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Imperfection impact on behavior of the secondary nonstructural elements and vertical non precise erection of members

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Abstract. In this paper of works will be try to present the fundamental computation referring to the imperfection impacts phenomena of non-precise erection effects of the structural members as are vertical columns. Depends from the structural type, the structure should have a vertical structural members with the enough vertical and shear capacity provoked from horizontal action of earthquake, wind, dead and imposed vertical loads. The structural designers, during the structural computation are improve the several approximations creating the dynamic modeling, having into the consideration of structural elements classification in the prior and secondary structural elements. It is very none that the structural vertical elements have a designed capacity from the horizontal actions, the nonstructural elements has the indirect impact on the structural behavior at all. Also the non-precise erection phenomena or imperfection of the vertical structural members is very important in the structural behavior.

Key Words: Structure, nonstructural elements, non-precise erection - imperfection.

1. Introduction

Upon dealing with the designing of structural elements, based on best designing practices, without having into consideration the type of the material, its destination and stories (floors), it has do go through some phases which are in a way connected to each other. As the first phase has to do with the structural concept, the second phase deals with the static-dynamic analysis of the structure, the third phase deals with the dimensioning of comprised elements, usually the fourth one shows the details of elements and its verification. During the first phase, the designers mostly do the preliminary calculation by adopting dynamic calculation models, in a way that to do the dimensioning of structure elements. Within these calculation models are mainly taken into account the supporting elements, and not those that are treated as secondary elements – constructive. In this paper mainly is going to be treated the secondary elements (constructive) on the behavior and reaction of structures in general. Upon dealing with structures, especially with vertical load of high intensity, the issue of imperfection should be taken seriously into consideration as for dealing with single isolated elements, such as columns, and to those that are combined with each other, portal frames.

According to EN 1992-1-1 for single isolated column or portal frame under vertical load, imperfection can be expressed by supposing that the structure or its elements gets a deformation by creating an angle θ in respect to vertical axis, as shown below:

$$\theta_i = \theta_o \cdot \alpha_h \cdot \alpha_m = \frac{1}{200} \cdot \frac{2}{\sqrt{H}} \cdot \sqrt{0,50 \left(1 + \frac{1}{n'} \right)}$$

(1)

θ_0 - represents the base value that is recommended to be 1/200, but it can also be as a part of coefficients determined by National Annexes,

θ_h - represents a reduction factor which is in the function of column height or portal frame and has the values $2/3 \leq \theta_h \leq 1,0$,

θ_m - represents a factor of reduction for the number of elements,

H- the height of elements that are taken into consideration (columns or portal frames),

n'- represents the number of vertical elements that do contribute on the effect of imperfection.

In Figure 1 is shown the way of calculation upon the effect of imperfection on the single vertical structural elements, such as columns, respectively the calculation of horizontal component from the action of vertical loads.

The phenomena of imperfection can be calculated even for elements that are parts of the structure whereby in the Figure 2 will be represented three models and the way of its treatment for imperfection. The effect of vertical load upon the structure which shows the bending moment and rotation moment could be substituted with equivalent forces in multiple floor structure where its imperfection could be approximated by adding in every level of floors one horizontal force, as it is shown in the Figure 2, whereby their values can be calculated with the formula as it is shown below:

$$H_i = \frac{V_k \cdot \Delta_i}{H_{\text{story}}} = V_k \cdot \theta_i \quad k=1,2,3 \dots \quad (2)$$

where:

V_k - is the total load of one floor in the structure

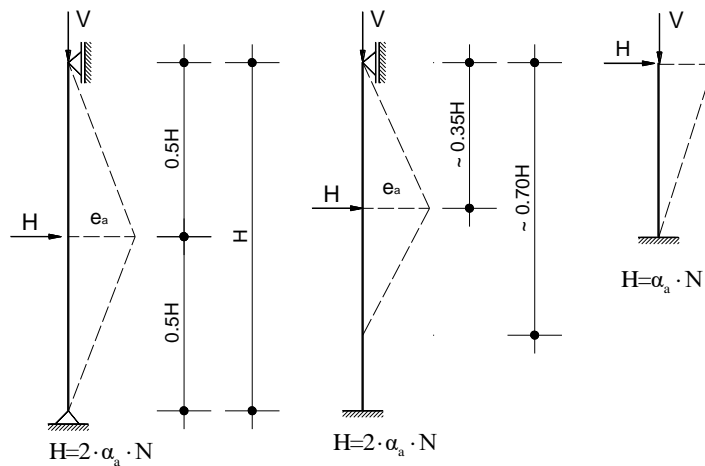


Figure 1. The presentation of horizontal load from the action of vertical loads as a result of imperfection upon the elements of the structure.

