POSSIBILITIES FOR CONSTRUCTION OF HIGH-RISE BUILDINGS IN BIHAĆ BOSNIA AND HERZEGOVINA

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Summary: *The Institute for Standardization in Bosnia and Herzegovina has recently published new interactive maps for characteristic values of snow load, basic wind velocity and map of seismic hazard with referential peak ground accelerations for territory of Bosnia and Herzegovina as part of national annexes to Eurocode 1 and Eurocode 8, that superseded former Yugoslav standards and rulebooks. Bihać is one of the largest cities in Bosnia and Herzegovina and administrative center of Una-Sana Canton. However, during the recent history, some buildings and structures in Bihać experienced damages or even collapse due to snow loads or wind actions. Bihać, unlike other cities in Bosnia and Herzegovina, was not one of the cities with newly constructed high – rise settlements. Somehow, most of the buildings were up to five storeys high, which shows awareness of engineers and architects about the suspect quality of the load bearing soil, as well as their attention to the seismic zone that Bihać belongs to. In spite of this, there are examples of the high–rises in Bihać, but in smaller scales than those in other cities. The highest high-rise in Bihać reaches 16 storeys, and it functioned as residential building with commercial services at the first two floors. As need for construction of high-rises in Bihać in future may arise, taking in consideration its administrative position and business development, this research is contribution for structural possibilities of construction of high-rises in Bihać, taking in consideration new annexes to Eurocodes 1 and 8.*

Keywords: *High-Rise Buildings, Structural Systems, Bihać, Eurocodes*

1. INTRODUCTION

The construction of high-rise buildings has become a trend in the developed world due to the increased need for business content concentrated in administrative and business centers, but also due to the greater tendency of the population to live in urban areas, as well as the explicit demand for demonstrating financial and business power. For significant number of designers, such tendency become a way of professional expression

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from the aspect of design and constructing solutions of high-rise buildings, as well as the application of new materials and challenging technologies. Based upon the numerous advantages, concrete slowly becomes the primary material when it comes to the construction of high-rise buildings. However, the high-rise buildings are at the same time an engineering challenge, as well as the selection of structural system and construction materials, the mode of transmission of vertical actions, foundation method, but especially when it comes to the behavior of the structure under the action of horizontal dynamic forces. The problem is even greater when the high-rise building is located in the active seismic area. As the building is higher, the issue of the action of horizontal forces is more pronounced. But the question is how to satisfy the wishes of investors for high-rise buildings in seismically active zones then.

The aim of this research is to provide guidelines for designers on the height, structural systems and dimensions of structural elements for high-rise buildings, from the technical and economic aspects in the construction conditions in the area of Bihać in Bosnia and Herzegovina. This research analyzes the behavior of the RC concrete load-bearing structure of a high-rise building for three different heights (35, 60 and 100 m) and three different structural systems: pure RC skeleton system, a skeleton system with RC concrete core and RC cross-wall structure exposed to the action of horizontal dynamic effects of natural origin (earthquake and wind). The research was carried out according to the conditions defined by BAS EN 1991-1-4/NA:2018 - Eurocode 1: Actions on structures: Part 1-4: General actions - Wind actions - National annex for the area of the town of Bihać when it comes to wind actions and BAS EN 1998-1/NA:2018 - Eurocode 8: Design of structures for earthquake resistance - Part 1: General rules, seismic actions and rules for buildings - National annex, when seismic actions are considered.

2. REINFORCED CONCRETE STRUCTURE

The reinforced concrete structures are 30 m x 30 m in layout with longitudinal and transverse distance between reinforced concrete frames of 6 m (*Figure 1*).

Due to the diversity of the displacement results depending on the dimensions of the columns, each system was analyzed for three different dimensions of the columns: 40/40, 60/60 and 100/100 cm/cm, giving a total of 27 models for analysis.

The assumption is that the data on the structural system and the height also depend on the height of the stories, therefore the height of the ground floor was 5 m and all others 3 m, which could give different data for each model when considering the drift and displacements.

