Oznaka poročila: ARRS-RPROJ-ZP-2014/34

ZAKLJUČNO POROČILO RAZISKOVALNEGA PROJEKTA

A. PODATKI O RAZISKOVALNEM PROJEKTU

1.Osnovni podatki o raziskovalnem projektu

Šifra projekta	Z2-4172
Naslov projekta	Analiza koncentriranega vnosa sil v vijačenih spojih z zagotavljanjem duktilnosti
Vodja projekta	24336 Primož Može
Tip projekta	Z Podoktorski projekt
Obseg raziskovalnih ur	3400
Cenovni razred	A
Trajanje projekta	07.2011 - 06.2013
Nosilna raziskovalna organizacija	792 Univerza v Ljubljani, Fakulteta za gradbeništvo in geodezijo
Raziskovalne organizacije - soizvajalke	
Raziskovalno področje po šifrantu ARRS	2 TEHNIKA 2.01 Gradbeništvo 2.01.03 Konstrukcije v gradbeništvu
Družbeno-ekonomski cilj	13.02 Tehnološke vede - RiR financiran iz drugih virov (ne iz SUF)
Raziskovalno področje po šifrantu FOS	2 Tehniške in tehnološke vede 2.01 Gradbeništvo

B. REZULTATI IN DOSEŽKI RAZISKOVALNEGA PROJEKTA

2.Povzetek raziskovalnega projekta[1]

SLO

Pogost tip stikovanja jeklenih elementov predstavljajo preklopni vijačeni spoji. Vezno sredstvo so strižno obremenjeni vijaki, ki prenašajo obremenitve med spojenimi elementi. Torej vijaki z bočnimi pritiski predstavljajo koncentriran vnos sil v jekleno pločevino. Rezultat je koncentracija napetosti v pločevini. Če material nima zadostne duktilnosti, koncentracija napetosti povzroči začetek loma. Jeklo običajne kvalitete je duktilno in zagotavlja otopitev napetostnih konic. Nosilnost na bočni pritisk je definirana v Evrokodu. Določena je bila na podlagi testov spojev z enim ali dvema vijakom. V znanstvena literatura, kjer so predstavljeni testi posameznih spojev navaja, da je obstoječa nosilnost na bočni pritisk konzervativna in da ne poda razporeditve sil med vijaki, ki je v določenih primerih neenakomerna. Prav tako ima omenjena nosilnost nejasno definicijo, saj omejuje deformacijo luknje za vijak, s tem da je deformacija podana kot omejitev napetosti. Tudi strokovno mednarodno telo ECCS TC10 je zainteresirano za rešitev problema.

V okviru projekta je bilo testiranih 48 preklopnih spojev z največ šestimi vijaki. Teste sem numerično simuliral. Na podlagi verificiranih numeričnih modelov sem z numerično parametrično študijo analiziral vpliv geometrije in materiala na nosilnost in razpored napetosti v preklopnih spojih. Ti rezultati in rezultati testov iz literature so služili za razumevanje mehanizma prenosa obremenitev, na podlagi česar sem razvil nov model za kontrolo bočnega pritiska v pločevini. Predlagani model obravnava jekla običajnih trdnosti in jekla visoke trdnosti. Ovrednotena je bila tudi deformacijska kapaciteta pločevine v bočnem pritisku, ki izraža mero duktilnosti. Zadostna mera deformacijske kapacitete omogoči prerazporeditev sil v spoju z več vijaki in s tem plastično analizo spoja. Razvit je bil tudi analitični model z nadomestnimi vzmetmi za račun togosti pločevine v bočnem pritisku.

Rezultati so bili objavljeni v mednarodnih in domači revijah in konferencah ter predstavljeni mednarodnim tehničnim odborom, z namenom, da se novo znanje vključi v revidirane evropske standarde.

ANG

Bolted tensile splices are commonly used to connect constructional steel elements. The bolts act as shear fasteners that transfer the load between steel elements. Thus, the bolt bearing represents concentrated transfer forces to steel plates. This results in stress concentration in the steel plate. If the material does not have sufficient ductility, the stress concentration causes fracture. Structural mild steel is ductile and provides the reduction of stress peaks. The bolt bearing resistance is defined in Eurocode. The resistance is based on the test results of the connections with one or two bolts. Scientific literature dealing with the tests of individual connections indicates that the existing bolt bearing resistance is conservative and that the distribution of forces between several bolts is not given. The distribution is in some cases not uniform. The resistance also has a vague definition. It limits the bolt hole elongation, but the elongation is given as a stress limit. Professional international committee ECCS TC10 is also interested to find the solution to the problem.

In the framework of the project 48 bolted connections with a maximum of six bolts were tested. The tests were numerically simulated. Numerical parametric studies were performed on the basis of verified numerical models. The parameters in the studies were the geometry of the connection and the material. These results and the results of tests from the literature were used to analyse and to understand the resistance mechanism on the basis of which the new model for the verification of the bearing resistance was developed. The proposed model deals with normal strength steel and high-strength steels. The bearing deformation capacity, which is a ductility measure, was evaluated. Only sufficient deformation capacity allows redistribution of forces in the connection with several bolts and the plastic analysis of the connection. A new analytical model with equivalent springs was developed for the account of the stiffness of the bolted lap connection.

The results were published in international and in the national journals and conferences and were presented to the international technical committees, with a view to incorporating new knowledge into revised European standards.

3.Poročilo o realizaciji predloženega programa dela na raziskovalnem projektu[2]

Spoji z mehanskimi veznimi sredstvi so najbolj uporabljen tip stikovanja konstrukcijskih elementov. V takšnem spoju se obtežba iz enega v drug konstrukcijski element prenese preko veznih sredstev, najpogosteje preko vijakov. V projektu sem se omejil na preklopne natezne spoje, kjer se obtežba prenaša neposredno, preko stebla vijaka na jekleno pločevino, torej s koncentriranim vnosom sil v pločevino. Zaradi lokalnih bočnih pritiskov vijaka, se pojavijo koncentracije tlačenih napetosti. V kolikor material nima zadostne lokalne duktilnosti, koncentracije napetosti povzročijo porušitev materiala. Duktilnost je sposobnost materiala, da se njegova nosilnost v območju plastičnih deformacij povečuje in da ob pretrgu doseže neko definirano deformacijo. Lokalna duktilnost je še posebej pomembna pri spojih z več vijaki, kjer se morajo posamezne luknje deformirati (ovalizirati), da se obtežba prerazporedi med vse vijake. Kontrola nosilnosti na bočni pritisk je zajeta v evropskem standardu EN 1993-1-8 (slovenski standard je identičen), ki obravnava načrtovanje spojev v jeklenih konstrukcijah. Kontrola je v osnovi preprosta in omejuje povprečno napetost, ki se razvije v pločevini zaradi pritiska vijaka. V svoji osnovni definiciji z omejitvijo napetosti želi preprečiti preveliko ovalizacijo luknje za vijak, ne definira pa mejne ovalizacije. Enačba v standardu je nastala v osemdesetih letih prejšnjega stoletja na osnovi testov preklopnih spojev v večini z enim vijakom za jeklene pločevine kvalitete S235. Analiza omenjenih rezultatov testov je pokazala, da so podatki bili posredovani iz različnih virov, ki so imeli različne metodologije testiranja. Zato je pretvorba teh podatkov na skupni imenovalec in ovrednotenje po enakih kriterijih povzročila velik raztros v primerjavi s predpostavljenim teoretičnim modelom nosilnosti na bočni pritisk in s tem konzervativnost projektne nosilnosti. Ker rezultatov za preklopne spoje z več kot dvema vijakoma sploh ni bilo na voljo, je bil model nosilnosti razvit na podlagi predpostavk, ki morajo biti varne. Ker običajna konstrukcijska jekla izkazujejo veliko duktilnost, se je domnevalo, da se obtežba lahko prerazporedi med vijake brez omejitev.

V projektu sem sistematično analiziral prenos koncentriranih sil z vijaka na pločevino na podlagi eksperimentalnih in numeričnih rezultatov [1-9], saj takšna sistematična analiza problema še ni bila predstavljena ne znanstveni, niti strokovni javnosti. Ovrednotil sem razdelitev sil med vijaki v preklopnih spojih za običajne kvalitete jekla [3] in opisal napetostno in deformacijsko polje v stikovanih pločevinah [6] in v vijakih ter ocenil ugoden vpliv trenja na nosilnost spoja in neugoden vpliv na vijake [3]. Razvil sem nov analitični postopek za izračun nosilnosti pločevin pri prenosu koncentriranih sil za jekla običajne in visoke trdnosti [6] in ovrednotil razpoložljivo deformacijsko kapaciteto ter podal omejitev bočnega pritiska za mejno stanje uporabnosti [1,6]. Razvita je bila tudi nova, poenostavljena enačba za izračun začetne in sekantne togosti za spoje z enim in več vijaki [4,5,7].

DELOVNI SKLOP 1: Eksperimentalni del preiskave

Zasnoval sem 48 preklopnih vijačenih spojev. Izmed teh je bilo 13 spojev z enim vijakom, 6 spojev z dvema vijakoma postavljenima liniji, ki je pravokotna na smer vnosa obremenitve, ostali spoji pa so imeli več kot dva vijaka v smeri vnosa obremenitve. Izmed zadnje skupine spojev je bilo 6 spojev z eno strižno ravnino. Izbral sem tri debeline pločevin 8, 12 in 16 mm iz jekla kvalitete S235. Posebno pozornost sem namenil dejanskim materialnim karakteristikam pločevin, da bi dosegel podobno nosilnost notranje in zunanjih pločevin v preklopnem spoju. Dejanske natezne trdnosti pločevin so bile med 400 do 450 MPa, pri čemer je bilo razmerje med natezno trdnostjo in napetostjo tečenja večje od 1,4, deformacija pri porušitvi pa je bila višja od 35 %. Med zunanji pločevini, ki sestavljata preklopni spoj z dvema strižnima ravninama, je bila privarjena pločevina tako, da so bile podobne vilicam. Med te vilice sem vstavil notranjo pločevino spoja in nato vse skupaj povezal z vijaki. Vijake dimenzij M16, M20 ali M24, vsi kvalitete 10.9, sem uporabil v luknjah standardne velikosti. Ker vijaki niso bili predmet preiskave, so bile dimenzije in kvaliteta ustrezno izbrane. Zasnovanih in testiranih je bilo več konfiguracij spojev z dvema strižnima ravninama. V osnovni konfiguraciji je bila osna togost in nosilnost notranje pločevine (16 mm) in zunanjih pločevin (obeh skupaj 2×8 mm=16 mm) približno enaka. Testiral sem konfiguracijo, kjer je bila debelina in s tem togost in nosilnost zunanjih pločevin približno dvakrat večja od osnovne konfiguracije. Takšna je bila tudi osnovna konfiguracija spojev z enim in dvema vijakoma. Obravnaval sem tudi spoje, kjer so luknje za vijake zamaknjene. Zaradi dovoljenih funkcijskih toleranc je bila ena luknja za vijak zamaknjena za največ 4 mm (to je dvojna razdalja rege med vijakom in luknjo). Tako se je obtežba prenesla preko enega vijaka, vse do deformacije oziroma podaljšanja luknje za 4 mm. Šele takrat se je obtežba začela prerazporejati tudi med ostale vijaki. Geometrije spojev sem zasnoval tako, da so nastale različne porušitve in da je bila razporeditev sil med vijaki tudi neenakomerna. Izbral sem najmanjše dovoljene (po SIST EN 1993-1-8) in običajne razdalje med vijaki in do razdalje roba pločevine.

Delovni sklop 2: Numerična simulacija testov (DS 2)

S programskim paketom ABAQUS sem numerično modeliral teste, ki sem jih naredil v DS 1. Ker je numerični test matematična kopija testa v laboratoriju, je potrebno poznati vse parametre, ki vplivajo na mehanski odziv spojev. V ta namen sem, poleg ostalih parametrov, ki sem jih zabeležil že pred ali med testom, izmeril tudi dejanske materialne lastnosti pločevin, iz katerih so bili narejeni spoji. Zasnoval sem napreden numerični model, izbral ustrezno gostoto mreže končnih elementov (KE) in predpisal ustrezne robne pogoje. Analize dolgih spojev so bile precej drage v smislu porabe procesorskega časa. Sledila je analiza rezultatov. Najprej sem primerjal (izmerjene količine) odziv sila-pomik testiranega spoja in numeričnega spoja. Pri vseh spojih se so numerični rezultati zelo lepo sovpadali s testi. Analiziral sem tudi napetostno in deformacijsko stanje v pločevini in razporeditev sil med vijaki. Zaradi večjega utrjevanja materiala obstaja bistvena razlika v primerjavi z jekli visoke trdnosti pri spojih z več vijakih. Tečenje polnega oziroma oslabljenega prereza pri običajnih jeklih deluje kot varovalka, ki običajno prepreči iztrg krajnega vijaka. Pri pritisku enega vijaka na pločevino bistvenih razlik med jekli običajne in visoke trdnosti ni.

