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Inovativne metode određivanja tvrdoće i gustoće drva

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Sažetak – Tvrdoća i gustoća drva ubrajaju se među najvažnija tehnička svojstva drvenih podnih obloga. Standardizirane metode određivanja navedenih svojstava postoje, ali se u tvorničkim uvjetima vrlo rijetko koriste. Razlog tome je što iziskuju skupocjenu specijaliziranu opremu, velik broj ispitnih uzoraka, osposobljeno mjerno osoblje te vremenski relativno dugo traju. Iz tih razloga pojavila se potreba za jednostavnijim, bržim i jeftinijim načinom za određivanje spomenutih svojstava drva. U radu je istražena mogućnost supstitucije standardne metode za određivanje tvrdoće po Brinellu s metodom relativne veličine utiska (RVU), te također mogućnost supstitucije standardne metode ispitivanja gustoće drva (HRN ISO 3131:1975) metodom mjerenja mase podnih elemenata poznatog volumena. Cilj istraživanja je pronalazak znanstveno utemeljenog, jednostavnijeg, bržeg i jeftinijeg načina određivanja spomenutih svojstava drva. Inovativne metode pokazale su se kao vrlo jednostavne i korisne s zadovoljavajućim rezultatima za praktičnu uporabu.

tvrdoća drva / gustoća drva / standardne metode / inovativne metode

1. UVOD

Tvrdoća i gustoća drva ubrajaju se među najvažnija tehnička svojstva drvenih podnih obloga. Tvrdoća se opisuje kao otpor materijala zadiranju stranog tijela u njegovu strukturu odnosno njegovu površinu. Gustoća drva je u direktnoj korelaciji s tvrdoćom drva. Vrste drva veće gustoće u pravilu karakterizira veća tvrdoća i obrnuto.

Postoje standardne metode za određivanje tvrdoće i gustoće drva. Tvrdoća drva najčešće se mjeri metodama po Brinellu (HRN EN 1534:2010) i Janki (HRN ISO 3350:1999) (NIEMZ i STÜBI 2000). Kod obje metode tvrdoća drva se mjeri utiskivanjem čelične kugle određenog promjera u površinu drva. Tvrdoća drva se mjeri na specijaliziranom mjernom uređaju koji je uglavnom stacioniran u jednom prostoru te s njime nije moguće izvoditi mjerenja na različitim lokacijama kao što su pogoni ili stambeni objekti. Standardna metoda određivanja gustoće drva (HRN ISO 3131:1999) također iziskuje specijaliziranu opremu te izradu relativno velikog broja ispitnih uzoraka, propisanih dimenzija.

Iako su standardne metode za određivanje tvrdoće i gustoće kod drva općeprihvaćene i znanstveno utemeljene, u tvorničkim uvjetima se vrlo rijetko koriste. Razlog tome je što iziskuju skupocjenu specijaliziranu opremu, velik broj ispitnih uzoraka, osposobljeno mjerno osoblje te vremenski relativno dugo traju. Iz tih razloga pojavila se potreba za jednostavnijim, bržim i jeftinijim načinom za određivanje spomenutih svojstava drva.

Standardnu metodu za određivanje tvrdoće po Brinellu moguće je zamijeniti metodom relativne veličine utiska (RVU) (BREHM, 2006). BREHM (2006) spominje mogućnost posrednog određivanja tvrdoće drva metodom pada čelične kuglice s određene visine na uzorak, pri čemu se u ovisnosti o promjeru ulupka zaključuje o tvrdoći drva. Navod literature je nepotpun i nepouzdan, pa je opravdanost primjene ove metode moguća usporedbom s metodom po Brinellu. Iako se u osnovi radi o dva razičita fizikalna principa ispitivanja (kod Brinella se radi o statičkom ispitivanju tvrdoće utiskivanjem profiliranog tijela, dok se kod RVU radi o dinamičkoj otpornosti na udar (HERRMANN i sur. 2006), pretpostavka je da bi metode mogle biti u dobroj korelaciji. S obzirom da je metodu relativne veličine uzorka lako izvesti na terenu i nije potrebna zahtjevna oprema, mogla bi poslužiti kao alternativna metoda za mjerenje tvrdoće parketa u pogonu ili na zgradama.

Gustoća drva je odnos mase i volumena drva. U proizvodnji drvenih podnih obloga posebna se pozornost obraća na točnost dimenzija svakog pojedinog elementa. Uz pretpostavku da su svi elementi jednakih dimenzija (uključujući utore i pera), tada im je jednak i volumen. Ako je poznat volumen, gustoću svakog pojedinog elementa moguće je izmjeriti mjerenjem mase na vagi.

2. CILJ ISTRAŽIVANJA

Cilj istraživanja je usporedba standardnih metoda određivanja tvrdoće i gustoće kod drva s nekonvencionalnim metodama u svrhu jednostavnijeg, bržeg i jeftinijeg načina određivanja spomenutih svojstava drva.

Prvi cilj je usporedba standardne metode ispitivanja tvrdoće po Brinellu (HRN EN 1534:2010) i metode RVU (Relativne veličine utiska) opisane u stručnoj literaturi (BREHM, 2006). Metoda ispitivanja RVU omogućuje mjerenje tvrdoće pojedinih podnih elemenata iz različitih vrsta drva u vrlo kratkom vremenskom periodu. Također omogućuje provođenje mjerenja s zadovoljavajućom točnošću na različitim lokacijama, a da za to nije potrebna zahtjevna i skupocjena mjerna oprema. Jedan od ciljeva je standardizacija primjene RVU metode u proizvodnim pogonima podnih obloga, te kod ekspertiza i ispitivanja ugrađenih drvenih podova. Čest je slučaj pritužbi novo useljenih stanara da parket nema odgovarajuću tvrdoću jer na njemu zaostaju tragovi od npr. utiska nogu stolica ili potpetica, što je nemoguće provjeriti bez razornog izuzimanja uzoraka za Brinell ispitivanje u laboratoriju.

Drugi cilj je mogućnost supstitucije standardne metode ispitivanja gustoće drva (HRN ISO 3131:1975) metodom mjerenja mase podnih elemenata poznatog volumena. Takav način mjerenja omogućio bi proizvođaču zadovoljavajuće točnu informaciju o gustoći drva, bez skupog i kompliciranog standardnog mjerenja. Instalacijom takvog mjerenja u proizvodnu liniju omogućilo bi automatsko odbacivanje elementa premale ili prevelike gustoće u odnosu na uobičajeni raspon vrijednosti, koja nepovoljno utječe i na ostala svojstva podnih obloga kao što su tvrdoća, bubrenje i utezanje i sl.