The concrete class C 30/37 is selected for the construction of the building. The reinforcement is consisted of rebar and meshes of f_{yk} = 500 MPa.

As shown in *Figure 1,* the structures can be categorized as being regular in elevation and in plan.

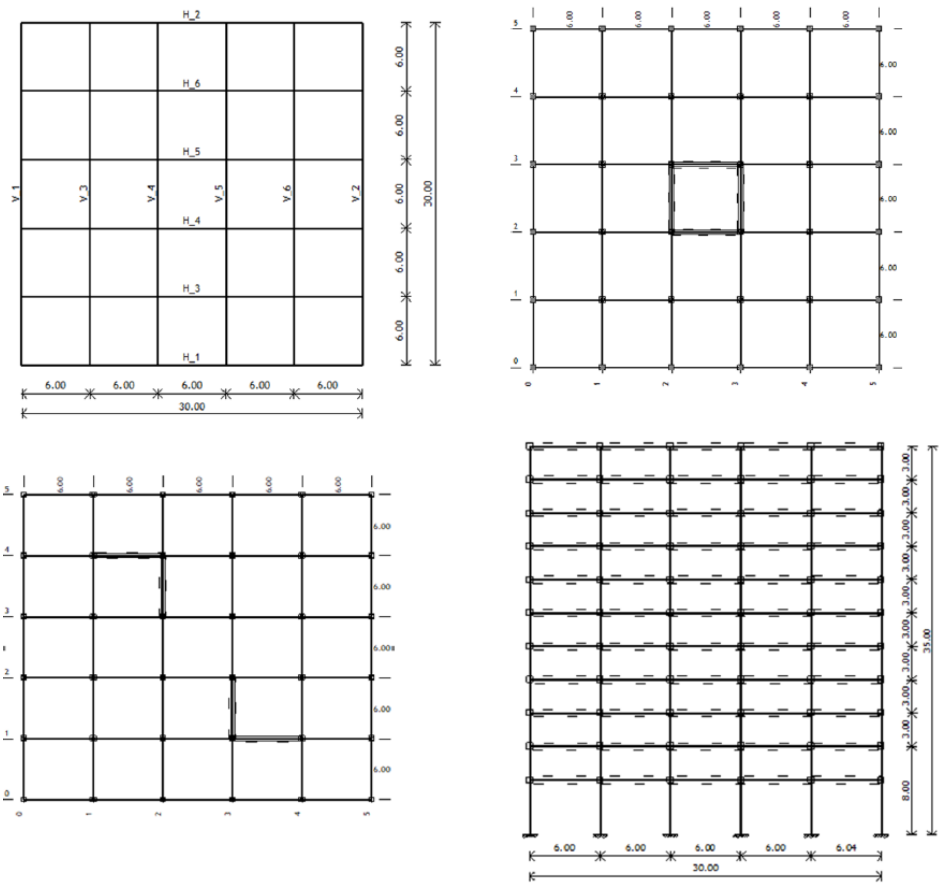

Figure 1. Floor Plans and Schematic Elevation Plan

3. ACTIONS

The analysis of actions includes all the actions that act on the structures: permanent and variable effects, wind and seismic actions. Permanent actions include: the self-weight of the structural elements and the weight of the layers on them, while the variable actions include: snow load and imposed loads for Category A and B as specified by BAS EN 1991-1-1/NA:2016 Eurocode 1 - Actions on structures: Part 1-1: General actions - Densities, self-weight and imposed loads for buildings - National annex.
The permanent action of roof storey was determined as $G_{k,,roof}$ = 8.89 kN/m^2, while permanent action for other floors was calculated of $G_{k,storey}$ = 7.20 kN/m^2. Serviceability imposed load was equal to 2.00 kN/m^2.
Snow load on roof was determined based upon the characteristic value of snow load on the ground (s_k) according to BAS EN 1991-1-3/NA:2018 Eurocode 1: Actions on structures - Part 1-3: General actions - Snow loads - National annex for City of Bihać that is $s_{k\,=}$ 2.28 kN/m^2.