Delovni sklop 3: Numerična parametrična študija (DS 3)
Naredil sem dve numerični parametrični študiji. V prvi sem študiral vpliv enega vijaka na vnos sile v pločevino. V študiji sem zajel 57 različnih geometrij spojev, narejenih iz dveh različnih materialov, kar je skupaj 114 analiz. Parametri so bili: oddaljenost vijaka od robov pločevine, debelina pločevine, premer vijaka in vrsta materiala. Rezultate te analize sem uporabil direktno pri razvoju teoretičnega modela odpornosti na bočni pritisk.

V drugi parametrični študiji sem obravnaval dolge spoje. Zasnovanih je bilo 27 geometrij, kjer so bili parametri število vijakov (med 4 in 20), razmik med vijaki, robna razdalja in širina pločevine. Dodatni parameter je bil material, tako da je študija obsegala 54 spojev. Poudariti je potrebno, da so bili narejeni zelo napredni numerični modeli, saj sem le z njimi lahko zajel fenomen lokalnega vnosa sile v pločevino in posledično razporeditev sil med vijaki. Sodoben, zmogljiv osebni računalnik je numerične analize računal nepretrgoma celih 71 dni. Težava je, ker se razporeditve sil med vijaki v laboratoriju praktično ne da izmeriti. Rezultati so zelo zanimivi. V nekaterih primerih je razporeditev sil med vijaki zelo neenakomerna in bistveno odstopa od sedaj znanih rezultatov iz literature. Na zunanjih vijakih je sila tudi dvakrat večja od sile, ki jo običajno upoštevamo pri projektiranju. Glavni parameter pri razporeditvi sil med vijaki je dolžina spoja oziroma število vijakov in način porušitve pločevine. Seveda sem predpostavil, da so vijaki dovolj močni, da kljubujejo odpornosti pločevine. Porušitev vijaka vodi v verižno reakcijo, kjer se vijaki rušijo eden za drugim. Podobno, kot se utrgajo gumbi na srajci pri sunkovitem potegu srajce.

Delovni sklop 4: Razvoj novega oziroma izboljšanega modela odpornosti, ki temelji na vnosu koncentriranih sil v jekleno pločevino (DS 4)
Direkten doprinos laboratorijskih testov (DS 1) in parametrične študije na enem vijaku (DS 3) je bil izboljšan model odpornosti zaradi lokalnega vnosa koncentrirane sile. Odpornost sem matematično predstavil s povprečno napetostjo pred vijakom. Ta napetost je izražena kot zmnožek natezne napetosti pločevine in koeficienta, ki je odvisen od razdalje med vijakom in robom pločevine. V primerjavi z modelom odpornosti, ki je podan v standardu SIST EN 1993-1-8 je ta računski model enostavnejši za uporabo in vsaj za 17 % pa vse do 45 % bolj optimističen (višji rezultati). Postavi tudi ločnico med jekli običajne trdnosti in jekli visoke trdnosti. Bistvenega pomena pri tej nalogi je bila definicija odpornosti in porušitve zaradi lokalnega vnosa koncentrirane sile.

Delovni sklop 5: Predstavitev rezultatov dela mednarodnim znanstvenim in strokovnim krogom (DS 5)
Rezultate projekta sem predstavil na dveh rednih sestankih mednarodnega tehničnega telesa ECCS TC10 (Evropska konvencija za jeklene konstrukcije, Tehnični odbor 10 – spoji v jeklenih konstrukcijah), in sicer oktobra 2011 v Bukarešti (priloga 01) in aprila 2013 v Liege-u (priloga 02). V aprilu 2014 sem bil povabljen (priloga 03) na sestanek projektne skupine za pripravo evropskega standarda EN 1993-1-12, kjer smo se dogovorili, da bodo rezultati tega projekta in tudi moje prejšnje delo predlagani za popravke evropskih standardov.

Objavljena sta bila znanstvena članka v mednarodni reviji, ki kotira v prvo četrtino na področju gradbeništva [6], v slovenski reviji [9] in na številnih mednarodnih [3,4,8] in domači konferenci [7]. V okviru projekta sta nastali tudi dve diplomi na univerzitetnem študiju [2,5].

[1] Može, P., Beg, D. 2011. Investigation of high strength steel connections with several bolts in double shear. Journal of Constructional Steel Research, 67, 3: 333-347.

[2] Remic, N. 2011. Bočni pritiski v preklopnih vijačenih spojih iz mehkih konstrukcijskih jekel. diplomska naloga, Univerza v Ljubljani, Fakulteta za gradbeništvo in geodezijo: 68 str.

[3] Može, P., Beg, D. 2012. Bearing resistance of bolted connections. Nordic Steel Construction Conference, NTNU, Oslo, 645-654.

[4] Može, P., Beg, D. 2013. Stiffness and strength of single bearing bolt connections Design, fabrication and economy of metal structures : International Conference Proceedings 2013, K. Jármai, J. Farkas, (ur.). Springer, Miskolc, Hungary, 327-332.

[5] Rigler, T. 2013. Togost in nosilnost vijačenih spojev. diplomska naloga, Univerza v Ljubljani, Fakulteta za gradbeništvo in geodezijo: 84 str.

[6] Može, P., Beg, D. 2014. A complete study of bearing stress in single bolt connections. Journal of Constructional Steel Research, 95, 0: 126-140.

[7] Može, P., Rigler, T., Beg, D. 2013. Togost jeklenih pločevin pri bočnem pritisku vijaka na pločevino. 35. zborovanje gradbenih konstruktorjev Slovenije, J. Lopatič, V. Markelj, F. Saje, (ur.). Ljubjana.

[8] Može, P., Beg, D. 2013. On the bearing resistance of bolted connections. 7th International Workshop on Connections in Steel Structures, European Convention for

Constructional Steelwork, Timisoara
[9] Može, P., Beg, D. 2014. Bočni pritisk vijaka na pločevino v spojih z enim vijakom. Gradbeni vestnik, 63, mar. 2014: 57-63.

4. Ocena stopnje realizacije programa dela na raziskovalnem projektu in zastavljenih raziskovalnih ciljev[3]

Raziskovalni cilji so bili izpolnjeni. Na osnovi rezultatov testov v laboratoriju (R1-R3 – glej prijavno vlogo) so bili izdelani numerični modeli, s katerimi sem opisal deformacijsko in napetostno polje v pločevini, obremenjeni s koncentriranim bočnim pritiskom (R4-R9). Predstavljen je nov model nosilnosti pločevine pri koncentriranem vnosu obremenitve (R10-R12). Problem je bil sistematično analiziran, potrjen s testi na projektu (48 testov), s testi iz literature in z numeričnimi rezultati za običajno jeklo in jeklo visoke trdnosti. Nov model je preprostejši in manj konservativen od tistega v standardu EN 1993-1-8 ter bolje opiše nosilnost izkazano s testi. Kot prvi sem ovrednotil deformacijsko kapaciteto pločevine pri koncentriranem vnosu obremenitve. Ker nova formula ni več tako konservativna je deformacijska kapaciteta izredno pomembna, saj kontrole nosilnosti pločevine, obremenjene s skupino veznih sredstev, temeljijo na izraženi duktilnosti. Rezultat je tudi enačba, ki zajame začetno in sekantno togost pločevine v bočnem pritisku. Predstavljen je bil tudi računski model z nadomestnimi vzmetmi, s katerim izračunamo togost preklopnega spoja z več vijaki. To je dodatni rezultat, ki v prijavno vlogi ni bil podan. Rezultati so bili objavljeni v ugledni mednarodni in domači reviji, predstavljeni na mednarodnih in domači konferenci (R13).

Izpostaviti želim, da so bili rezultati predstavljeni tudi mednarodnemu tehničnemu odboru za spoje ECCS TC 10 (Evropska konvencija za jeklene konstrukcije, Tehnični odbor 10 – spoji v jeklenih konstrukcijah - http://www.steelconstruct.com/) in projektni skupini za razvoj standarda EN 1993-1-12. Trenutno poteka verifikacija mojih rezultatov, z namenom, da se moje rezultate vključi v revidiran standard za spoje v jeklenih konstrukcijah EN 1993-1-8 in v revidiran standard EN 1993-1-1, ki obravnava splošna pravila za stavbe iz jeklenih konstrukcij (R14). Razumljivo je, da je sprememba standarda daljši proces, saj je zanjo potreben splošen konsenz.

5. Utemeljitev morebitnih sprememb programa raziskovalnega projekta oziroma sprememb, povečanja ali zmanjšanja sestave projektne skupine[4]

Ni bilo sprememb.

6. Najpomembnejši znanstveni rezultati projektne skupine[5]

	Znanstveni dosežek			
1.	COBISS ID		6514785	Vir: COBISS.SI
	Naslov	*SLO*	Študija bočnega pritiska v spojih z enim vijakom	
		ANG	A complete study of bearing stress in single bolt connections	
	Opis	*SLO*	V prispevku predstavljamo rezultate testov spojev z enim in dvema vijakoma. Spoji so bili narejeni iz pločevin kvalitete S235. Rezultate testov primerjamo z rezultati testov na podobnih spojih, narejenih iz jekla visoke trdnosti in jih dodatno podkrepimo z numerično parametrično študijo. S temi rezultati podrobno analiziramo pločevino, obremenjeno s pritiskom vijaka. Podajamo kritično oceno kontrole nosilnosti v bočnem pritisku po SIST EN 1993-1-8 in predlagamo spremenjeno kontrolo nosilnosti, ki je konceptualno enaka obstoječi kontroli, vendar je enostavnejša, manj konservativna in se bolje ujema z rezultati testov. Obravnavamo tudi kontrolo nosilnosti oslabljenega prereza in strižnega iztrga skupine vijakov po SIST EN 1993, kjer tudi predlagamo možne izboljšave kontrol.	
			The paper presents experiments on connections with one and two bolts made of mild steel grade S235. The results are compared with the tests on connections made of high strength steel. The test results are substantiated with numerical parametric analysis. The effect of bolt bearing is thoroughly	

<table>
<tr><td rowspan="3"></td><td></td><td>ANG</td><td colspan="2">analysed. The bearing strength at bolt holes according to standard EN 1993-1-8 is critically evaluated and a modified design check is proposed. The modified check is conceptually the same as the current one, but it is simpler, less conservative and it is in better correlation to the test results. The block shear strength and net cross-section strength are also discussed and modifications to the EN 1993 design rules are given.</td></tr>
<tr><td colspan="2">Objavljeno v</td><td colspan="2">Elsevier; Journal of Constructional Steel Research; 2014; Letn. 95; str. 126-140; Impact Factor: 1.327;Srednja vrednost revije / Medium Category Impact Factor: 1.001; A': 1; WoS: FA, IM; Avtorji / Authors: Može Primož, Beg Darko</td></tr>
<tr><td colspan="2">Tipologija</td><td colspan="2">1.01 Izvirni znanstveni članek</td></tr>
<tr><td rowspan="7">2.</td><td colspan="2">COBISS ID</td><td>5173345</td><td>Vir: COBISS.SI</td></tr>
<tr><td rowspan="2">Naslov</td><td>SLO</td><td colspan="2">Raziskava vijačenih spojev iz jekel visoke trdnosti s strižno obremenjenimi vijaki</td></tr>
<tr><td>ANG</td><td colspan="2">Investigation of high strength steel connections with several bolts in double shear</td></tr>
<tr><td rowspan="2">Opis</td><td>SLO</td><td colspan="2">Izvirnost članka je v testih na preklopnih spojih iz jekla S690 s tremi ali štirimi vijaki postavljenimi v smeri obremenitve. Testi so bili tudi numerično simulirani z namenom, da bi ovrednotili deformacijsko in napetostno polje v pločevinah kot posledica bočnih pritiskov vijakov. Ugotovili smo, da se obtežba lahko neenakomerno razporedi med vijake in kot takšna ni obravnavana v standardu evrokod. Rezultate smo primerjali tudi s kontrolo bočne nosilnosti po standardu evrokod in ugotovili, da ta kontrola slabo definira nosilnost na bočni pritisk, prav tako pa smiselno ne omeji deformacije lukenj za vijake. Ugotovili smo, da tudi neugoden začetni položaj vijakov, ki je posledica toleranc izdelave, bistveno ne vpliva na nosilnost in razporeditev sil. V članku je prikazana nova formula za izračun mejne obremenitve pločevine, obremenjene z bočnimi pritiski, ki na konsistenten način opiše dejansko nosilnost na bočni pritisk. Nova formula tudi loči različne tipe porušitev. Rezultati izračunani po tej formuli bistveno bolje ustrezajo vrednostim iz testov kot rezultati formule iz standardu evrokod.</td></tr>
<tr><td>ANG</td><td colspan="2">The originality of this paper is in the presentation of the experimental results on tension splices in steel S690 with three or four bolts, positioned in the direction of loading. The tests were also numerically simulated to evaluate the stress and deformation state in the steel plates due to localized pressure of the bolts. It was shown that the distribution of forces between bots may be non-uniform and as such it is not included in any of the Eurocode rules. The results were compared to the Eurocode bearing resistance formula and it was proven that the bearing resistance is not properly defined and it also does not properly limit the bolt-hole deformation. Moreover, the unfavourable initial position of the bolts due to fabrication tolerances did not significantly affect the force distribution or the resistance. The new bearing resistance formula is also presented in the paper. The new formula is defined consistenly to the Eurocode and differs between failure types. It gives better results than Eurocode bearing resistance formula if compared to the test results.</td></tr>
<tr><td colspan="2">Objavljeno v</td><td colspan="2">Elsevier; Journal of Constructional Steel Research; 2011; letn. 67, št. 3; str. 333-347; Impact Factor: 1.251;Srednja vrednost revije / Medium Category Impact Factor: 0.895; A': 1; WoS: FA, IM; Avtorji / Authors: Može Primož, Beg Darko</td></tr>
<tr><td colspan="2">Tipologija</td><td colspan="2">1.01 Izvirni znanstveni članek</td></tr>
<tr><td rowspan="3">3.</td><td colspan="2">COBISS ID</td><td>6487137</td><td>Vir: COBISS.SI</td></tr>
<tr><td rowspan="2">Naslov</td><td>SLO</td><td colspan="2">Togost jeklenih pločevin pri bočnem pritisku vijaka na pločevino</td></tr>
<tr><td>ANG</td><td colspan="2">Bearing stiffness at bolt holes</td></tr>
</table>

