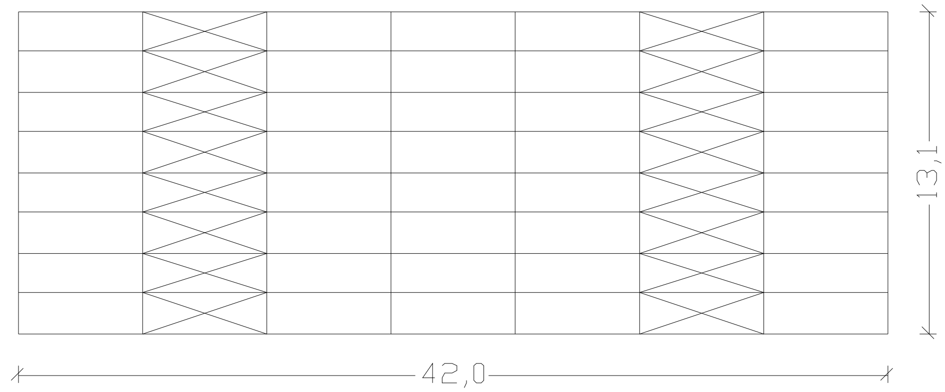
$$N_{Sd} = \frac{Q_{izb.}}{\sin\alpha} = \frac{0.218kN}{\sin 45^{\circ}} = 0.308kN$$

$$A_{potr.} = \frac{N_{Sdx} \cdot \gamma_{M1}}{\chi \cdot f_y} = \frac{0.308kN \cdot 1.1}{0.5 \cdot 27.5kN/cm^2} = 0.025cm^2$$

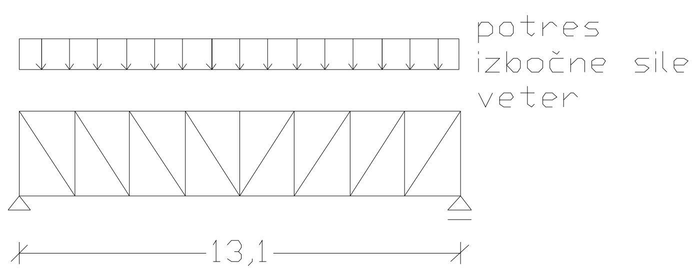
Izberem kotnik 40 / 40 / 6mm

5.2 Horizontalno zavetrovanje

5.2.1 Zasnova



5.2.2 Računski model



5.2.3 Obtežba

5.2.3.1 Potresna sila

$A_{Ed} = 2.69\text{kN}$ ... glej diplomska naloga, stran 45.

$$A'_{Ed} = \frac{A_{Ed}}{B} = \frac{2.69\text{kN}}{6\text{m}} = 0.448\text{kN/m}$$

$$A^{I}_{Ed} = A'_{Ed} \cdot b = 0.448\text{kN/m} \cdot 1.64\text{m} = 0.735\text{kN} \ldots \text{v vmesnih vozliščih}$$

$$A^{II}_{Ed} = A'_{Ed} \cdot \frac{b}{2} = 0.448\text{kN/m} \cdot \frac{1.64\text{m}}{2} = 0.367\text{kN} \ldots \text{v krajnem vozlišču}$$

5.2.3.2 Veter

$$A_{eff} = h \cdot L = 1.65m \cdot 15.5m = 25.58m^2$$

$W = 0.93kN$ ... glej diplomska naloga, stran 20.

$$w = \frac{W \cdot A_{eff}}{L} = \frac{0.93kN/m^2 \cdot 25.58m^2}{15.5m} = 1.53kN/m$$

$$w_I = w \cdot 1m = 1.53kN$$

$$w_{II} = w \cdot \frac{1m}{2} = 0.765kN$$

5.2.3.3 Izbočne sile

$$\sum q = \beta \cdot \frac{\sum N_{Sd}}{L}$$

$$M_{max} = 20.0kNm$$

$$N_{Sd} = \frac{M_{max}}{h} = \frac{20.0kNm}{0.4m} = 50kN$$

$$\sum N_{Sd} = n \cdot N_{Sd} = 4 \cdot 50kN = 200kN$$

n…št. primarnih nosilcev, ki jih prenesemo z enim horizontalnim povezjem

$$n = \frac{\text{št. okvirjev}}{\text{št. povezij}} = \frac{8}{2} = 4$$

$$\delta = \frac{L}{1500} \Rightarrow \beta = \frac{1}{62.5} = 0.016$$

$$\sum q = \beta \cdot \frac{\sum N_{Sd}}{L} = 0.016 \cdot \frac{200kN}{24m} = 0.133kN/m$$

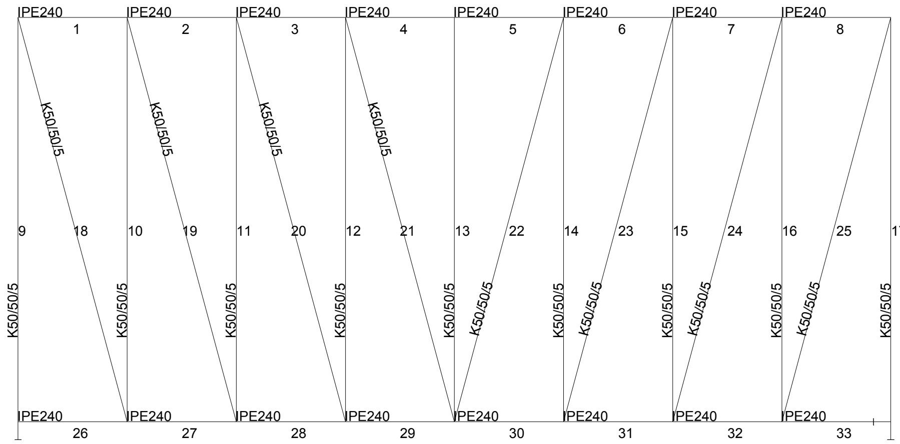
$$P_{izb.} = \sum q \cdot l = 0.133kN/m \cdot 1.64m = 0.218kN$$

$$P_{izb.,rob} = \sum q \cdot \frac{l}{2} = 0.133kN/m \cdot \frac{1.64m}{2} = 0.109kN$$

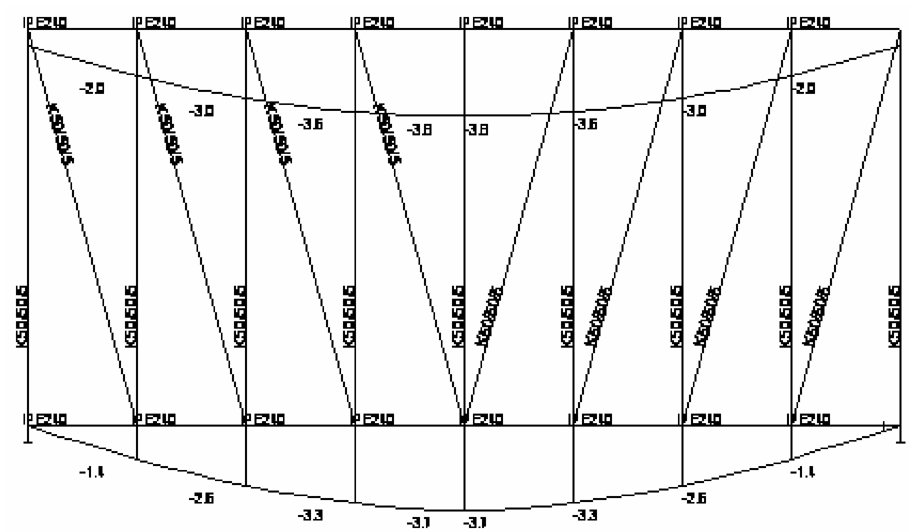
5.2.4 Kontrola pomikov

$$u_{z,max} = 0.0038m \leq u_{z,dov} = \frac{L}{250} = \frac{24m}{250} = 0.096m$$

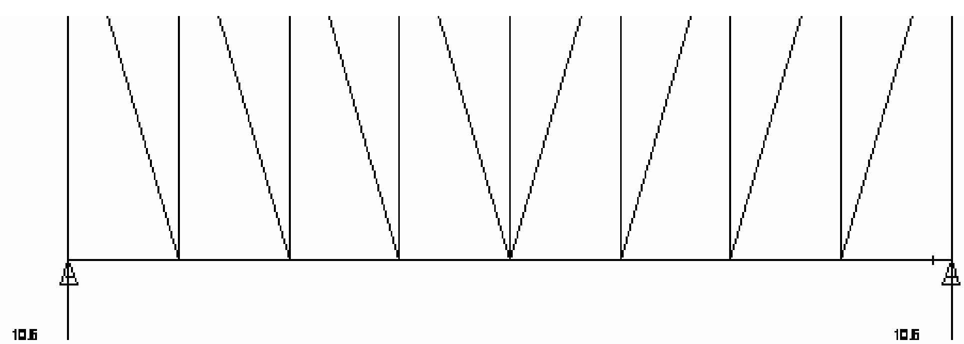
5.2.5 Rezultati dobljeni s programom ESA – Prima Win



Geometrija



Pomiki - MSU[mm]



Reakcije

Kontrola nosilnosti in stabilnosti

EC3 Code Check
Cross-section : 2 - K50/50/5

Macro 2	Member 9	K50/50/5	S 275	Non-Lin. Comb. 4	0.69

NSd| [kN]	Vy.Sd| [kN]	Vz.Sd| [kN]	Mt.Sd| [kNm]	My.Sd| [kNm]	Mz.Sd | [kNm]
-10.36	-0.00	-0.00	0.00	-0.02	-0.00

The critical check is on position 6.00 m

Buckling parameters	yy	zz	
type	sway	sway	
Slenderness	168.95	197.06	
Reduced slenderness	1.95	2.77	
Buckling curve	a	a	
Imperfection	0.21	0.21	
Reduction factor	0.23	0.17	
Length	6.00	6.00	m
Buckling factor	1.00	1.00	
Buckling length	6.00	6.00	m
Critical Euler load	65.35	17.44	kN

LTB		
LTB length	3.00	m
k	1.00	
kw	1.00	
C1	2.57	
C2	0.05	
C3	0.68	

load in center of gravity

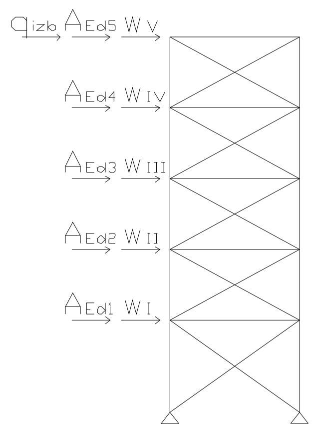
SECTION CHECK	
Vz	0.00 < 1
M	0.01 < 1

STABILITY CHECK	
Buckling	0.69 < 1
LTB	0.01 < 1
Compression + Moment	0.20 < 1
Compression + LTB	0.69 < 1

5.3 Vertikalno zavetrovanje

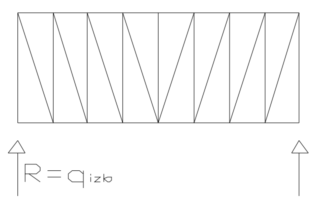
Diagonale dimenzioniramo na nateg. Ker je pri objektu B streha v betonski izvedbi, ne upoštevamo izbočnih sil kot pri objektu A.

5.3.1 Zasnova



5.3.2 Obtežba

5.3.2.1 Izbočna sila



$q_{izb.} = R(ESA) = 10.6kN$

5.3.2.2 Potresna sila

Potresne sile - glej diplomska naloga, stran 45. in 48.

Objekt A:	Objekt B:
F_1 = 37.01kN	F_1 = 35.76kN
F_2 = 28.26kN	F_2 = 27.31kN
F_3 = 28.11kN	F_3 = 27.16kN
F_4 = 27.35kN	F_4 = 23.63kN
F_5 = 2.69kN	

5.3.2.3 Veter

Objekt A:

$W = 0.78kN/m^2$ ... glej diplomska naloga, stran 19.

$B/2 = 7.75m$

$h_1 = 4.3m$	$w_1 = W \cdot h_1 = 0.78kN/m^2 \cdot 4.3m = 3.28kN/m$	$F_1 = 25.42kN$
$h_2 = 3.3m$	$w_2 = W \cdot h_2 = 0.78kN/m^2 \cdot 3.3m = 2.57kN/m$	$F_2 = 19.92kN$
$h_3 = 3.3m$	$w_3 = W \cdot h_3 = 0.78kN/m^2 \cdot 3.3m = 2.57kN/m$	$F_3 = 19.92kN$
$h_4 = 3.3m$	$w_4 = W \cdot h_4 = 0.78kN/m^2 \cdot 3.3m = 2.57kN/m$	$F_4 = 19.92kN$
$h_5 = 3.3m$	$w_5 = W \cdot h_5 = 0.78kN/m^2 \cdot 3.3m = 2.57kN/m$	$F_5 = 19.92kN$

Objekt B:

$W = 0.78kN/m^2$ ... glej diplomska naloga, stran 19.

$B/2 = 7.75m$

$h_1 = 4.3m$	$w_1 = W \cdot h_1 = 0.78kN/m^2 \cdot 4.3m = 3.28kN/m$	$F_1 = 25.42kN$
$h_2 = 3.3m$	$w_2 = W \cdot h_2 = 0.78kN/m^2 \cdot 3.3m = 2.57kN/m$	$F_2 = 19.92kN$
$h_3 = 3.3m$	$w_3 = W \cdot h_3 = 0.78kN/m^2 \cdot 3.3m = 2.57kN/m$	$F_3 = 19.92kN$
$h_4 = 3.3m$	$w_4 = W \cdot h_4 = 0.78kN/m^2 \cdot 3.3m = 2.57kN/m$	$F_4 = 19.92kN$

5.3.3 Obtežne kombinacije

5.3.3.1 MSN

Objekt A:	Objekt B:
1.) $1.0A_{Ed} + 0.7q_{izb}$	1.) $1.0A_{Ed}$
2.) $1.5w + 1.0q_{izb}$	2.) $1.5w$

5.3.3.2 MSU

Objekt A:	Objekt B:
3.) $1.0A_{Ed} + 0.7q_{izb}$	3.) $1.0A_{Ed}$
4.) $1.0w + 0.7q_{izb}$	4.) $1.0w$

5.3.4 Dimenzioniranje

5.3.4.1 MSN

Dimenzionirano s programom ESA-Prima Win.

5.3.4.2 MSU

Kontrola horizontalnih pomikov:

Večetažna zgradba: -posamezna etaža: $\delta_i \leq \delta_{max\ i} = \frac{h_i}{300}$

-celotna višina zgradbe: $\delta \leq \delta_{max} = \frac{H}{500}$

Objekt A:	Objekt B:
$\delta_1 = 0.0038m \leq \delta_{max\ 1} = 0.014m$	$\delta_1 = 0.0037m \leq \delta_{max\ 1} = 0.014m$
$\delta_2 = 0.0070m \leq \delta_{max\ 2} = 0.025m$	$\delta_2 = 0.0072m \leq \delta_{max\ 2} = 0.025m$
$\delta_3 = 0.0097m \leq \delta_{max\ 3} = 0.036m$	$\delta_3 = 0.0097m \leq \delta_{max\ 3} = 0.036m$
$\delta_4 = 0.0127m \leq \delta_{max\ 4} = 0.047m$	$\delta_4 = 0.0128m \leq \delta_{max\ 4} = 0.047m$
$\delta_5 = 0.0159m \leq \delta_{max\ 5} = 0.058m$	$\delta = 0.0128m \leq \delta_{max} = 0.0284m$
$\delta = 0.0159m \leq \delta_{max} = 0.035m$	

5.3.5 Posebna pravila za diagonalna centrična povezja (OSIST ENV 1998-1-3)

Objekt A:

$$\frac{|A^+ - A^-|}{A^+ + A^-} = 0 \leq 0.05$$

$$A^+ = A^- = A \cdot \cos\alpha$$

$$\bar{\lambda} = \frac{l_u}{i_z \lambda_1} \qquad 1.3 \leq \bar{\lambda} \leq 2.0$$

$i_{z1} = 44.87mm$

$i_{z2} = i_{z3} = 39.72mm$

$i_{z4} = 15.49mm$

$i_{z5} = 4.45mm$

$l_{u1} = 7380mm$

$l_{u2} = l_{u3} = l_{u4} = l_{u5} = 6840mm$

$$\lambda_1 = 93.9\sqrt{\frac{235MPa}{275MPa}} = 86.8$$

$$\bar{\lambda}_1 = \frac{l_{u1}}{i_{z1}\lambda_1} = \frac{7380mm}{44.87mm \cdot 86.8} = 1.895$$

$$\bar{\lambda}_2 = \bar{\lambda}_3 = \frac{l_{u2}}{i_{z2}\lambda_1} = \frac{6840mm}{39.72mm \cdot 86.8} = 1.984$$

$$\bar{\lambda}_4 = \frac{l_{u4}}{i_{z4}\lambda_1} = \frac{6840mm}{15.49mm \cdot 86.8} = 4.82$$

$$\bar{\lambda}_5 = \frac{l_{u5}}{i_{z5}\lambda_1} = \frac{6840mm}{4.45mm \cdot 86.8} = 17.71$$

Da zagotovimo enakomerno disipativno obnašanje diagonal, moramo prerez diagonal v višjih nadstropjih zmanjševati, saj je tam prečna sila etaže manjša. V mojem primeru je v zadnjih dveh etažah ta prerez tako majhen, da ne zadostimo pogoju o relativni vitkosti.

$$N_{pl,Rd} = A \cdot \frac{f_y}{\gamma_{M1}}$$

$$\Omega = \left(\frac{N_{pl,Rd,i}}{N_{Ed,E,i}}\right) \qquad \text{i...diagonale}$$

	Profil:	$A[cm^2]$	$N_{Ed,max}[kN]$	$N_{pl,Rd}[kN]$	Ω
1.etaža	B 133/5.6	23,86	355,4	596,5	1,68
2.etaža	B 114.3/4.5	15,52	224,1	388,0	1,73
3.etaža	B 114.3/4	12,52	159,8	313,0	1,96
4.etaža	B 48.3/4.5	6,192	79,4	154,80	1,95
5.etaža	B 16/4	1,508	18,9	37,70	1,99

$$\frac{\Omega_{max} - \Omega_{min}}{\Omega_{max}} = \frac{1.99 - 1.68}{1.68} = 0.18 \leq 0.25$$

Kontrola za prečke in stebre:

$$N_{pl,Rd} = \chi \cdot A \cdot \frac{f_y}{\gamma_{M1}} = 0.86 \cdot 143.0cm^2 \cdot \frac{27.5kN/cm^2}{1.1} = 3074.5kN$$

$$N_{Ed,G} = N_{Ed.G}^{mom.okvir} = 502.6kN$$

$$N_{Ed,E}^{steber} = N_{Ed,E}^{okvirx} + 0.3 \cdot N_{Ed,E}^{okviry} = 36.3kN + 0.3 \cdot 431.5kN = 165.75kN$$

$$N_{Ed,E}^{steber} = 0.3 \cdot N_{Ed,E}^{okvirx} + N_{Ed,E}^{okviry} = 0.3 \cdot 36.3kN + 431.5kN = 442.39kN$$

$$N_{pl,Rd}(M_{Ed}) \geq N_{Ed,G} + 1.1 \cdot \gamma_{0V} \cdot \Omega \cdot N_{Ed,E} = 502.6kN + 1.1 \cdot 1.1 \cdot 1.68 \cdot 442.39kN$$

$$N_{pl,Rd}(M_{Ed}) = 3074.5kN \geq 1401.89kN$$

Objekt B:

$$\frac{\left|A^+ - A^-\right|}{A^+ + A^-} = 0 \leq 0.05$$

$$A^+ = A^- = A \cdot \cos\alpha$$

$$\bar{\lambda} = \frac{l_u}{i_z \lambda_1} \qquad 1.3 \leq \bar{\lambda} \leq 2.0$$