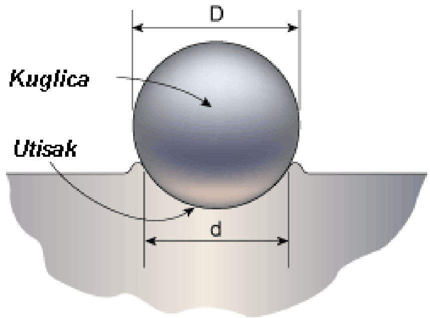
3. MATERIJAL I METODE ISTRAŽIVANJA

3.1. Određivanje tvrdoće drva

Usporedno mjerenje tvrdoće drva metodom po Brinellu i metodom RVU obavljeno je na 8 različitih vrsta drva s po 10 uzoraka klasičnog parketa dimenzija 22×56×500 mm za svaku vrstu drva. Od vrsta drva ispitivane su: bagremovina, bukovina, grabovina, hrastovina, jasenovina, javorovina, johovina i trešnjevina. Za svaku vrstu drva utisnuto je po 50 utisaka metodom po Brinellu i 50 utisaka metodom RVU. Sadržaj vode svih uzoraka kretao se u granicama od 7-11%.

3.1.1. Ispitivanje tvrdoće metodom po Brinellu (HRN EN 1534:2010)

Tvrdoća drva po Brinellu ispitana je utiskivanjem čelične kuglice (slika 1) promjera 10±0,01 mm silom koja je u vremenskom periodu od 15±3 s morala dostići 1 kN, te je tu silu bilo potrebno kontinuirano održavati 25±5 s. Nakon utiskivanja mjerena su dva unakrsna promjera utiska; paralelno s vlakancima (d_1) i okomito na vlakanca (d_2) s točnošću od ± 0,2 mm te je izračunata tvrdoća prema izrazu (1). Ispitivanje je provedeno na univerzalnom stroju za ispitivanje mehaničkih svojstava drva (Otto Wolpert – Werke GMBH model U4).



Slika 1. Skica načina ispitivanja tvrdoće drva po Brinellu i RVU

Tvrdoća po Brinellu izračunata je prema izrazu (1):

$$HB = \frac{2 \times F}{g \times \pi \times D \times \left[D - (D^2 - d^2)^{\frac{1}{2}}\right]} \qquad (1)$$

HB – tvrdoća po Brinellu (kN/mm²)
F – nominalna sila (1 kN)
g – ubrzanje gravitacijske sile od ≈10 m/s²
D – promjer čelične kuglice od 10 mm
d – srednja vrijednost promjera utiska (mm)
π – „pi" faktor, (≈ 3,14)

3.1.2. Ispitivanje tvrdoće metodom određivanja relativne veličine utiska (RVU)

Tvrdoća drva metodom RVU ispitana je tako da je čelična kugla puštana slobodnim padom kroz cijev, nakon čega su mjerena dva unakrsna promjera utiska; paralelno s vlakancima (d_1) i okomito na vlakanca (d_2) s točnošću od ±0,2 mm (slika 1).

Za ispitivanje je korištena čelična kugla i PVC cijev. S obzirom da većina podopolagača koristi CM uređaj za mjerenje sadržaja vode estriha prije polaganja drvenih podova, korištena je najveća kugla iz kompleta, promjera 30 mm i težine 110 g. PVC cijev korištena u ispitivanju promjera je 35 mm i dužine 1,5 m. Razlika promjera kuglice i cijevi od 5 mm smatrana je dovoljnom da se zanemari trenje kuglice u cijevi, tj. da se dužina cijevi od 1,5 m uzme kao visina slobodnoga pada.

Vodilo se računa da su dva utiska (Brinell i RVU) što bliže jedan drugome, u parovima, zbog razlike u gustoći duž pojedinačne daščice (slika 2).

Slika 2. Kugla iz CM uređaja i utisak kugle po RVU (lijevo); kuglica i utisak po Brinell-u (desno)

3.2. Određivanje gustoće drva

Mjerenje gustoće drva obavljeno je na 8 različitih vrsta drva s po 10 uzoraka klasičnog parketa dimenzija 22×56×400 mm i 21×70×300 mm za svaku vrstu drva. Od vrsta drva ispitivane su: bagremovina, bukovina, grabovina, hrastovina, jasenovina, javorovina, johovina i trešnjevina. Nakon odabira uzoraka klasičnog parketa koji su odgovarali napucima norme (HRN ISO 3131:1975), isti su vagani te im je određena masa. Iz razloga što su uzorci klasičnog parketa nepravilnog oblika njihov volumen nije bilo moguće odrediti pomičnim mjerilom. Da bi se odredio točan volumen izvaganih daščica klasičnog parketa izrađeni su 3D modeli u programu SolidWorks. Na osnovi izrađenih modela određen je koeficijent volumena, tj. razlika između stvarnog volumena daščica i volumena određenog umnoškom osnovnih dimenzija daščica. Na temelju koeficijenta volumena određene su gustoće izvaganih uzoraka parketa. Osim za navedene dvije dimenzije masivnog parketa izrađeni su 3D modeli za ukupno 15 različitih dimenzija drvenih podnih elemenata.

4. REZULTATI I DISKUSIJA

4.1. Određivanje tvrdoće drva

Tablica 1. Statistička odstupanja promjera utisaka pojedine vrste drva od srednje vrijednosti za preračun iz metode RVU u metodu po Brinellu.

	Promjer utiska Db za HB (n = 50)			Promjer utiska Dr za RVU (n = 50)			Odnos promjera za preračun vrijednosti Db/Dr	Odstupanje odnosa promjera pojedine vrste drva od srednje vrijednosti za preračun (%)	Stat. znač. odstupanja odnosa za preračun vrijednosti od srednjeg odnosa za preračun vrijednosti
	s.v.	st. dev.	k.v.	s.v.	st. dev.	k.v.			
JO	7,79	0,397	5,10	11,09	0,675	6,09	**0,702**	5,32	značajno
TR	7,18	0,864	12,04	10,88	0,815	7,49	**0,660**	-1,03	ne značajno
JAV	6,66	0,513	7,71	9,51	0,422	4,44	**0,700**	4,99	značajno
GR	6,05	0,476	7,86	9,03	0,476	5,27	**0,670**	0,52	ne značajno
HR	5,67	0,584	10,3	8,53	0,794	9,31	**0,665**	-0,30	ne značajno
BU	5,56	0,314	5,65	8,47	0,753	8,89	**0,656**	-1,60	ne značajno
BAG	5,06	0,356	7,04	8,31	0,533	6,41	**0,608**	-8,80	značajno
JAS	5,44	0,627	11,51	8,09	0,805	9,95	**0,673**	0,91	ne značajno
				srednja vrijednost			**0,667**		
				standardna devijacija			0,029		
				koeficijent varijacije			4,398		

Legenda: Db – promjer utiska po Brinellu, Dr – promjer utiska po RVU, s.v. – srednja vrijednost, st.dev. – standardna devijacija, k.v. – koeficijent varijacije, JO – johovina, TR – trešnjevina, JAV – javorovina, GR – grabovina, HR – hrastovina, BU – bukovina, BAG – bagremovina, JAS – jasenovina.