	Opis	SLO	Prispevek obravnava togost jeklenih pločevin pri koncentriranem vnosu sile, na primer preko vijaka. Takšna situacija se pojavi v preklopnih spojih, kjer so vijaki obremenjeni v strigu, obremenitve pa prenašajo s kontaktom med vijakom in pločevino. Začetna kontaktna površina je zelo majhna. Zato se pojavijo koncentracije napetosti, ki se s tečenjem otopijo. Tečenje materiala s plastičnimi deformacijami omogoči ugnezdenje vijaka v pločevino in s tem večjo kontaktno površino. Takšen odziv opišemo kot nominalno elastičen odziv, saj v okolici luknje za vijak material preide v področje plastičnosti, praktično takoj, ko na vijak deluje sila. Odziv pločevine pri bočnem vnosu koncentrirane sile je zelo nelinearen, zato izračun togosti ni trivialen. V prispevku podajamo togost, ki je podana v SIST EN 1993-1-8 in jo primerjamo z rezultati testov in numeričnih simulacij spojev. Podamo tudi enostavno enačbo, ki na preprost način opiše začetno in sekantno togost pločevine v bočnem pritisku in jo uporabimo na spojih z enim in več vijaki.	
		ANG	The paper deals with the bearing stiffness at bolt holes. In bearing-type joints the connected plates are in contact with the bolt shank and the load is transmitted by shear on the bolts and high bearing stress in the plates around the bolt holes. A bearing stress in the material is developed due to the contact pressure. Initially, the contact area is very small, causing stress concentrations and yielding of the material at very low loads. Yielding allows embedment of the bolt on a larger contact area. Such behaviour is interpreted as nominally elastic behaviour, as stress concentrations are eliminated by yielding of the material occurring at early load stage. The behaviour of bearing at bolt holes is very nonlinear, therefore the evaluation of the bearing stiffness is not trivial. The bearing stiffness given in EN 1993-1-8 is given and compared to the test results and to the results of the numerical simulations of single bolt connections. The simple equation that defines the initial and secant bearing stiffness at bolt holes is given and applied to the test results of lap joints with one and several bolts.	
	Objavljeno v		Slovensko društvo gradbenih konstruktorjev; Zbornik 35. zborovanja gradbenih konstruktorjev Slovenije, Ljubljana, Fakulteta za gradbeništvo in geodezijo, 22. november, 2013; 2013; Str. 117-124; Avtorji / Authors: Može Primož, Rigler Tamara, Beg Darko	
	Tipologija		1.08 Objavljeni znanstveni prispevek na konferenci	
4.	COBISS ID		5918561	Vir: COBISS.SI
	Naslov	SLO	O bočnem pritisku v vijačenih spojih	
		ANG	On the bearing resistance of bolted connections	
	Opis	SLO	Članek opisuje 48 testov na preklopnih spojih z vijaki v strigu. Spoji z enim in največ šest vijaki, postavljenimi v smeri obremenitve, so bili testirani z namenom, da se ugotovi deformacijsko kapaciteto in nosilnost pri koncentriranem vnosu sile v pločevino. Testirane so bile različne konfiguracije spoja, med drugim tudi spoji z eno strižno ravnino. Nosilnost smo primerjali s pravili iz Evrokoda 3. Predstavljena je tudi numerična parametrična študija spojev z enim vijakom. Študija obsega 114 spojev. Rezultate smo primerjali z Evrokodom in z novo enačbo za izračun nosilnosti na bočni pritisk, ki je bila razvita za jekla visoke trdnosti.	
		ANG	The paper presents 48 tests on the connections with bolts in bearing. Single bolts connections as well as the connections with up to six bolts positioned in the direction of loading were testes in order to obtain the evidence on bolt bearing deformation capacity and resistance. Several connection configurations including connection with bolts in single shear were tested. The bolt bearing resistance and the connection resistance are compared to Eurocode 3 design rules. Moreover, the numerical parametric study on 114 single bolt connections is presented. The results of the study are compared tothe Eurocode bearing resistance formula, as well as to the	

			new bearing resistance formula that is based on the results of high strength steel bolt bearing connections.	
	Objavljeno v		European Convention for Constructional Steelwork; Connections VII; 2013; Str. 35-46; Avtorji / Authors: Može Primož, Beg Darko	
	Tipologija		1.06 Objavljeni znanstveni prispevek na konferenci (vabljeno predavanje)	
5.	COBISS ID		6545249	Vir: COBISS.SI
	Naslov	SLO	Zaostale napetosti v enakokrakih kotnikih večjih dimenzij	
		ANG	Residual stress distribution of large steel equal leg angles	
	Opis	SLO	Na tržišču so se pojavili kotniki večjih dimenzij, z največjim L350/35. V članku je predstavljena raziskava polja zaostalih napetosti. Zaostale napetosti, ki neposredno vplivajo na uklonsko nosilnost, smo izmerili v šestih vroče valjanih in dveh varjenih kotnikih. Napetosti smo izmerili z razrezno metodo, kjer smo kotnike rezali z vodnim curkom. Sproščene deformacije smo izmerili z uporovnimi merilnimi lističi. Na podlagi statističnega ovrednotenja rezultatov smo določili primerne krivulje poteka zaostalih napetosti po prerezu. Te krivulje smo neposredno uporabili v numerični analizi. Rezultat geometrijsko in materialno nelinearne analize so bile uklonske krivulje za enakokrake kotnike.	
		ANG	The market offers new large steel angle profiles, the largest being L300/35. To check their buckling resistance, the investigation of the residual stress field is presented in this paper. Since the buckling behaviour of steel angles is significantly affected by the residual stresses, the stresses were measured on six hot rolled and two welded equal angles by sectioning method. The traditional sectioning method was improved by introducing the water jet cutting. The released deformations were measured by the strain gauges. On the basis of the statistical evaluation of the test results, the most appropriate residual stress distribution models were considered in the numerical analysis. The results of the geometrical and material nonlinear numerical analysis were equal angle buckling curves.	
	Objavljeno v		Elsevier Science; Engineering structures; 2014; Letn. XX, št. X; str. XX; Impact Factor: 1.713;Srednja vrednost revije / Medium Category Impact Factor: 0.989; A': 1; WoS: IM; Avtorji / Authors: Može Primož, Cajot Luis-Guy, Sinur Franc, Rejec Klemen, Beg Darko	
	Tipologija		1.01 Izvirni znanstveni članek	

7.Najpomembnejši družbeno-ekonomski rezultati projektne skupine[6]

	Družbeno-ekonomski dosežek			
1.	COBISS ID		6146913	Vir: COBISS.SI
	Naslov	SLO	Projektiranje jeklenih delov cestnega mostu preko jezera Farris na Norveškem	
		ANG	Design of steel elements of highway bridge over Farris lake in Norway	
	Opis	SLO	V prispevku so predstavljene osnovne rešitve dimenzioniranja jeklenih delov mostu preko jezera Farris na Norveškem. Skupna dolžina mostu je 569 m, od tega je glavni razpon dolžine 120 m. Ta del mostu je iz sovprežnih nosilcev, ki so dodatno podprti s poševnimi vrvmi na razdalji 16,5 m. Prikazane so končne rešitve dimenzioniranja vzdolžnih nosilcev, primarnih prečnih nosilcev in konzol, ki povezujejo dva sosednja primarna prečna nosilca in na koncu katerih so sidrane jeklene vrvi. Vzdolžni jekleni prerezi so tankostenski, ojačeni z zaprtimi vzdolžnimi ojačitvami. Tudi vsi prečni nosilci so tankostenski. Ojačeni so le v območju odprtin. Jekleni	

			elementi so bili dimenzionirani v skladu s standardi EN 1993. Zaradi kompleksne geometrije nekaterih elementov (konzole in prečni nosilci) smo za le-te opravili tudi napredne numerične simulacije v programu ABAQUS. Naročnik projekta je bilo norveško podjetje Ramboll (http://www.ramboll.com/projects/group/farris-bridge-e18).	
		ANG	In this paper the basic solutions of the steel elements of the bridge over Farris lake are presented. The bridge is 569 m long with main span 120 m. Main span is made of composite cross-section supported by stay-cables. The distance between stay-cables is 16,5 m. Final design solutions of longitudinal girders, primary transverse girders and brackets connecting two transverse girders are given. At the end of the bracket the cables are attached. The longitudinal girders are made of thin plates and stiffened with trapezoidal longitudinal stiffeners. Also the web of the transverse girder is made of thin plate and it was stiffened only in the area of wholes. The design was done in accordance to Eurocode EN 1993 standards. Due to complex geometry of some elements the design of those was done also using more sophisticated analysis in ABAQUS software. The project client was Norwegian company Ramboll (http://www.ramboll.com/projects/group/farris-bridge-e18).	
	Šifra		F.34 Svetovalna dejavnost	
	Objavljeno v		Slovensko društvo gradbenih konstruktorjev; Zbornik 34. zborovanja gradbenih konstruktorjev Slovenije, Bled, Hotel Golf, 11.-12. oktober 2012; 2012; Str. 29-36; Avtorji / Authors: Beg Darko, Može Primož, Rejec Klemen, Sinur Franc	
	Tipologija		1.09 Objavljeni strokovni prispevek na konferenci	
2.	COBISS ID		6312289	Vir: COBISS.SI
	Naslov	*SLO*	Rekonstrukcija rezervoarja za težja goriva BFOT-1	
		ANG	Reconstruction of Heavy fuel oil storage tank BFOT-1	
	Opis	*SLO*	Rezervoar za nafte derivate s premerom 53.4 m je bil poškodovan v požaru. Načrt rekonstrukcije je predvidel montažo ojačitev na poškodovanem delu rezervoarja. Naše naloge so bile kontrola nizkočikliočnega utrujanja, ki bi lahko nastalo zaradi omenjenih ojačitev, zasnova detajlov med ojačitvami in jeklenim plaščem in izračun geometrije rezervoarja po prvem oziroma naknadnem polnjenju in praznjenju rezervoarja. Naročnik je posredoval meritve geometrije rezervoarja oziroma meritve nepopolnosti. Te meritve smo uporabili v našem naprednem računskem modelu. Naši izračuni so zelo dobro ocenili deformacijsko stanje po prvem polnjenju rezervoarja. Z naprednimi analizami smo naročniku prihranili veliko sredstev in časa, ki bi jih potreboval, če bi se odločil za standardno rešitev.	
		ANG	The heavy fuel tank with diameter of 53.4 m was damaged during a fire. The plan of reconstruction was to weld the stiffeners on the damaged part of the tank. Due to the change in stiffness, cause by the stiffeners, the low cycle fatigue was put under consideration. The low-cycle fatigue could be present due to yielding in the initial and further filling of the tank. The damaged (deformed) geometry of the tank was considered in our advanced numerical model. The model gave a very well estimation of the deformation state after the first filling of the tank. Our advanced analysis and state of the art knowledge saved resources and time for the reconstruction of the tank, if compared to the standard solution.	
	Šifra		F.17 Prenos obstoječih tehnologij, znanj, metod in postopkov v prakso	
	Objavljeno v		University of Ljubljana, Faculty of Civil and Geodetic Engineering; 2013; 22 f.; Avtorji / Authors: Beg Darko, Može Primož	
	Tipologija		2.15 Izvedensko mnenje, arbitražna odločba	