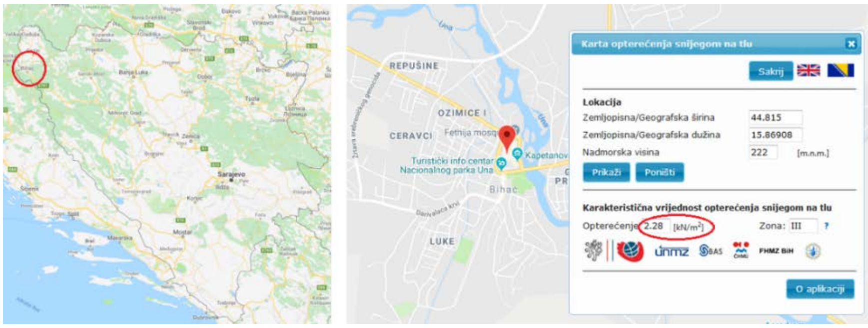

Figure 2. Characteristic Snow Load on the Ground for Bihać
according to BAS EN 1991-1-3/NA:2018 [19]

BAS EN 1991-1-4/NA:2018 Eurocode 1: Actions on structures - Part 1-4: General actions - Wind actions - National annex specifies wind action in Bosnia and Herzegovina. According to this standard, basic wind velocity for Bihać is 20.86 m/s.

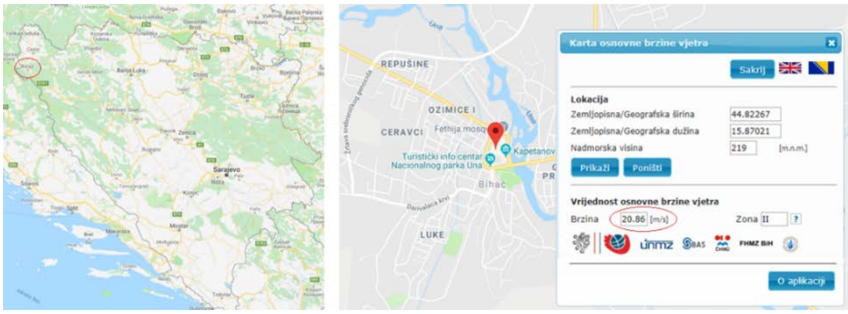

Figure 3. Basic Wind Velocity for Bihać
according to BAS EN 1991-1-4/NA:2018 [20]

The standard that define reference peak ground acceleration for determination of seismic forces on the structure in return period of 475 years is BAS EN 1998-1/NA:2018 - Eurocode 8: Design of structures for earthquake resistance - Part 1: General rules, seismic actions and rules for buildings - National annex, and for Bihać is 0.12 g.

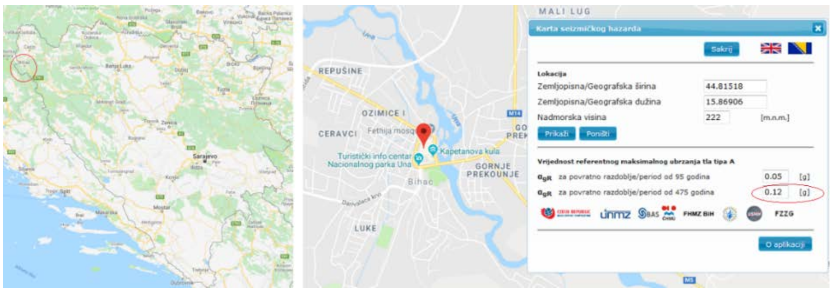

Figure 4. Referent Peak Ground Acceleration for Bihać
according to BAS EN 1998-1/NA:2018 [21]

Using method of modal response spectrum analysis, the seismic forces are presented in *Table 1*,