U tablici 1 načinjena je statistička analiza skupova utisaka u svrhu izračuna pretvorbenog faktora dimenzija utiska dobivenih metodom RVU i metodom po Brinellu. Intencija je da se jednoznačnim koeficijentom pretvorbe omogući izračunavanje tvrdoće drva temeljem promjera utisaka metodom RVU, bez kompliciranog laboratorijskog mjerenja metodom po Brinellu. Iz tablice 1. vidljivo je da odstupanja odnosa promjera pojedine vrste drva od srednje vrijednosti za preračun u pravilu nisu veća od 9 %, te da oni odnosi koji su manji od 4,5 % nemaju statistički značajna odstupanja. To znači da temeljem navedenog možemo utvrditi koeficijent za preračun vrijednosti za izračun tvrdoće po Brinellu za svaku pojedinu vrstu drva. Pri tome se smatra da odstupanje koeficijenata od 5 %, čak i ako je statistički značajno, nije tehnološki značajno, odnosno ono je zadovoljavajuće za pogonske i gradilišne uvjete. Prema izračunu za 8 vrsta drva pretvorbeni faktor iznosi 0,667, tj. promjer utiska dobiven metodom RVU treba pomnožiti prema izrazu (2) da se dobije promjer po Brinellu.
Tvrdoća po Brinellu dobivena metodom RVU izračunata je prema izrazu (2):

$$d_{HB} = k \times d_{RVU}$$

$$HB = \frac{2 \times F}{g \times \pi \times D \times \left[D - (D^2 - d_{HB}{}^2)^{\frac{1}{2}}\right]} \qquad (2)$$

HB – tvrdoća po Brinellu (kN/mm²)
F – nominalna sila (1 kN)
g – ubrzanje gravitacijske sile od ≈10 m/s²
D – promjer čelične kuglice od 10 mm
d_{HB} *– preračunata srednja vrijednost promjera utiska prema Brinellu (mm)*
d_{RVU} *–srednja vrijednost promjera utiska prema metodi RVU (mm)*
k – pretvorbeni faktor od 0,667

Tablica 2 predstavlja višestruku analizu varijanci skupova, od kojih svaki obuhvaća 50 utisaka po pojedinoj vrsti drva i metodi utiskivanja. Na temelju prikazanih p vrijednosti moguće je uočiti koji se skupovi utisaka (za bilo koju vrstu drva i za bilo koju od dviju metoda) statistički značajno razlikuju. Ukoliko većina međusobnih kombinacija ne bi bila značajno različitih rasipanja, onda bi se moglo utvrditi da pretvorbeni faktor promjera utiska RVU u promjere utiska po Brinellu u iznosu od 0,667 pouzdano vrijedi za sve vrste drva.

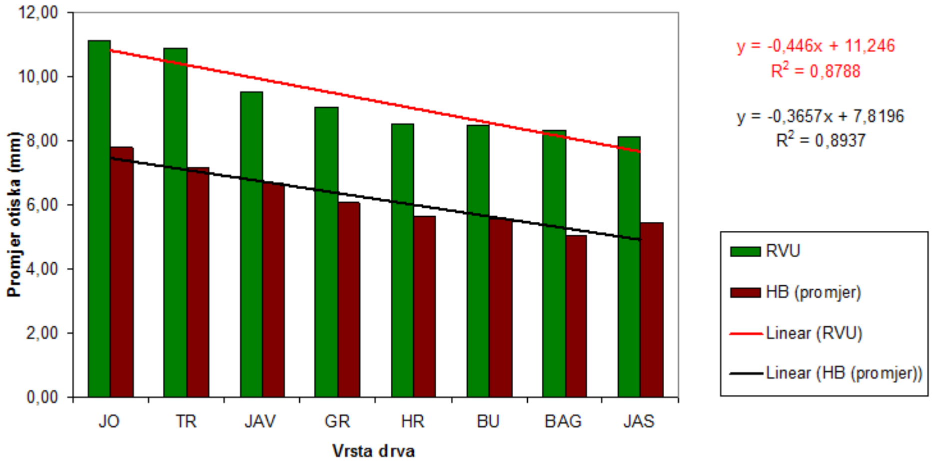
S obzirom da je iz tablice 2 vidljivo da se bagremovina statistički značajno razlikuje od svih vrsta drva (jer je imala skoro 9 % niži koeficijent pretvorbe od prosječnoga), te da se johovina statistički razlikuje samo u odnosu na bukovinu, možemo utvrditi da pretvorbeni faktor vrijedi za većinu ispitanih vrsta drva osim za bagremovinu. Ako bi se bagremovina isključila iz proračuna, tada se srednja vrijednost sa 0,667 diže na 0,675, pa ni johovina više ne bi bila statistički značajno različitih vrijednosti od bukovine.

Odstupanja od 5 % za johovinu ili 8,8 % za bagremovinu, ako su i statistički značajna, nisu tehnološki značajna, jer je odstupanje promjera ulupka znatno manje nego što je raspon standardnih gustoća pojedine vrste drva, pa se mogućnost jako pogrešne procjene tvrdoće drva, uzrokovana greškom u pretvorbenom faktoru manjom od 10 %, može smatrati malo utjecajnom.

Tablica 2. Višestruka usporedba utiska RVU-a sa utiskom po Brinellu

	JO R: 257,84	TR R: 195,05	JAV R: 252,09	GRA R: 206,05	HRA R: 198,25	BUK R: 180,06	JAS R: 205,58	BAG R: 109,08
JO		0,1853	1,0000	0,7030	0,2790	0,0215	0,6668	0,0000
TR	0,1853		0,3817	1,0000	1,0000	1,0000	1,0000	0,0056
JAV	1,0000	0,3817		1,0000	0,5569	0,0515	1,0000	0,0000
GR	0,7030	1,0000	1,0000		1,0000	1,0000	1,0000	0,0008
HR	0,2790	1,0000	0,5569	1,0000		1,0000	1,0000	0,0032
BU	0,0215	1,0000	0,0515	1,0000	1,0000		1,0000	0,0600
JAS	0,6668	1,0000	1,0000	1,0000	1,0000	1,0000		0,0008
BAG	0,0000	0,0056	0,0000	0,0008	0,0032	0,0600	0,0008	

Legenda: JO – johovina, TR – trešnjevina, JAV – javorovina, GR – grabovina, HR – hrastovina, BU – bukovina, BAG – bagremovina, JAS – jasenovina, crvenom bojom označene p vrijednosti označavaju kombinacije skupova koji se međusobno statistički značajno razlikuju.