$i_{z1} = 44.87mm$

$i_{z2} = i_{z3} = 39.72mm$

$i_{z4} = 13.58mm$

$l_{u1} = 7380mm$

$l_{u2} = l_{u3} = l_{u4} = 6840mm$

$$\lambda_1 = 93.9\sqrt{\frac{235MPa}{275MPa}} = 86.8$$

$$\bar{\lambda}_1 = \frac{l_{u1}}{i_{z1}\lambda_1} = \frac{7380mm}{44.87mm \cdot 86.8} = 1.895$$

$$\bar{\lambda}_2 = \frac{l_{u2}}{i_{z2}\lambda_1} = \frac{6840mm}{39.72mm \cdot 86.8} = 1.984$$

$$\bar{\lambda}_3 = \frac{l_{u2}}{i_{z2}\lambda_1} = \frac{6840mm}{39.56mm \cdot 86.8} = 1.99$$

$$\bar{\lambda}_4 = \frac{l_{u4}}{i_{z4}\lambda_1} = \frac{6840mm}{13.58mm \cdot 86.8} = 5.50$$

Da zagotovimo enakomerno disipativno obnašanje diagonal, moramo prerez diagonal v višjih nadstropjih zmanjševati, saj je tam prečna sila etaže manjša. V mojem primeru je v zadnji etaži ta prerez tako majhen, da ne zadostimo pogoju o relativni vitkosti.

$$N_{pl,Rd} = A \cdot \frac{f_y}{\gamma_{M1}}$$

$$\Omega = \left(\frac{N_{pl,Rd,i}}{N_{Ed,E,i}}\right) \qquad \text{i...diagonale}$$

	Profil:	A[cm^2]	$N_{Ed,max}$[kN]	$N_{pl,Rd}$[kN]	Ω
1.etaža	B 133/5.6	23.86	317.3	596.5	1.88
2.etaža	B 114.3/4.5	15.52	207.8	388.0	1.87
3.etaža	B 114.3/4	12.52	157.8	313.0	1.98
4.etaža	B 42.4/4	4.825	62.7	120.63	1.92

$$\frac{\Omega_{max} - \Omega_{min}}{\Omega_{max}} = \frac{1.98 - 1.87}{1.87} = 0.06 \le 0.25$$

Kontrola za prečke in stebre:

$$N_{pl,Rd} = \chi \cdot A \cdot \frac{f_y}{\gamma_{M1}} = 0.86 \cdot 143.0cm^2 \cdot \frac{27.5kN/cm^2}{1.1} = 3074.5kN$$

$$N_{Ed,G} = N_{Ed.G}^{mom.okvir} = 506.8kN$$

$$N_{Ed,E}^{steber} = N_{Ed,E}^{okvirx} + 0.3 \cdot N_{Ed,E}^{okviry} = 31.5kN + 0.3 \cdot 387.5kN = 147.75kN$$

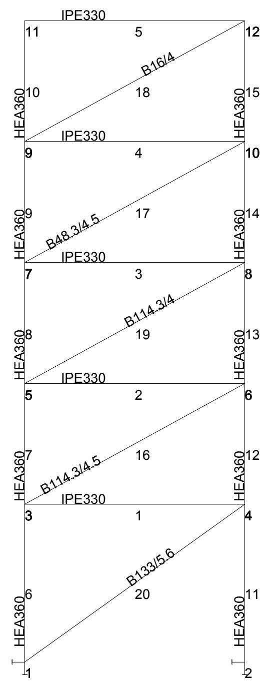
$$N_{Ed,E}^{steber} = 0.3 \cdot N_{Ed,E}^{okvirx} + N_{Ed,E}^{okviry} = 0.3 \cdot 31.5kN + 387.5kN = 396.95kN$$

$$N_{pl,Rd}(M_{Ed}) \ge N_{Ed,G} + 1.1 \cdot \gamma_{0V} \cdot \Omega \cdot N_{Ed,E} = 506.8kN + 1.1 \cdot 1.1 \cdot 1.87 \cdot 396.95kN$$

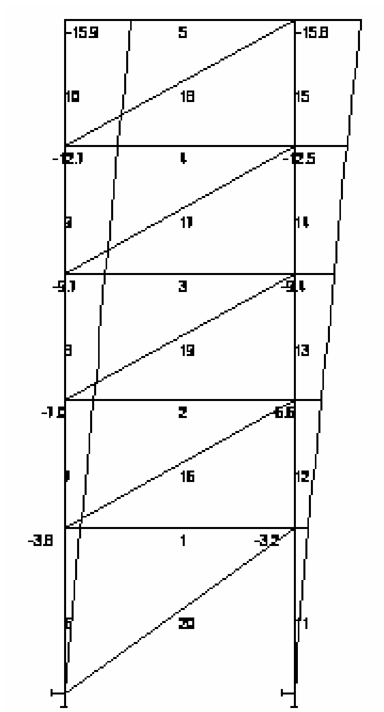
$$N_{pl,Rd}(M_{Ed}) = 3074.5kN \ge 1404.98kN$$

5.3.5 Rezultati dobljeni s programom ESA – Prima Win

Objekt A:



Geometrija



Pomiki ux – MSU[mm]

Kontrola nosilnosti in stabilnosti

EC3 Code Check
Cross-section : 2 - IPE330

Macro 1	Member 1	IPE330	S 275	Non-Lin. Comb. 2	0.54

NSd| [kN]	Vy.Sd| [kN]	Vz.Sd| [kN]	Mt.Sd| [kNm]	My.Sd| [kNm]	Mz.Sd | [kNm]
-184.77	-0.00	0.00	-0.00	0.00	-0.00

The critical check is on position 4.91 m

Buckling parameters	yy	zz	
type	sway	non-sway	
Slenderness	43.76	169.12	
Reduced slenderness	0.50	1.95	
Buckling curve	a	b	
Imperfection	0.21	0.34	
Reduction factor	0.92	0.22	
Length	6.00	6.00	m
Buckling factor	1.00	0.50	
Buckling length	6.00	3.00	m
Critical Euler load	6776.64	453.73	kN

LTB		
LTB length	3.00	m
k	1.00	
kw	1.00	
C1	1.00	
C2	0.00	
C3	1.00	

load in center of gravity

SECTION CHECK	
M	0.12 < 1

STABILITY CHECK	
Buckling	0.54 < 1
Compression + Moment	0.13 < 1
Compression + LTB	0.54 < 1

Cross-section : 3 - B114.3/4.5

Macro 8	Member 16	B114.3/4.5	S 275	Non-Lin. Comb. 2	0.38

NSd| [kN]	Vy.Sd| [kN]	Vz.Sd| [kN]	Mt.Sd| [kNm]	My.Sd| [kNm]	Mz.Sd | [kNm]
145.39	0.00	0.00	0.00	0.00	-0.00

The critical check is on position 0.00 m

LTB		
LTB length	6.85	m
k	1.00	
kw	1.00	
C1	1.00	

LTB		
C2	0.00	
C3	1.00	

load in center of gravity

SECTION CHECK	
N	0.38 < 1

Cross-section : 4 - B114.3/4

Macro 11	Member 19	B114.3/4	S 275	Non-Lin. Comb. 2	0.34

NSd| [kN]	Vy.Sd| [kN]	Vz.Sd| [kN]	Mt.Sd| [kNm]	My.Sd| [kNm]	Mz.Sd | [kNm]
117.13	-0.00	0.00	0.00	-0.00	-0.00

The critical check is on position 0.00 m

LTB		
LTB length	6.85	m
k	1.00	
kw	1.00	
C1	1.00	
C2	0.00	
C3	1.00	

load in center of gravity

SECTION CHECK	
N	0.34 < 1

Cross-section : 5 - B133/5.6

Macro 12	Member 20	B133/5.6	S 275	Non-Lin. Comb. 2	0.38

NSd| [kN]	Vy.Sd| [kN]	Vz.Sd| [kN]	Mt.Sd| [kNm]	My.Sd| [kNm]	Mz.Sd | [kNm]
208.75	-0.00	0.00	-0.00	-0.00	0.00

The critical check is on position 0.00 m

LTB		
LTB length	7.38	m
k	1.00	
kw	1.00	
C1	1.00	
C2	0.00	
C3	1.00	

load in center of gravity

SECTION CHECK	
N	0.38 < 1

Cross-section : 6 - B48.3/4.5

Macro 9	**Member 17**	**B48.3/4.5**	**S 275**	**Non-Lin. Comb. 2**	**0.57**

NSd| [kN]	Vy.Sd| [kN]	Vz.Sd| [kN]	Mt.Sd| [kNm]	My.Sd| [kNm]	Mz.Sd | [kNm]
87.85	-0.00	-0.00	-0.00	0.00	0.00

The critical check is on position 0.00 m

LTB		
LTB length	6.85	m
k	1.00	
kw	1.00	
C1	1.00	
C2	0.00	
C3	1.00	

SECTION CHECK	
N	0.57 < 1

Cross-section : 7 - B16/4

Macro 10	**Member 18**	**B16/4**	**S 275**	**Non-Lin. Comb. 2**	**0.92**

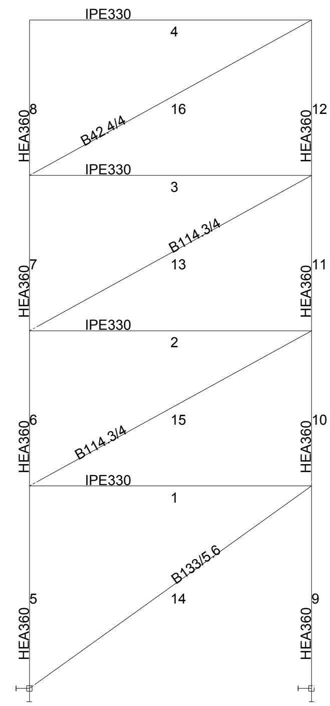
NSd| [kN]	Vy.Sd| [kN]	Vz.Sd| [kN]	Mt.Sd| [kNm]	My.Sd| [kNm]	Mz.Sd | [kNm]
37.37	0.00	-0.00	-0.00	0.00	0.00

The critical check is on position 1.14 m

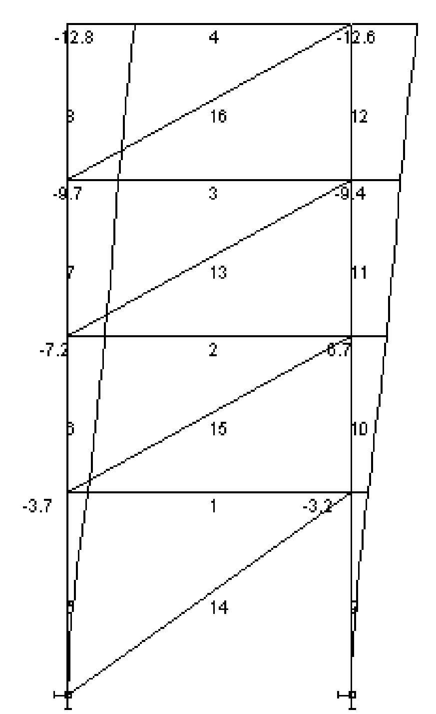
LTB		
LTB length	6.85	m
k	1.00	
kw	1.00	
C1	1.00	
C2	0.00	
C3	1.00	

SECTION CHECK	
N	0.92 < 1
Vz	0.00 < 1
M	0.92 < 1

Objekt B:



Geometrija



Pomiki ux – MSU[mm]

Kontrola nosilnosti in stabilnosti

EC3 Code Check
Cross-section : 2 - IPE330

Macro 1	Member 1	IPE330	S 275	Non-Lin. Comb. 2	0.41

NSd| [kN]	Vy.Sd| [kN]	Vz.Sd| [kN]	Mt.Sd| [kNm]	My.Sd| [kNm]	Mz.Sd | [kNm]
-142.34	-0.00	0.00	0.00	0.00	0.00

The critical check is on position 0.00 m

Buckling parameters	yy	zz	
type	sway	non-sway	
Slenderness	43.76	169.12	
Reduced slenderness	0.50	1.95	
Buckling curve	a	b	
Imperfection	0.21	0.34	
Reduction factor	0.92	0.22	
Length	6.00	6.00	m
Buckling factor	1.00	0.50	
Buckling length	6.00	3.00	m
Critical Euler load	6776.64	453.73	kN

LTB		
LTB length	3.00	m
k	1.00	
kw	1.00	
C1	1.00	
C2	0.00	
C3	1.00	

load in center of gravity

SECTION CHECK	
Vz	0.00 < 1
M	0.09 < 1

STABILITY CHECK	
Buckling	0.41 < 1
Compression + Moment	0.41 < 1
Compression + LTB	0.41 < 1

Cross-section : 3 - B133/5.6

Macro 8	Member 14	B133/5.6	S 275	Non-Lin. Comb. 2	0.27

NSd| [kN]	Vy.Sd| [kN]	Vz.Sd| [kN]	Mt.Sd| [kNm]	My.Sd| [kNm]	Mz.Sd | [kNm]
151.82	0.00	0.00	-0.00	-0.00	-0.00

The critical check is on position 0.00 m

LTB		
LTB length	0.07	m
k	1.00	

LTB		
kw	1.00	
C1	1.00	
C2	0.00	
C3	1.00	

load in center of gravity

SECTION CHECK	
N	0.27 < 1

Cross-section : 4 - B42.4/4

Macro 10	Member 16	B42.4/4	S 275	Non-Lin. Comb. 2	0.28

NSd| [kN]	Vy.Sd| [kN]	Vz.Sd| [kN]	Mt.Sd| [kNm]	My.Sd| [kNm]	Mz.Sd | [kNm]
32.92	0.00	-0.00	-0.00	0.00	-0.00

The critical check is on position 0.00 m

LTB		
LTB length	0.07	m
k	1.00	
kw	1.00	
C1	1.00	
C2	0.00	
C3	1.00	

load in center of gravity

SECTION CHECK	
N	0.28 < 1

Cross-section : 5 - B114.3/4

Macro 9	Member 15	B114.3/4	S 275	Non-Lin. Comb. 2	0.29

NSd| [kN]	Vy.Sd| [kN]	Vz.Sd| [kN]	Mt.Sd| [kNm]	My.Sd| [kNm]	Mz.Sd | [kNm]
100.87	0.00	0.00	0.00	0.00	0.00

The critical check is on position 0.00 m

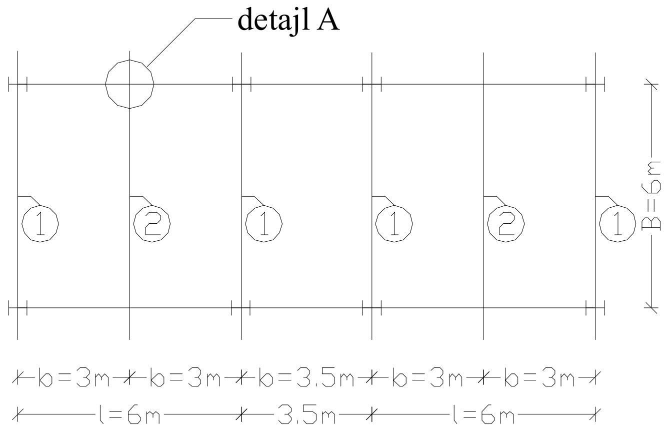
LTB		
LTB length	0.07	m
k	1.00	
kw	1.00	
C1	1.00	
C2	0.00	
C3	1.00	

load in center of gravity

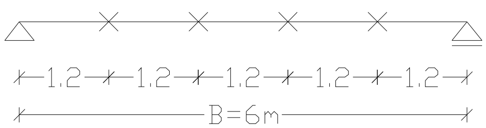
SECTION CHECK	
N	0.29 < 1

6 MEDETAŽNA KONSTRUKCIJA

6.1 Zasnova



Bočno podpiranje v fazi montaže



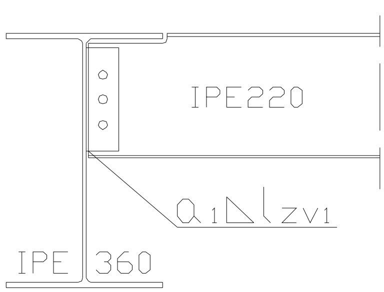
POZ 1:

nosilec IPE360

POZ 2:

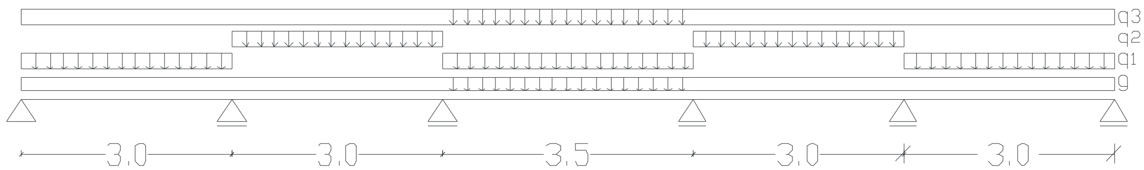
sovprežni nosilec IPE220

detajl A:



6.2 AB plošča

6.2.1 Zasnova



6.2.2 Obtežba

g = G · 1m = 4.31kN/m^2 · 1m = 4.31kN/m ... glej diplomska naloga, stran 100.

q = Q · 1m = 2.34kN/m^2 · 1m = 2.34kN/m ... glej diplomska naloga, stran 101.

6.2.2 Obtežne kombinacije

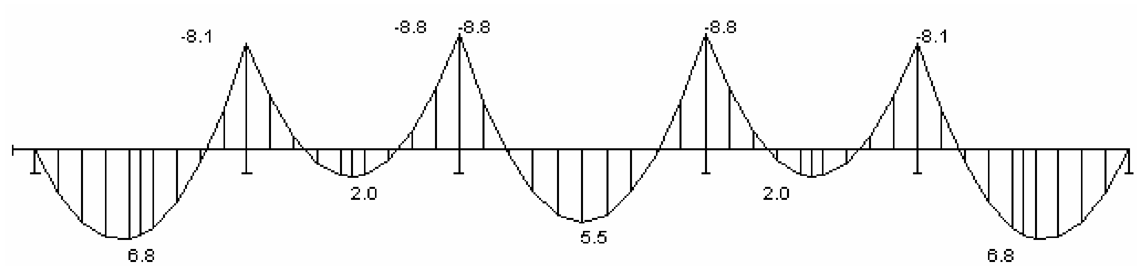
6.2.2.1 MSN

C1. 1.35G + 1.5Q

6.2.2.1 MSU

C2. 1.0G + 1.0Q

6.2.3 Potek notranjih sil



Momenti [kNm]

Momente nad podporami zmanjšamo za 25%, v polju pa povečamo za absolutno vrednost razlike nad podporami.