3.	COBISS ID		5710177	Vir: COBISS.SI
	Naslov	*SLO*	Numerična simulacija prestavitve rezervoarja B 8400	
		ANG	Numerical simulations of the relocated of the tank B 8400	
	Opis	*SLO*	Jekleni rezervoar B 8400 s prostornino 500 m3 je namenjen shranjevanju vode. Njegova oblika je cilindrična z notranjim premerom 4000 mm, z višino 9795 mm in konstantno debelino cilindra 6 mm. Rezervoar je pokrit s samonosilno streho v obliki konusa z naklonom 20° in debelino pločevine 7 mm. Streha je privarjena na zgornjo obročno ojačitev na cilindru. Zaradi posebnih okoliščin se je rezervoar gradil 30 m od svoje končne lokacije. Na končno mesto je bil postavljen s pomočjo dvigala, brez dodatnega podpiranja strehe. Detajl pritrjevanja vrvi za dvigovanje in odziv rezervoarja med dvigovanjem smo numerično simulirali s programskim orodjem Abaqus. Simulacija je imela dve stopnji. V prvi se je rezervoar dvignil, v drugi pa položil na temeljno podlago pod kotom 2%. Takšna gradnja rezervoarja z njegovo prestavitvijo je bila ekonomično najučinkovitejša in tudi najhitrejša, zahteven računski dokaz varnosti pa je prikazan v projektu.	
		ANG	The steel tank B 8400 with the volume 500 m3 is intended for the storage of water. The shape of the tank is cylindrical with the inner radius 4000 mm, height 9795 mm and constant wall thickness 6 mm. The tank is covered with the self-supported cone steel roof with the inclination of 20° and with the thickness of 7 mm welded to the top ring stiffener. Due to specific conditions of the tank final location, the water tank B 8400 was fabricated 30 m away from its final position and then relocated with the help of a crane without any additional supports of the tank roof. To check the proper attachment of lifting equipment and to check the response of the tank during lifting, FE numerical simulation (software tool ABAQUS) was performed in two stages. In the first stage the reservoir was lifted and in the second stage it was placed on the foundation inclined by 2% to the bottom of the tank. Such fabrication with the tank relocation was economically the most efficient and the fastest. The safety of the relocation was proven in the project by a complex and demanding calculation.	
	Šifra		F.09 Razvoj novega tehnološkega procesa oz. tehnologije	
	Objavljeno v		University of Ljubljana, Faculty of civil and geodetic engineering, Chair for metal structures; 2011; 7 str.; Avtorji / Authors: Beg Darko, Može Primož, Sinur Franc	
	Tipologija		2.14 Projektna dokumentacija (idejni projekt, izvedbeni projekt)	
4.	COBISS ID		6147681	Vir: COBISS.SI
	Naslov	*SLO*	Meritve zaostalih napetosti in numerično izvrednotenje uklonskih krivulj za kotne profile večjih dimenzij	
		ANG	Residual stress measurements and numerical determination of buckling curves for large angle profiles	
	Opis	*SLO*	Naročnik študije je bil koncern ArcelorMittal, ki je dal na tržišče nov proizvod – največje vroče valjane kotne profile in je želel dobiti podatke o uklonski nosilnosti elementov, narejenih iz teh profilov. V prispevku je prikazana metodologija in procedura merjenja zaostalih napetosti na kotnih profilih večjih dimenzij. Prikazani so rezultati meritev in definicija splošnega poteka zaostalih napetosti po prečnem prerezu. Splošen potek napetosti predstavlja nekakšno neugodno ovojnico meritev v območju standardnega odklona, ki je vhodni podatek za parametrično numerično, geometrijsko in materialno nelinearno, analizo, katere rezultati so uklonske krivulje za kotne profile. Rezultati so pokazali, višje uklonske nosilnosti od sedaj predvideni v evropskem standardu EN 1993-1-1. Ustrezne dopolnitve standarda bodo predlagane.	

		ANG	The client, ArceloMittal, put a new product on the market – biggest hot rolled angle profiles and wanted to obtain information on the buckling resistance of structural elements made of such angles. This paper presents the methodology and procedure of residual stresses measurement in the large angle profiles. The results of the measurements as well as the definition of the general distribution of residual stress in the cross-section are presented. The general distribution represents a kind of unfavorable envelope of the measurements in the range of standard deviation that is the input data for the numerical parametric, geometrical and material nonlinear, analysis, the results of which are the buckling curves for angle profiles. The results show that the results of this study give more favourable results than the European standard EN 1993-1-1 and the corresponding improvements will be proposed.
	Šifra		F.06 Razvoj novega izdelka
	Objavljeno v		Slovensko društvo gradbenih konstruktorjev; Zbornik 34. zborovanja gradbenih konstruktorjev Slovenije, Bled, Hotel Golf, 11.-12. oktober 2012; 2012; Str. 227-234; Avtorji / Authors: Beg Darko, Sinur Franc, Rejec Klemen, Može Primož
	Tipologija		1.08 Objavljeni znanstveni prispevek na konferenci

8.Drugi pomembni rezultati projetne skupine[7]

Članek v reviji Journal of Constructional Steel Research:

Može, P., Beg, D. 2011. Investigation of high strength steel connections with several bolts in double shear. Journal of Constructional Steel Research, 67, 3: 333-347.
se je v letu 2011 po branosti uvrstil na 18. mesto.

http://top25.sciencedirect.com/subject/engineering/12/journal/journal-of-constructional-steel-research/0143974X/archive/36/

Moji rezultati za jekla visoke trdnosti predstavljajo osnovno literaturo v še trajajočem projektu RFCS »Rules On High Strength Steel – RUOSTE« (pogodba št. RFSR-CT-2012-00036).

9.Pomen raziskovalnih rezultatov projektne skupine[8]

9.1.Pomen za razvoj znanosti[9]

SLO

V okviru projekta sem dosegel pomembne rezultate v mednarodnem merilu. Koncentriran vnos sile v pločevino preko bočnega pritiska vijaka je bil sistematično analiziran, tako za jekla običajne trdnosti, kot za jekla visoke trdnosti. Z numeričnimi analizami so pojasnjeni mehanizmi prenosa obremenitev. Razvita je bila nova kontrola nosilnosti pločevine v bočnem pritisku, njena uporabnost pa je bila definirana na osnovi obsežnih testov v laboratoriju in numeričnih analiz. Deformacijska kapaciteta pločevine v bočnem pritisku je bila prvič ovrednotena za konstrukcijska jekla do kvalitete S700. S tem so postavljeni temelji za kontrolo nosilnosti pločevine, obremenjene s skupino veznih sredstev. Podan je bil nov računski model z nadomestnimi vzmetmi za izračun togosti pločevine v bočnem pritisku, ki podaja odlične rezultate za preklopne spoje z enim ali več vijaki.

Rezultati projekta so bili predstavljeni mednarodnim tehničnim odborom (ECCS TC 10, EvG 1993-1-12) z namenom, da se kontrolo nosilnosti pločevine v bočnem pritisku in kontrolo nosilnosti oslabljenega prereza v standardih EN 1993-1-8 in EN 1993-1-1 ustrezno spremeni. Pričakujem, da bodo predvidene spremembe uspešno vključene v popravke omenjenih standardov, saj so predlagane rešitve enostavnejše in manj konservativne od obstoječih.

ANG

Significant results at the international level were achieved in the framework of this project. Concentrated transfer of forces in bolted connections by means of ductility was systematic analysed for mild steel grades as well as for high steel grades. The mechanism of the resistance was explained by numerical analysis. Furthermore, a new verification check for bearing resistance was developed. Its definition is based on extensive experimental testing and on the results of the numerical parametric studies. An original contribution of the project is also the evaluation of the bearing deformation capacity for steel grades up to S700. The bearing capacity is crucial for the redistribution of forces in the connection with several bolts. The model with equivalent springs for the calculation of the bearing stiffness was proposed. It provides excellent results for the connections with one or more bolts.

The project results were presented to the international technical committees (ECCS TC 10, EvG 1993-1-12) in order to include the new knowledge (verification of the bearing resistance and net cross-section resistance) to standards EN 1993-1-1 and EN 1993-1-8. It is expected that the proposed amendments will get a general consensus, since the proposed solutions are simpler and less conservative than the existing.

9.2.Pomen za razvoj Slovenije[10]

SLO

Rezultati projekta bodo imeli neposreden vpliv v Sloveniji, upoštevajoč predloge za spremembe standardov EN 1993-1-1 in EN 1993-1-8, saj slovenska zakonodaja predpisuje uporabo slovenskih standardov družine Evrokod, ki pa so po vsebini enaki evropskim. Pričakujem, da bodo predvidene spremembe uspešno vključene v popravke omenjenih standardov, saj so predlagane rešitve enostavnejše in manj konservativne od obstoječih.

Na Univerzi v Ljubljani bo pridobljeno znanje vključeno v predavanja pri predmetih, ki obravnavajo jeklene konstrukcije. Znanje se podaja tudi projektantom preko objav v slovenskih strokovnih revijah in drugod.

ANG

The results of the project will have a direct impact in Slovenia, taking into account the proposed amendments to standards EN 1993-1-1 and EN 1993-1-8. The Eurocode standards are also used in Slovenia. It is expected that the proposed amendments will get a general consensus, since the proposed solutions are simpler and less conservative than the existing.

At the University of Ljubljana the knowledge obtained in this project will be included in the lectures dealing with steel structures. The knowledge is also disseminated to the designers through publications in Slovenian professional journals and elsewhere.

10.Samo za aplikativne projekte in podoktorske projekte iz gospodarstva! Označite, katerega od navedenih ciljev ste si zastavili pri projektu, katere konkretne rezultate ste dosegli in v kakšni meri so doseženi rezultati uporabljeni

Cilj		
F.01	**Pridobitev novih praktičnih znanj, informacij in veščin**	
	Zastavljen cilj	◯ DA ◯ NE
	Rezultat	
	Uporaba rezultatov	
F.02	**Pridobitev novih znanstvenih spoznanj**	
	Zastavljen cilj	◯ DA ◯ NE
	Rezultat	
	Uporaba rezultatov	
F.03	**Večja usposobljenost raziskovalno-razvojnega osebja**	

	Zastavljen cilj	◯ DA ◯ NE
	Rezultat	
	Uporaba rezultatov	
F.04	**Dvig tehnološke ravni**	
	Zastavljen cilj	◯ DA ◯ NE
	Rezultat	
	Uporaba rezultatov	
F.05	**Sposobnost za začetek novega tehnološkega razvoja**	
	Zastavljen cilj	◯ DA ◯ NE
	Rezultat	
	Uporaba rezultatov	
F.06	**Razvoj novega izdelka**	
	Zastavljen cilj	◯ DA ◯ NE
	Rezultat	
	Uporaba rezultatov	
F.07	**Izboljšanje obstoječega izdelka**	
	Zastavljen cilj	◯ DA ◯ NE
	Rezultat	
	Uporaba rezultatov	
F.08	**Razvoj in izdelava prototipa**	
	Zastavljen cilj	◯ DA ◯ NE
	Rezultat	
	Uporaba rezultatov	
F.09	**Razvoj novega tehnološkega procesa oz. tehnologije**	
	Zastavljen cilj	◯ DA ◯ NE
	Rezultat	
	Uporaba rezultatov	
F.10	**Izboljšanje obstoječega tehnološkega procesa oz. tehnologije**	
	Zastavljen cilj	◯ DA ◯ NE
	Rezultat	
	Uporaba rezultatov	
F.11	**Razvoj nove storitve**	
	Zastavljen cilj	◯ DA ◯ NE
	Rezultat	
	Uporaba rezultatov	

F.12	**Izboljšanje obstoječe storitve**	
	Zastavljen cilj	◯ DA ◯ NE
	Rezultat	
	Uporaba rezultatov	
F.13	**Razvoj novih proizvodnih metod in instrumentov oz. proizvodnih procesov**	
	Zastavljen cilj	◯ DA ◯ NE
	Rezultat	
	Uporaba rezultatov	
F.14	**Izboljšanje obstoječih proizvodnih metod in instrumentov oz. proizvodnih procesov**	
	Zastavljen cilj	◯ DA ◯ NE
	Rezultat	
	Uporaba rezultatov	
F.15	**Razvoj novega informacijskega sistema/podatkovnih baz**	
	Zastavljen cilj	◯ DA ◯ NE
	Rezultat	
	Uporaba rezultatov	
F.16	**Izboljšanje obstoječega informacijskega sistema/podatkovnih baz**	
	Zastavljen cilj	◯ DA ◯ NE
	Rezultat	
	Uporaba rezultatov	
F.17	**Prenos obstoječih tehnologij, znanj, metod in postopkov v prakso**	
	Zastavljen cilj	◯ DA ◯ NE
	Rezultat	
	Uporaba rezultatov	
F.18	**Posredovanje novih znanj neposrednim uporabnikom (seminarji, forumi, konference)**	
	Zastavljen cilj	◯ DA ◯ NE
	Rezultat	
	Uporaba rezultatov	
F.19	**Znanje, ki vodi k ustanovitvi novega podjetja ("spin off")**	
	Zastavljen cilj	◯ DA ◯ NE
	Rezultat	
	Uporaba rezultatov	
F.20	**Ustanovitev novega podjetja ("spin off")**	
	Zastavljen cilj	◯ DA ◯ NE