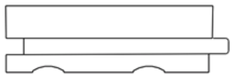
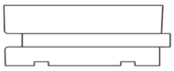
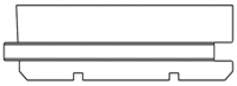
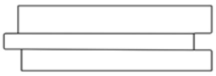
Slika 3. Usporedba utiska tvrdoće po Brinellu i RVU

Rezultati mjerenja promjera utiska za tvrdoću po Brinellu i tvrdoću po metodi RVU pokazuju da je stupanj korelacije za 8 vrsta drva vrlo visok što vidljivo iz slike 3. Odnosom prosječne izmjerene vrijednosti metodom RVU i prosječne vrijednosti utiska po Brinellu utvrđeno je da pretvorbeni faktor varira od *0,6-0,7* ovisno o vrsti drva.

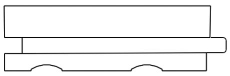
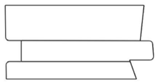
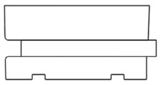
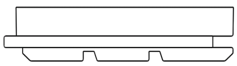
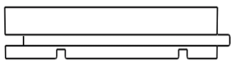
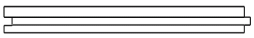
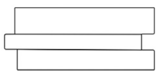
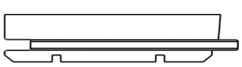
4.1. Određivanje gustoće drva

U tablici 3 i 4 prikazani su izrađeni 3D modeli za ukupno 15 različitih dimenzija drvenih podnih elemenata. Na elementima je izračunat idealni i stvarni volumen i izračunato je njihovo odtupanje. U tablici 4 vidljivo je da su odstupanja idealnog volumena manja od 5,5 %, te da je kod daščica većih dimenzija odstupanje proporcionalno manje nego kod manjih daščica. Također je uočljivo da oblik daščice utječe na odstupanje. Na uzorku 6 odstupanje je zanemarivih 0,37 % dok je kod uzorka složenijeg oblika (tip 4) odstupanje 4,55b%. Uzorak 9 jasno prikazuje tezu kako manji uzorci imaju veća odstupanja od idealnog volumena. U tablici 3 u kojoj su prikazani različiti profili parketnih daščica istih dimenzija vidljivo je da su odstupanja slična, osim između vrlo složenog i jednostavnog profila gdje su odstupanja u rasponu od 1,13 % do 5,39 % što je ekvivalent masi od 24,3 g.

Tablica 3. Odnos odstupanja idealnog od stvarnog volumena pojedinih oblika masivnih parketnih daščica istih dimenzija

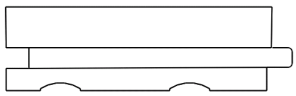
Red. br.	Profil parketa	Dimenzije (mm)			Volumen (cm³)		Odstupanje
		debljina	širina	dužina	idealni	stvarni	%
1		22	65	300	429,00	414,39	**3,41**
2		22	65	300	429,00	412,27	**3,90**
3		22	65	300	429,00	416,09	**3,01**
4		22	65	300	429,00	405,86	**5,39**
5		22	65	300	429,00	416,13	**3,00**
6		22	65	300	429,00	424,15	**1,13**

Tablica 4. Odnos odstupanja idealnog od stvarnog volumena pojedinih oblika masivnih parketnih daščica

Red. br.	Profil parketa	Dimenzije (mm)			Volumen (cm³)		Odstupanje
		debljina	širina	dužina	idealni	stvarni	%
1		21,5	70	500	752,50	728,27	**3,22**
2		21	40	300	252,00	240,08	**4,73**
3		22,5	45	300	303,75	292,07	**3,85**
4		14	70	450	441,00	420,92	**4,55**
5		14	75	350	367,50	358,57	**2,43**
6		10	30	300	90,00	88,77	**1,37**
		10	70	500	350,00	348,72	**0,37**
7		21	70	750	1102,50	1074,77	**2,52**
		21	70	500	735,00	715,51	**2,65**
8		22	56	400	492,80	485,99	**1,38**
		22	56	500	616,00	607,56	**1,37**
9		14	50	300	210,00	201,17	**4,20**
		14	70	500	490,00	476,12	**2,83**
		14	90	1000	1260,00	1232,04	**2,22**

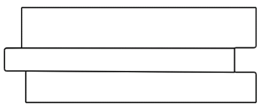
Tablice 5 i 6 prikazuju minimalne i maksimalne dozvoljene mase daščica parketa uz odstupanje volumena na 8 vrsta drva. Odstupanje se odnosi na razliku idealnog i stvarnog volumena daščica kod 15 % sadržaja vode. Za određivanje minimalne i maksimalne mase parketnih elemenata koristila se formula (4), dok se za određivanje gustoće daščica unutar područja od 7 do 17 % sadržaja vode koristila preračunska formula (3).

Tablica 5. Prikaz masa daščice konstrukcijskog tipa 1 iz tablice 3 za 8 vrsta drva

Dimenzije (mm)			Vrsta drva	Gustoća (g/cm^3)	Masa (g)		
debljina	**širina**	**dužina**		$\rho_{15\%}$	**min.$_{OD}$**		**max.$_{OD}$**
21	70	300	**Bagrem**	0,74..0,80	306,4	**326,2**	352,5
Volumen (cm^3)		**Odstupanje**	**Bukva**	0,70..0,79	289,9	**311,2**	348,1
idealni	**stvarni**	**%**	**Grab**	0,75..0,86	310,6	**359,9**	378,9
441	427,35	3,10	**Hrast**	0,65..0,76	269,2	**286,3**	334,9
			**Jasen**	0,68..0,76	281,6	**312,7**	334,9
			Javor	0,61..0,66	252,6	**277,1**	290,8
			Joha	0,49..0,57	202,9	**234,3**	251,1
			Trešnja	0,56..0,66	231,9	**241,8**	290,8

*Legenda: **min.$_{OD}$** – minimalna dozvoljena masa uzorka uz odstupanje od 3,1 %, **max.$_{OD}$** – maksimalna dozvoljena masa uzorka uz odstupanje od 3,1%. Gustoća kod 15% sadržaja vode (SELL, 1997).*

Tablica 6. Prikaz masa daščice konstrukcijskog tipa 8 iz tablice 3 za 8 vrsta drva

Dimenzije (mm)			Vrsta drva	Gustoća (g/cm^3)	Masa (g)		
debljina	**širina**	**dužina**		$\rho_{15\%}$	**min.$_{OD}$**		**max.$_{OD}$**
22	56	400	**Bagrem**	0,74..0,80	354,7	**361,1**	394,2
Volumen (cm^3)		**Odstupanje**	**Bukva**	0,70..0,79	335,5	**352,4**	389,2
idealni	**stvarni**	**%**	**Grab**	0,75..0,86	359,5	**398,3**	423,7
492,8	485,99	1,38	**Hrast**	0,65..0,76	311,5	**365,2**	374,4
			**Jasen**	0,68..0,76	325,9	**333,8**	374,4
			Javor	0,61..0,66	292,4	**310,0**	325,2
			Joha	0,49..0,57	234,8	**256,3**	280,8
			Trešnja	0,56..0,66	268,4	**292,3**	325,2

Legenda: min.$_{OD}$ – minimalna dozvoljena masa uzorka uz odstupanje od 1,38 %, max.$_{OD}$ – maksimalna dozvoljena masa uzorka uz odstupanje od 1,38%. Gustoća kod 15% sadržaja vode (SELL, 1997).