Nad podporami (armatura zgoraj):

$M_{Ed} = -8.8kNm$

$M_{Sd} = 0.75 \cdot M_{Ed} = 0.75 \cdot (-8.8kNm) = -6.6kNm$

$$k_h = \frac{|M_{Sd}|}{\alpha \cdot f_{cd} \cdot b \cdot d^2} = \frac{660kNcm}{1.42kN/cm^2 \cdot 100cm \cdot 10^2 cm^2} = 0.047$$

$k_s = 1.041$

$$A_s = k_s \cdot \frac{|M_{Sd}|}{f_{yd} \cdot d} = 1.041 \cdot \frac{660kNcm}{43.5kN/cm^2 \cdot 10cm} = 1.58cm^2$$

Izberemo mrežno armaturo Q166.

Polje (armatura spodaj):

$M_{Ed} = -6.8kNm$

$M_{Sd} = 0.25 \cdot |M_{Ed,podpora}| + M_{Ed,polje} = 0.25 \cdot 8.8kNm + 6.8kNm = 9.0kNm$

$$k_h = \frac{|M_{Sd}|}{\alpha \cdot f_{cd} \cdot b \cdot d^2} = \frac{900kNcm}{1.42kN/cm^2 \cdot 100cm \cdot 10^2 cm^2} = 0.063$$

$k_s = 1.048$

$$A_s = k_s \cdot \frac{|M_{Sd}|}{f_{yd} \cdot d} = 1.048 \cdot \frac{900kNcm}{43.5kN/cm^2 \cdot 10cm} = 2.17cm^2$$

Izberemo mrežno armaturo Q226.

6.3 Obtežba

6.3.1 Lastna in stalna obtežba

$g = G \cdot b = 4.31kN/m \cdot 3.5m = 15.1kN/m$

zaključni sloj.................1cm	$0.01m \cdot 25kN/m^3 = 0.25kN/m^2$
cementni estrih..............4cm	$0.04m \cdot 24kN/m^3 = 0.96kN/m^2$
TI + spuščeni strop	$0.10kN/m^2$
AB plošča....................12cm	$0.12m \cdot 25kN/m^3 = 3.00kN/m^2$
jeklen nosilec IPE 220	$26.2kg/m \cdot 9.81m/s^2 = 0.26kN/m^2$
	$G = 4.31kN/m^2$
	$G_{IPE220} = 0.26kN/m$

6.3.2 Koristna obtežba

$Q = \alpha_A \cdot q_P = 0.78 \cdot 3.0kN/m^2 = 2.34kN/m^2$

$q = Q \cdot b = 2.34kN/m \cdot 3.5m = 8.19kN/m$

6.3.3 Obtežba med gradnjo (delavci, oprema)

$M_1 = m_1 \cdot b = 0.75kN/m^2 \cdot 3.5m = 2.63kN/m$

6.3.4 Kopičenje betona (1.5kN/m² na površini 3m · 3m)

$M_2 = m_2 \cdot b = 1.5kN/m^2 \cdot 3.5m = 5.25kN/m$

6.4 Faza montaže

6.4.1 Obtežne kombinacije

MSN:

$q_{Ed} = 1.35G_{IPE220} + 1.5(g + M_1 + M_2)$

$q_{Ed} = 1.35 \cdot 0.26kN/m + 1.5 \cdot (15.1kN/m + 2.63kN/m + 5.25kN/m) = 34.82kN/m$

MSU:

$q_{Ed} = 1.0g + 1.0G_{IPE220} = 15.1kN/m + 0.26kN/m = 15.36kN/m$

6.4.2 Dimenzioniranje

$$M_{Ed} = \frac{q_{Ed}^{MSN} \cdot B^2}{8} = \frac{34.82kN/m \cdot 6^2 m^2}{8} = 156.69kNm$$

$$V_{Ed} = \frac{q_{Ed}^{MSN} \cdot B}{2} = \frac{34.82kN/m \cdot 6m}{2} = 104.46kN$$

Nosilnost jeklenega prereza:

$$M_{Ed} = 156.69kNm \leq M_{Rd} = W_{el,y} \cdot \frac{f_y}{\gamma_{M1}} = 252.0cm^3 \cdot \frac{27.5kN/cm^2}{1.1} = 63.0kNm$$

$$V_{Ed} = 104.46kN \leq V_{pl,Rd} = \frac{f_y}{\sqrt{3} \cdot \gamma_{M0}} \cdot A_v = \frac{27.5kN/cm^2}{\sqrt{3} \cdot 1.1} \cdot 13.5cm^2 = 194.86kN$$

Kontrola nosilnosti jeklenega prereza v času montaže ne zadošča, zato nosilec v celoti podpremo. Podpore odmaknemo šele, ko se beton strdi in se doseže sovprežno stanje.

Kontrola bočne zvrnitve:

$$\bar{\lambda}_{LT} = \sqrt{\frac{M_{el}}{M_{cr}}} = \sqrt{\frac{69.30\text{kNm}}{45.43\text{kNm}}} = 1.23 \geq 0.2$$

$$M_{el} = W_{el,y} \cdot f_y = 252.0\text{cm}^3 \cdot 27.5\text{kN/cm}^2 = 69.30\text{kNm}$$

$$M_{cr} = C_1 \cdot \frac{\pi}{k \cdot L} \cdot \sqrt{E \cdot I_z \cdot G \cdot I_t + \frac{\pi^2 \cdot E \cdot I_w \cdot E \cdot I_z}{(k_w \cdot L)^2}}$$

$$M_{cr} = 1.323 \cdot \frac{\pi}{1 \cdot 120\text{cm}} \cdot \sqrt{\begin{array}{l} 21000\text{kN/cm}^2 \cdot 205\text{cm}^4 \cdot 8077\text{kN/cm}^2 \cdot 9.07\text{cm}^4 + \\ \left(\frac{\pi^2 \cdot 21000\text{kN/cm}^2 \cdot 22670\text{cm}^6 \cdot 21000\text{kN/cm}^2 \cdot 205\text{cm}^4}{(1 \cdot 120\text{cm})^2} \right) \end{array}}$$

$$M_{cr} = 45.43\text{kNm}$$

$$\Phi_{LT} = 0.5\left(1.0 + \alpha_{LT}\left(\bar{\lambda}_{LT} - 0.2\right) + \bar{\lambda}_{LT}^2\right) = 0.5\left(1.0 + 0.21\left(1.23 - 0.2\right) + 1.23^2\right) = 1.36$$

$$\chi_{LT} = \frac{1}{\Phi_{LT} + \left(\Phi_{LT}^2 - \lambda_{LT}^2\right)^{0.5}} = \frac{1}{1.36 + \left(1.36^2 - 1.23^2\right)^{0.5}} = 0.77$$

$$M_{Sd} = 156.69\text{kNm} \leq M_{b,Rd} = \chi_{LT} \cdot W_{el,y} \cdot \frac{f_y}{\gamma_{M1}} = 0.77 \cdot 252.0\text{cm}^3 \cdot \frac{27.5\text{kN/cm}^2}{1.1} = 48.51\text{kNm}$$

Ker se nam kontrola ne izide, moramo nosilec v času montaže bočno podpreti.

Kontrola kompaktnosti:

$$\varepsilon = \sqrt{\frac{f_y}{235}} = \sqrt{\frac{275\text{kN/cm}^2}{235\text{kN/cm}^2}} = 1.08$$

-stojina: $\frac{d}{t_w} = \frac{177\text{mm}}{5.9\text{mm}} = 30 \leq 72\varepsilon = 77.76$

-pasnica: $\frac{c}{t_f} = \frac{55\text{mm}}{9.2\text{mm}} = 5.98 \leq 10\varepsilon = 10.80$

-stojina v strigu: $\frac{d}{t_w} = \frac{177\text{mm}}{5.9\text{mm}} = 30 \leq 69\varepsilon = 74.52$

Kontrola pomikov:

$$w_{dop.} = \frac{B}{250} = \frac{6000\text{mm}}{250} = 24\text{mm}$$

$$w = \frac{5 \cdot q_{Ed}^{MSU} \cdot L^4}{384 \cdot E_S \cdot I_y} = \frac{5 \cdot 0.1536kN/cm \cdot (600cm)^4}{384 \cdot 21000kN/cm^2 \cdot 2770cm^4} = 44.57mm \leq 24mm$$

Ker pridejo vertikalni pomiki preveliki moramo nosilec v času montaže na sredini podpreti.

6.5 Sovprežno stanje

6.5.1 Obtežne kombinacije

MSN:

$q_{Ed} = 1.35(G_{IPE220} + g) + 1.5q = 1.35 \cdot 15.36kN/m + 1.5 \cdot 8.19kN/m = 33.02kN/m$

MSU:

$q_{Ed} = 1.0(G_{IPE220} + g) + 1.0q = 15.36kN/m + 8.19kN/m = 23.57kN/m$

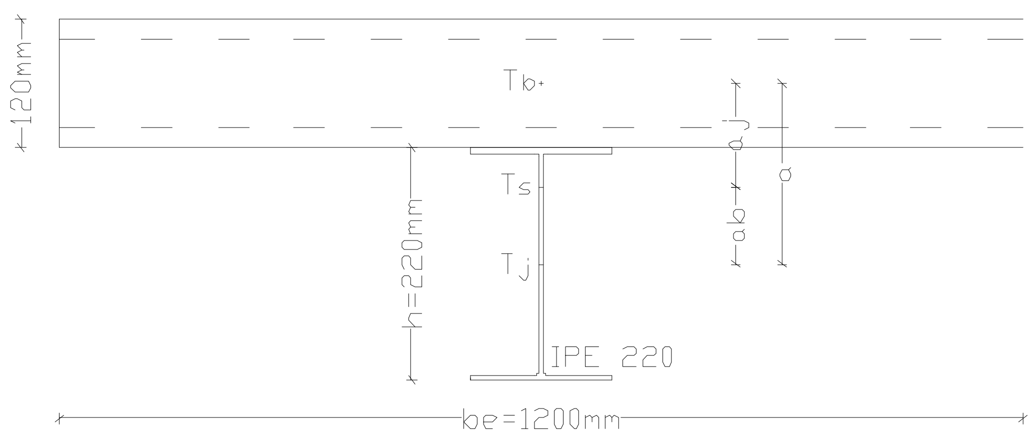
6.5.2 Dimenzioniranje

$$M_{Ed} = \frac{q_{Ed}^{MSN} \cdot B^2}{8} = \frac{33.02kN/m \cdot 6^2 m^2}{8} = 148.59kNm$$

$$V_{Ed} = \frac{q_{Ed}^{MSN} \cdot B}{2} = \frac{33.02kN/m \cdot 6m}{2} = 99.06kN$$

Izberem nosilec IPE 220 $\Rightarrow$ $h_j \approx \frac{B}{25} = \frac{600cm}{25} = 24cm$

Prerez v polju:



$$b_{e1} = \frac{0.8 \cdot l}{8} = \frac{0.8 \cdot 600cm}{8} = 60cm$$

$$b_e = 2 \cdot b_{e1} = 2 \cdot 60cm = 120cm$$

$$a = \frac{12cm}{2} + \frac{22cm}{2} = 17cm$$

$A_j = 33.4cm^2 \quad I_j = 2770cm^2$

$A_b = 120cm \cdot 4.9cm = 588cm^2$

$$I_b = \frac{120cm \cdot 4.9^3 cm^3}{12} = 1176.5cm^3$$

$$a_j = \frac{A_b \cdot a}{n_\infty \cdot A_s} = \frac{588cm^2 \cdot 17cm}{20.6 \cdot 61.94cm^2} = 7.83cm$$

$$A_s = A_j + \frac{A_b}{n_\infty} = 33.4cm^2 + \frac{588cm^2}{20.6} = 61.94cm^2$$

$$a_b = \frac{A_j}{A_s} \cdot a = \frac{33.4cm^2}{61.94cm^2} \cdot 17cm = 9.17cm$$

$$I_{sovp.} = I_j + a_j^2 \cdot A_j + \frac{1}{n_\infty}\left(I_b + a_b^2 \cdot A_b\right)$$

$$I_{sovp.} = 2770cm^4 + 7.83^2 cm^2 \cdot 33.4cm^2 + \frac{1}{20.6} \cdot \left(1176.5cm^4 + 9.17^2 cm^2 \cdot 588cm^2\right)$$

$$I_{sovp.} = 7275cm^4$$

$n_0 = 10.3 \qquad n_\infty = 2n_0 = 20.6$

Beton C 25/30

$$F_{cf,c} = 0.85 \cdot \frac{f_{ck}}{\gamma_c} \cdot b_{eff} \cdot h_b = 0.85 \cdot \frac{2.5kN/cm^2}{1.5} \cdot 120cm \cdot 12cm = 2040kN$$

Jeklo: IPE 220 (S 275)

$$F_{cf,s} = \frac{f_y}{\gamma_{M0}} \cdot A = \frac{27.5kN/cm^2}{1.1} \cdot 33.4cm^2 = 835.0kN$$

Lega nevtralne osi:

$F_{cf,c} = 2040kN \geq F_{cf,s} = 835kN \Rightarrow$ nevtralna os je v betonu.

Ravnotežje:

Jeklo: IPE 220 (S 275)

$$F_{cf,s} = \frac{f_y}{\gamma_{M0}} \cdot A = \frac{27.5kN/cm^2}{1.1} \cdot 33.4cm^2 = 835.0kN$$

Beton C 25/30

$$F_{cf,c} = 0.85 \cdot \frac{f_{ck}}{\gamma_c} \cdot b_{eff} \cdot h_c = 0.85 \cdot \frac{2.5kN/cm^2}{1.5} \cdot 120cm \cdot h_c = 170kN/cm \cdot h_c$$

$F_{cf,C} = F_{cf,S} \Rightarrow 170kN/cm \cdot h_c = 835.0kN$

$$h_c = \frac{835kN}{170kN/cm} = 4.9cm$$

$$F_{cf,c} = 0.85 \cdot \frac{f_{ck}}{\gamma_c} \cdot b_{eff} \cdot h_c = 0.85 \cdot \frac{2.5kN/cm^2}{1.5} \cdot 120cm \cdot 4.9cm = 835kN$$

$$e = \frac{h}{2} + h_b - \frac{h_c}{2} = \frac{18cm}{2} + 12cm - \frac{4.9cm}{2} = 18.55cm$$

Upogibna nosilnost sovprežnega nosilca:

$$M_{Rd} = F_{cf,S} \cdot e = 835.0kN \cdot 18.55cm = 160.46kNm$$

Kontrola upogibne nosilnosti:

$M_{Rd} = 160.46kNm \geq M_{Sd} = 148.59kNm$

Izkoriščenost:

$$I = \frac{M_{Ed}}{M_{Rd}} \cdot 100\% = \frac{148.59kNm}{160.46kNm} \cdot 100\% = 92.6\%$$

Vertikalni strig:

$$V_{Ed} = 99.06kN \leq V_{pl,Rd} = A_v \cdot \frac{f_y}{\sqrt{3} \cdot \gamma_{M0}} = 13.5cm^2 \cdot \frac{27.5kN/cm^2}{\sqrt{3} \cdot 1.1} = 194.86kN$$

Pri sovprežnih nosilcih ves strig prevzame jekleni element.

Kontrola pomikov (MSU):

B = 6000mm

L = 6000mm

$E_s = 21000kN/cm^2$

$q_{Ed} = 23.57kN/m$

$$w_{dop} \leq \frac{B}{250} = \frac{600cm}{250} = 2.4cm$$

$$w_{dop} = \frac{5 \cdot q_{Ed} \cdot L^4}{384 \cdot E_s \cdot I_{sovp.}} = \frac{5 \cdot 0.2357kN/cm \cdot 600^4 cm^4}{384 \cdot 21000kN/cm^2 \cdot 7275cm^4} = 2.39cm \leq 2.4cm$$

6.6 Mozniki

Predpostavljena je polna sovprežnost.

Izberemo moznike NELSON

d = 19mm

h = 80mm

$f_u = 45kN/cm^2$

Pogoji:

$t_f \geq 0.4d \quad \Rightarrow 10mm \geq 0.4 \cdot 19mm = 7.6mm$

$h_c - h \geq 2cm \quad \Rightarrow 12cm - 8cm = 4cm \geq 2cm$

$h \geq 3d \quad \Rightarrow 80mm \geq 3 \cdot 19mm = 57mm$

Nosilnost enega moznika:

$$P_{Rd} = \frac{1}{\gamma_{M2}} \left(0.29\alpha^2 \sqrt{E_{cm} f_{ck}}\right)$$ ...bočni pritisk moznika na beton

$E_{cm} = 3050kN/cm^2$

$\gamma_{M2} = 1.25$

$$P_{Rd} = \frac{1}{1.25} \cdot \left(0.29 \cdot 1 \cdot 1.9^2 cm^2 \cdot \sqrt{3050kN/cm^2 \cdot 2.5kN/cm^2}\right) = 64.35kN$$

$$P_{Rd} = 0.8 \cdot f_u \cdot \frac{\pi \cdot d^2}{4\gamma_{M_2}}$$ ...prestrig moznika

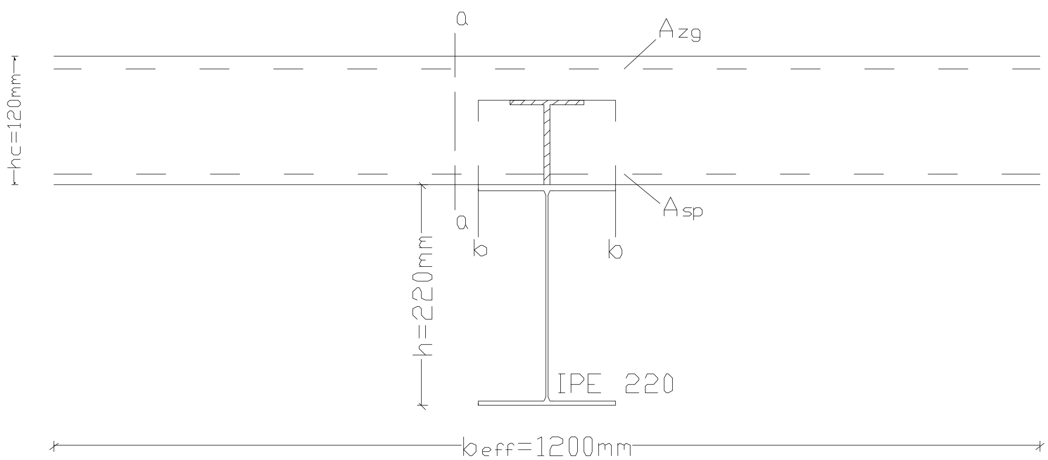
$$P_{Rd} = 0.8 \cdot 45kN/cm^2 \cdot \frac{\pi \cdot 1.9^2 cm^2}{4 \cdot 1.25} = 81.61kN$$

Število moznikov:

$$n = \frac{F_{cf,S}}{P_{Rd}} = \frac{835.0kN}{64.35kN} = \frac{1195kN}{73.13kN} = 12.98$$

Izberemo n = 12

6.7 Strižna armatura



Izberemo armaturo:

A_e…prerez armature

$A_e = A_{zg} + A_{sp} = 1.66cm^2 + 1.66cm^2 = 3.32cm^2 \geq 0.002 \cdot h_c \cdot 100cm = 2.4cm^2$