Table 1 – Seismic Forces

Structural System	Height [m]	Dimensions of Columns b/h [cm/cm]	Vibration period [s]	Seismic Force Fx [kN]	Seismic Force Fy [kN]
Skeleton	35	40/40	2.31	2086.0	625.81
		60/60	1.24	4042.0	1212.8
		100/100	0.64	12910.0	3783.0
	65	40/40	4.03	3762.0	1128.9
		60/60	2.22	4699.3	1409.8
		100/100	1.20	12181.9	3654.6
	100	40/40	6,37	5673.0	1701.9
		60/60	3.62	7022.7	2106.8
		100/100	2.10	11253.3	3376.0
Skeleton with Core	35	40/40	1.00	3315.9	995.0
		60/60	0.78	5788.2	1736.5
		100/100	0.54	15182.6	4554.8
	65	40/40	2.80	3229.7	968.9
		60/60	1.66	4994.2	1498.3
		100/100	1.07	13452.2	4035.7
	100	40/40	4.38	5043.9	1512.9
		60/60	2.98	6602.1	1980.6
		100/100	1.93	11076.4	3322.9
Skeleton with Crossed Walls	35	40/40	1.3	3018.3	514.7
		60/60	0.87	5600.6	1260.8
		100/100	0.55	15061.1	4079.7
	65	40/40	2.77	3307.9	1045.9
		60/60	1.79	4909.9	1222.5
		100/100	1.00	13373.1	3717.8
	100	40/40	4.91	5153.5	1638.8
		60/60	3.13	6661.1	2070.5
		100/100	1.97	11162.7	3268.3

while combination of actions used in this research are presented in *Table 2*.

Table 2 – Combination of Actions

Design Situation	No.	Combinations of Actions
Permanent and Transient Design Situations	1.	$1.35 \cdot G$
	2.	$1.35 \cdot G + 1.5 \cdot Q_{sl} + 1.5 \cdot 0.5 \cdot Q_s$
	3.	$1.35 \cdot G + 1.5 \cdot 0.7 \cdot Q_{sl} + 1.5 \cdot Q_s$
	4.	$1.35 \cdot G + 1.5 \cdot Q_{sl} + 1.5 \cdot 0.6 \cdot Q_w$
	5.	$1.35 \cdot G + 1.5 \cdot 0{,}7 \cdot Q_{sl} + 1.5 \cdot Q_w$
Seismic	6.	$1.0 \cdot G + 0.3 \cdot Q_{sl} + S_x$
	7.	$1.0 \cdot G + 0.3 \cdot Q_{sl} + Sy$

4. RESULTS

The dynamic analysis conducted on three different RC structural systems (RC skeleton, RC skeleton with core and RC skeleton with crossed walls) of three different heights for each structural system (35, 65 and 100 m) and three dimensions of columns, where center of mass of the building coincides with the center of stiffness, which prevents the rotation of the mass around the stiffness in the event of an earthquake For the structures undergoing this dynamic analysis, the conditions of seismicity in the area of Bihać and foundation conditions Ground Type B. The minimal random eccentricities are taken into account. The displacement analyses of the top storey vs. the foundation is presented in *Table 3*.

Table 3 – Displacements

Structural System	Height [m]	Dimensions of Columns b/h [cm/cm]	Maximal Displacement δ [cm]
Skeleton	35	40/40	4.00
		60/60	1.81
		100/100	0.96
	65	40/40	12.95
		60/60	3.90
		100/100	1.89
	100	40/40	32.00
		60/60	10.60
		100/100	3.70
Skeleton with Core	35	40/40	1.68
		60/60	1.26
		100/100	0.82
	65	40/40	4.91
		60/60	2.67
		100/100	1.70
	100	40/40	16.39
		60/60	7.44
		100/100	3.21
Skeleton with Crossed Walls	35	40/40	2.12
		60/60	1.22
		100/100	0.79
	65	40/40	5.89
		60/60	2.50
		100/100	1.65
	100	40/40	17.64
		60/60	7.23
		100/100	3.15