Formula za preračunavanje gustoće kod nekog sadržaja vode u rasponu od 7 do 17 % (3):

$$\rho_W = \rho_0 \times \frac{1+W}{1+0,84 \times \rho_0 \times W} \quad (3)$$

ρ_w – gustoća kod nekog sadržaja vode (g/cm^3)
ρ_0 – gustoća u apsolutno suhom stanju (g/cm^3)
W – sadržaj vode

Formule za izračun minimalne i maksimalne mase parketnih elemenata (4):

$$V_{stvarni} = V_{idealni} \times k \quad (4)$$

$$m_{min} = \rho_{W\,min} \times V_{stvarni}$$

$$m_{max} = \rho_{W\,max} \times V_{stvarni}$$

$V_{stvarni}$ *– stvarni volumen (cm^3)*
$V_{idealni}$ *– idealni volumen (cm3)*
k – faktor oblika (odstupanje)

4. ZAKLJUČCI

Usporedba standardiziranoga mjerenja tvrdoće drva po Brinellu i procjene tvrdoće metodom relativne veličine utiska (RVU) pokazala je vrlo zadovoljavajuće rezultate. Iz rezultata se može pretpostaviti da bi metoda RVU mogla zamijeniti metodu po Brinellu u pogonskim, odnosno gradilišnim uvjetima gdje mala odstupanja koeficijenta za preračun vrijednosti nisu tehnološki značajna.

Metoda procjene gustoće drva mjerenjem mase daščica u proizvodnji parketa pokazala se vrlo jednostavnom i korisnom. Za kvalitetan rezultat potreban je samo izračun stvarnoga volumena parketne daščice koji se lako odredi u 3D programu po izboru. Tako je moguće utvrditi granice raspona masa unutar kojih se moraju nalaziti parketne daščice u proizvodnji.

4. LITERATURA

BREHM, T. (ED.), (2006): *Fachbuch für Parkettleger*. SV Fachverlag, Hamburg.

HERRMANN, K.; PATKOVSZKY, I.; BEHRENS, B.A.; KAMMLER, M., (2006): *Anwendung dynamischer Kräfte in der Werkstoffprüfung*. Technisches Messen 73: 646-654.

NIEMZ, P.; STÜBI, T., (2000): *Investigations of hardness measurements on wood based materials using a new universal measurement system.* In: Proc. Symp. on "Wood machining, properties of wood and wood composites related to wood machining". Vienna, Austria, September, 2000. 51-61.

BREHM, T. (ED.), (2006): *Fachbuch für Parkettleger*. SV Fachverlag, Hamburg.

SELL, J. (1997): *Eigenschaften und Kenngrössen von Holzarten*. LIGNUM: Zürich

HRN EN STANDARD 1534 (1999): Wood and parquet flooring - Determination of resistance to indentation (Brinell).

HRN ISO STANDARD 3131 (1999): Wood – Determination of density for physical and mechanical tests.

HRN ISO STANDARD 3350 (1999): Wood – Determination of static hardness.

Innovative test methods for determination of the wood hardness and density

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Summary - Hardness and density of the wood are considered to be among the most important technical properties of wood flooring. There are standardized methods for determining specified properties, but in factory conditions they are rarely used. The reason is that they require expensive specialized equipment, a large number of test samples, trained staff, and they are relatively long lasting. For these reasons, there was a need for simpler, faster and less expensive method to determine the above mentioned properties of wood. This paper explores the possibility of substitution of the standard methods for determining Brinell hardness with the method of the relative size of the impression (RSI), and also the possibility of substitution of standard test methods for determine wood density (ISO 3131: 1975) with method of measuring the mass of floor elements whose volume is known. The aim of the research is finding a scientifically based, simpler, faster and cheaper ways of determining the aforementioned properties of wood. Innovative methods have proven to be very simple and useful with satisfactory results for practical use.

wood hardness / wood density / standard test methods / innovative test methods

1. INTRODUCTION

Hardness and density of the wood are considered to be among the most important technical properties of wood flooring. Hardness is described as a resistance material encroachment of a foreign body in its structure and its surface. Density of wood is in direct correlation with hardness of the wood. Wood species with higher density are generally characterized with higher hardness and vice versa.

There are standard methods to determine hardness and density of the wood. Hardness of the wood is most commonly measured with Brinell method (EN 1534: 2010) and Janka method (ISO 3350: 1999) (NIEMZ and STÜBI, 2000). Both methods for determining hardness of wood are measured by injecting a steel ball of certain diameter in the wood surface. Hardness of wood is measured with specialized measuring instrument that is mostly stationed in one place, and with it is not possible to perform measurements at different locations such as plants or residential buildings. Standard method for determining density of wood (ISO 3131: 1999) also requires specialized equipment and making a relatively large number of test samples with specified dimensions.

Although standard methods for determining hardness and density of wood are generally accepted and scientifically based, in factory conditions they are rarely used. The reason is that they require expensive specialized equipment, a large number of test samples, trained measuring staff, and they are relatively long lasting. For these reasons, there was a need for simpler, faster and less expensive method to determine the above mentioned properties of wood.

Standard method for determining Brinell hardness can be replaced using the relative size of the impression (RSI) (BREHM, 2006). BREHM (2006) mentions the possibility of indirect determination of hardness of the wood with the use of steel ball that falls from a certain height on the sample. Whereby depending on the diameter impression concludes on the hardness of the wood. Quoted literature is incomplete and unreliable, so the justification of the use of this method is possible by comparison with the Brinell method. Although, basically these are two differed physical principles tests (Brinell hardness is the static test of the indentation by moulded body, and RSI method is a test of dynamic impact resistance (HERRMANN et al. 2006)), the assumption is that methods could be in a good correlation. Since the RSI method is easily performed and doesn't require demanding equipment, it could serve as an alternative method for measuring the hardness of parquet in factory or in buildings.

Density of wood is the ratio of mass and volume of wood. In the wood flooring production, special attention is paid to dimensional accuracy of each element. Assuming that all the elements are the same size (including slots and pen), then their volume should be equal. If volume of element is known, density of each element can be measured only by measuring the weight on the scale.

2. AIM OF RESEARCH

The aim of research is to compare the standard methods for determining hardness and density of wood with unconventional methods in order to find simplified, faster and cheaper ways to determine aforementioned properties of wood.

The first objective was to compare standard test method of Brinell hardness (EN 1534: 2010) and RSI (Relative size impression) method, described in the scientific literature (Brehm, 2006). RSI method allows measuring hardness of individual floor elements from different types of wood in a very short period of time. It also allows you to perform measurements with satisfactory accuracy in different locations, and doesn't require demanding and expensive measuring equipment. One of the objectives is to standardize the application of RSI method in wood flooring factories, in expertise and in testing of embedded wooden floors. It is often the case of complaints in new residents that parquet doesn't have sufficient hardness because of impressed traces from chair leg or heels. It's impossible to examine it without destruction of floor to seclude samples for Brinell testing in the laboratory.