A_{zg} [Q166] = A_{sp} [Q166] = $1.66cm^2$

Nosilnost proti vzdolžnem strigu:

b = 11.1cm

$\beta = 1.0$ ...velja za običajni beton

$\tau_{Rd} = 0.03$ ...strižna nosilnost betona

$f_{sk} = 50kN/cm^2$ $\gamma_s = 1.15$

$f_{ck} = 2.5kN/cm^2$ $\gamma_c = 1.5$

Prerez a – a ⇒ $A_{cv} = 2 \cdot h_c \cdot 100cm = 2 \cdot 12cm \cdot 100cm = 2400cm^2/m'$

$$V_{Rd} = 2.5 \cdot A_{cv} \cdot \beta \cdot \tau_{Rd} + \frac{A_e \cdot f_{sk}}{\gamma_s}$$

$$V_{Rd} = 2.5 \cdot 2400cm^2 \cdot 1.0 \cdot 0.03kN/cm^2 + \frac{3.32cm^2 \cdot 50kN/cm^2}{1.15} = 324.35kN$$

$$V_{Rd} = 0.2 \cdot A_{cv} \cdot \beta \cdot \frac{f_{ck}}{\gamma_c}$$

$$V_{Rd} = 0.2 \cdot 2400cm^2 \cdot 1.0 \cdot \frac{2.5kN/cm^2}{1.5} = 800kN$$

$V_{Rd} = 324.35kN \geq V_{Ed} = 77.8kN$

Prerez b – b ⇒ $A_{cv} = (2h + b) \cdot 100cm = (2 \cdot 10cm + 11.1cm) \cdot 100cm = 3110cm^2/m'$

$$V_{Rd} = 2.5 \cdot A_{cv} \cdot \beta \cdot \tau_{Rd} + \frac{A_e \cdot f_{sk}}{\gamma_s}$$

$$V_{Rd} = 2.5 \cdot 3110cm^2 \cdot 1.0 \cdot 0.03kN/cm^2 + \frac{3.32cm^2 \cdot 50kN/cm^2}{1.15} = 377.60kN$$

$$V_{Rd} = 0.2 \cdot A_{cv} \cdot \beta \cdot \frac{f_{ck}}{\gamma_c}$$

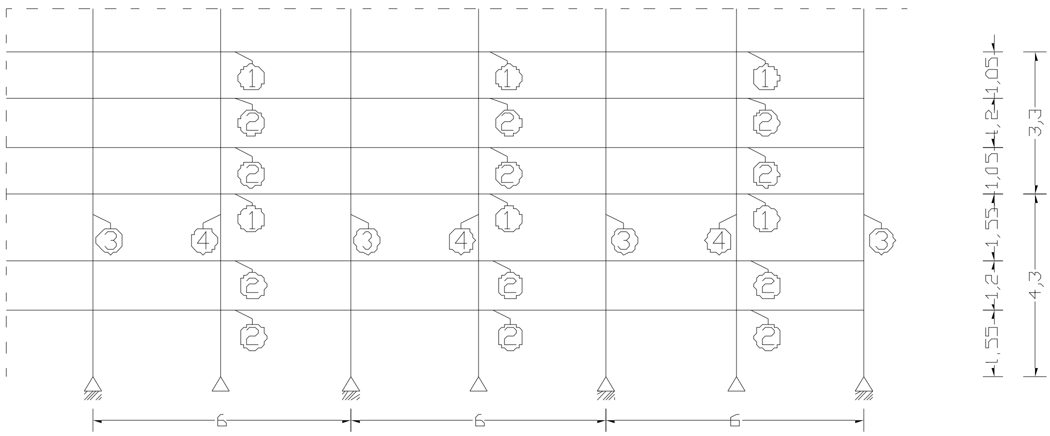
$$V_{Rd} = 0.2 \cdot 3110cm^2 \cdot 1.0 \cdot \frac{2.5kN/cm^2}{1.5} = 1036.67kN$$

$V_{Rd} = 377.6kN \geq V_{Ed} = 77.8kN$

7 FASADNA PODKONSTRUKCIJA

7.1 Stranska fasada

7.1.1 Zasnova



POZ 1 – prečka IPE 330

POZ 2 – fasadna lega 70/70/4mm

POZ 3 – steber HEA 360

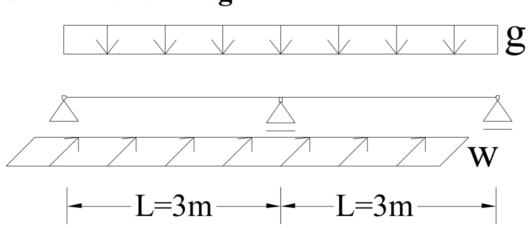
POZ 4 – steber HEA 100

$\gamma_{okna} = 27kN/m^3$ $g_{okna} = 0.3kN/m^2$

$d_{stekla} = 0.01m$

$g_{fasadna\ pl} = 0.3kN/m^2$

7.1.2 Fasadna lega



Izberem škatlast profil 70/70/4mm

$E = 21000kN/cm^2$ $I_y = I_z = 76.9cm^4$

$W_{pl} = 26.15cm^3$ $L = 300cm$

$f_{yk} = 27.5kN/cm^2$ $\gamma_{M1} = 1.1$

$g = g_f \cdot h = 0.3kN/m^2 \cdot 2m = 0.6kN/m$

$w = W \cdot h = 0.66kN/m^2 \cdot 2m = 1.32kN/m$ ... glej diplomska naloga, stran 19.

$$M_{y,Sd} = 1.35 \cdot \frac{g \cdot L^2}{8} = 1.35 \cdot \frac{0.6kN/m \cdot 3^2 m^2}{8} = 0.91kNm$$

$$M_{z,Sd} = 1.5 \cdot \frac{w \cdot L^2}{8} = 1.5 \cdot \frac{1.32kN/m \cdot 3^2 m^2}{8} = 2.23kNm$$

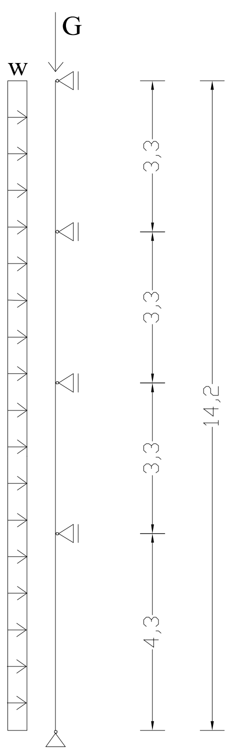
$$M_{y,Rd} = M_{z,Rd} = W_{pl} \cdot \frac{f_{yk}}{\gamma_{M1}} = 26.15cm^3 \cdot \frac{27.5kN/cm^2}{1.1} = 6.54kNm$$

$$\frac{M_{y,Sd}}{M_{y,Rd}} + \frac{M_{z,Sd}}{M_{z,Rd}} = \frac{0.91kNm}{6.54kNm} + \frac{2.23kNm}{6.54kNm} = 0.48 \leq 1.0$$

$$u_y = \frac{5 \cdot g \cdot L^4}{384 \cdot E \cdot I_y} = \frac{5 \cdot 0.006kN/cm \cdot 300^4 cm^4}{384 \cdot 21000kN/cm^2 \cdot 76.9cm^4} = 0.39cm \leq \frac{L}{250} = 2.4cm$$

$$u_z = \frac{5 \cdot w \cdot L^4}{384 \cdot E \cdot I_z} = \frac{5 \cdot 0.0132kN/cm \cdot 300^4 cm^4}{384 \cdot 21000kN/cm^2 \cdot 76.9cm^4} = 0.86cm \leq \frac{L}{250} = 2.4cm$$

7.1.3 Fasadni steber



Izberem vročevaljani H profil HEA 100

W_{pl}= 83.0cm^3 L_{max} = 430cm

A = 21.2cm^2 I_y = 349cm^4

vš…vplivna širina vš = 3m

W = 0.66kN/m^2 ... glej diplomska naloga, stran 19.

w = W · vš = 0.66kN/m^2 · 3m = 1.98kN/m

Lastna teža:

G_{lege} = $v_š$ · št. leg · teža lege

G_{lege} = 3m · 10 · (3m · 14.37kg/m · 9.81m/s^2) = 12.69kN

$G_{menjalniki}$ = h · št. menj./steber · teža menj. =

$G_{menjalniki}$ = 1.2m · 12 · (1.2m · 5.34kg/m · 9.81m/s^2) = 0.9kN

G_{fasada} = $v_š$ · L_{max} · teža fasade = 3m · 4.3m · 0.5kN/m^2 = 6.45kN

G = G_{lege} + $G_{menjalnik}$ + G_{fasada} = 12.69kN + 0.9kN + 6.12kN = 19.71kN

$$M_{y,Sd} = 1.5 \cdot \frac{w \cdot L_{max}^2}{8} = 1.5 \cdot \frac{1.98 kN/m \cdot 4.3^2 m^2}{8} = 6.86 kNm$$

$$M_{y,Rd} = W_{pl} \cdot \frac{f_{yk}}{\gamma_{M1}} = 83.0 cm^3 \cdot \frac{27.5 kN/cm^2}{1.1} = 20.75 kNm$$

$M_{y,Sd} = 6.86 kNm \leq M_{y,Rd} = 20.75 kNm$

$N_{Sd} = 1.35 \cdot G = 1.35 \cdot 19.71 kN = 26.6 kN$

$$N_{Rd} = A \cdot \frac{f_{yk}}{\gamma_{M1}} = 21.2 cm^2 \cdot \frac{27.5 kN/cm^2}{1.1} = 530 kN$$

$N_{Sd} = 26.6 kN \leq N_{Rd} = 530 kN$

Kontrola pomikov:

$$u_{max} = \frac{5 \cdot w \cdot L_{max}^4}{384 \cdot E \cdot I_z} = \frac{5 \cdot 0.0198 kN/cm \cdot 430^4 cm^4}{384 \cdot 21000 kN/cm^2 \cdot 349 cm^4} = 1.21 cm \leq \frac{L_{max}}{250} = 1.72 cm$$

Kontrola uklona:

$$N_{b,Rd} = \chi \cdot A \cdot \frac{f_{yk}}{\gamma_{M1}} = 0.85 \cdot 21.2 cm^2 \cdot \frac{27.5 kN/cm^2}{1.1} = 450.5 kN$$

$N_{Sd} = 26.6 kN \leq N_{b,Rd} = 118.2 kN$

$$\bar{\lambda} = \frac{\lambda}{\lambda_1} = \frac{61.75}{86.8} = 0.71$$

$$\lambda = \frac{l_u}{i_z} = \frac{155 cm}{2.51 cm} = 61.75$$

$l_u = 1.55 m$ ... glej zasnova, stran 109.

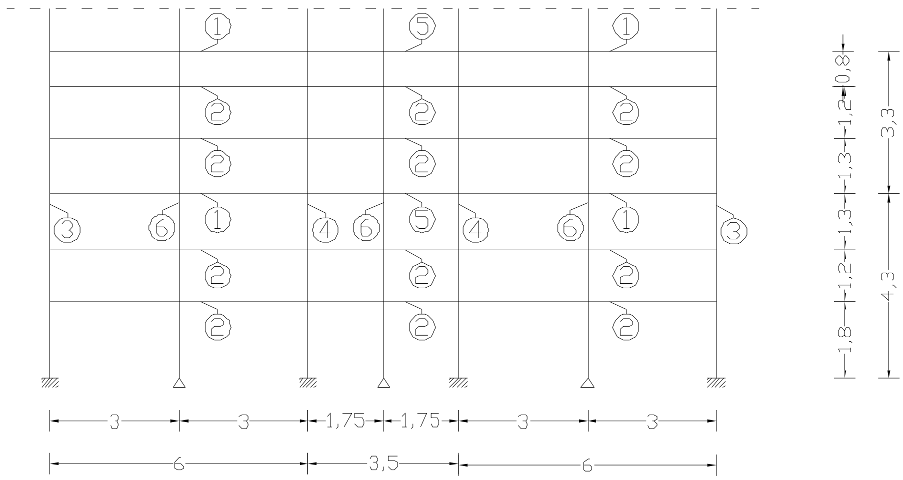
$$i_z = \sqrt{\frac{I_z}{A}} = \sqrt{\frac{134 cm^4}{21.2 cm^2}} = 2.51 cm$$

$$\lambda_1 = 93.9 \cdot \sqrt{\frac{235}{f_y}} = 93.9 \cdot \sqrt{\frac{235}{275}} = 86.8$$

$\chi = \chi(\bar{\lambda}) \quad \Rightarrow \quad$ Uklonska krivulja a $\quad \Rightarrow \quad \chi = 0.85$

7.2 Čelna fasada

7.2.1 Zasnova



POZ 1 – prečka IPE 450

POZ 2 – fasadna lega 70/70/4mm

POZ 3 – steber HEA 260

POZ 4 – steber HEA 450

POZ 5 – prečka IPE 400

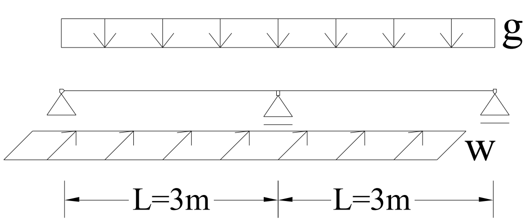
POZ 6 – steber HEA 100

$\gamma_{okna} = 27kN/m^3$ $g_{okna} = 0.3kN/m^2$

$d_{stekla} = 0.01m$

$g_{fasadna\ pl} = 0.3kN/m^2$

7.2.2 Fasadna lega



Izberem škatlast profil 70/70/4mm

$E = 21000kN/cm^2$ $I_y = I_z = 76.9cm^4$

$W_{pl} = 26.15cm^3$ $L = 300cm$

$f_{yk} = 27.5kN/cm^2$ $\gamma_{M1} = 1.1$

$g = g_f \cdot h = 0.3kN/m^2 \cdot 2m = 0.6kN/m$

$w = W \cdot h = 0.66kN/m^2 \cdot 2m = 1.32kN/m$ ... glej stran 19.

$$M_{y,Sd} = 1.35 \cdot \frac{g \cdot L^2}{8} = 1.35 \cdot \frac{0.6kN/m \cdot 3^2 m^2}{8} = 0.91kNm$$

$$M_{z,Sd} = 1.5 \cdot \frac{w \cdot L^2}{8} = 1.5 \cdot \frac{1.32kN/m \cdot 3^2 m^2}{8} = 2.23kNm$$

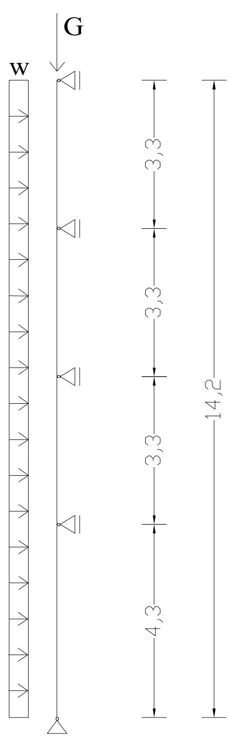
$$M_{y,Rd} = M_{z,Rd} = W_{pl} \cdot \frac{f_{yk}}{\gamma_{M1}} = 26.15cm^3 \cdot \frac{27.5kN/cm^2}{1.1} = 6.54kNm$$

$$\frac{M_{y,Sd}}{M_{y,Rd}} + \frac{M_{z,Sd}}{M_{z,Rd}} = \frac{0.91kNm}{6.54kNm} + \frac{2.23kNm}{6.54kNm} = 0.48 \le 1.0$$

$$u_y = \frac{5 \cdot g \cdot L^4}{384 \cdot E \cdot I_y} = \frac{5 \cdot 0.006kN/cm \cdot 300^4 cm^4}{384 \cdot 21000kN/cm^2 \cdot 76.9cm^4} = 0.39cm \le \frac{L}{250} = 2.4cm$$

$$u_z = \frac{5 \cdot w \cdot L^4}{384 \cdot E \cdot I_z} = \frac{5 \cdot 0.0132kN/cm \cdot 300^4 cm^4}{384 \cdot 21000kN/cm^2 \cdot 76.9cm^4} = 0.86cm \le \frac{L}{250} = 2.4cm$$

7.2.3 Fasadni steber



Izberem vročevaljani H profil HEA 100

$W_{pl} = 83.0cm^3$ $L_{max} = 430cm$

$A = 21.2cm^2$ $I_y = 349cm^4$

vš…vplivna širina vš = 3m

$W = 0.66kN/m^2$ ... glej diplomska naloga, stran 19.

$w = W \cdot vš = 0.66kN/m^2 \cdot 3m = 1.98kN/m$

Lastna teža:

$G_{lege} = v_š \cdot$ št. leg $\cdot$ teža lege

$G_{lege} = 3m \cdot 10 \cdot (3m \cdot 14.37kg/m \cdot 9.81m/s^2) = 12.69kN$

$G_{menjalniki} = h \cdot$ št. menj./steber $\cdot$ teža menj. =

$G_{menjalniki} = 1.2m \cdot 12 \cdot (1.2m \cdot 5.34kg/m \cdot 9.81m/s^2) = 0.9kN$

$G_{fasada} = v_š \cdot L_{max} \cdot$ teža fasade $= 3m \cdot 4.3m \cdot 0.5kN/m^2 = 6.45kN$

$G = G_{lege} + G_{menjalnik} + G_{fasada} = 12.69kN + 0.9kN + 6.12kN = 19.71kN$

$$M_{y,Sd} = 1.5 \cdot \frac{w \cdot L_{max}^2}{8} = 1.5 \cdot \frac{1.98kN/m \cdot 4.3^2 m^2}{8} = 6.86kNm$$

$$M_{y,Rd} = W_{pl} \cdot \frac{f_{yk}}{\gamma_{M1}} = 83.0cm^3 \cdot \frac{27.5kN/cm^2}{1.1} = 20.75kNm$$

$M_{y,Sd} = 6.86kNm \leq M_{y,Rd} = 20.75kNm$

$N_{Sd} = 1.35 \cdot G = 1.35 \cdot 19.71kN = 26.6kN$

$$N_{Rd} = A \cdot \frac{f_{yk}}{\gamma_{M1}} = 21.2cm^2 \cdot \frac{27.5kN/cm^2}{1.1} = 530kN$$

$N_{Sd} = 26.6kN \leq N_{Rd} = 530kN$

Kontrola pomikov:

$$u_{max} = \frac{5 \cdot w \cdot L_{max}^4}{384 \cdot E \cdot I_z} = \frac{5 \cdot 0.0198kN/cm \cdot 430^4 cm^4}{384 \cdot 21000kN/cm^2 \cdot 349cm^4} = 1.21cm \leq \frac{L_{max}}{250} = 1.72cm$$

Kontrola uklona:

$$N_{b,Rd} = \chi \cdot A \cdot \frac{f_{yk}}{\gamma_{M1}} = 0.85 \cdot 21.2cm^2 \cdot \frac{27.5kN/cm^2}{1.1} = 450.5kN$$

$N_{Sd} = 26.6kN \leq N_{b,Rd} = 118.2kN$

$$\bar{\lambda} = \frac{\lambda}{\lambda_1} = \frac{61.75}{86.8} = 0.71$$

$$\lambda = \frac{l_u}{i_z} = \frac{155\, cm}{2.51\, cm} = 61.75$$

$l_u = 1.55m$ ... glej zasnova, stran 109.

$$i_z = \sqrt{\frac{I_z}{A}} = \sqrt{\frac{134cm^4}{21.2\, cm^2}} = 2.51\, cm$$

$$\lambda_1 = 93.9 \cdot \sqrt{\frac{235}{f_y}} = 93.9 \cdot \sqrt{\frac{235}{275}} = 86.8$$