BAS EN 1998-1:2017 proscribes the limitation of the interstorey drift. Unless otherwise specified, the following limits shall be observed:

a) for buildings having non-structural elements of brittle materials attached to the structure:

$$d_r \cdot \nu \leq 0{,}005 \cdot h \quad (1)$$

b) for buildings having ductile non-structural elements:

$$d_r \cdot \nu \leq 0{,}0075 \cdot h \quad (2)$$

c) for buildings having non-structural elements fixed in a way so as not to interfere with structural deformations, or without non-structural elements:

$$d_r \cdot \nu \leq 0{,}010 \cdot h \qquad (3)$$

where

d_r - is the design interstorey drift;
h - is the storey height;
ν - is the reduction factor which takes into account the lower return period of the seismic action associated with the damage limitation requirement (in this particular case 0.4), and
q - displacement behaviour factor (in this particular case 0.39).

Table 4 displays maximal inerstorey drifts in this analysis.

Table 4 – Maximal Interstorey Drifts

Structural System	Height [m]	Dimensions of Columns b/h [cm/cm]	Maximal Interstorey Drift d_r (cm)	d_r*q*$\nu \leq$ 3,2 (a)	d_r*q*$\nu \leq$ 2,4 (b)	d_r*q*$\nu \leq$ 1,6 (c)
Skeleton	35	40/40	0.39	0.60	0.60	0.60
		60/60	0.17	0.26	0.26	0.26
		100/100	0.10	0.14	0.14	0.14
	65	40/40	0.65	1.00	1.00	1.00
		60/60	0.20	0.31	0.31	0.31
		100/100	0.10	0.15	0.15	0.15
	100	40/40	1.64	2.55	2.55	2.55
		60/60	0.35	0.55	0.55	0.55
		100/100	0.08	0.12	0.12	0.12
Skeleton with Core	35	40/40	0.16	0.25	0.25	0.25
		60/60	0.12	0.19	0.19	0.19
		100/100	0.09	0.14	0.14	0.14
	65	40/40	0.27	0.42	0.42	0.42
		60/60	0.13	0.20	0.20	0.20
		100/100	0.09	0.14	0.14	0.14
	100	40/40	0.56	0.87	0.87	0.87
		60/60	0.25	0.40	0.40	0.40
		100/100	0.11	0.17	0.17	0.17
Skeleton with Crossed Walls	35	40/40	0.16	0.25	0.25	0.25
		60/60	0.12	0.19	0.19	0.19
		100/100	0.07	0.10	0.10	0.10
	65	40/40	0.33	0.51	0.51	0.51
		60/60	0.15	0.23	0.23	0.23
		100/100	0.09	0.14	0.14	0.14
	100	40/40	0.65	1.00	1.00	1.00
		60/60	0.25	0.40	0.40	0.40
		100/100	0.097	0.14	0.14	0.14

The results for interstorey drifts for the floor height of 3 mts show that all considered structural systems, for height of building of 35, 65 and 100 mts satisfy interstorey draft limits for all considered dimensions of rectangular columns, except in a case of skeleton system, 100 mts of height and column dimensions 40 cm x 40 cm.

In the case of groundfloor height of 5 m, drifts are significantly greater that was shown in *Table 5*.

Table 5 – Groundfloor Interstorey Drifts for Skeleton System (h = 5 m)

Structural System	Height [m]	Dimensions of Columns b/h [cm/cm]	Maximal Interstorey Drift d_r (cm)	$d_r*q*v \leq 3,2$ (a)	$d_r*q*v \leq 2,4$ (b)	$d_r*q*v \leq 1,6$ (c)
Skeleton	35	40/40	1.27	1.98	1.98	1.98
	65	40/40	1.97	3.20	3.20	3.20
	100	40/40	2.97	4.60	4.60	4.60

From the results displayed in *Table 5*, it is evident that for high-rise structures with a floor groundfloor height of 5 m, the actual drift exceeds the limit of the interstorey drift for skeleton system and dimensions of the columns 40 cm /40 cm, considering requirements for the high-rise structures containing ductile non-load bearing elements and for buildings that have non load-bearing elements of brittle materials.