Another objective is the possibility to substitute standard test method for wood density (ISO 3131: 1975) with method of measuring the mass of floor elements with known volume. This method of measurement would allow the manufacturer satisfactory accurate information on the density of the wood, without the expensive and complicated standard measurements. Installation of such measurements in the production line would allow the automatic rejection of elements that have under or over-density in comparison to the usual range of values, which adversely affect other properties of floor coverings such as hardness, swelling and shrinkage, etc.

3. MATERIALS AND METHODS

3.1. Determination of wood hardness

Simultaneous measurement of wood hardness with Brinell method and RSI method was performed on eight different types of wood species with 10 samples of parquet dimensions 22×56×500 mm. Examined wood species were: black locust, beech, hornbeam, oak, ash, maple, alder and cherry. 50 impressions of Brinell method and 50 impressions of RSI method were made for each wood species. The water content of all samples was in range of 7-11 %.

3.1.1. Brinell hardness testing method (HRN EN 1534:2010)

Brinell hardness of wood was tested by injecting steel ball (Figure 1) (diameter 10±0.01 mm) with force that had to reach 1 kN in the period of 15±3 s, and that force was necessary to continuously maintain in period 25±5 s. After injection, two perpendicular impression diameters were measured; parallel to the grain (d_1) and across the grain (d_2) with an accuracy of ± 0.2 mm. Wood hardness was calculated according to the expression (1). Testing was conducted on a universal machine for testing the mechanical properties of wood (Otto Wolpert - Werke GMBH model U4).

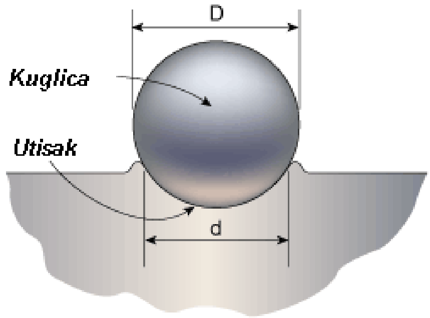


Figure 1 Sketch of tests mode of Brinell and RSI hardness

Brinell hardness was calculated according to the expression (1):

$$HB = \frac{2 \times F}{g \times \pi \times D \times \left[D - (D^2 - d^2)^{\frac{1}{2}}\right]} \quad (1)$$

HB – Brinell hardness (kN/mm²)
F – nominal force (1 kN)
g – acceleration of gravity (≈10 m/s²)
D – diameter of the ball (10 mm)
d – diameter of the residual indentation (mm)
π – „pi" factor, (≈ 3,14)

3.1.2. Relative size impression (RSI) hardness testing method

The wood hardness RSI method was performed as follows: steel ball was released to free fall through the tube and made an impression. After that, two perpendicular impression diameters were measured; parallel to the grain (d_1) and across the grain (d_2) with an accuracy of ± 0.2 mm. (Figure 1).

Only steel ball and PVC pipe was used for the test. Given that most of the floor layers use the CM device to measure water content of the screed before installing wooden flooring, the largest steel ball (30 mm in diameter and weighing 110 g) from set was used. PVC pipe used in the assay was 35 mm in diameter and length of 1.5 m. Diameter difference from steel ball and tube of 5 mm was considered sufficient to override the friction of ball in the tube. Tube length of 1.5 m is taken as the height of free fall.

Care was taken that the two impressions (Brinell and RSI) were tested close to each other, in pairs, due to differences in density along the individual strips (Figure 2).

Figure 2 The sphere from CM device and impression according to RSI (left) and Brinell (right)

3.2. Wood density measurement

Measuring of wood density was carried out on eight different types of wood species with 10 parquet samples (dimensions 22×56×400 mm and 21×70×300 mm). Examined wood species were: black locust, beech, hornbeam, oak, ash, maple, alder and cherry. After sampling parquet according to the standard (ISO 3131: 1975), the mass of samples was measured. Because of irregularity of parquet samples shape, volume couldn't be measured with calliper. To determine the exact volume of weighted parquet samples 3D models in SolidWorks program were made. On the basis of constructed model coefficient of volume was determined, act. the difference between the actual volume of samples and the basic volume was determined. Coefficient volume was used to calculate density of parquet samples. In addition to these two dimensions of solid parquet, 3D models for total of 15 different sizes of wooden flooring elements were designed.

4. RESULTS AND DISCUSSION

4.1. Determination of wood hardness

In table 1 statistical analysis was used to determine discrepancies of impression diameters for certain types of wood from the mean value for the conversion of RSI methods and Brinell method. The intention is that conversion coefficient can be used to calculate the hardness of wood based on the diameter of impressions using RSI method, without complicated laboratory measurement. Table 1 shows that discrepancies of impression diameters for certain types of wood from the mean value for the conversion are generally higher than 9 %, and that relations that are less than 4,5 % do not have statistically significant deviations. This means that based on the above we can determine the coefficient for calculation of values for the calculation of the Brinell hardness for each type of wood. It is considered that the deviation coefficients of 5 %, even if it is statistically significant, is not technologically significant, ie. it is sufficient for the factory and building conditions. According to calculations from 8 types of wood species, conversion factor is 0.667, i.e. diameter impression obtained by the RSI method should be multiplied according to the equation (2) to obtain the diameter according to Brinell.

Table 1 Statistical discrepancies of impression diameters for certain types of wood from the mean value for the conversion of RSI methods and Brinell method.

	Impression diameter (D_b) HB (n = 50)			Impression diameter (D_r) RSI (n = 50)			Ratio between impression diameters D_b/D_r	Discrepancies of impression diameters for certain types of wood from the mean value (%)	Significant discrepancies of impression diameters for certain types of wood from the mean value
	m.v.	st. dev.	c.v.	m.v.	st. dev.	c.v.			
AL	7,79	0,397	5,10	11,09	0,675	6,09	**0,702**	5,32	significant
CH	7,18	0,864	12,04	10,88	0,815	7,49	**0,660**	-1,03	not significant
MA	6,66	0,513	7,71	9,51	0,422	4,44	**0,700**	4,99	significant
HO	6,05	0,476	7,86	9,03	0,476	5,27	**0,670**	0,52	not significant
OK	5,67	0,584	10,3	8,53	0,794	9,31	**0,665**	-0,30	not significant
BE	5,56	0,314	5,65	8,47	0,753	8,89	**0,656**	-1,60	not significant
BL	5,06	0,356	7,04	8,31	0,533	6,41	**0,608**	-8,80	significant
AS	5,44	0,627	11,51	8,09	0,805	9,95	**0,673**	0,91	not significant
				mean value			**0,667**		
				standard deviation			0,029		
				coefficient of variation			4,398		

Legend: Db – impression diameters according to Brinell, Dr – impression diameters according to RSI, m.v. – mean value, st.dev. – standard deviation, c.v. – coefficient of variation, AL – alder, CH – cherry, MA – maple, HO – hornbeam, OK – oak, BE – beech, BL – black locust, AS – ash.