	Rezultat	
	Uporaba rezultatov	
F.21	**Razvoj novih zdravstvenih/diagnostičnih metod/postopkov**	
	Zastavljen cilj	◯ DA ◯ NE
	Rezultat	
	Uporaba rezultatov	
F.22	**Izboljšanje obstoječih zdravstvenih/diagnostičnih metod/postopkov**	
	Zastavljen cilj	◯ DA ◯ NE
	Rezultat	
	Uporaba rezultatov	
F.23	**Razvoj novih sistemskih, normativnih, programskih in metodoloških rešitev**	
	Zastavljen cilj	◯ DA ◯ NE
	Rezultat	
	Uporaba rezultatov	
F.24	**Izboljšanje obstoječih sistemskih, normativnih, programskih in metodoloških rešitev**	
	Zastavljen cilj	◯ DA ◯ NE
	Rezultat	
	Uporaba rezultatov	
F.25	**Razvoj novih organizacijskih in upravljavskih rešitev**	
	Zastavljen cilj	◯ DA ◯ NE
	Rezultat	
	Uporaba rezultatov	
F.26	**Izboljšanje obstoječih organizacijskih in upravljavskih rešitev**	
	Zastavljen cilj	◯ DA ◯ NE
	Rezultat	
	Uporaba rezultatov	
F.27	**Prispevek k ohranjanju/varovanje naravne in kulturne dediščine**	
	Zastavljen cilj	◯ DA ◯ NE
	Rezultat	
	Uporaba rezultatov	
F.28	**Priprava/organizacija razstave**	
	Zastavljen cilj	◯ DA ◯ NE
	Rezultat	
	Uporaba rezultatov	

F.29	**Prispevek k razvoju nacionalne kulturne identitete**	
	Zastavljen cilj	○ DA ○ NE
	Rezultat	
	Uporaba rezultatov	
F.30	**Strokovna ocena stanja**	
	Zastavljen cilj	○ DA ○ NE
	Rezultat	
	Uporaba rezultatov	
F.31	**Razvoj standardov**	
	Zastavljen cilj	○ DA ○ NE
	Rezultat	
	Uporaba rezultatov	
F.32	**Mednarodni patent**	
	Zastavljen cilj	○ DA ○ NE
	Rezultat	
	Uporaba rezultatov	
F.33	**Patent v Sloveniji**	
	Zastavljen cilj	○ DA ○ NE
	Rezultat	
	Uporaba rezultatov	
F.34	**Svetovalna dejavnost**	
	Zastavljen cilj	○ DA ○ NE
	Rezultat	
	Uporaba rezultatov	
F.35	**Drugo**	
	Zastavljen cilj	○ DA ○ NE
	Rezultat	
	Uporaba rezultatov	

Komentar

11. Samo za aplikativne projekte in podoktorske projekte iz gospodarstva!
Označite potencialne vplive oziroma učinke vaših rezultatov na navedena področja

	Vpliv	Ni vpliva	Majhen vpliv	Srednji vpliv	Velik vpliv	
G.01	**Razvoj visokošolskega izobraževanja**					

G.01.01.	Razvoj dodiplomskega izobraževanja	○	○	○	○	
G.01.02.	Razvoj podiplomskega izobraževanja	○	○	○	○	
G.01.03.	Drugo:	○	○	○	○	
G.02	**Gospodarski razvoj**					
G.02.01	Razširitev ponudbe novih izdelkov/storitev na trgu	○	○	○	○	
G.02.02.	Širitev obstoječih trgov	○	○	○	○	
G.02.03.	Znižanje stroškov proizvodnje	○	○	○	○	
G.02.04.	Zmanjšanje porabe materialov in energije	○	○	○	○	
G.02.05.	Razširitev področja dejavnosti	○	○	○	○	
G.02.06.	Večja konkurenčna sposobnost	○	○	○	○	
G.02.07.	Večji delež izvoza	○	○	○	○	
G.02.08.	Povečanje dobička	○	○	○	○	
G.02.09.	Nova delovna mesta	○	○	○	○	
G.02.10.	Dvig izobrazbene strukture zaposlenih	○	○	○	○	
G.02.11.	Nov investicijski zagon	○	○	○	○	
G.02.12.	Drugo:	○	○	○	○	
G.03	**Tehnološki razvoj**					
G.03.01.	Tehnološka razširitev/posodobitev dejavnosti	○	○	○	○	
G.03.02.	Tehnološko prestrukturiranje dejavnosti	○	○	○	○	
G.03.03.	Uvajanje novih tehnologij	○	○	○	○	
G.03.04.	Drugo:	○	○	○	○	
G.04	**Družbeni razvoj**					
G.04.01	Dvig kvalitete življenja	○	○	○	○	
G.04.02.	Izboljšanje vodenja in upravljanja	○	○	○	○	
G.04.03.	Izboljšanje delovanja administracije in javne uprave	○	○	○	○	
G.04.04.	Razvoj socialnih dejavnosti	○	○	○	○	
G.04.05.	Razvoj civilne družbe	○	○	○	○	
G.04.06.	Drugo:	○	○	○	○	
G.05.	**Ohranjanje in razvoj nacionalne naravne in kulturne dediščine in identitete**	○	○	○	○	
G.06.	**Varovanje okolja in trajnostni razvoj**	○	○	○	○	
G.07	**Razvoj družbene infrastrukture**					
G.07.01.	Informacijsko-komunikacijska infrastruktura	○	○	○	○	
G.07.02.	Prometna infrastruktura	○	○	○	○	
G.07.03.	Energetska infrastruktura	○	○	○	○	

G.07.04.	Drugo:		○	○	○	○	
G.08.	**Varovanje zdravja in razvoj zdravstvenega varstva**		○	○	○	○	
G.09.	**Drugo:**		○	○	○	○	

Komentar

12.Pomen raziskovanja za sofinancerje[11]

	Sofinancer			
1.	Naziv			
	Naslov			
	Vrednost sofinanciranja za celotno obdobje trajanja projekta je znašala:			EUR
	Odstotek od utemeljenih stroškov projekta:			%
	Najpomembnejši rezultati raziskovanja za sofinancerja			Šifra
		1.		
		2.		
		3.		
		4.		
		5.		
	Komentar			
	Ocena			

13.Izjemni dosežek v letu 2013[12]

13.1. Izjemni znanstveni dosežek

V okviru projekta je bilo testiranih 48 preklopnih spojev z največ šestimi vijaki. Na podlagi verificiranih numeričnih modelov je bil analiziran vpliv geometrije in materiala na nosilnost in razpored napetosti v preklopnih spojih. Ti rezultati in rezultati testov iz literature so služili za razumevanje mehanizma prenosa obremenitev, na podlagi česar je bil razvit nov model za kontrolo bočnega pritiska v pločevini. Predlagani model obravnava jekla običajnih trdnosti in jekla visoke trdnosti. Ovrednotena je bila tudi deformacijska kapaciteta pločevine v bočnem pritisku, ki izraža mero duktilnosti. Razvit je bil tudi analitični model z nadomestnimi vzmetmi za račun togosti pločevine v bočnem pritisku.

Rezultati so bili predstavljeni mednarodnim tehničnim odborom, z namenom, da se novo znanje vključi v revidirane evropske standarde. Pričakujemo, da bodo predvidene spremembe uspešno vključene v standarde, saj so predlagane rešitve enostavnejše in manj konservativne od obstoječih.

13.2. Izjemni družbeno-ekonomski dosežek

C. IZJAVE

Podpisani izjavljam/o, da:

- so vsi podatki, ki jih navajamo v poročilu, resnični in točni
- se strinjamo z obdelavo podatkov v skladu z zakonodajo o varstvu osebnih podatkov za potrebe ocenjevanja ter obdelavo teh podatkov za evidence ARRS
- so vsi podatki v obrazcu v elektronski obliki identični podatkom v obrazcu v pisni obliki
- so z vsebino zaključnega poročila seznanjeni in se strinjajo vsi soizvajalci projekta

Podpisi:

zastopnik oz. pooblaščena oseba raziskovalne organizacije:	in	*vodja raziskovalnega projekta:*
Univerza v Ljubljani, Fakulteta za gradbeništvo in geodezijo		Primož Može
____________________		____________________

ŽIG

Kraj in datum: Ljubljana, 15.4.2014

Oznaka prijave: ARRS-RPROJ-ZP-2014/34

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[1] Napišite povzetek raziskovalnega projekta (največ 3.000 znakov v slovenskem in angleškem jeziku) Nazaj

[2] Napišite kratko vsebinsko poročilo, kjer boste predstavili raziskovalno hipotezo in opis raziskovanja. Navedite ključne ugotovitve, znanstvena spoznanja, rezultate in učinke raziskovalnega projekta in njihovo uporabo ter sodelovanje s tujimi partnerji. Največ 12.000 znakov vključno s presledki (približno dve strani, velikost pisave 11). Nazaj

[3] Realizacija raziskovalne hipoteze. Največ 3.000 znakov vključno s presledki (približno pol strani, velikost pisave 11) Nazaj

[4] V primeru bistvenih odstopanj in sprememb od predvidenega programa raziskovalnega projekta, kot je bil zapisan v predlogu raziskovalnega projekta oziroma v primeru sprememb, povečanja ali zmanjšanja sestave projektne skupine v zadnjem letu izvajanja projekta, napišite obrazložitev. V primeru, da sprememb ni bilo, to navedite. Največ 6.000 znakov vključno s presledki (približno ena stran, velikost pisave 11). Nazaj

[5] Navedite znanstvene dosežke, ki so nastali v okviru tega projekta. Raziskovalni dosežek iz obdobja izvajanja projekta (do oddaje zaključnega poročila) vpišete tako, da izpolnite COBISS kodo dosežka – sistem nato sam izpolni naslov objave, naziv, IF in srednjo vrednost revije, naziv FOS področja ter podatek, ali je dosežek uvrščen v A'' ali A'. Nazaj

[6] Navedite družbeno-ekonomske dosežke, ki so nastali v okviru tega projekta. Družbeno-ekonomski rezultat iz obdobja izvajanja projekta (do oddaje zaključnega poročila) vpišete tako, da izpolnite COBISS kodo dosežka – sistem nato sam izpolni naslov objave, naziv, IF in srednjo vrednost revije, naziv FOS področja ter podatek, ali je dosežek uvrščen v A'' ali A'.

Družbeno-ekonomski dosežek je po svoji strukturi drugačen kot znanstveni dosežek. Povzetek znanstvenega dosežka je praviloma povzetek bibliografske enote (članka, knjige), v kateri je dosežek objavljen.

Povzetek družbeno-ekonomskega dosežka praviloma ni povzetek bibliografske enote, ki ta dosežek dokumentira, ker je dosežek sklop več rezultatov raziskovanja, ki je lahko dokumentiran v različnih bibliografskih enotah. COBISS ID zato ni enoznačen, izjemoma pa ga lahko tudi ni (npr. prehod mlajših sodelavcev v gospodarstvo na pomembnih raziskovalnih nalogah, ali ustanovitev podjetja kot rezultat projekta … - v obeh primerih ni COBISS ID). Nazaj

[7] Navedite rezultate raziskovalnega projekta iz obdobja izvajanja projekta (do oddaje zaključnega poročila) v primeru, da katerega od rezultatov ni mogoče navesti v točkah 6 in 7 (npr. ni voden v sistemu COBISS). Največ 2.000 znakov, vključno s presledki. Nazaj

[8] Pomen raziskovalnih rezultatov za razvoj znanosti in za razvoj Slovenije bo objavljen na spletni strani: http://sicris.izum.si/ za posamezen projekt, ki je predmet poročanja Nazaj

[9] Največ 4.000 znakov, vključno s presledki Nazaj

[10] Največ 4.000 znakov, vključno s presledki Nazaj

[11] Rubrike izpolnite / prepišite skladno z obrazcem "izjava sofinancerja" http://www.arrs.gov.si/sl/progproj/rproj/gradivo/, ki ga mora izpolniti sofinancer. Podpisan obrazec "Izjava sofinancerja" pridobi in hrani nosilna raziskovalna organizacija – izvajalka projekta. Nazaj

[12] Navedite en izjemni znanstveni dosežek in/ali en izjemni družbeno-ekonomski dosežek raziskovalnega projekta v letu 2013 (največ 1000 znakov, vključno s presledki). Za dosežek pripravite diapozitiv, ki vsebuje sliko ali drugo slikovno gradivo v zvezi z izjemnim dosežkom (velikost pisave najmanj 16, približno pol strani) in opis izjemnega dosežka (velikost pisave 12, približno pol strani). Diapozitiv/-a priložite kot priponko/-i k temu poročilu. Vzorec diapozitiva je objavljen na spletni strani ARRS http://www.arrs.gov.si/sl/gradivo/, predstavitve dosežkov za pretekla leta pa so objavljena na spletni strani http://www.arrs.gov.si/sl/analize/dosez/. Nazaj

Obrazec: ARRS-RPROJ-ZP/2014 v1.03
F9-EE-B4-84-D6-78-B5-73-FA-2F-3D-55-2C-24-37-82-32-6D-AF-B5

Priloga 1

European Convention for Constructional Steelwork
Technical Committee 10 – Structural Connections

Proceedings of the 100th meeting in Bucharest
06-07 October 2011

Attendances:

Name:	Country:	2011-10-06	2011-10-07	Remarks:
Belder, Edwin	The Netherlands	X	X	Secretary
Bijlaard, Frans	The Netherlands	X	X	Chairman
Braham, Marc	Luxemburg	X	X	
Couchaux, Maël	France	X	X	
Dima, Serban	Romania	X	X	(Host) Guest
Dubina, Dan	Romania	X	X	
Girao, Ana M.	Portugal	X	X	
Grecea, Daniel	Romania	X	X	
Gresnigt, Nol	The Netherlands	X	X	
Iglesias, Gorka	Spain	X	X	
Kober, Helmuth	Romania	X	X	Guest
Malik, Abdul	United Kingdom	X	X	
Može, Primož	Slovenia	X	X	Guest
Mustard, Trevor R.	United Kingdom	X	X	
Oly, René	Luxemburg	X	X	
Puthli, Ram	Germany	X	X	
Schneider, Marcel	Germany	X	X	
Ummenhofer, Thomas	Germany	X	X	
Wald, František	Czech Republic	X	X	
Weynand, Klaus	Germany	X	-	

Apologies:

Name:	Country:	2011-10-06	2011-10-07	Remarks:
Aasen, Bjørn	Norway	-	-	Holiday in Scotland
Anderson, David	United Kingdom	-	-	
Beg, Darko	Slovenia	-	-	
Bjorhovde, Reidar	United States	-	-	Meeting in Berlin
Brettle, Mary	United Kingdom	-	-	
Kouhi, Jouko	Finland	-	-	
Moore, David	United Kingdom	-	-	
Ryan, Ivor	France	-	-	
Santiago, Aldina	Portugal	-	-	
Stefanescu, Bogdan	Romania	-	-	Host, Illness
Veljkovic, Milan	Sweden	-	-	Conference in Bled (Slovenia)
Wardenier, Jaap	The Netherlands	-	-	

Schedule of the meetings:
Thursday 2011-10-06 → ECCS TC10 Regular Meeting
Friday 2011-10-07 → ECCS TC10 Regular Meeting

European Convention for Constructional Steelwork
Technical Committee 10 – Structural Connections
Proceedings of the 100th meeting in Bucharest
06-07 October

1. Opening and apologies

Frans Bijlaard opened the meeting and welcomed delegates to Bucharest. See previous page for apologies.

2. Meeting arrangements

Prof. Dr. Ing. **Serban Dima** explains the situation (illness) of **Bogdan Stefanescu**. It is foreseen that he will recover within a few weeks. The committee wishes **Bogdan** a quick recovery and hope to see him in good health at the coming meetings. **Serban Dima** presents the activities and research of the Technical University of Civil Engineering of Bucharest, and presents the arrangements for lunch, the bus-tour after the meeting and dining in a restaurant in the centre of Bucharest.

3. Approval of Agenda (Doc 732)

The agenda was approved; the presentations of **Nol Gresnigt** and **Rene Oly** were added to the agenda.

4. Membership

Maël Couchaux, who was already a familiar face in the committee, is now the official successor of Ivor Ryan in ECCS-TC10.

5. Proceedings

The proceedings of the 99th meeting in Karlsruhe (Doc 721) were approved.

Amendments

6. Actions from the 99th meeting in Karlsruhe (Doc 721)

Abdul Malik: No further remarks on the research regarding tying forces.
Abdul Malik asks the committee for documents or research concerning the required robustness of connections.
Frans Bijlaard: There is no clear statement in EN 1993-1-8 about the required robustness of a connection. Such a requirement or design rule could clarify the way to design in case of prohibiting progressive collapse.
Abdul Malik: SCI has made some documents concerning this topic; these will be distributed to ECCS TC10 participants.

7. Discussion about corrigenda and amendments on Chapter 7 of EN 1993-1-8 "Hollow Section Joints

(Frans Bijlaard, Gorka Iglesias)

Prior to the meeting both **Ram Puthli** and **Gorka Iglesias** issued documents with comments on the proposed corrections for EN 1993-1-8 "Hollow Section Joints".
Frans will discuss with Gorka and Ram on agreed (green) and not agreed points (grey) points within these documents and will prepare an advice to SC3.

Chord force interaction will be investigated at the KIT in Karlsruhe under the guidance of Thomas Ummenhofer. The results will be reviewed by the committee in 2013/2014.
The extension of the range of validity for tubes to a wall thickness below 2.5mm will also be investigated by the KIT. In order to do so, all available information will be assembled.
Japanese information/investigation about this subject will be send around by **Ram Puthli**.

8. Workshop Connections VII

The next International Connections Workshop is to be held in Timisoara in 2012
Dan Dubina presents the preparations and progress of the workshop so far. The schedule below shows the timetable for paper submission a.o.t.

Timetable

- **Last call for participants & abstracts**
  - **Next week**
  - **Deadline 15 November 2011**
- **Workshop webpage** — **December 2011**
- **Template for papers** — **End December 2011**
- **Paper submission (uploading)** — **15 March 2012**
- **Tentative program** — **March 30, 2012**
  - **3 days technical sessions** — **May 30 – June 01, 2012**
  - **Technical/tourist tour** — **June 01, 2012**
  - **Welcome reception** — **May 30, 2012**
  - **Dinner** — **May 31, 2012**
- **Final program** — **April 30, 2012**

Joints

9. Tests of tension splices with bolts in bearing (Steel Grade S235).

The test results were presented by **Primoz Moze**, who is cooperating with **Darko Beg.**
Several tests were performed, using various configurations (plate thicknesses, single shear and double shear connections, number of bolts (10.9) and bolt diameters). Bolts with quality 10.9 were used so they would not be governing as a failure mode. When the end distance e1 is smaller than pitch distance p1, an uneven distribution of bearing occurs. This phenomenon is not specifically explained in EN1993-1-8. The test results showed that some failure modes are

unexpectedly governing while EC indicates otherwise. Nevertheless, it was concluded that the bearing resistance as defined in EC give safe results.

10. Actual status on the development of CoP2 (Klaus Weynand)

The design tables for the design of tubular connections are now available and currently being verified by German building authorities. The design tables are for free and are (or will be) available at V&M.
Other developments are Cop Lite for ***Simple Joints*** and Cop Professional (available in the spring of 2012).

Comment regarding ***Simple Joints***:
Frans Bijlaard mentions that (for now) no rules are implemented in EN1993-1-8 regarding LTB (Lateral Torsional Buckling)i.e. out of plane buckling for fin plate connections. Some additional rules, such as a recommended geometry (ref: "Simple Connections" –BCSA- chapter 6.3), can clarify or close the gap between EC and some National Codes.

11. Observations resulting from intensive use of EN1993-1-8 chapter 7 (hollow section joints) while developing design tools

Klaus Weynand explains that during the development of the design tool some strange results occurred. For instance, the values for some failure modes dramatically changed due to variations in section thicknesses or inner forces in the chord. These are just observations and this does not mean that the code is not correct. Because of used ratios and boundaries these phenomena appear, perhaps this can be solved in the future.

12. Bending resistance of bolted circular flange connections

Because most methods for the design of bolted circular flange connections only permit the determination of the tensile resistance, **Maël Couchaux** proposed a general EC3-model for combinations of axial force and bending in his presentation.
Experimental tests were performed with tubes diam. 762 x 6 mm, flange thickness of 40mm (S355) and bolts M24-10.9 (preloaded).
In these tests failure modes occurred at the tube wall (buckling) and the bolts (yielding).
In addition **František Wald** presented results from circular hollow section base plates analyses according the component method. The failure mode of the baseplate was mainly influenced by the position of the bolts.

Joints under seismic actions

13. (no input this meeting)

Composite joints

14 (no input this meeting)

15. Joints under fire condition

František Wald presented results from tests with end plate connections, which were partially encased in concrete slabs. In a series of experiments going back to 2007, combined with numerical simulations it has become clear that partial encasing provides a beneficial effect on the connections.

Connectors

16. QUERY: (Abdul Malik)

"In response to a recent query, I notice that there's very little said about fit bolts in Eurocode 3-1-8, other than acknowledging their existence".

Section 4 of the EN 14399-8 High-strength structural bolting for preloading – Part 8: System HV – Heaxagon fit bolt and nut assemblies Section 4 covers dimensions, tolerances, mechanical properties and suitability for preloading of Fit Bolts.

"I have two basic queries – what class of connection would be achieved with a fit bolt? Presumably it would be equivalent to class C but that class is for preloaded bolts only".

Based on the EN 14399-8 this should be class C.

"What tolerances would be needed to enable the connection to be designed as a fit bolt connection? I cannot find a class of fit or hole tolerance in EN 1090-2, nor can I find any direction as to which standard a fit bolt should be manufactured. Clearly product grade B to ISO 4014 would be much more suitable than product grade C to ISO 4016, for example, but is that what is required and are those bolts commonly available?"

according EN 1993-8 section 3.6.1

(9) The hole tolerance used for fit bolts should be in accordance with 1.2.7 Reference Standards: Group 7.

1.2.7 Reference Standard, Group 7: Execution of steel structures

EN 1090-2 Requirements for the execution of steel structures

according EN 1090-2 section 6.6.1 Dimensions of holes
(below table 11)

For fit bolts the nominal hole diameter shall be equal to the shank diameter of the bolt.

High strength steel

17. (no input this meeting)

Publications

18. (no input this meeting)

AOB

19. Test-loads

Marc Braham showed the committee a photo of a building testing facility. Water bags filled with water are the representative of the (approx.) SLS-load. The testing of buildings with test-loads like these, as Marc explained, is common practice in Italy.

20. Pedestrian bridge

Nol Gresnigt presented his analyses of a pedestrian bridge which is located across a motorway. The bridge consists of trusses in the walls and the roof and a concrete slab on the floor. In the horizontal plane it is curved. Because of that the cross section is loaded by combinations of bending moment and torsional moment. In the design and in the erection no allowance was made for distortions due to the torsional moments. Apart from deformations of the members also considerable distortions were the result of the hole clearances. A pre camber (out of plane) was not applied and large distortions occurred. Furthermore, the connections between the concrete slab and steel members were not stiff and not strong enough and even some bolts were missing. In conclusion, both the design and the execution were poor. The behaviour of such bridges and requirements were not understood.

21. Punching of holes

Rene Oly encountered some difficulties with an inspector concerning connections. Punching of holes with a diameter less than the plate thickness is not allowed because of rules in EN 1090-2.

Punching is permitted provided that the nominal thickness of the component is not greater than the nominal diameter of the hole, or for a non-circular hole, its minimum dimension (6.6.3 Execution of holing)

However, in practice the execution of these holes is possible with good results.
Rene Oly feels that there is now too much restriction and believes that the rules should be updated to modern standards.
Rene Oly will prepare a proposal which will be distributed.

22. Date and place of next meetings

Due to the workshop in Timisoara, a one day (afternoon) meeting is scheduled on the 29th of May at **16:00 h.** The following meeting will be on the 4rd and 5th of April 2013. The location of this meeting will be determined later on.

23. New chairman

For the assignment of the new chairman, acceptance is needed by the manager-board of ECCS. When accepted, the participants of ECCS TC10 will be informed. In that case **Frans Bijlaard** will resign his chairmanship after the workshop in Timisoara, Romania.

Closure

The chairman thanked all present for their contributions to the meeting and especially the hosts for their great hospitality.

Edwin Belder
Secretary
May 2012

Priloga 2

ECCS-TC10
102th ECCS TC10 Meeting, Liege
April 2013

European Convention for Constructional Steelwork
Technical Committee 10 – Structural Connections

Proceedings of the 102th meeting in Liege
10 and 11 of April 2013

Attendances:

Name:	Country:	2013-04-10	2013-04-11	Remarks:
Aasen, Bjørn	Norway	X	X	
Anderson, David	United Kingdom	X	X	
Bayo, Eduardo	Spain	X	X	
Beg, Darko	Slovenia	X		
Belder, Edwin	The Netherlands	X	X	Secretary
Bijlaard, Frans	The Netherlands	X	X	Resigning chairman
Couchaux, Maël	France	X	X	
da Silva, Luis Simões	Portugal	X	X	
Demonceau, Jean-François	Belgium	X	X	
Dubina, Dan	Romania	X	X	
Fischl, Andreas	Germany	X	X	
Girao, Ana M.	Portugal	X	X	
Grecea, Daniel	Romania	X	X	
Gresnigt,Nol	The Netherlands	X	X	
Hoffman, Nadine	Germany	X	X	Guest, replaces Ulrike Kuhlmann
Jaspart, Jean-Pierre	Belgium	X	X	Host
Knödel, Peter	Germany	X	X	Guest
Kozlowski, Aleksander	Poland	X	X	
Malik, Abdul	United Kingdom	X	X	
Moore, David	United Kingdom	X	X	
Može, Primož	Slovenia	X	X	Guest
Mustard, Trevor R.	United Kingdom	X	X	
Oly, René	Luxemburg	X	X	
Puthli, Ram	Germany	X	X	
Servetto, Chiara	Italy	X	X	
Sleczka, Lucjan	Poland	X	X	Guest
Stefanescu, Bogdan	Romania	X	X	
Szlendak, Jerzy	Poland	X	X	

Ummenhofer, Thomas	Germany	X	X	New chairman
Ungermann, Dieter	Germany	X	X	
Veljkovic,Milan	Sweden	X	X	
Wald,František	CzechRepublic	X	X	
Weynand, Klaus	Germany	X		
Piraprez, Eugene	Belgium	X	X	Guest

Apologies:

Name:	Country:	Remarks:
Bjorhovde,Reidar	United States	
Borges, Luis	Switzerland	
Bucak,Ömar	Germany	
Heinisuo, Markku	Finland	New Member, ill
Iglesias, Gorka	Spain	
Kouhi, Jouko	Finland	
Kuhlmann, Ulrike	Germany	Meeting Paris
Oerder, Ralf	Germany	
Santiago, Aldina	Portugal	
Schneider, Marcel	Germany	
Wardenier, Jaap	The Netherlands	
Xiao, Robert	United Kingdom	
Zandonini, Riccardo	Italy	Meeting Paris
Braham, Marc	Luxemburg	

The place and schedule of the meeting:
Salle des Professeurs
University of Liège
Bâtiment A1
Place du XX Août, 7
B-4000 LIEGE

Wednesday April 10th → 09:00 – 16:00

Thursday April 11th → 09:00 – 16:00

General

1. Opening and apologies
   Frans Bijlaard opened the meeting and welcomed delegates to Liege. See previous page for apologies.