5. CONCLUSION

In the City of Bihać, it is possible to build reinforced concrete high-rise buildings up to 100 m of height of regular plan and elevation (up to distance of frames of 6 mts), using skeleton systems with or without cores or crossed walls, with a floor height of up to 3 m in majority of cases. However, for buildings with a floor height exceeding 3 m, buildings can be built up to 100 m, using structural systems of skeleton with reinforced concrete cores and/or walls, while pure skeleton systems can be used for buildings up to 35 m in height.

REFERENCES

Book / Monograph:

[1] Hrasnica M, 2005, “Seizmička analiza zgrada”, Građevinski fakultet Univerziteta u Sarajevu, ISBN 9958-9461-8-X, Sarajevo, Bosnia and Herzegovina;
[2] Hrasnica M, 2012, “Aseizmičko građenje”, Građevinski fakultet Univerziteta u Sarajevu, ISBN 978-9958-638-31-2, Sarajevo, Bosnia and Herzegovina;
[3] Hrasnica M, Markova J, Kurtović A, Čaušević A, Dević D, Kulukčija S, Hadžović R, Zalihić S, Džidić S, Hodžić E, 2018, “Priručnik za Eurokodove, Institut za standardizaciju Bosne i Hercegovine – BAS i Češka kancelarija za standarde, mjeriteljtsvo i ispitivanje – ÚNMZ, CIP006.77(497.6)(035), 006.4:624.04(497.6)(035), ISBN: 978-9958-530-03-6, COBISS.BH-ID 25694982, Sarajevo, Bosna and Herzegovina;

[4] Kovačević I, Džidić S, 2018, “High-Rise Buildings-Structures and Materials”, International BURCH University Sarajevo, CIP 725.222(075.8), ISBN; 978-9958-834-58-5, COBISS.BH-ID 24904454, Sarajevo, Bosna and Hercegovina;

Papers:

[5] Kovačević I, Džidić S, 2018, “Modern Structural Concepts for High-Rise Buildings”, Book of Proceedings of the 13th Scientific Conference with International Participation "Contemporary Theory and Practice in Construction” May 24-25, ISSN 2566-4484, DOI: 10.7251/STP1813549K, pp 549-561, Banja Luka, Bosnia and Herzegovina;

[6] Kovačević I, Džidić S, 2018, “High-Strength Concrete (HSC) – Material for High-Rise Buildings”, Proceedings of the 12th Scientific Research Symposium with International Participation "Metallic and Nonmetallic Materials: production-properties-application", April 19-20, 2018, Year 12 (2018), No. 12, ISSN 2566-4344, pp 214-223, Vlašić, Bosnia and Herzegovina;

[7] Kovačević I, Džidić S, 2018, “Lateral and Accidental Actions – Risk of Progressive Collapse in High-Rise Buildings”, Conference Proceedings of the 6th International Conference “Contemporary Achievements in Civil Engineering”, April 20, 2018, ISBN 978-86-80297-73-6, UDK:624,042, DOI:10.14415/konferencijaGFS2018.009, pp 101-112, Subotica, Serbia;

Standards:

[8] BAS EN 1990:2014-Eurocode-Basis of structural design, Institut za standardizaciju Bosne i Hercegovine, Istočno Sarajevo, Bosnia and Hercegovina;

[9] BAS EN 1990/NA:2015-Eurocode - Basis of structural design - National annex, Institut za standardizaciju Bosne i Hercegovine, Istočno Sarajevo, Bosnia and Hercegovina;

[10] BAS EN 1991-1-1:2015 Eurocode 1 - Actions on structures: Part 1-1: General actions - Densities, self-weight and imposed loads for buildings, Institut za standardizaciju Bosne i Hercegovine, Istočno Sarajevo, Bosnia and Hercegovina;

[11] BAS EN 1991-1-1/NA:2016 Eurocode 1 - Actions on structures: Part 1-1: General actions - Densities, self-weight and imposed loads for buildings - National annex, Institut za standardizaciju Bosne i Hercegovine, Istočno Sarajevo, Bosnia and Hercegovina;