Brinell hardness according to RSI method was calculated by equation (2):

$$d_{HB} = k \times d_{RSI}$$

$$HB = \frac{2 \times F}{g \times \pi \times D \times \left[D - (D^2 - d_{HB}{}^2)^{\frac{1}{2}}\right]} \quad (2)$$

HB – Brinell hardness (kN/mm²)
F – nominal force (1 kN)
g – acceleration of gravity (≈10 m/s²)
D – diameter of the ball (10 mm)
d_{HB} *– mean value of impression diameter according to Brinell (mm)*
d_{RSI} *– mean value of impression diameter according to RSI (mm)*
k – conversion factor - 0,667

Table 2 presents multiple analysis of variance sets. Each of them includes 50 impressions for each type of wood and the method of injection. On the basis of p value should be noted that the sets of impressions (for any type of wood, and for any of the two methods) differ significantly. If a majority of mutual combination would not be significantly different, then it could be determined that the conversion factor of diameter impression according to RSI to Brinell is 0.667 and it can be applied to all types of wood.

Table 2 Multiple comparisson of impression diameter according to RSI and Brinell.

	AL R: 257,84	CH R: 195,05	MA R: 252,09	HO R: 206,05	OK R: 198,25	BE R: 180,06	AS R: 205,58	BL R: 109,08
AL		0,1853	1,0000	0,7030	0,2790	0,0215	0,6668	0,0000
CH	0,1853		0,3817	1,0000	1,0000	1,0000	1,0000	0,0056
MA	1,0000	0,3817		1,0000	0,5569	0,0515	1,0000	0,0000
HO	0,7030	1,0000	1,0000		1,0000	1,0000	1,0000	0,0008
OK	0,2790	1,0000	0,5569	1,0000		1,0000	1,0000	0,0032
BE	0,0215	1,0000	0,0515	1,0000	1,0000		1,0000	0,0600
AS	0,6668	1,0000	1,0000	1,0000	1,0000	1,0000		0,0008
BL	0,0000	0,0056	0,0000	0,0008	0,0032	0,0600	0,0008	

Legend: AL – alder, CH – cherry, MA – maple, HO – hornbeam, OK – oak, BE – beech, BL – black locust, AS – ash., red marked are p values that indicate combinations with statistical difference

From table 2 it is visible that the black locust hardness is significantly different from all types of wood (because it had nearly 9 % lower conversion coefficient from the average), and that alder hardness statistically differ only in comparison to the beech. It can be determined that the conversion factor is valid for most of the surveyed types of wood except for black locust. If we exclude black locust from calculation, then the mean value of 0.667 rises to 0.675. In that case alder would not be significantly different from beech wood.

Deviations from 5 % for alder wood and 8,8 % for black locust wood are statistically significant, but aren't technologically significant, because the deviation in diameter impression is considerably less than the range of standard density of certain types of wood. Possibility of serious misjudging of wood hardness, caused by a defect in the conversion factor less than 10 %, can be considered as a small influence.

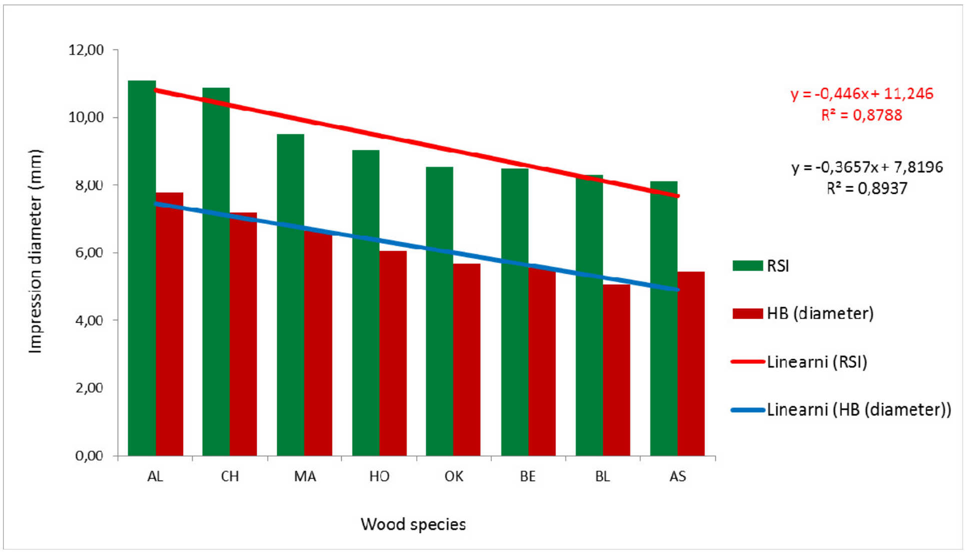


Figure 3. Comparison of impression diameters between Brinell and RSI hardness

From comparison of impression diameters between Brinell and RSI hardness (Figure 3) it is visible that the degree of correlation for eight types of wood species is very high. The relationship between the average values measured using RSI and the average value of Brinell impression it was found that the conversion factor varies from 0.6 to 0.7 depending on the type of wood species.

4.1. Determination of wood density

In table 3 and 4 are 3D models for total of 15 different sizes of wooden flooring elements. Ideal volume, actual volume and their deviation was calculated on the elements. In table 4 it's visible that deviations of element sizes from ideal volume are less than 5 %, and that deviation is proportionally less in bigger than in smaller elements. It is also obvious that the shape of boards affects the deviation. In sample 6 deviation is negligible 0.37 % while in the complex shape sample 4, deviation is 4.55 %. Sample 9 clearly shows the thesis that smaller samples have larger deviations from the ideal volume. Table 3 shows different profiles of parquet boards of the same size. It is evident that variations are similar, apart from a very simple and complex profiles where the deviation in the range of 1.13 % to 5.39 %. That range is equivalent to weight of 24.3 g.