2. Meeting arrangements
   The host of our meeting in Liege, **Jean-Pierre Jaspart**, welcomes the delegates and provides information for the meeting arrangements.

3. Approval of Agenda
   Item 9a , 11a and 22 were added to the agenda.

4. Change of chairmanship ECCS TC10 **(Frans Bijlaard, Thomas Ummenhofer)**
   After some 14 years as chairman of ECCS TC10, **Frans Bijlaard** handed over the chairmanship to **Thomas Ummenhofer**. The committee thanks our (now) former chairman for all his efforts during the years as member and chairman of ECCS TC10.

Membership

5. New members in ECCS TC10 and new faces

   The following new members were present during the meeting. Prof.**Aleksander Kozlowski** (FM) and Prof.**Jerzy Szlendak** (FM) from Poland and **Henri Perttola** (CM) from Finland. Prof.**Markku Heinisuo** (FM) could not attend the meeting due to illness, hopefully we can welcome him the next meeting. Nadine Hoffman is the replacement of **Ulrike Kuhlmann** for the duration of the meeting. **Peter Knödel** came along as a guest (and colleague) of **Thomas Ummenhofer**, although he is already a familiar face to some of our colleagues. Members of the Evolution Group also attended the meeting, **EugènePiraprez**, **Chiara Servetto** and **Jean-François Demonceau** were welcomed.

   In the future all Evolution Group members of EN1993-1-8 will be invited to the meetings of ECCS TC10 in order to streamline the flow of information regarding possible changes or questions about the code. Please inform the secretary about possible candidates of the Evolution Group which are interested to attend future meetings.

Proceedings

6. Approval of the proceedings of the 101th meeting in Timisoara (Doc 751)
   The proceedings of the 101th meeting in Timisoara (Doc 751) were approved.

Workshop

7. High Strength Steel in Seismic Resistant Building Frames (workshop information)**(Dan Dubina)**
   Dan Dubina provides the committee information regarding the International Workshop High Strength Steel in Seismic Resistant Structures which is to be held at the 28-29 June 2013, Naples, Italy.

8. Brief information concerning the Proceedings of Connections VII **(Daniel Grecea)**
   The proceedings of Connection VII have been send to participants during the period in-between the meeting and finalization of the Liege proceedings. The committee thanks **Daniel Grecea**, **Dan Dubina** and their team for the efforts and hardship of organizing Connections VII and the preparation of this document.

9. ECCS Quality Manual - issues directly relevant for TCs & use of ECCS website for TC10**(Luís da Silva)**
   Luis da Silva provided further information about the ECCS Quality Manual which has distributed before the meeting. He continued with the endorsement of the use of the ECCS website, which is available to all ECCS TC10 members, in order to archive the presentations, papers and proceedings which are beneficial to the ECCS, the committees and the development of steel structures as a whole. Old documents (from earlier meetings) which are not available in a digital format are preferred to be scanned so they will be preserved for the future.

9a.Bearing strength at bolt holes. Evaluation of design resistance **(Darko Beg, Primož Može)**
Primož Može presented the experience gained from the recent years of research on the bearing strength at bolt holes. During this project tests of tension splices were performed on high strength steel of S690 and S235. Important parameters within the tests were the local ductility and the connection geometry. Numerical simulations of tests were performed with ABAQUS.
The numerical parametric study was performed in order to obtain the bolt bearing forces for single bolt connections. The study included 2×114 connections on the steel grades S235 and S690.
The typical failure modes were Shear failure, Splitting failure and Net cross-section failure.
The test results compared to the required Eurocode resistance shows that the actual failures correspond to the design check, but not for all.
Based on the testresults **Primož Može** suggests modications on the Eurocode resistances, such as the bearing resistance per bolt. Net cross section resistance and Block shear resistance (same as AISC). With this modifications implemented, the actual failure corresponded to the design check for all results.

EC3 Part 1.8 evolution group

10. EC3 Part 1.8 evolution group discussion (preferred on Wednesday due to absence of several members on Thursday)
    As discussed in Timisoara the Evolution Group 1.8 is considered to be a part of ECCS TC10 However, to avoid any miscommunications all known members of the Evolution Group will be invited to future meetings of ECCS TC10.

Amendments

11. Actions from the 101th meeting in Timisoara (Doc 751) or earlier meetings

Punching of holes; part of Bucharest Proceedings ECCS-TC10-11-733
Rene Oly encountered some difficulties with an inspector concerning connections. Punching of holes with a diameter less than the plate thickness is not allowed because of rules in EN 1090-2.

Punching is permitted provided that the nominal thickness of the component is not greater than the nominal diameter of the hole, or for a non-circular hole, its minimum dimension (6.6.3 Execution of holing)
However, in practice the execution of these holes is possible with good results.
Rene Oly feels that there is now too much restriction and believes that the rules should be updated to modern standards.
Rene Oly will prepare a proposal which will be distributed.
Proposal has been prepared and will be distributed

11a. SC3 documents and Mirror-groups

The proposals for corrections and amendments regarding the EN 1993-1-8 have been send to SC3 and they have to inform the National Mirror Groups. In addition, It is recommended that the Mirror Groups should also be informed by the national delegate of the ECCS TC10 committee about current and future developments regarding the EN 1993-1-8. This enables the shortening of discussions and streamlining the process of developing the code.

Frans Bijlaard represented a list of amendments and corrections that has been agreed upon by all participants. After further presentation it was concluded to send these lists to SC3.

Joints

12. Several proposals to improve EN 1993-1-8 (2 parts) **(Aleksander Kozlowski)**

Aleksander Kozlowski presented several changes and corrections to be made in order to improve the EN 1993-1-8. The proposals need to be discussed within the committee.
It comprised the following:

- A correction of table 6.2
- A correction of table 6.7
- A modification of chapter 6.2.7.2 (9)
- A modification of chapter 6.4.2.
- Some comments and editorial changes

A new change of proposals for corrections and amendments regarding the EN 1993-1-8 will be within a few years ,a part from a major error which has to be corrected straight away.

In his second presentation **Aleksander Kozlowski** proposes a new Annex (A):
Simplified method to assess structural properties of joints.
Aleksander explains that, although the 1-8 contains design methods to determine the structural properties of joints in frames, that these are very time consuming and require many information about the joint which are likely not to be available at the early stage of design. The proposal comprises a set of simplified formulas to be used in the pre-design phase. This enables the designer to use this is an input for the global analysis of the structure.

13. New joint types in offshore topside structures **(BjørnAasen)**

Bjørn Aasen held a presentation about welded joints between CHS brace members and H section chords with elliptical stiffeners. This type of connections is a challenge for a practitioner due to the complex load transfer within the joint. Several essential checks has to be performed in order to obtain a reliable connection.

14. Component method for baseplate with embedded plate **(František Wald)**
In Liege **František Wald** presented principles of a component model for column with an embedded plate and headed studs and a base plate with threaded studs. As a part of the INFASO project experimental tests and FEM simulations were performed. **František Wald** foresees new market changes with this innovative fastening solution. A component model for a column base with embedded plate and headed studs and a base plate with threaded studs is now prepared. This model will be presented in Manuals for design of steel-to-concrete joints, which will be available by the end of this year.

15. Behaviour of the reverse channel joint component **(Milan Veljkovic& Luis da Silva)**
Milan Veljkovic held a presentation on the preliminary results regarding the research on the Behavior of Reverse Channel Sections. The objective of this research is the development of a comprehensive component-based design methodology for composite joints against fire. Tensile and compressive tests were performed in Abaqus to provide characteristic data and develop simple models to predict temperature-force-deflection behavior. An extended parametric study is to be followed in which various effects, such a variation of bolt rows, bolt spacing and plate thicknesses will be studied.

Welded Connections

16.
Query:*EN 1993-1-8, clause 4.3.2.1 (2) states "Angles smaller than 60 degrees are also permitted. However, in such cases the weld should be considered to be a partial penetration butt weld". Can you please explain what is meant by "considered to be a partial penetration butt weld" ? For hollow sections the limiting angle is 30 degrees, so why the limit of 60 degrees in 4.3.2.1 (2)?* ***(Abdul Malik)***
At an angle of 30 degrees a buttweld automatically occurs, and at an angle of 60 degrees a fillet weld is achievable. The text and sketch in code requires some improvement/ clarifications. **Peter Knödel** will prepare a proposal for this clarification.

17. Comments on the effective full penetration of T-butt welds, i.e. Figure 4.6 of Eurocode 3 Part1.8 **(BjørnAasen)**
During this short presentation **BjørnAasen** suggests an addition/change to the text supporting figure 4.6. The text is to be defined in line with ENV 1993-1-1 6.6.6.3 Tee-butt joints.

Bolted Connections

18.
Query: *For a bolt in tension the resistance is described as: Fu = 0,9 As fu / gamma M2.*
The resistance based on yielding of the bolt is ignored: Fy = As fy / gamma M0.
The question came from Danmark whether it would be necessary to also add the resistance based on yielding.
The answer is that for bolts, where there is a relative short length of the threaded portion, the failure in tests can only be observed clearly when the bolt breaks. Yielding, which occurs first is confined in the stress area, produces very small elongations and hardening takes rapidly place anyway so the resistance for bolts is based on Fu = 0,9 As fu / gamma M2 for all bolt grades given in EC3 Part 1-8. Looking to the numerical outcome, when comparing Fu and Fy for all bolt

grades, one can see that in all cases (except for 4.6 and 5.6 bolt grade) the result based on Fu is smaller than based on Fy. However, for 4.6 and for 5.6 bolt grade Fu is larger than Fy.
For "normal bolts" it is still acceptable to base the resistance on Fu, motivated by the strain hardening phenomena. But in case of threaded bars with treaded portion all along, this is questionable. So a discussion in ECCS-TC10 is required.

Frans Bijlaard states that some tests on threaded bars are beneficial to clarify this matter.
Test results will maybe be available at the next meeting

19.
Query: *Proposal to amend the α-Chart given in Figure 6.11 of EC3: Part 1.8, in particular to remove the values for 2π and above, and allow mathematical expression to be used in place of the table.* **(Abdul Malik)**
The charts are based on research and test results of **Martin Steenhuis**. An earlier proposal to amend the charts was not agreed upon. It is possible to create one's own mathematical equation. The last 2 charts already have one (7&8), and will be distributed by **Jean Pierre Jaspart**.

20. How can an existing bolt standard comply with the new requirements in ENh 15048 on Structural Bolting? **(BjørnAasen)**
Below a partly copy of the commentary of **BjørnAasen**:
For many years non-preloaded bolted connections have caused severe problems for the safety of steel structures.
Example, In Germany the so-called "Maschinenbauschrauben" according to DIN 931, DIN 933 and DIN 934 shall not be used in steelworks for buildings, bridges, towers and masts. These DIN-standards were withdrawn more than 20 years ago and were replaced by ISO 4014, ISO 4017 and ISO 4032. However, bolt suppliers worldwide are still providing the DIN-bolts.
In order to have steel structures which comply with essential requirement for strength and mechanical stability in the Building products directive CEN has published so-called harmonized standards, e.g. ENh xyz. For non-preloaded bolted connections the relevant standard is ENh 15048.
It is the responsibility of the steel fabricator to use the bolts which are required according the code. The EN 1090 provides rules for the execution of steel structures and which bolted connections are allowed to be used. For the non-pre-tensioned connections EN 15048 applies and provides the necessary information for which bolt grades are allowed to be used.

21.Current work on bearing resistance in bolted connections **(Primož Može)**
Ref. no. 9A

22. Application of 6.2.8 Design resistance of column bases with base plates and proposal for modification of 6.2.8. **(Nol Gresnigt)**
The use of table 6.7 provides practical problems while designing baseplates and that it is hard to understand for practitioners. **Nol Gresnigt** described the problems which occurred with the design of a bus station in which the majority of the connections where rigid.
The thickness of the base plates following the rules became very thick due to stiffness issues. He suggests to skip table 6.7 (value of e is not clear) and to make a new proposal which describes the calculation of the components and the assembly of the components.
This proposal is foreseen to be presented at the next meeting.