[12] BAS EN 1991-1-3/A1:2018 Eurocode 1 - Actions on structures - Part 1-3: General actions - Snow loads, Institut za standardizaciju Bosne i Hercegovine, Istočno Sarajevo, Bosnia and Hercegovina;

[13] BAS EN 1991-1-3/NA:2018 Eurocode 1: Actions on structures - Part 1-3: General actions - Snow loads - National annex, Institut za standardizaciju Bosne i Hercegovine, Istočno Sarajevo, Bosnia and Hercegovina;

[14] BAS EN 1991-1-4:2015 Eurocode 1: Actions on structures - Part 1-4: General actions - Wind actions, Institut za standardizaciju Bosne i Hercegovine, Istočno Sarajevo, Bosnia and Hercegovina;

[15] BAS EN 1991-1-4/NA:2018 Eurocode 1: Actions on structures: Part 1-4: General actions - Wind actions - National annex, Institut za standardizaciju Bosne i Hercegovine, Istočno Sarajevo, Bosnia and Hercegovina;

[16] BAS EN 1998-1:2017 Eurocode 8: Design of structures for earthquake resistance - Part 1: General rules, seismic actions and rules for buildings, Institut za standardizaciju Bosne i Hercegovine, Istočno Sarajevo, Bosnia and Hercegovina;
[17] BAS EN 1998-1/NA:2018 Eurocode 8: Design of structures for earthquake resistance - Part 1: General rules, seismic actions and rules for buildings - National annex, Institut za standardizaciju Bosne i Hercegovine, Istočno Sarajevo, Bosnia and Hercegovina;
[18] BAS EN 1992-1-1:2017 Eurocode 2: Design of concrete structures - Part 1-1: General rules and rules for buildings, Institut za standardizaciju Bosne i Hercegovine, Istočno Sarajevo, Bosnia and Hercegovina;

Internet:

[19] http://eurokodovi.ba/snijeg/
[20] http://eurokodovi.ba/vjetar/
[21] http://eurokodovi.ba/seizmika/

МОГУЋНОСТ ИЗГРАДЊЕ ВИСОКИХ ОБЈЕКАТА У БИХАЋУ У БОСНИ И ХЕРЦЕГОВИНИ

Резиме: *Институт за стандардизацију Босне и Херцеговине је недавно објавио нове интерактивне карте за карактеристичне вриједности оптерећења снијегом на тло, основне вриједности брзине вјетра и карту сеизмичког хазарда за територију Босне и Херцеговине, као дио националних додатка уз Еурокод 1 и Еурокод 8, који су замијенили стандарде и прописе из Југославије. Бихаћ је један од највећих градова у Босни и Херцеговини и административни центар Унско-Санског кантона. Међутим, у недавној прошлости, неки објекти и носиве конструкције у Бихаћу су доживјеле оштећења или су се чак срушиле због оптерећења снијегом или дјеловања вјетра. Бихаћ, за разлику од других већих градова у Босни и Херцеговини није био један од градова са значајним бројем високих објеката. Већина зграда је била висине до пет спратова, што указује на свијест инжењера и архитеката о суспектном квалитету носивог тла и сеизмичкој зони у којој се Бихаћ налази. Упркос томе, постоје изграђени високи објекти у Бихаћу, али не тако високи као у другим већим градовима у Босни и Херцеговини. Највиши високи објекат у Бихаћу је висине шеснаест спратова стамбене намјене са пословним садржајима на прва два спрата. С обзиром да се може очекивати потреба за изградњом високих објеката у наредном периоду у Бихаћу, као админситративном и пословном центру, ово истраживање представља допринос анализи конструктивних могућности изградње високих објеката у Бихаћу узимајући у обзир нове националне додатке за Еурокодове 1 и 8.*

Кључне ријечи: *Високи објекти, Конструктивни систем, Бихаћ, Еурокодови*