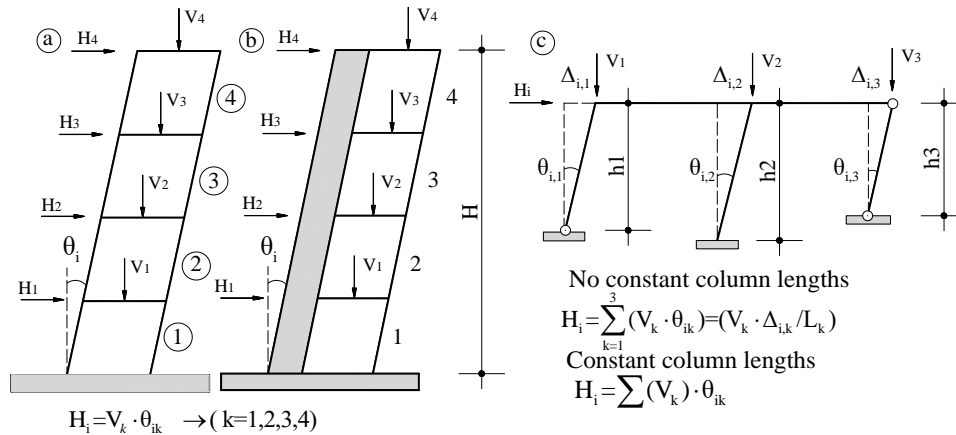


Figure 2. Types of structures with vertical loads and the determination of its imperfection a) the structure type of portal frame, b) combined structure and c) portal frame structure with two spans

Structures without stiffness elements could be treated as non-moveable construction joints if every element (column) holds more than 70% of the central average force $N_{Ed,m}$, which is calculated with the formula as shown below:

$$N_{Edm} = 0,70 \cdot \sum \frac{V_{Ed}}{n} \quad (3)$$

$$\sum V_{Ed} = \sum G_{Ed} + \sum Q_{Ed} \quad (4)$$

- n - the number of vertical elements of the structure including columns and walls,
 G_{Ed} - the sum of vertical loads calculated as dead load,
 Q_{Ed} - the sum of horizontal loads calculated as live load.

Point 4.2.2 (4) of EN-1988-1, suggest that the total contribution of all secondary seismic elements (constructive), on the side rigidity shall not exceed the value 15% of the contribution of all primary seismic elements.

$$\frac{P_w}{P_{MR}} = \frac{K_{MR}}{K_w} \leq 15\% \quad (5)$$

2. Numerical part

To better analyze the phenomena of imperfection in Figure 3 it shown the multistory object P+14, with residential destination. The height of all floors is $h=300$ cm. The elements that are about to be taken into consideration are the secondary vertical construction elements towards its reaction of imperfection phenomena. During the analysis of the given structure, in order to absorb the horizontal loads from seismic movements, for our analysis are taken into account only the vertical elements, as it is shown in the Figure 3, that are walls W-1, W-2 and W-3, and the effect of imperfection by vertical loads it is not taken into consideration.

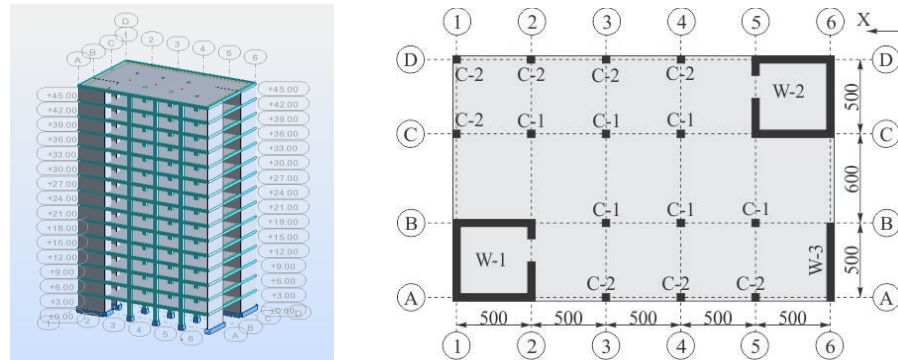

Figure 3. Plan and the view of analyzed structure

Table 1. The material quality use the structure

Analysis	Statics	Seismic
Concrete C 30/37	$f_{ck}=30\text{N/mm}^2$ $\gamma_c=1,50$ $f_{cd}=f_{ck}/\gamma_c=20.0\text{ N/mm}^2$ $E=32000\text{N/mm}^2$	$f_{ck}=30\text{N/mm}^2$ $\gamma_c=(1,30-1,50)$ $f_{cd}=f_{ck}/\gamma_c=20.0\text{N/mm}^2$ $E/2=16000\text{N/mm}^2$
Reinforcement S-500	$f_{yk}=500\text{N/mm}^2$ $\gamma_s=1,15$ $f_{yd}=f_{yk}/\gamma_s=435\text{N/mm}^2$ $E=200000\text{N/mm}^2$	$f_{yk}=500\text{N/mm}^2$ $\gamma_s=(1,0-1,15)$ $f_{yd}=f_{yk}/\gamma_s=435\text{N/mm}^2$ $E=200000\text{N/mm}^2$