Table 3 Relationship between ideal and actual volume of certain forms of solid parquet boards of the same dimensions

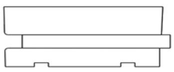
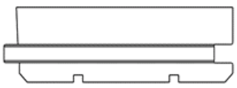
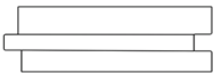
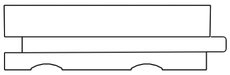
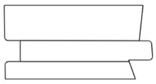
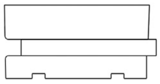
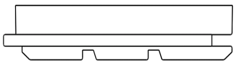
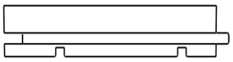
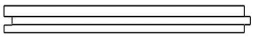
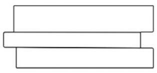
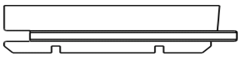
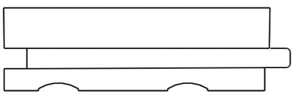
Nr.	Parquet	Dimensions (mm)			Volume (cm^3)		Deviation
		thickness	width	height	ideal	actual	%
1		22	65	300	429,00	414,39	**3,41**
2		22	65	300	429,00	412,27	**3,90**
3		22	65	300	429,00	416,09	**3,01**
4		22	65	300	429,00	405,86	**5,39**
5		22	65	300	429,00	416,13	**3,00**
6		22	65	300	429,00	424,15	**1,13**

Table 4 Relationship between ideal and actual volume of certain forms of solid parquet boards

Nr.	Parquet	Dimensions (mm)			Volume (cm³)		Deviation
		thickness	width	height	ideal	actual	%
1		21,5	70	500	752,50	728,27	**3,22**
2		21	40	300	252,00	240,08	**4,73**
3		22,5	45	300	303,75	292,07	**3,85**
4		14	70	450	441,00	420,92	**4,55**
5		14	75	350	367,50	358,57	**2,43**
6		10	30	300	90,00	88,77	**1,37**
		10	70	500	350,00	348,72	**0,37**
7		21	70	750	1102,50	1074,77	**2,52**
		21	70	500	735,00	715,51	**2,65**
8		22	56	400	492,80	485,99	**1,38**
		22	56	500	616,00	607,56	**1,37**
9		14	50	300	210,00	201,17	**4,20**
		14	70	500	490,00	476,12	**2,83**
		14	90	1000	1260,00	1232,04	**2,22**

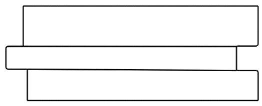
In tables 5 and 6 the minimum and maximum permissible mass of small boards with deviation in volume for eight species of wood are presented. Deviation refers to the difference between ideal and the actual volume of elements of 15 % water content. Minimum and maximum weight of parquet elements was calculated with equation (4). The density of elements within an area from 7 to 17 % of water content was calculated according to equation (3).

Table 5 Mass of elements structural type 1 from table 3 for 8 types of wood

Dimensions (mm)			**Wood species**	**Density (g/cm³)**	**Mass (g)**		
thickness	**width**	**height**		**$\rho_{15\%}$**	**min.$_{DE}$**		**max.$_{DE}$**
21	70	300	**Black loc.**	0,74..0,80	306,4	**326,2**	352,5
Volume (cm³)		**Deviation**	**Beech**	0,70..0,79	289,9	**311,2**	348,1
ideal	**actual**	**%**	**Hornbeam**	0,75..0,86	310,6	**359,9**	378,9
441	427,35	3,10	**Oak**	0,65..0,76	269,2	**286,3**	334,9
			**Ash**	0,68..0,76	281,6	**312,7**	334,9
			Maple	0,61..0,66	252,6	**277,1**	290,8
			Alder	0,49..0,57	202,9	**234,3**	251,1
			Cherry	0,56..0,66	231,9	**241,8**	290,8

Legend: ***min.$_{DE}$*** *- minimum permissible mass of sample with a deviation of 3,1 %,* ***max.$_{DE}$*** *- the maximum permissible mass of sample with a deviation of 3,1 %. Density at 15% of water content (SELL, 1997).*

Table 5 Mass of elements structural type 8 from table 3 for 8 types of wood

Dimensions (mm)			Wood species	Density (g/cm^3) $\rho_{15\%}$	Mass (g)		
thickness	**width**	**height**			**min.$_{DE}$**		**max.$_{DE}$**
22	56	400	**Black loc.**	0,74..0,80	354,7	**361,1**	394,2
Volume (cm³)		**Deviation**	**Beech**	0,70..0,79	335,5	**352,4**	389,2
ideal	**actual**	**%**	**Hornbeam**	0,75..0,86	359,5	**398,3**	423,7
492,8	485,99	1,38	**Oak**	0,65..0,76	311,5	**365,2**	374,4
			**Ash**	0,68..0,76	325,9	**333,8**	374,4
			Maple	0,61..0,66	292,4	**310,0**	325,2
			Alder	0,49..0,57	234,8	**256,3**	280,8
			Cherry	0,56..0,66	268,4	**292,3**	325,2

Legend: ***min.$_{DE}$*** *- minimum permissible mass of sample with a deviation of 1,38 %,* ***max.$_{DE}$*** *- the maximum permissible mass of sample with a deviation of 1,38 %. Density at 15 % of water content (SELL, 1997).*

Equation for calculating density of elements within an area from 7 to 17% of water content (3):

$$\rho_w = \rho_0 \times \frac{1+W}{1+0,84 \times \rho_0 \times W} \qquad (3)$$

ρ_w – density at certain water content (g/cm^3)
ρ_0 – density in absolutely dry condition (g/cm^3)
W – water content

Equations for calculating minimum and maximum mass of elements (4):

$$V_{actual} = V_{ideal} \times k \qquad (4)$$

$$m_{min} = \rho_{w\,min} \times V_{actual}$$

$$m_{max} = \rho_{w\,max} \times V_{actual}$$

V_{actual} – actual volume (cm^3)
V_{ideal} – ideal volume (cm3)
k – correction factor(deviation)

4. CONCLUSIONS

Comparison of standardized measurement of Brinell hardness method and estimation with the relative size of the impression method (RSI) showed very satisfactory results. From the results it can be assumed that the RSI method could replace Brinell method in operating or site conditions where small variations of the coefficient for conversion values are not technologically significant.

The method of wood density estimation by measuring the mass of parquet boards, proved to be very simple and useful in production. For a high quality result is required only to calculate the actual volume of parquet elements that can be easily determine with the 3D program of choice. So it is possible to determine the range of parquet boards mass in production.

4. REFERENCES

BREHM, T. (ED.), (2006): *Fachbuch für Parkettleger*. SV Fachverlag, Hamburg.

HERRMANN, K.; PATKOVSZKY, I.; BEHRENS, B.A.; KAMMLER, M., (2006): *Anwendung dynamischer Kräfte in der Werkstoffprüfung*. Technisches Messen 73: 646-654.

NIEMZ, P.; STÜBI, T., (2000): *Investigations of hardness measurements on wood based materials using a new universal measurement system.* In: Proc. Symp. on "Wood machining, properties of wood and wood composites related to wood machining". Vienna, Austria, September, 2000. 51-61.

BREHM, T. (ED.), (2006): *Fachbuch für Parkettleger*. SV Fachverlag, Hamburg.

SELL, J. (1997): *Eigenschaften und Kenngrössen von Holzarten*. LIGNUM: Zürich

HRN EN STANDARD 1534 (1999): Wood and parquet flooring - Determination of resistance to indentation (Brinell).

HRN ISO STANDARD 3131 (1999): Wood – Determination of density for physical and mechanical tests.

HRN ISO STANDARD 3350 (1999): Wood – Determination of static hardness.