Joints under seismic actions

23. Outcome of the ATTEL RFCS project **(J.P. Jaspart)**

Jean Pierre Jaspart presented the outcome of the Attel RFCS project, Performance-based Approaches for high strength Tubular Columns and Connections under Earthquake and fire loadings. The project was divided in several work-packages in which various universities participated (project-partners). The main project objective was the exploitation of HSS in composite tubular columns and connections subjected to accidental loads, like earthquake and fire. The work-packages comprised, collection and evaluation of test data and design procedures, design of specimen, testing, calibration and the preparation of design guides. All related publications are available on http://orbi.ulg.ac.be/.

24. Behaviour of welded Beam-to-Colum Joints of CFRHS columns and I beams under Monotonic and Cyclic Loading.**(CristianVulcu, Dan Dubina)**
Dan Dubina presented results of the Timisoara University research regarding the Behavior of welded Beam to Column Joints of CRFHS columns and I beams under Monotonic and Cyclic behaviour. The study is part of a broader research project in which various universities, steel producers and research/design companies participate. The experimental program comprised material tests, load introduction tests and beam to column tests. The joints were also performed in Abaqus (numerical investigation) followed by a parametric study. The output of the experimental and numerical studies were used to come up with a component method for the joint design. Further research objectives related to the topic are planned in the future, as in:

- Investigation of joints with larger cross section members
- Investigation of two way joints

Composite joints

25. --------------------------

Joints under fire conditions

26. Outcome of the ROBUSTFIRE RFCS project **(J.F. Demonceau)**
In this project an accidental situation of a local fire of one or more cars in a car park has been analyzed. The main objective is the development of an assessment approach and design guidance in order to ensure the robustness of steel composite car parks under localized fire. One of the topics was the behavior of joints under M-N at elevated temperatures. An analytical was developed based on work of **Cerfontaine** and **Demonceau** in which the model was extended to steel-concrete composite joints. As a result, analytical models are now available to predict the M-N resistance curve for both steel joints and composite at room and elevated temperatures.

Connectors

27. ---------------------------

High strength steel

28. Outcome of the HITUBES RFCS project **(J.P. Jaspart / J.F. Demonceau)**
The HITUBES RFCS comprises the design and integrity assessment of high strength tubular structures for extreme loading conditions. Several experimental tests combined with numerical and analytical studies were performed on bolted flange joints under monotonic, repeated and fatigue loadings. The project is to result in proposals, in conjunction with current methods, for design recommendations. The final report is (or will be) available at http://orbi.ulg.ac.be/.

Publications

29. --------------------------

AOB

30. Co-operation with other Evolution Groups

Maël Couchaux points out the fact that the evolution group of part 3-1 of Eurocode 3 (for mast and tower) work on the proposition of a method for bolted circular flange joint in tension.
He proposes that the evolution group of part 1-8 work with this evolution group in order to keep a certain coherence (particularly for prying effect).

František Wald suggests a similar co-operation between ECCS TC10 and members of other committees which are involved with the EN1992-1-1 or EN1992-1-4 regarding design rules for base plates and anchor bolts.

31. Date and place of next meetings

The next ECCS TC 10 & Evolution Group EC3 Part 1.8 meeting will be held on ***Thursday 10th and Friday 11th of October 2013 in Karlsruhe*** on kind invitation of Thomas Ummenhofer
The meeting will take place at:
Karlsruher Institut für Technologie (KIT) – Stahl- und Leichtbau
Versuchsanstalt für Stahl, Holz und Steine
Otto-Ammann-Platz 1
Geb. 10.81, Raum 318 (large meeting room)
76131 Karlsruhe

The meeting after Karlsruhe will be held in Coimbra (Portugal) on 10 and 11 April 2014

Closure

The chairman thanked our host **Jean Pierre Jaspart** for the hospitality and the participants for their contribution to the meeting.

Date: September 2013
Edwin Belder
Secretary ECCS TC10

Priloga 3

Može, Primož

From: Ove Lagerqvist <ove@prodevelopment.se>
Sent: 20. marec 2014 9:28
To: Može, Primož
Cc: U.Kuhlmann@ke.uni-stuttgart.de
Subject: Re: EvG EN 1993-1-12 - Preliminary agenda for the 2nd meeting in Stockholm 2014-04-03

Dear Dr Moze,

You are very welcome!

It would be grateful if you can give a presentation on your work with net cross-section and bearing resistance of HSS.

So far, the following have confirmed participation in the meeting:
Ulrike Kuhlmann
Bernt Johansson
Jouko Kuohi
Richard Stroetmann

Best regards,
Ove

Från: Može, Primož <Primoz.Moze@fgg.uni-lj.si>
Datum: torsdag 20 mars 2014 09:20
Till: Ove Lagerqvist <ove@prodevelopment.se>
Kopia: "U.Kuhlmann@ke.uni-stuttgart.de" <U.Kuhlmann@ke.uni-stuttgart.de>
Ämne: RE: EvG EN 1993-1-12 - Preliminary agenda for the 2nd meeting in Stockholm 2014-04-03

Dear Prof Langerquist,

Thank you for the invitation. I confirm my participation. If you agree, I could give short presentation on the verification of net cross-section and bearing resistance of HSS.

Kind regards,

Primož Može

Primož MOŽE, Ph.D., C.E.
University of Ljubljana
Faculty of Civil and Geodetic Engineering
Chair for Metal Structures
Jamova 2, SI-1000 Ljubljana, Slovenia
tel.: + 386 1 476 8 625
fax.: + 386 1 476 8 629
e-mail: primoz.moze@fgg.uni-lj.si

From: Ove Lagerqvist [mailto:ove@prodevelopment.se]
Sent: Wednesday, March 19, 2014 9:36 PM

To: Može, Primož
Subject: FW: EvG EN 1993-1-12 - Preliminary agenda for the 2nd meeting in Stockholm 2014-04-03

Dear Primos,

As suggested by Ulrike Kuhlmann (see below) I invite you to the meeting with EvG EN 1993-1-12 in Stockholm 2014-04-03.

Ove Lagerqvist,
Convenor for EvG EN 1993-1-12

Dear Ove,
I confirm my participation.
In addition I suggest to invite Primos Moze from the University of Ljubljana (primoz.moze@fgg.uni-lj.si) to contribute in replacement of Darko Beg who was always an active member of this group. As you might know they have worked on the issue of bolted connections for HSS and should be able to give a valuable contribution.
Looking forward seeing you
Best regards
Ulrike

Från: Ove Lagerqvist <ove@prodevelopment.se>
Datum: måndag 17 mars 2014 22:18
Till: Ove Lagerqvist <ove@prodevelopment.se>, "bucak@bau.hm.edu" <bucak@bau.hm.edu>, "feldmann@stb.rwth-aachen.de" <feldmann@stb.rwth-aachen.de>, Bernt Johansson <bernt.h.johansson@gmail.com>, "jouko.kouhi@rakennusteollisuus.fi" <jouko.kouhi@rakennusteollisuus.fi>, "U.kuhlmann@ke.uni-stuttgart.de" <U.kuhlmann@ke.uni-stuttgart.de>, "richard.stroetmann@tu-dresden.de" <richard.stroetmann@tu-dresden.de>, Milan Veljkovic <Milan.Veljkovic@ltu.se>, "laurence.davaine@ingerop.com" <laurence.davaine@ingerop.com>
Kopia: "rasche@ing-nellingen.de" <rasche@ing-nellingen.de>, Andreas Kleiner <Andreas.Kleiner@ke.uni-stuttgart.de>, Silvia Ankelin <Silvia.Ankelin@ke.uni-stuttgart.de>, "Måns Sjölander (SIS)" <mans.sjolander@sis.se>
Ämne: EvG EN 1993-1-12 - Preliminary agenda for the 2nd meeting in Stockholm 2014-04-03

Dear all,

As I informed you a couple of weeks ago the second meeting with EvG EN 1993-1-12 will be in Stockholm according to the following:
Date: Thursday 3 April 2014
Place: SIS, Swedish Standards Institute, Sankt Paulsgatan 6, Stockholm (see attached map)
Room: Oden (in SIS conference centre)
Hours: 10.00 – 17.00

I attach a preliminary agenda for the meeting. Feel free to suggest additional items. I also attach (again) the minutes from our previous meeting in Stuttgart and document N1986 together with some of the other documents we discussed at the meeting in Stuttgart.

I am grateful if you inform me (and all others) if you will attend the meeting or not. Until now Richard Stroetmann and Bernt Johansson have confirmed participation in the meeting.

Bets regards,
Ove Lagerqvist

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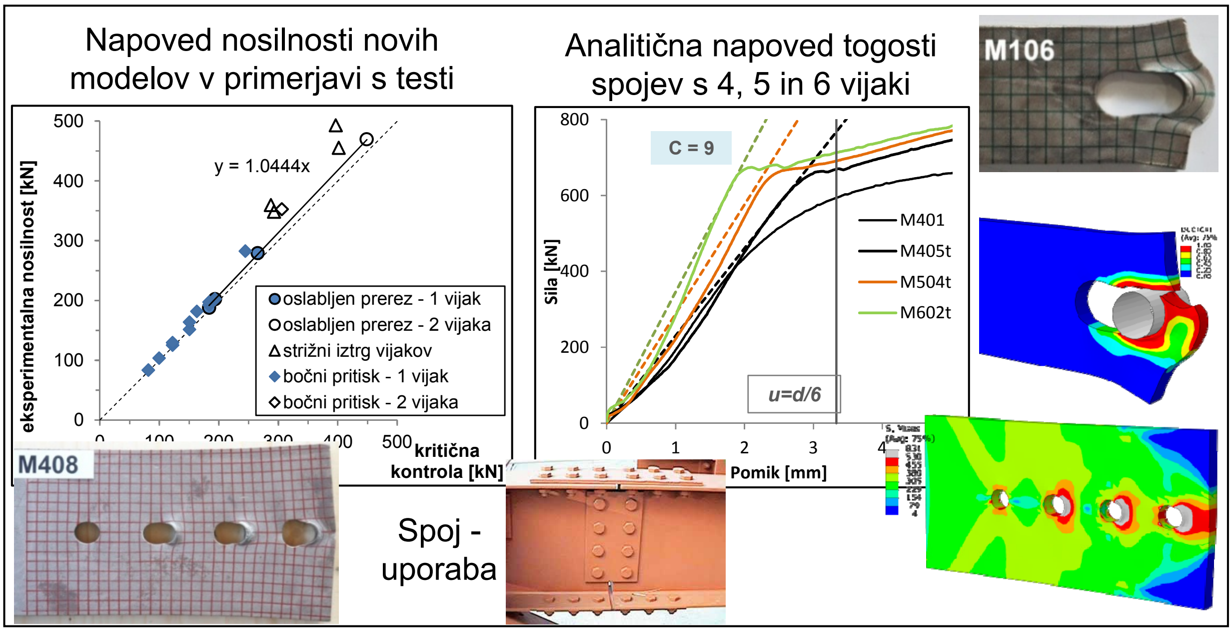
www.prodevelopment.se

Priloga 4

TEHNIKA
Področje: 2.01 Gradbeništvo

Dosežek 1: Analiza koncentriranega vnosa sil v vijačenih spojih z zagotavljanjem duktilnosti

Vir: Može, Primož, Beg, Darko. 2014. A complete study of bearing stress in single bolt connections. Journal of Constructional Steel Research, 95, 0: 126-140.



Vijačeni preklopni spoji so pogost tip stikovanja jeklenih elementov. Vijaki kot vezno sredstvo prenašajo obremenitve med spojenimi elementi. Torej, vijaki z bočnimi pritiski predstavljajo koncentriran vnos sil v jekleno pločevino. Če material nima zadostne duktilnosti, koncentracija napetosti povzroči začetek loma. Konstrukcijsko jeklo običajne kvalitete je duktilno in zagotavlja otopitev napetostnih konic in s tem prenos obremenitve med veznimi sredstvi. Seveda je zaradi nelinearnosti težko določiti nosilnost in napovedati porušni mehanizem. V okviru projekta je bilo testiranih 48 preklopnih spojev z največ šestimi vijaki. Na podlagi verificiranih numeričnih modelov je bil analiziran vpliv geometrije in materiala na nosilnost in razpored napetosti v preklopnih spojih. Ti rezultati in rezultati testov iz literature so služili za razumevanje mehanizma prenosa obremenitev, na podlagi česar je bil razvit nov model za kontrolo bočnega pritiska v pločevini. Predlagani model obravnava jekla običajnih trdnosti in jekla visoke trdnosti. Ovrednotena je bila tudi deformacijska kapaciteta pločevine v bočnem pritisku, ki izraža mero duktilnosti. Razvit je bil tudi analitični model z nadomestnimi vzmetmi za račun togosti pločevine v bočnem pritisku.

Rezultati so bili predstavljeni mednarodnim tehničnim odborom, z namenom, da se novo znanje vključi v revidirane evropske standarde. Pričakujemo, da bodo predvidene spremembe uspešno vključene v standarde, saj so predlagane rešitve enostavnejše in manj konservativne od obstoječih.