$\chi = \chi(\bar{\lambda}) \quad \Rightarrow \quad$ Uklonska krivulja a $\quad \Rightarrow \quad \chi = 0.85$

8 SPOJ STEBRA NA TEMELJ

8.1 Projektne vrednosti notranjih sil $E_{F,d}$ v priključku na temelj

IPE 300

$h_{w,nosilec} = 24.8cm$ $\quad W_{pl,Rd,i} = 628.0cm^3$

$$M_{pl,Rd,i} = \frac{f_y}{\gamma_{M0}} \cdot W_{pl,Rd,i} = \frac{27.5kN/cm^2}{1.1} \cdot 628.0cm^3 = 157.0kNm$$

$M_{Ed,i} = 105.5kNm$

$$\Omega = \min\left(\frac{M_{pl,Rd,i}}{M_{Ed,i}}\right) = \frac{157.0kNm}{105.5kNm} = 1.49$$

IPE 360

$h_{w,nosilec} = 29.8cm$ $\quad W_{pl,Rd,i} = 1019.0cm^3$

$$M_{pl,Rd,i} = \frac{f_y}{\gamma_{M0}} \cdot W_{pl,Rd,i} = \frac{27.5kN/cm^2}{1.1} \cdot 1019.0cm^3 = 254.75kNm$$

$M_{Ed,i} = 242.7kNm$

$$\Omega = \min\left(\frac{M_{pl,Rd,i}}{M_{Ed,i}}\right) = \frac{254.75kNm}{242.7kNm} = 1.05$$

8.1.1 Projektne vrednosti notranjih sil $E_{F,d}$ stebra HEA 260 v priključku na temelj

$$N_{Ed} = N_{Ed,G} + 1.1 \cdot \gamma_{0V} \cdot \Omega \cdot N_{Ed,E}$$

$N_{Ed} = 254.6kN + 1.1 \cdot 1.1 \cdot 1.05 \cdot 219.72kN = 533.75kN$

$$M_{Ed} = M_{Ed,G} + 1.1 \cdot \gamma_{0V} \cdot \Omega \cdot M_{Ed,E}$$

$M_{Ed} = 25.8kNm + 1.1 \cdot 1.1 \cdot 1.05 \cdot 18.03kNm = 48.71kNm$

$$V_{Ed} = V_{Ed,G} + 1.1 \cdot \gamma_{0V} \cdot \Omega \cdot V_{Ed,E}$$

$V_{Ed} = 14.4kN + 1.1 \cdot 1.1 \cdot 1.05 \cdot 7.52kN = 23.95kN$

8.1.2 Projektne vrednosti notranjih sil $E_{F,d}$ stebra HEA 320 v priključku na temelj

$$N_{Ed} = N_{Ed,G} + 1.1 \cdot \gamma_{0V} \cdot \Omega \cdot N_{Ed,E}$$

$N_{Ed} = 443.6kN + 1.1 \cdot 1.1 \cdot 1.05 \cdot 222.22kN = 725.93kN$

$$M_{Ed} = M_{Ed,G} + 1.1 \cdot \gamma_{0V} \cdot \Omega \cdot M_{Ed,E}$$

$M_{Ed} = 29.3kNm + 1.1 \cdot 1.1 \cdot 1.05 \cdot 78.33kNm = 128.82kNm$

$V_{Ed} = V_{Ed,G} + 1.1 \cdot \gamma_{0V} \cdot \Omega \cdot V_{Ed,E}$

$V_{Ed} = 17.0kN + 1.1 \cdot 1.1 \cdot 1.05 \cdot 28.32kN = 52.98kN$

8.1.3 Projektne vrednosti notranjih sil $E_{F,d}$ stebra HEA 360 v priključku na temelj

$N_{Ed} = N_{Ed,G} + 1.1 \cdot \gamma_{0V} \cdot \Omega \cdot N_{Ed,E}$

$N_{Ed} = 511.0kN + 1.1 \cdot 1.1 \cdot 1.05 \cdot 204.76kN = 771.15kN$

$M_{Ed} = M_{Ed,G} + 1.1 \cdot \gamma_{0V} \cdot \Omega \cdot M_{Ed,E}$

$M_{Ed} = 76.5kNm + 1.1 \cdot 1.1 \cdot 1.05 \cdot 38.58kNm = 125.52kNm$

$V_{Ed} = V_{Ed,G} + 1.1 \cdot \gamma_{0V} \cdot \Omega \cdot V_{Ed,E}$

$V_{Ed} = 39.9kN + 1.1 \cdot 1.1 \cdot 1.05 \cdot 12.23kN = 55.44kN$

8.1.4 Projektne vrednosti notranjih sil $E_{F,d}$ stebra HEA 450 v priključku na temelj

$N_{Ed} = N_{Ed,G} + 1.1 \cdot \gamma_{0V} \cdot \Omega \cdot N_{Ed,E}$

$N_{Ed} = 972.3kN + 1.1 \cdot 1.1 \cdot 1.05 \cdot 203.56kN = 1230.92kN$

$M_{Ed} = M_{Ed,G} + 1.1 \cdot \gamma_{0V} \cdot \Omega \cdot M_{Ed,E}$

$M_{Ed} = 81.2kNm + 1.1 \cdot 1.1 \cdot 1.05 \cdot 152.2kNm = 274.57kNm$

$V_{Ed} = V_{Ed,G} + 1.1 \cdot \gamma_{0V} \cdot \Omega \cdot V_{Ed,E}$

$V_{Ed} = 39.3kN + 1.1 \cdot 1.1 \cdot 1.05 \cdot 43.63kN = 94.73kN$

8.1.4 Projektne vrednosti notranjih sil $E_{F,d}$ stebra HEA 550 v priključku na temelj

$N_{Ed} = N_{Ed,G} + 1.1 \cdot \gamma_{0V} \cdot \Omega \cdot N_{Ed,E}$

$N_{Ed} = 924.64kN + 1.1 \cdot 1.1 \cdot 1.05 \cdot 26.0kN = 957.67kN$

$M_{Ed} = M_{Ed,G} + 1.1 \cdot \gamma_{0V} \cdot \Omega \cdot M_{Ed,E}$

$M_{Ed} = 89.87kNm + 1.1 \cdot 1.1 \cdot 1.05 \cdot 119.92kNm = 242.23kNm$

$V_{Ed} = V_{Ed,G} + 1.1 \cdot \gamma_{0V} \cdot \Omega \cdot V_{Ed,E}$

$V_{Ed} = 38.81kN + 1.1 \cdot 1.1 \cdot 1.05 \cdot 27.33kN = 73.53kN$

8.2 Projektne vrednosti notranjih sil $E_{F,d}$ v temeljih

$$E_{F,d} = 1.2 \cdot (E_{F,G} + \alpha \cdot E_{F,E})$$

$$\alpha = \frac{R_{d,i}}{S_{d,i}}$$

Notranji stebri prevzamejo potresno obtežbo samo v x smeri. Za zunanje stebre pa velja, da prevzemajo potresno obtežbo v obeh smereh.

$$E_{Ed,x} + 0.3 \cdot E_{Ed,y}$$

$$0.3 \cdot E_{Ed,x} + E_{Ed,y}$$

1. Zunanji momentni okvir – srednji steber:

$$\alpha = 3.09$$

$$M_{F,d} = 1.2 \cdot (M_{F,G} + \alpha \cdot M_{F,E}) = 1.2 \cdot (-12.11\text{kNm} + 3.09 \cdot (-76.5\text{kNm})) = -298.19\text{kNm}$$

$$N_{F,d} = 1.2 \cdot (N_{F,G} + \alpha \cdot N_{F,E}) = 1.2 \cdot (-443.62\text{kN} + 3.09 \cdot (-25.33\text{kN})) = -626.27\text{kN}$$

$$V_{F,d} = 1.2 \cdot (V_{F,G} + \alpha \cdot V_{F,E}) = 1.2 \cdot (7.7\text{kN} + 3.09 \cdot 27.91\text{kN}) = 112.73\text{kN}$$

2. Notranji momentni okvir – srednji steber:

$$\alpha = 3.09$$

$$M_{F,d} = 1.2 \cdot (M_{F,G} + \alpha \cdot M_{F,E}) = 1.2 \cdot (-23.2\text{kNm} + 3.09 \cdot (-167.7\text{kNm})) = -649.67\text{kNm}$$

$$N_{F,d} = 1.2 \cdot (N_{F,G} + \alpha \cdot N_{F,E}) = 1.2 \cdot (-794.0\text{kN} + 3.09 \cdot (-31.7\text{kN})) = -1070.34\text{kN}$$

$$V_{F,d} = 1.2 \cdot (V_{F,G} + \alpha \cdot V_{F,E}) = 1.2 \cdot (14.2\text{kN} + 3.09 \cdot 48.4\text{kN}) = 156.51\text{kN}$$

3. Okvir z diagonalnim centričnim povezjem – krajni temelj:

a) $\sum G_{k,i} + \sum \psi_{k,i} Q_{k,i}$

$$N_{F,G} = N_{dx} + 0.3 \cdot N_{dy} = -502.6\text{kN} + 0.3 \cdot (-468.7\text{kN}) = -643.21\text{kN}$$

$$N_{F,G} = 0.3 \cdot N_{dx} + N_{dy} = 0.3 \cdot (-502.6\text{kN}) + (-468.7\text{kN}) = -619.48\text{kN}$$

$$V_{F,G} = V_{dx} + 0.3 \cdot V_{dy} = 13.0\text{kN} + 0.3 \cdot 0 = 13.0\text{kN}$$

$$V_{F,G} = 0.3 \cdot V_{dx} + V_{dy} = 0.3 \cdot 13\text{kN} + 0 = 3.9\text{kN}$$

$$M_{F,G} = M_{dx} + 0.3 \cdot M_{dy} = -36.3kN + 0.3 \cdot 0 = -36.3kN$$

$$M_{F,G} = 0.3 \cdot M_{dx} + M_{dy} = 0.3 \cdot (-36.3kN) + 0 = -10.89kN$$

b) $\gamma_I A_{Ed}$

$$N_{F,E} = N_{dx} + 0.3 \cdot N_{dy} = -36.3kN + 0.3 \cdot (-383.5kN) = -151.35kN$$

$$N_{F,E} = 0.3 \cdot N_{dx} + N_{dy} = 0.3 \cdot (-36.3kN) + (-383.5kN) = -394.39kN$$

$$V_{F,E} = V_{dx} + 0.3 \cdot V_{dy} = 11.8kN + 0.3 \cdot 0 = 11.8kN$$

$$V_{F,E} = 0.3 \cdot V_{dx} + V_{dy} = 0.3 \cdot 11.8kN + 0 = 3.54kN$$

$$M_{F,E} = M_{dx} + 0.3 \cdot M_{dy} = -33.4kN + 0.3 \cdot 0 = -33.4kN$$

$$M_{F,E} = 0.3 \cdot M_{dx} + M_{dy} = 0.3 \cdot (-33.4kN) + 0 = -10.02kN$$

$$\alpha = 1.64$$

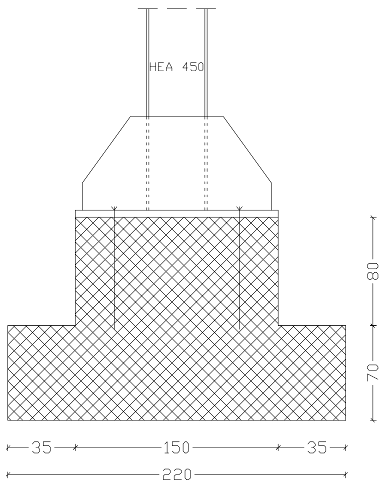
$$N_{F,d} = 1.2 \cdot \left(\max N_{F,G} + \alpha \cdot \max N_{F,E}\right) = 1.2 \cdot \left(-643.21kN + 1.64 \cdot (-394.39kN)\right) = -1548.01kN$$

$$V_{F,d} = 1.2 \cdot \left(\max V_{F,G} + \alpha \cdot \max V_{F,E}\right) = 1.2 \cdot \left(13.0kN + 1.64 \cdot 11.8kN\right) = 38.82kN$$

$$M_{F,d} = 1.2 \cdot \left(\max M_{F,G} + \alpha \cdot \max M_{F,E}\right) = 1.2 \cdot \left(-36.3kNm + 1.64 \cdot (-33.4kNm)\right) = -109.29kNm$$

9 OCENA NOSILNOSTI TEMELJNIH TAL

9.1 Zasnova



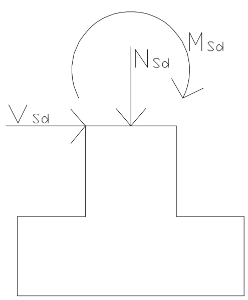
$G_{temelja} = V \cdot \gamma$

$G_{temelja} = 5.188m^3 \cdot 25kN/m^3 = 129.7kN$

$G_{zemljine} = V \cdot \gamma$

$G_{zemljine} = 2.07m^3 \cdot 20.5kN/m^3 = 42.48kN$

9.2 Obtežba



1.Dinamična analiza:

$N_{Sd} = 1548.01kN$

$M_{Sd} = 109.29kNm$

$V_{Sd} = 38.82kN$

2.Statična analiza (ovojnica):

$N_{Sd} = 643.21kN$

$M_{Sd} = 36.3kNm$

$V_{Sd} = 13.0kN$

$P_1 = N_{Sd} + G_{temelja} + G_{zemljine} = 1548.01kN + 129.7kN + 42.48kN = 1720.2kN$

$P_2 = N_{Sd} + G_{temelja} + G_{zemljine} = 643.21kN + 129.7kN + 42.48kN = 815.39kN$

9.3 Račun nosilnosti temeljnih tal

ENV 1997 – 1 ANNEX B

Drenirani pogoji:

Podatki:

$\gamma = 20.5kN/m^3$ $\quad \gamma_c = 1.6$ $\quad \gamma_\varphi = 1.25$

$$c = 12kN/m^2 \quad \Rightarrow \quad c' = \frac{c}{\gamma_c} = \frac{12kN/m^2}{1.6} = 7.5kN/m^2$$

$$\varphi = 22^{o} \quad \Rightarrow \quad \varphi' = \text{arctg}\left(\frac{\text{tg}\varphi}{\gamma_\varphi}\right) = \text{arctg}\left(\frac{\text{tg} \cdot 22^\circ}{1.25}\right) = 17.91^\circ$$

$\gamma' = \gamma - \gamma_w = 20.5\text{kN/m}^3 + 10\text{kN/m}^3 = 10.5\text{kN/m}^3$

$L' = L = 2.2\text{m}$

$B' = B = 2.2\text{m}$

$A' = B' \cdot L' = 2.2\text{m} \cdot 2.2\text{m} = 4.84\text{m}^2$

$q = \gamma \cdot V \qquad \Rightarrow \qquad q' = \gamma' \cdot V = 10.5\text{kN/m}^3 \cdot 5.188\text{m}^3 = 54.5\text{kN}$

$$N_q = e^{\pi \tan\varphi'} \cdot tg^2\left(45 + \frac{\varphi'}{2}\right) = e^{\pi \tan 17.91^\circ} \cdot tg^2\left(45 + \frac{17.91^\circ}{2}\right) = 5.21$$

$$N_c = (N_q - 1) \cdot ctg\varphi' = (5.21 - 1) \cdot ctg17.91^\circ = 13.03$$

$$N_\gamma = 2 \cdot (N_q - 1) \cdot tg\varphi' = 2 \cdot (5.21 - 1) \cdot tg17.91^\circ = 2.72$$

Faktorji oblike (temelj je kvadratne oblike):

$$S_q = 1 + \sin\varphi' = 1 + \sin 17.91^\circ = 1.31$$

$$S_\gamma = 0.7$$

$$S_c = \frac{S_q \cdot N_q - 1}{N_q - 1} = \frac{1.31 \cdot 5.21 - 1}{5.21 - 1} = 1.38$$

$$i_q = i_\gamma = 1 - \frac{H}{P + A' \cdot c' \cdot tg\varphi'} = 1 - \frac{38.82\text{kN}}{1720.2\text{kN} + 4.48\text{m}^2 \cdot 7.5\text{kN/m}^2 \cdot tg17.91^\circ} = 0.98$$

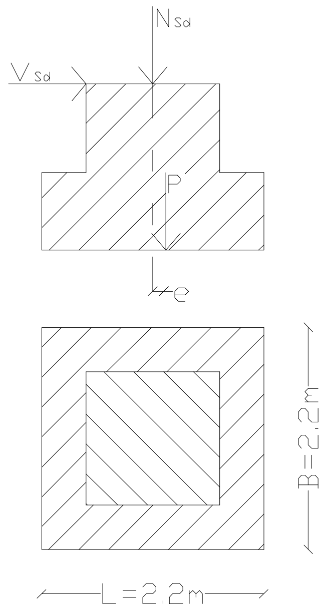
$$i_c = \frac{i_q \cdot N_q - 1}{N_q - 1} = \frac{0.98 \cdot 5.21 - 1}{5.21 - 1} = 0.97$$

$$\frac{R}{A'} = c' \cdot N_c \cdot S_c \cdot i_c + q' \cdot N_q \cdot S_q \cdot i_q + 0.5 \cdot \gamma' \cdot B' \cdot N_\gamma \cdot S_\gamma \cdot i_\gamma$$

$$R = 4.48\text{m}^2 \cdot \begin{pmatrix} 7.5\text{kN/m}^2 \cdot 13.03 \cdot 1.38 \cdot 0.97 + 54.5\text{kN} \cdot 5.21 \cdot 1.31 \cdot 0.98 + \\ 0.5 \cdot 10.5\text{kN/m}^3 \cdot 2.2\text{m} \cdot 2.72 \cdot 0.7 \cdot 0.98 \end{pmatrix}$$

$$\boxed{R = 2315.69\text{kN}}$$

9.4 Dimenzioniranje temelja



$$P = 1720.2\text{kN}$$

$$M = 109.29\text{kNm}$$

$$e = \frac{M}{P} = \frac{109.29\text{kNm}}{1720.2\text{kN}} = 0.06\text{m} \leq \frac{L}{6} = \frac{2.5\text{m}}{6} = 0.42\text{m}$$

$$e \leq \frac{L}{6} \Rightarrow \sigma_{1,2} = \frac{P}{A} \pm \frac{M}{W}$$

$$e \geq \frac{L}{6} \Rightarrow \sigma_{1,2} = \frac{2P}{3c \cdot B}$$

$$W = \frac{L^2 \cdot B}{6} = \frac{2.2^2\,\text{m}^2 \cdot 2.2\text{m}}{6} = 1.77\text{m}^3$$

$$A = 4.48\text{m}^2$$

$$\sigma_{tal} = \frac{R}{A} = \frac{2315.69\text{kN}}{4.48\text{m}^2} = 516.89\text{kN/m}^2$$

$$\sigma_1 = \frac{P}{A} + \frac{M}{W} = \frac{1720.2\text{kN}}{4.48\text{m}^2} + \frac{109.29\text{kNm}}{1.77\text{m}^3} = 445.72\text{kN/m}^2 \leq \sigma_{tal} = 516.89\text{kN/m}^2$$

$$\sigma_2 = \frac{P}{A} - \frac{M}{W} = \frac{1720.2\text{kN}}{4.48\text{m}^2} - \frac{109.29\text{kNm}}{1.77\text{m}^3} = 322.23\text{kN/m}^2 \leq \sigma_{tal} = 516.89\text{kN/m}^2$$

10 RAČUN ZNAČILNIH SPOJEV

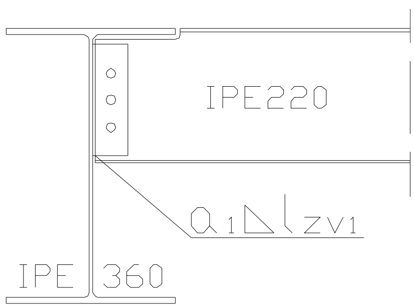
10.1 Členkasti spoj sekundarnega nosilca na primarni nosilec

10.1.1 Material

Jeklo S275

Visokovredni vijaki 10.9

10.1.2 Geometrija



10.1.3 Obtežba

$q_{Sd} = 25.92kN/m$

10.1.4 Obremenitev

$$V_{Sd} = \frac{q_{Sd} \cdot B}{2} = \frac{25.92kN/m \cdot 6m}{2} = 77.76kN$$

10.1.5 Dimenzioniranje

Izberemo vijake M12 10.9

$d_0 = d + 1mm = 12mm + 1mm = 13mm$

Vezna pločevina:

$t_V = 6mm$

$h_V = 140mm$

Razporeditev vijakov:

$e_1 \approx 2d_0 \approx 30mm$

$e_2 \approx 1.5d_0 \approx 20mm$

$$p_1 = \frac{h_V - 2e_1}{2} = \frac{140mm - 2 \cdot 30mm}{2} = 40mm$$

Stik v ravnini I:

Dejanski členek je med ravnino II in zunanjim robom vezne pločevine v ravnini I.

$M^{I\text{-}I} = V_{Sd} \cdot e = 77.76kN \cdot 4.5cm = 349.92kNcm$

$e = \Delta + 2e_2 = 5mm + 2 \cdot 20mm = 45mm$

Zvar:

$a \approx 0.4t = 0.4 \cdot 6mm = 2.4mm$

$a = 4mm$

$l_{zv} = 2e_1 + 2p_1 - 2s = 2 \cdot 30mm + 2 \cdot 40mm - 2 \cdot 5.66mm = 128.7mm$

$l_{zv} = 125mm$

$s = a \cdot \sqrt{2} = 4mm \cdot \sqrt{2} = 5.66mm$

Izberemo a Δ l_{zv} = 4mm Δ 125mm

Kontrola zvara:

$$n = \frac{M^{I-I}}{W_{zv}} = \frac{349.92\,kNcm}{20.83\,cm^3} = 16.8kN/cm^2$$

$$W_{zv} = 2 \cdot \frac{l_{zv}^2 \cdot a}{6} = 2 \cdot \frac{12.5^2\,cm^2 \cdot 0.4cm}{6} = 20.83\,cm^3$$

$$v_{||} = \frac{V_{Sd}}{A_{zv}} = \frac{77.76\,kN}{10\,cm^2} = 7.78\,kN/cm^2$$

$A_{zv} = 2 \cdot l_{zv} \cdot a = 2 \cdot 12.5cm \cdot 0.4cm = 10cm^2$

$$\sqrt{n^2 + v_{||}^2} \le f_{v,w,d}$$

$$f_{v,w,d} = \frac{f_U}{\sqrt{3} \cdot \beta_w \cdot \gamma_w} = \frac{43kN/cm^2}{\sqrt{3} \cdot 0.8 \cdot 1.25} = 23.4\,kN/cm^2$$

$$\sqrt{\left(16.8kN/cm^2\right)^2 + \left(7.78kN/cm^2\right)^2} = 18.51kN/cm^2 \le 23.4kN/cm^2$$

Kontrola nosilnosti:

–vezne pločevine v ravnini I–I:

$$M^{I\text{-}I} = 349.92kN \le M_{el,Rd,v} = W_{el,y,v} \cdot \frac{f_y}{\gamma_{M1}} = 19.6cm^3 \cdot \frac{27.5\,kN/cm^2}{1.1} = 490kNcm$$

$$W_{el,y,v} = \frac{h_v^2 \cdot t_v}{6} = \frac{14^2 cm^2 \cdot 0.6cm}{6} = 19.6cm^3$$

$$V_{Sd} = 77.76kN \leq A_v \cdot \frac{f_y}{\sqrt{3} \cdot \gamma_{M1}} = 8.4cm^2 \cdot \frac{27.5kN/cm^2}{\sqrt{3} \cdot 1.1} = 121.24kN$$

$A_v = h_v \cdot t_v = 14cm \cdot 0.6cm = 8.4cm^2$

–vijakov:

$M = V_{Sd} \cdot e_2 = 77.76kN \cdot 2cm = 155.52kNcm$

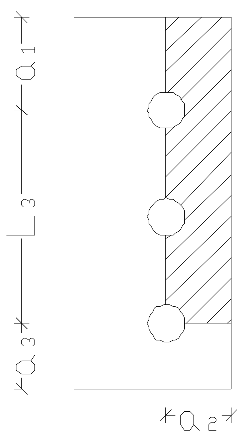
Sila, ki odpade na en vijak:

$$\sqrt{\left(\frac{V_{Sd}}{3}\right)^2 + \left(\frac{M}{2p_1}\right)^2} \leq F_{v,Rd}$$

$$F_{v,Rd} = n \cdot \frac{0.6 \cdot f_{ub} \cdot A}{\gamma_{Mb}} = 1 \cdot \frac{0.6 \cdot 100kN/cm^2 \cdot 1.13cm^2}{1.25} = 54.24kN$$

$$\sqrt{\left(\frac{77.76kN}{3}\right)^2 + \left(\frac{155.52kNcm}{2 \cdot 4cm}\right)^2} = 32.4kN \leq 54.24kN$$

Kontrola proti strižnemu pretrgu ob robu pločevine:



$$V_{Sd} = 77.76kN \leq V_{eff.,Rd} = A_{v,eff.} \cdot \frac{f_y}{\sqrt{3} \cdot \gamma_{M1}} = 7.79cm^2 \cdot \frac{27.5kN/cm^2}{\sqrt{3} \cdot 1.1} = 112.58kN$$

$$A_{v,eff.} = t_v \cdot L_{v,eff.} = 0.6cm \cdot 13cm = 7.8cm^2$$

$L_{v,eff.} = L_v + L_1 + L_2 = 80mm + 30mm + 20mm = 130mm \leq 130mm$

$L_1 = a_1 = 30mm \leq 5d = 5 \cdot 12mm = 60mm$

$$L_2 = (a_2 - k \cdot d_{0,t})\frac{f_U}{f_y} = (2cm - 0.5 \cdot 1.4cm) \cdot \frac{43kN/cm^2}{27.5kN/cm^2} = 20mm$$

Lv = 2p1 = 2 · 40mm = 80mm

$$L_3 = L_v + a_1 + a_3 \leq (L_v + a_1 + a_2 - nd_{0,v})\frac{f_U}{f_y}$$

$$L_3 = 80mm + 30mm + 20mm \leq (80mm + 30mm + 20mm - 3 \cdot 14mm) \cdot \frac{43kN/cm^2}{27.5kN/cm^2}$$

$$L_3 = 130mm \leq 137.6mm$$

$$a_3 = a_2 = e_2 = 20mm$$

10.2 Priključek stebra na temelj

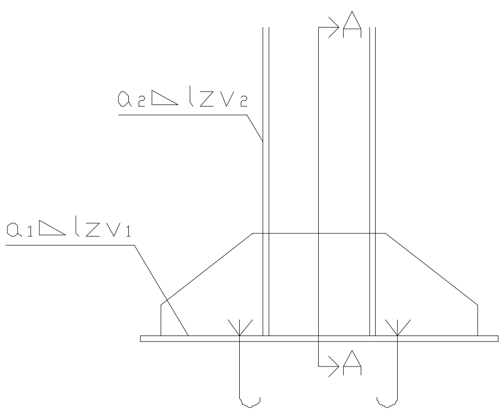
10.2.1 Material

AB temelj C25/30

Jeklo S275

Visokovredni vijaki 10.9

10.2.2 Geometrija



10.2.3 Obtežba/Obremenitev

N_{Sd} = 1230.92kN

M_{Sd} = 274.57kNm

V_{Sd} = 94.73kN

10.2.4 Dimenzioniranje

1. Prenos obtežbe:

Obtežba se preko pasnic prenese v vertikalne vezne pločevine in naprej v čelno pločevino. Obtežba, ki odpade na stojino, se prenese direktno v čelno pločevino. Iz čelne pločevine se obtežba prenese v temelj preko sidrnih vijakov.

2. Razdelitev obtežbe v razmerju togosti:

$$M^f = \frac{I^f}{I_y} \cdot M_{Sd} = \frac{57678.21\text{cm}^4}{63720\text{cm}^4} \cdot 27457\text{kNcm} = 24853.59\text{kNcm}$$

$$M^w = \frac{I^w}{I_y} \cdot M_{Sd} = \frac{6041.79\text{cm}^4}{63720\text{cm}^4} \cdot 27457\text{kNcm} = 2603.38\text{kNcm}$$

$$I^f = I_y - I^w = 63720\text{cm}^4 - 6041.79\text{cm}^4 = 57678.21\text{cm}^4$$

$$I^w = \frac{h_w^3 \cdot t_w}{12} = \frac{39.8^3\text{cm}^3 \cdot 1.15\text{cm}}{12} = 6041.79\text{cm}^4$$

$$N^f = \frac{A^f}{A} \cdot N_{Sd} = \frac{63\text{cm}^2}{108.77\text{cm}^2} \cdot 1230.92\text{kN} = 712.95\text{kN}$$

$$N^w = \frac{A^w}{A} \cdot N_{Sd} = \frac{45.77\text{cm}^2}{108.77\text{cm}^2} \cdot 1230.92\text{kN} = 517.97\text{kN}$$

$A_f = b \cdot t_f = 30\text{cm} \cdot 2.1\text{cm} = 63\text{cm}^2$

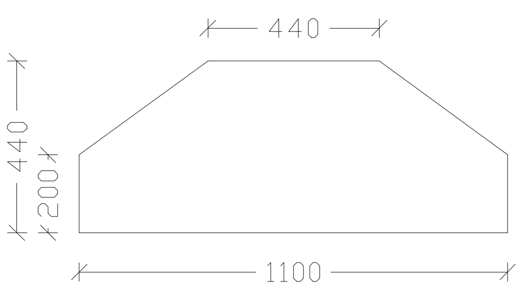
$A_w = h_w \cdot t_w = 39.8\text{cm} \cdot 1.15\text{cm} = 45.77\text{cm}^2$

$A = A_f + A_w = 108.77\text{cm}^2$

$V^f = 0$

$V^w = V_{Sd} = 94.73\text{kN}$

3. Vezna pločevina:



$t_v = t_f = 21\text{mm}$

4. Zvari med pasnico in vezno pločevino:

$$N = \frac{M^f}{h} = \frac{24853.59\text{kNcm}}{41.9\text{cm}} = 593.16\text{kN}$$

Sila, ki odpade na en zvar:

$$F_l = \frac{N^f}{8} + \frac{N}{4} = \frac{712.95\,\text{kN}}{8} + \frac{517.97\text{kN}}{4} = 218.61\text{kN}$$

$$\frac{F_l}{A_{zv}} = \frac{F_l}{a_1 \cdot l_{zv1}} \leq f_{v,w,d} \qquad f_{v,w,d} = \frac{f_U}{\sqrt{3} \cdot \beta_w \cdot \gamma_w} = \frac{43\text{kN/cm}^2}{\sqrt{3} \cdot 0.85 \cdot 1.25} = 23.4\text{kN/cm}^2$$

Priporočilo: $0.75h_w \leq l_{zv1} \leq h_v - 2s$

$0.75 \cdot 398\text{mm} \leq l_{zv1} \leq 440\text{mm} - 2 \cdot (5\text{mm} \cdot \sqrt{2})$

$298.5\text{mm} \leq l_{zv1} \leq 425.86\text{mm}$

Kontrola: $l_{zv1} = 400\text{mm} \leq 150a_1 = 750\text{mm}$

$$a_1 \geq \frac{F_l}{f_{v,w,d} \cdot l_{zv1}} = \frac{204.08\text{kN}}{23.4\text{kN/cm}^2 \cdot 60\text{cm}} = 0.145\text{cm}$$

Kontrola: $3\text{mm} \leq a_1 \leq 0.7t = 0.7 \cdot 11.5\text{mm} = 8.05\text{mm}$

$t = \min(t_v, t_f)$

Izberemo $a_1 \Delta l_{zv1} = 5\text{mm} \Delta 400\text{mm}$

5. Zvar med stojino in čelno pločevino:

$$\sqrt{v_{\parallel}^2 + v_{\perp}^2 + n^2} \leq f_{v,w,d}$$

$$\sqrt{\left(2.96\text{kN/cm}^2\right)^2 + \left(16.19\text{kN/cm}^2\right)^2 + \left(16.2\text{kN/cm}^2\right)^2} = 23.09\text{kN/cm}^2 \leq 23.4\text{kN/cm}^2$$

$$v_{\parallel} = \frac{V^w}{A_{zv2}} = \frac{94.73\text{kN}}{32\text{cm}^2} = 2.96\text{kN/cm}^2$$

$A_{zv2} = 2l_{zv} \cdot a_2 = 2 \cdot 32\text{cm} \cdot 0.5\text{cm} = 32\text{cm}^2$

$$v_{\perp} = \frac{N^w}{A_{zv2}} = \frac{517.97\text{kN}}{32\text{cm}^2} = 16.19\text{kN/cm}^2$$

$$n = \frac{M^w}{W_{zv2}} = \frac{2603.38\text{kNcm}}{160.67\text{cm}^3} = 16.2\text{kN/cm}^2$$

$$W_{zv2} = 2 \cdot \frac{l_{zv}^2 \cdot a_2}{6} = 2 \cdot \frac{32^2\,\text{cm}^2 \cdot 0.5\text{cm}}{6} = 170.67\text{cm}^3$$

$l_{zv2} \leq h_w - 2 \cdot 3t_w = 398mm - 2 \cdot 3 \cdot 11.5mm = 329mm$

$l_{zv2} = 320$ mm

$a_2 \approx 0.4t = 0.4 \cdot 11.5mm = 4.6mm$

$a_2 = 5mm$

Izberemo $a_2 \Delta l_{zv2} = 5mm \Delta 320mm$

6. Zvar med vezno in čelno pločevino:

Za en zvar:

$$\sqrt{v_\perp^2 + n^2} \leq f_{v,w,d}$$

$$\sqrt{\left(3.24kN/cm^2\right)^2 + \left(3.08kN/cm^2\right)^2} = 4.47kN/cm^2 \leq 23.4kN/cm^2$$

$$v_\perp = \frac{N^f}{A_{zv3}} = \frac{712.95kN}{220cm^2} = 3.24kN/cm^2$$

$$n = \frac{M^f}{W_{zv3}} = \frac{24853.59kNcm}{8066.67cm^3} = 3.08kN/cm^2$$

$A_{zv3} = 2l_{zv3} \cdot a_3 = 2 \cdot 110cm \cdot 1cm = 220cm^2$

$a_3 \approx 0.4t = 0.4 \cdot 21mm = 8.4mm$

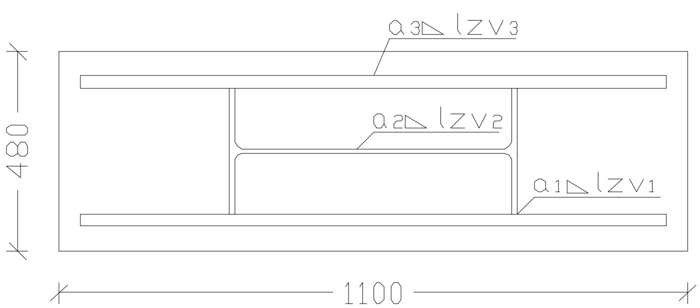
$a_3 = 10mm$

$$W_{zv3} = \frac{2 \cdot l_{zv}^2 \cdot a_3}{3} = \frac{2 \cdot 110^2 cm^2 \cdot 1cm}{3} = 8066.67cm^3$$

Izberemo $a_3 \Delta l_{zv3} = 10mm \Delta 1100mm$

7 Čelna pločevina:

$t_{čp} = t_v = 21mm$



Izberemo $\neq b_{čp} / t_{čp} / l_{čp} = 480mm / 21mm / 1200mm$

8. Sidrni vijaki:

Vijaki so obremenjeni z natezno in strižno silo.

$r_1 = h + 2 \cdot 2d_0 = 440mm + 4 \cdot 33mm = 572mm$

$r_2 = h + 2 \cdot 2d_0 + 2p_1 = 440mm + 4 \cdot 33mm + 2 \cdot 100mm = 772mm$

$r = (r_1 + r_2) / 2 = (572mm + 772mm) / 2 = 672mm$

Sila, ki odpade na en vijak:

$$\frac{M_{Sd}}{4r} - \frac{N_{Sd}}{8} \leq F_{t,Rd} = \frac{0.9 \cdot f_{ub} \cdot A_s}{\gamma_{Mb}}$$

$$\frac{27457kNcm}{4 \cdot 67.2cm} - \frac{1230.92kN}{8} = -51.72kN \leq \frac{0.9 \cdot 51kN/cm^2 \cdot 5.61cm^2}{1.25} = 206.0kN$$

$$\frac{V_{Sd}}{8 \cdot F_{v,Rd}} + \frac{M_{Sd}}{1.4 \cdot F_{t,Rd} \cdot 4r} \leq 1.0$$

$$\frac{94.73kN}{8 \cdot 137.3kN} + \frac{27457kNcm}{1.4 \cdot 206.0kN \cdot 4 \cdot 67.2cm} = 0.44 \leq 1.0$$

Izberemo vijake M30 (S 355)

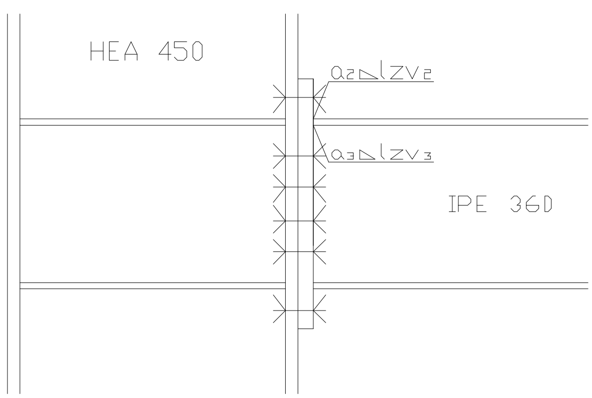
10.3 Momentni spoj primarnega nosilca in stebra prečnega okvirja

10.3.1 Material

Jeklo S275

Visokovredni vijaki 10.9

10.3.2 Geometrija



10.3.3 Obtežba/Obremenitev

$M_{Sd} = 1.2M_{pl,y} = 1.2 \cdot 25475kNcm = 30570kNcm$

$$M_{pl,y} = W_{pl,y} \cdot \frac{f_y}{\gamma_{M1}} = 1019cm^3 \cdot \frac{27.5kN/cm^2}{1.1} = 25475kNcm$$

$$V_{Sd} = \frac{2M_{pl,y}}{L} = \frac{2 \cdot 30570kNcm}{600cm} = 101.9kN$$

10.3.4 Dimenzioniranje zvarov med nosilcem in čelno pločevino

$a \approx 0.4t = 0.4 \cdot 8.0mm = 3.2mm$

$t = \min(t_w, t_f) = 8.0mm$

$a = 5mm$

Kontrola: $3mm \leq a \leq 0.7t = 0.7 \cdot 8.0mm = 5.4mm$

$$l_{zv1} = h_w - 2\sqrt{2} \cdot a - 2s = 334.6mm - 2\sqrt{2} \cdot 5mm - 2\sqrt{2} \cdot 5mm = 310mm$$

$$l_{zv2} = b_{čp} - 2\sqrt{2} \cdot a = 170mm - 2\sqrt{2} \cdot 5mm = 155mm$$

$$l_{zv3} = \left(b_{čp} - t_w - 2\sqrt{2} \cdot a\right)/2 - 2s = \left(170mm - 8.0mm - 2\sqrt{2} \cdot 5mm\right)/2 - 2\sqrt{2} \cdot 5mm = 60mm$$

Kontrola: $l_{zv} \leq 150a = 150 \cdot 5mm = 750mm$ ... velja za vse tri zvare

$$A_{zv} = 2l_{zv1} \cdot a + 2l_{zv2} \cdot a + 4l_{z3} \cdot a$$

$$A_{zv} = 2 \cdot 310mm \cdot 5mm + 2 \cdot 155mm \cdot 5mm + 4 \cdot 60mm \cdot 5mm = 5850mm$$

$$I_{zv} = 2 \cdot \frac{l_{zv1}^3 \cdot a}{12} + 2 \cdot \left(l_{zv2} + 2l_{zv3}\right) \cdot a \cdot \left(\frac{h_T}{2}\right)^2$$

$$I_{zv} = 2 \cdot \frac{310^3 mm^3 \cdot 5mm}{12} + 2 \cdot \left(155mm + 2 \cdot 60mm\right) \cdot 5mm \cdot \left(\frac{347.3mm}{2}\right)^2 = 10775.02cm^4$$

$$W_{zv1} = \frac{I_{zv}}{\frac{h}{2}} = \frac{10775.02cm^4}{\frac{36cm}{2}} = 598.61cm^3$$

$$W_{zv2} = \frac{I_{zv}}{\frac{l_{zv1}}{2}} = \frac{10775.02cm^4}{\frac{31cm}{2}} = 695.16cm^3$$

Točka 1:

$$\frac{M_{Sd}}{W_{zv1}} = \frac{30570kNcm}{598.61cm^3} = 51.07kN/cm^2 \leq f_{v,w,d} = \frac{f_U}{\sqrt{3} \cdot \beta_w \cdot \gamma_{Mw}} = \frac{43kN/cm^2}{\sqrt{3} \cdot 0.85 \cdot 1.25} = 23.4kN/cm^2$$

Opomba: Glede na to, da smo vzeli največje dimenzije zvarov in se nam kontrola ne izide predpišemo čelni zvar.

10.3.5 Razporeditev obtežbe med vijaki

Izberemo vijake M24 10.9

$d_0 = d + 2mm = 24mm + 2mm = 26mm$

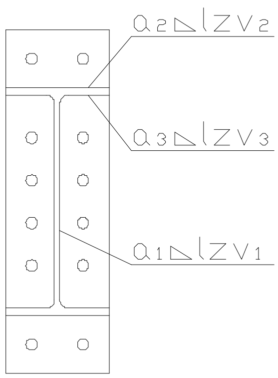
Izberemo debelino čelne pločevine:

$t_{čp} \geq d$; $t_{čp} = 30mm$

Razporeditev vijakov:

$e_1 = 60mm$

$p_1 = 80mm$



Steber s prečnimi ojačitvami:

$$F_{max} = \frac{M_{Sd} \cdot r_{max}}{\sum_{i=1}^{n-1} r_i^2} = \frac{30570kNcm \cdot 43.905cm}{2 \cdot 3636.7cm^2} = 185.62kN$$

$$r_1 = \frac{t_f}{2} + e_1 = \frac{12.7mm}{2} + 60mm = 66.35mm$$

$$r_2 = r_1 + p_1 = 66.35mm + 80mm = 146.35mm$$

$$r_3 = r_2 + p_1 = 146.35mm + 80mm = 226.35mm$$

$$r_4 = r_3 + p_1 = 226.35mm + 80mm = 306.35mm$$

$$r_5 = r_4 + 2e_1 + t_f = 306.35mm + 2 \cdot 60mm + 12.7mm = 439.05mm$$

Kontrola natezne nosilnosti vijakov:

$$F_{t,Sd} = F_{max} = 185.62kN \leq F_{t,Rd} = \frac{0.9 \cdot f_{ub} \cdot A_s}{\gamma_{Mb}} = \frac{0.9 \cdot 100kN/cm^2 \cdot 3.53cm^2}{1.25} = 254.16kN/cm^2$$

Kontrola strižne nosilnosti vijakov:

$$F_{v,Sd} = \frac{V_{Sd}}{12} = \frac{101.9kN}{12} = 8.5kN \leq F_{v,Rd} = n \cdot \frac{0.6 \cdot f_{ub} \cdot A}{\gamma_{Mb}} = 1 \cdot \frac{0.6 \cdot 100kN \cdot 4.52cm^2}{1.25} = 217kN$$

Interakcija striga in natega:

$$\frac{F_{v,Sd}}{F_{v,Rd}} + \frac{F_{t,Sd}}{1.4 \cdot F_{t,Rd}} = \frac{8.5kN}{217kN} + \frac{185.62kN}{1.4 \cdot 254.16kN} = 0.56 \leq 1.0$$

Kontrola nosilnosti na preboj pločevine:

$$t_p = \min(t_{čp}, t_f) \Rightarrow t_p = 21mm$$

$$F_{t,Sd} = 185.62kN \leq B_{p,Rd} = \frac{0.6 \cdot \pi \cdot d_m \cdot t_p \cdot f_u}{\gamma_{Mb}} = \frac{0.6 \cdot \pi \cdot 4.26cm \cdot 2.1cm \cdot 43kN/cm^2}{1.25} = 580.08kN$$

Kontrola bočnih pritiskov:

$$F_{v,Sd} = 8.5kN \leq F_{b,Rd} = 2.5\alpha \cdot d \cdot t \cdot \frac{f_u}{\gamma_{Mb}} = 2.5 \cdot 0.77 \cdot 2.4cm \cdot 2.1cm \cdot \frac{43kN/cm^2}{1.25} = 333.75kN$$

$$\alpha = \min: \quad \frac{e_1}{3 \cdot d_0} = \frac{60mm}{3 \cdot 26mm} = 0.77$$

$$\frac{p_1}{3 \cdot d_o} - \frac{1}{4} = \frac{80mm}{3 \cdot 26mm} - \frac{1}{4} = 0.78$$

$$\frac{f_{ub}}{f_u} = \frac{100}{43} = 2.33$$

$$1$$

Kontrola nosilnosti stebra v področju stika:

1. Čelna pločevina:

$t_{čp} = 30mm \geq d = 24mm$

2. Pasnica stebra v območju natezne obremenitve:

$t_f = 2.1cm \geq 0.5t_{čp} = 0.5 \cdot 3cm = 1.5cm$

$t_f = 2.1cm \geq 0.8d = 0.8 \cdot 2.4cm = 1.9cm$

3. Stojina stebra v tlaku:

$$b_s = t_f^{nosilca} + 2 \cdot t_{čp} + 5 \cdot k = 1.27cm + 2 \cdot 3.0cm + 5 \cdot 1.97cm = 17.12cm$$

$$k = t_f + \sqrt{2} \cdot a = 1.27cm + \sqrt{2} \cdot 0.5cm = 1.97cm$$

$a \approx 0.5 \cdot t_w = 0.5 \cdot 8.0mm = 4.0mm$

$a = 5mm$

4. Prerez, ki prevzame koncentrirano tlačno silo $F_{c,Sd}$:

Sila, ki jo prevzame sodelujoči del nosilca:

$$N_{Rd1} = b_s \cdot t_w \cdot \frac{f_y}{\gamma_{M0}} = 17.12cm \cdot 1.15cm \cdot \frac{27.5kN/cm^2}{1.1} = 492.2kN$$

Sila, ki jo mora prevzeti prečna ojačitev:

$$N_{Sd} = F_{c,Sd} - N_{Rd1} = 500.76kN - 492.2kN = 8.56kN$$

$$F_{c,Sd} = \sum_{i=1}^{n-1} F_i = 500.76kN$$

$$F_i = \frac{r_i}{r_{i,max}} F_{max}$$

$$F_1 = \frac{6.635cm}{43.905cm} \cdot 185.62kN = 28.05kN$$

$$F_2 = \frac{14.635cm}{43.905cm} \cdot 185.62kN = 61.87kN$$

$$F_3 = \frac{22.635cm}{43.905cm} \cdot 185.62kN = 95.70kN$$

$$F_4 = \frac{30.635cm}{43.905cm} \cdot 185.62kN = 129.52kN$$

$$F_5 = 185.62kN$$

Kontrola nosilnosti prečnih ojačitev:

$$b_{po} \geq \frac{N_{Sd} \cdot \gamma_{M0}}{t_{po} \cdot f_y} = \frac{8.56kN \cdot 1.1}{1.27cm \cdot 27.5kN/cm^2} = 0.27cm$$

Izberem $t_{po} = t_f = 12.7mm$

Izberem $b_{po} = 10mm$

$b_{po} = 10mm \leq b = 170mm$

Stojina stebra v strigu:

$$V_{Sd} = F_{c,Sd} = 101.9kN \leq V_{pl,Rd} = h_w \cdot t_w \cdot \frac{f_y}{\gamma_{M0} \cdot \sqrt{3}} = 33.46cm \cdot 0.8cm \cdot \frac{27.5kN/cm^2}{1.1 \cdot \sqrt{3}} = 386.4kN$$

Ne rabimo diagonalnih prečnih ojačitev.

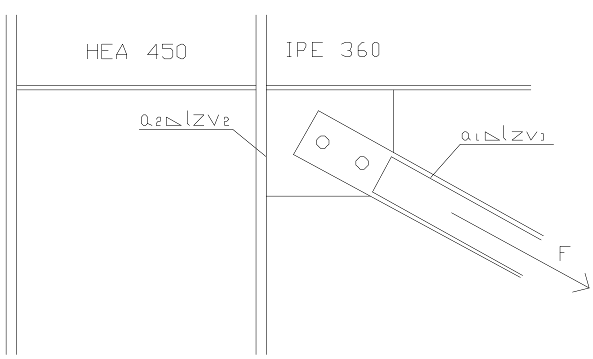
10.4 Stik diagonale s stebrom

10.3.1 Material

Jeklo S275

Visokovredni vijaki 10.9

10.3.2 Geometrija



10.3.3 Obtežba/Obremenitev

$F = 1.2N_{pl,Rd} = 1.2 \cdot 388kN = 465.6kN$

$$N_{pl,Rd} = A \cdot \frac{f_y}{\gamma_{M1}} = 15.52cm^2 \cdot \frac{27.5kN/cm^2}{1.1} = 388kN$$

10.4.4 Dimenzioniranje

1. Zvar med diagonalo in vezno pločevino:

$$\sqrt{v_{II}^2} = \sqrt{\left(19.4\text{kN/cm}^2\right)^2} = 19.4\text{kN/cm}^2 \leq f_{v,w,d} = 23.4\text{kN/cm2} \quad (\text{S } 275)$$

$$v = \frac{F}{A_{zv}} = \frac{465.6\text{kN}}{24\text{cm}^2} = 19.4\text{kN/cm}^2$$

$$A_{zv} = 4 \cdot a_1 \cdot l_{zv1} = 4 \cdot 0.3\text{cm} \cdot 20\text{cm} = 24\text{cm}$$

$a_1 \approx 0.4t = 0.4 \cdot 4.5\text{mm} = 1.8\text{mm}$

$a_1 = 3\text{mm}$

Kontrola: $3\text{mm} \leq a_1 = 3\text{mm} \leq 0.7t = 0.7 \cdot 4.5\text{mm} = 3.15\text{mm}$

$l_{zv1} = 200\text{mm}$

Kontrola: $l_{zv1} \leq 150a_1 = 150 \cdot 3\text{mm} = 450\text{mm}$

Izberemo: $a_1 \Delta l_{zv1} = 3\text{mm}\Delta 200\text{mm}$

2. Zvar med vezno pločevino in stebrom/prečko:

Čelni zvar.

3. Nosilnost vezne pločevine 1 (S 275):

bruto:

$$N_{Sd} = 465.6\text{kN} \leq N_{pl,Rd} = A \cdot \frac{f_y}{\gamma_{M1}} = 30\text{cm}^2 \cdot \frac{27.5\text{kN/cm}^2}{1.1} = 750\text{kN}$$

neto:

$$N_{Sd} = 465.6\text{kN} \leq N_{u,Rd} = 0.9 \cdot A_{net} \cdot \frac{f_u}{\gamma_{M2}} = 0.9 \cdot 23.4\text{cm}^2 \cdot \frac{43\text{kN/cm}^2}{1.25} = 724.46\text{kN}$$

$$A_{net.} = (15\text{cm} - 3.3\text{cm}) \cdot 2.0\text{cm} = 23.4\text{cm}^2$$

4. Nosilnost vezne pločevine 2 (S 275):

$$N_{Sd} = 465.6\text{kN} \leq N_{pl,Rd} = A \cdot \frac{f_y}{\gamma_{M1}} = 30\text{cm}^2 \cdot \frac{27.5\text{kN/cm}^2}{1.1} = 750\text{kN}$$

5. Vijaki:

Izberemo vijake M33 10.9

$d_0 = d + 3mm = 33mm + 3mm = 36mm$

število vijakov: n = 2

$e_1 = 80mm$

$p_1 = 110mm$

$l_{v1} = 2e_1 + p_1 = 2 \cdot 80mm + 110mm = 270mm$

$l_{v2} = 200mm + 270mm = 470mm$

$t_{v1} = t_{v2} = 20mm$

$$F_{v,Sd} = \frac{465.6kN}{2} = 232.8kN \le F_{v,Rd} = 0.6 \cdot \frac{f_{ub} \cdot A}{\gamma_{Mb}} = 0.6 \cdot \frac{100kN/cm^2 \cdot 7.07cm^2}{1.25} = 339.36kN$$

$$F_{v,Sd} = 232.8kN \le F_{b,Rd} = 2.5\alpha \cdot d \cdot t \cdot \frac{f_u}{\gamma_{Mb}} = 2.5 \cdot 0.81 \cdot 3.3cm \cdot 2.0cm \cdot \frac{43kN/cm^2}{1.25} = 459.76kN$$

$$\alpha = \min: \quad \frac{e_1}{3 \cdot d_0} = \frac{80mm}{3 \cdot 33mm} = 0.81$$

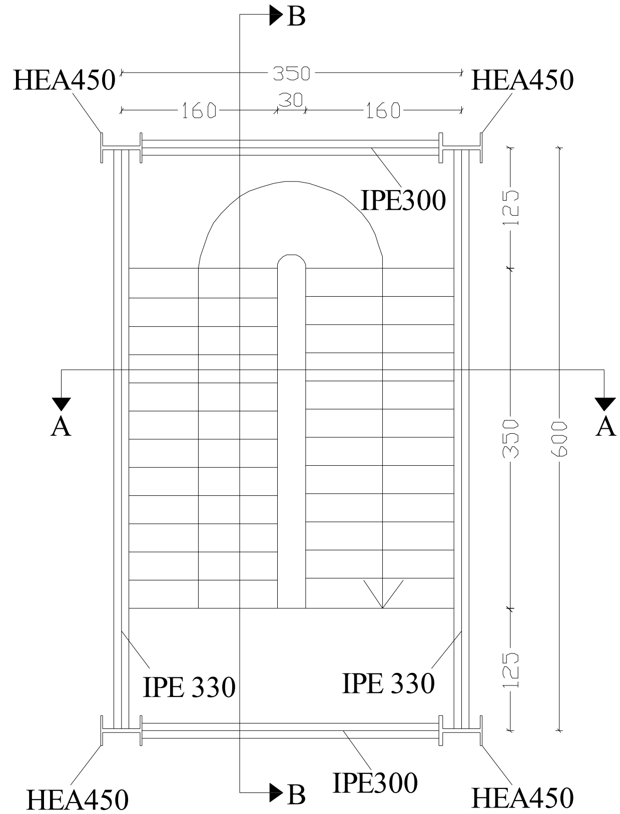
$$\frac{p_1}{3 \cdot d_o} - \frac{1}{4} = \frac{110mm}{3 \cdot 33mm} - \frac{1}{4} = 0.86$$

$$\frac{f_{ub}}{f_u} = \frac{100}{36} = 2.78$$

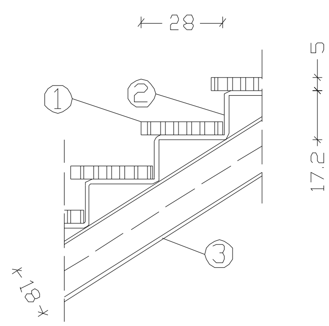
$$1$$

11 STOPNIŠČE

11.1 Geometrija

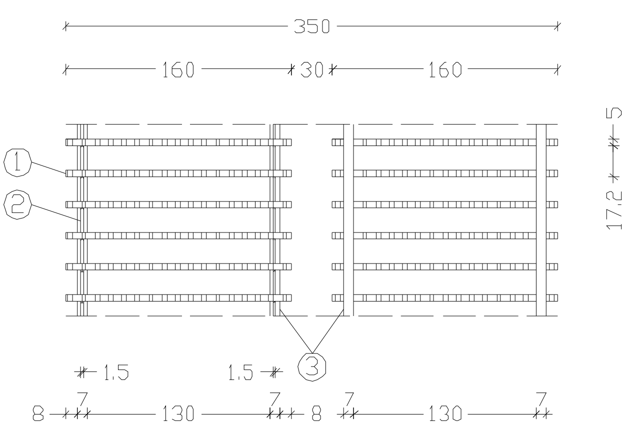


prerez B

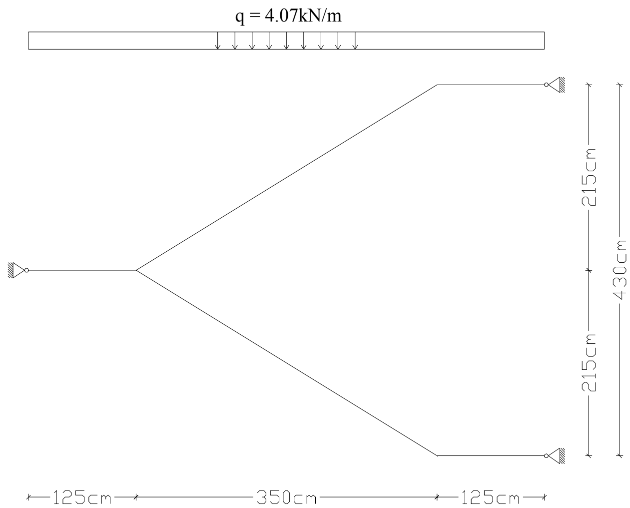


POZ 1 Stopnica iz ekspandirane plo čevine
POZ 2 Jekleni profil okroglega prereza
(privarjen) na nosilec
POZ 3 Jeklen ramenski nosilec (profil U180)

prerez A



11.1.1 Računski model



11.2 Zasnova

Stopnice so dvoramne in so narejene iz jeklenih nosilcev [profila, ki so z vijaki prostovrtljivo priključeni na nosilno konstrukcijo. Stopnice in podest iz pločevine, sta privarjena na [nosilce.

Stopnišče je zvočno izolirano s plastično maso, ki prekriva stopnišče in je ločeno od okolice s požarno odpornimi zidovi in vrati.

11.2.1 Širina stopniščnih ram

Dvoramne stopnice

B = 110cm + 50cm = 160cm ... Seliškar N.: Stavbarstvo, poglavje V, stran 3.

11.2.2 Naklon stopnic

v ... višina ene stopnice

š ... globina ene stopnice

2v + š ≈ k = 63cm ... Seliškar N.: Stavbarstvo, poglavje V, stran 7.

Pritličje: 25 stopnic v/š = 17.2 / 28cm

Etaže: 20 stopnic v/š = 16.5 / 28cm

11.2.3 Globina podesta

p ... globina podesta

$p \geq k + š = 63cm + 28cm = 91cm$ ... Seliškar N.: Stavbarstvo, poglavje V, stran 9.

Izberemo p = 125cm

11.3 Obtežba

11.3.1 Lastna in stalna

nosilec [180	0.22kN/m
pločevina................................0.2cm	$78.5kN/m^3 \cdot 0.8m \cdot 0.002m = 0.126kN/m$
jeklen nosilec.........................1.0cm	$0.4kN/m^3 \cdot 0.8m \cdot 0.01m = 0.0032kN/m$
	G = 0.35kN/m

11.3.2 Koristna obtežba

$q_S = 3.0kN/m^2$ ... glej stran 11.

B = 160cm

$Q = q_S \cdot B/2 = 3.0kN/m^2 \cdot 0.8m = 2.4kN/m$

11.4 Obtežna kombinacija

$q = 1.35G + 1.5Q = 1.35 \cdot 0.35kN/m + 1.5 \cdot 2.4kN/m$

$q = 4.07kN/m$

11.5 Rezultati dobljeni s programom ESA – Prima Win

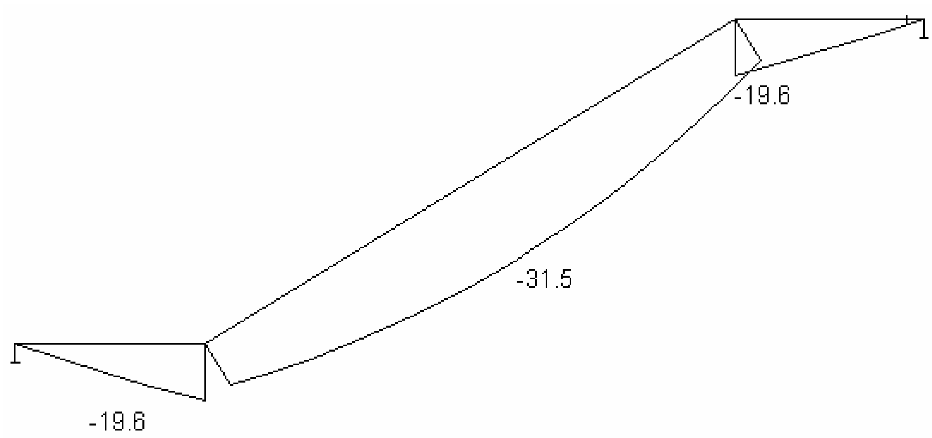
Ker so rezultati spodnje in zgornje stopniščne rame zelo podobni, smo obravnavali samo zgornjo.

Notranje sile:

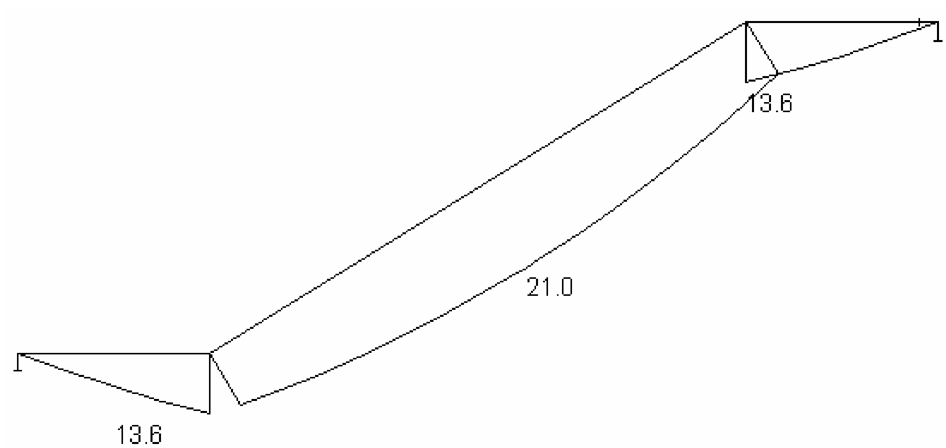
$M_{Sd} = 21.0kNm$ ...... v polju

$V_{Sd} = 13.5kN$ .... na mestu priključka

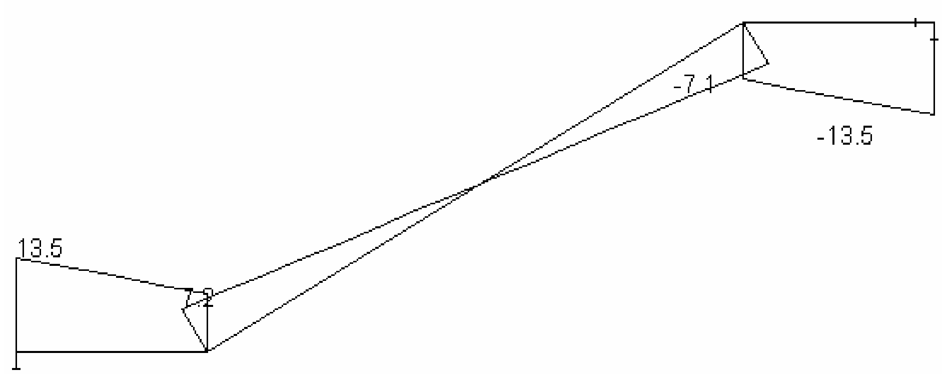
$N_{Sd} = 4.5kN$ .... natezna sila



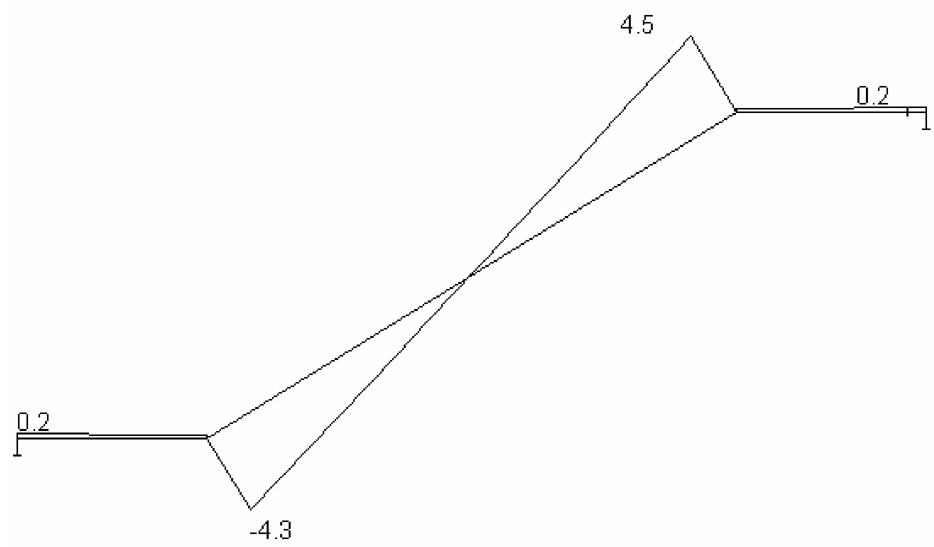
Pomiki - MSU [mm]



Upogibni moment [kNm]



Prečna sila [kN]



Osna sila [kN]

11.6 Račun nosilnosti elementov stopnišča

11.6.1 Nosilci stopniščnih ram

$$W = \frac{M_{Sd} \cdot \gamma_{M0}}{f_y} = \frac{2100kNcm \cdot 1.1}{27.5kN/cm^2} = 84cm^3 \Rightarrow \text{ U 180}$$

Izberem profil U 180 $W = 150cm^3$ … nosilci stopniščne rame

11.6.2 Kontrola strižne nosilnosti

$$A_S = 0.843cm^2$$

$$f_{ub} = 50kN/cm^2$$

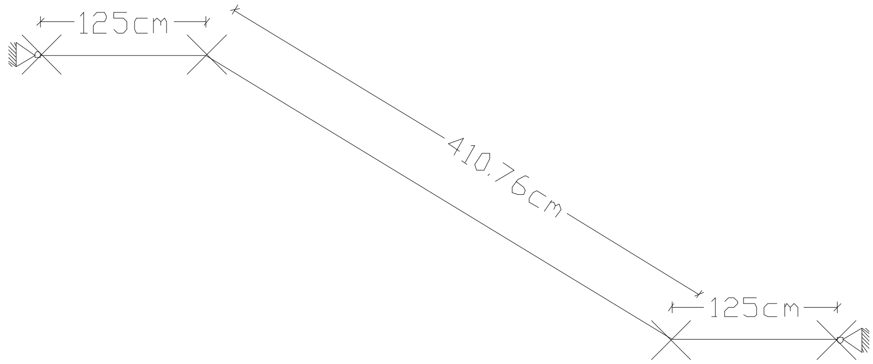
$$F_{v,Sd} = \frac{N_{Sd}}{2} = \frac{13.6kN}{2} = 6.8kN$$

$$F_{v,Rd} = \frac{0.6 \cdot f_{ub} \cdot A_S}{\gamma_{Mb}} = \frac{0.6 \cdot 50kN/cm^2 \cdot 0.843cm^2}{1.25} = 20.23kN$$

$$F_{v,Sd} = 6.8kN \leq F_{v,Rd} = 20.23kN$$

11.6.3 Kontrola bočne zvrnitve

Mesta, kjer je stopnišče bočno podprto



$$W_{el,y} = 150cm^3$$

$$\bar{\lambda}_{LT} = \sqrt{\frac{M_{el}}{M_{cr}}} = \sqrt{\frac{41.25kNm}{51.12kNm}} = 0.90 \geq 0.2$$

$$M_{el} = W_{el,y} \cdot f_y = 150cm^3 \cdot 27.5kN/cm^2 = 41.25kNm$$

$$E = 21000kN/cm^2$$

$$G = 807.7kN/cm^2$$

$$L = 410.76cm$$

$$k = k_w = 1$$

$$M_{cr} = C_1 \cdot \frac{\pi}{k \cdot L} \cdot \sqrt{E \cdot I_z \cdot G \cdot I_t + \frac{\pi^2 \cdot E \cdot I_w \cdot E \cdot I_z}{(k_w \cdot L)^2}}$$

$$M_{cr} = 1.132 \cdot \frac{\pi}{1 \cdot 410.76cm} \cdot \sqrt{\begin{aligned}&21000kN/cm^2 \cdot 114cm^4 \cdot 8077kN/cm^2 \cdot 9.55cm^4 + \\ &\left(\frac{\pi^2 \cdot 21000kN/cm^2 \cdot 55700cm^6 \cdot 21000kN/cm^2 \cdot 114cm^4}{(1 \cdot 410.76cm)^2}\right)\end{aligned}}$$

$$M_{cr} = 51.12kNm$$

$$\Phi_{LT} = 0.5\left(1.0 + \alpha_{LT}\left(\bar{\lambda}_{LT} - 0.2\right) + \bar{\lambda}_{LT}^2\right) = 0.5\left(1.0 + 0.21(0.90 - 0.2) + 0.90^2\right) = 0.98$$

$$\chi_{LT} = \frac{1}{\Phi_{LT} + \left(\Phi_{LT}^2 - \lambda_{LT}^2\right)^{0.5}} = \frac{1}{0.98 + \left(0.98^2 - 0.90^2\right)^{0.5}} = 0.73$$

$$M_{Sd} = 20.9kNm \leq M_{b,Rd} = \chi_{LT} \cdot W_{el,y} \cdot \frac{f_y}{\gamma_{M1}} = 0.73 \cdot 150cm^3 \cdot \frac{27.5kN/cm^2}{1.1} = 27.38kNm$$

11 IZVLEČEK MATERIALA

pozicija	opis	dimenzije, prerez	kg/m	dolžina enega kosa [m]	št.kosov	masa enega kosa[kg]	masa skupaj[kg]
1	steber	HEA 260	68,20	3,30	20	225,06	4501,20
2	steber	HEA 260	68,20	4,30	6	293,26	1759,56
3	steber	HEA 320	97,60	3,30	26	322,08	8374,08
4	steber	HEA 320	97,60	4,30	8	419,68	3357,44
5	prečka	IPE 360	57,10	6,00	104	342,60	35630,40
7	prečka	IPE 300	42,20	3,50	60	147,70	8862,00
9	steber	HEA 450	140,00	3,30	68	462,00	31416,00
10	steber	HEA 450	140,00	4,30	20	602,00	12040,00
11	steber	HEA 360	112,00	3,30	68	369,60	25132,80
12	steber	HEA 360	112,00	4,30	20	481,60	9632,00
13	prečka	IPE 400	66,30	6,80	16	450,84	7213,44
15	prečka	IPE 330	49,10	6,00	196	294,60	57741,60
16	prečka	IPE 160	15,80	6,00	63	94,80	5972,40
17	diagonala	B133/5.6	17,59	7,38	12	129,81	1557,77
18	diagonala	B114.3/4.5	12,19	6,84	12	83,38	1000,56
19	diagonala	B114.3/4	10,88	6,84	12	74,42	893,03
20	diagonala	B48.3/4.5	4,86	6,84	4	33,25	133,00
21	diagonala	B42.4/4	3,79	6,84	8	25,91	207,28
22	diagonala	B16/4	1,18	6,84	8	8,10	64,79
23	prečka	IPE 400	66,30	5,90	8	391,17	3129,36
24	prečka	IPE 600	122,00	9,80	8	1195,60	9564,80
25	steber	HEA 550	166,00	3,30	9	547,80	4930,20
26	steber	HEA 550	166,00	4,30	3	713,80	2141,40
27	prečka	IPE 220	26,20	6,00	100	157,20	15720,00
28	steber	HEA 100	16,70	14,20	11	237,14	2608,54
29	steber	HEA 100	16,70	17,50	17	292,25	4968,25
30	prečka	C 180	22,00	1,25	32	27,50	880,00
31	prečka	C 180	22,00	4,10	32	90,20	2886,40
32	prečke	K70/70/4	11,30	6,00	140	67,80	9492,00

CELOTNA KONSTRUKCIJA:

S=	**271810,29**	**kg**
zvari(1,5%)=	**4077,15**	**kg**
detajli (5%)	**13590,51**	**kg**
SKUPAJ:	**289477,96**	**kg**

12 ZAKLJUČEK

Namen diplomske naloge je bil statični izračun jeklene konstrukcije po evropskih standardih EVROKOD, ki upoštevajo večje varnostne faktorje, zaradi česar je konstrukcija iz statičnega vidika varnejša. Delo po evropskih predstandardih zahteva računalniško podprto projektiranje in omogoča inženirjem po celi Evropi dobro sodelovanje na področju projektiranja. Za izračun notranjih statičnih količin in dimenzioniranje elementov konstrukcije smo uporabili programsko orodje ESA-Prima Win.

Glavna razlika med izvedbama je v tem, da je pri diplomski nalogi nosilna konstrukcija v celoti iz jekla izračunana po evropskih standardih, pri obstoječem stanju pa je nosilna konstrukcija v mešani izvedbi (60% beton, 40% jeklo) izračunana še po standardih JUS.

Statični sistem konstrukcije v diplomski nalogi predstavlja tog prostorski okvir, ki je obravnavan kot ravninski v obeh glavnih smereh (X in Y) z upoštevanjem medsebojnega vpliva. V smeri X so momentni, neojačani in nepomični glavni okvirji. Pravokotno na glavne okvirje pa so priključene prostovrtljive prečke, ki skupaj s stebri predstavljajo štiri pomične sekundarne okvirje, ki so povezani z nateznimi diagonalami. Pri obstoječem stanju pa so stebri momentnih okvirjev v šibki osi ojačani z AB stebri debeline 20cm. Pravokotno na glavne okvirje so togo priključene prečke v AB izvedbi. Sekundarni okvirji pa so bili povezani z nateznimi diagonalami samo v času montaže.

Ker je nosilna konstrukcija v diplomski nalogi v celoti iz jekla, je objekt zaradi svoje nesimetrične oblike z dilatacijo ločen na dva, ki sta potem obravnavana vsak za sebe. Pri obstoječem stanju pa je nosilna konstrukcija v mešani izvedbi in je nesimetričnost objekta rešena z armiranobetonskim jedrom in stenami, ki prenesejo velike obremenitve.

Primerjava porabe materialov:

	obstoječi objekt	objekt v diplomski nalogi
beton	2893949kg	1921470kg
armatura	363451kg	241667kg
konstrukcijsko jeklo	145303kg	289478kg
SKUPAJ	3402703kg	2452615kg

Na koncu želim še poudariti prednosti jeklenih konstrukcij pred betonskimi:

- Večji del dela se opravi v tovarnah, ne na gradbišču
- Montažna gradnja
- Za gradnjo je potreben manjši gradbeni prostor
- Konstrukcije so lažje
- V visokogradnji ima jeklo boljše fizikalne lastnosti
- V inženirskem pogledu je jeklo kot gradbeni material natančneje opisano
- Požarna in korozijska zaščita sta kvalitetno rešeni
- Zaradi hitrejše gradnje so jeklene stavbe tudi cenejše.

VIRI

Beg D.: 1999, Projektiranje jeklenih konstrukcij po evropskem predstandardu ENV 1993-1-1, Ljubljana, Univerza v Ljubljani, Fakulteta za gradbeništvo in geodezijo.

Seliškar N.: 1997, Stavbarstvo, Ljubljana, Univerza v Ljubljani, Fakulteta za gradbeništvo in geodezijo.

SIST ENV 1991-1 Osnove projektiranja in vplivi na konstrukcije: Osnove projektiranja

SIST ENV 1991-2-1 Osnove projektiranja in vplivi na konstrukcije: Vplivi na konstrukcije - Gostote, lastne teže in koristne obtežbe

SIST ENV 1991-2-3 Osnove projektiranja in vplivi na konstrukcije: Vplivi na konstrukcije - Obtežbe snega

SIST ENV 1991-2-4 Osnove projektiranja in vplivi na konstrukcije: Vplivi na konstrukcije - Vplivi vetra

SIST ENV 1992 Projektiranje betonskih konstrukcij: Splošna pravila in pravila za stavbe

SIST ENV 1993-1-1 Projektiranje jeklenih konstrukcij: Splošna pravila in pravila za stavbe

SIST ENV 1994 Projektiranje sovprežnih konstrukcij iz jekla in betona: Splošna pravila in pravila za stavbe

OSIST ENV 1998-1-1 Projektiranje potresno odpornih konstrukcij: Splošna pravila - Potresna obtežba in splošne zahteve za konstrukcije

OSIST ENV 1998-1-2 Projektiranje potresno odpornih konstrukcij: Splošna pravila - Splošna pravila za stavbe

OSIST ENV 1998-1-3 Projektiranje potresno odpornih konstrukcij: Splošna pravila - Posebna pravila za različne materiale in elemente