Table 2. Seismic forces and following parameters

Directions	unit	X-X	Y-Y
weight	[kN]	70737	70737
center of stiffness	[m]	11,843	7,90
center of masses	[m]	12,50	8,00
static eccentricity	[m]	0,657	0,10
accidental eccentricity	[m]	1,250	0,80
dynamic eccentricity	[m]	0,873	0,10
maximum eccentricity	[m]	2,780	1,00
minimum eccentricity	[m]	-0,9215	-0,75
bending	[λ]	1,56	1,56
torsional radius r_t	[m]	11,30	12,38
L_s	[m]	8,568	8,568
$0,30e_{oi}$	[m]	3,39	3,72
e_{oi}	[m]	0,657	0,10
base acceleration a_g	[m/s ²]	0,25g	0,25g
fundamental period T_c	[s]	1,7096	1,695
behavior factor	no	3,00	3,00
spectral type	no	B	B
spectral ordinate	no	0,07312	0,07375
coefficient λ	no	0,85	0,85
factor importance γ_I	no	1,00	1,00
base seismic forces	[kN]	4396,50	4434,33

Shear control stability and torsion using European code, for designing, are given with the expression shown below:

$$\alpha_{xy} = h_{tot} \cdot \sqrt{\frac{F_v}{E_{cm} \cdot I_c}} \leq \begin{cases} 0,2 + 0,1n & \text{for } n \leq 3 \\ 0,6 & \text{for } n \geq 4 \end{cases} \quad (6)$$

$$\alpha_T = \varphi \cdot h_{tot} \sqrt{\frac{F_v}{E_{cm} \cdot I_w} \cdot \left(\frac{d^2}{12} + c^2 \right)} \leq \begin{cases} 0,2 + 0,1n & \text{for } n \leq 3 \\ 0,6 & \text{for } n \geq 4 \end{cases} \quad (7)$$

Table3. Control stability in shear and torsion

Loads		Geometrical data	Stability control		
Permanent	Live	Structure height	Shear -x direction	Shear -y direction	Torsional
kN/m ²	kN/m ²	m	α_x	α_y	α_T
10.65	2.00	45.00	0.352	0.321	0.24

Table 4. Distribution of seismic force on the floors of the structure in the direction x-x

Level	Zi (m)	Wi (kN)	WiZi (kNm)	Fb (kN)	Fi (kN)
15	45	3860.7	173731.5	4396.5	455.07
14	42	4776.88	200628.96	4396.5	525.52
13	39	4776.88	186298.32	4396.5	487.99
12	36	4776.88	171967.68	4396.5	450.45
11	33	4776.88	157637.04	4396.5	412.91
10	30	4776.88	143306.4	4396.5	375.37
9	27	4776.88	128975.76	4396.5	337.84
8	24	4776.88	114645.12	4396.5	300.30
7	21	4776.88	100314.48	4396.5	262.76
6	18	4776.88	85983.84	4396.5	225.22
5	15	4776.88	71653.2	4396.5	187.69
4	12	4776.88	57322.56	4396.5	150.15
3	9	4776.88	42991.92	4396.5	112.61
2	6	4776.88	28661.28	4396.5	75.07
1	3	4776.88	14330.64	4396.5	37.54
Shuma:		70737.02	1678448.7		4396.50

Table 5. Distribution of seismic force on the floors of the structure in the direction y-y

Level	Zi (m)	Wi (kN)	WiZi (kNm)	Fb (kN)	Fi (kN)
15	45	3860.7	173731.5	4434.33	458.99
14	42	4776.88	200628.96	4434.33	530.05
13	39	4776.88	186298.32	4434.33	492.19
12	36	4776.88	171967.68	4434.33	454.33
11	33	4776.88	157637.04	4434.33	416.46
10	30	4776.88	143306.4	4434.33	378.60
9	27	4776.88	128975.76	4434.33	340.74
8	24	4776.88	114645.12	4434.33	302.88
7	21	4776.88	100314.48	4434.33	265.02
6	18	4776.88	85983.84	4434.33	227.16
5	15	4776.88	71653.2	4434.33	189.30
4	12	4776.88	57322.56	4434.33	151.44
3	9	4776.88	42991.92	4434.33	113.58
2	6	4776.88	28661.28	4434.33	75.72
1	3	4776.88	14330.64	4434.33	37.86
Shuma:		70737.02	1678448.7		4434.33

After the axial value is calculated in vertical elements, such as columns and walls, depending its position and location upon the structure, it results that the value of the axial force on axis A-A and D-D have the value $N_{Ed} = 126,75$ kN respectively $N_{Ed} = 213,0$ kN, which is lower than $N_{Ed,0.70}$, therefore

are not taken into calculation, and the number of elements that have impact in the effects of imperfection is equal to 10.

Table 6. Imperfection phenomena coefficients determination

α_{a1}	$\sum V_{Ed}$ (kN)	$N_{Ed,m}$ (kN)	n (members)	$N_{Ed,0.70}$ (kN)	n' (members)	α_n
$5 \cdot 10^{-3}$	7486,80	440,40	17	308,28	10	0.742

Table 7. Presentation of additional impacts from vertical loads upon the structure

Level	Zi (m)	Wi (kN)	θ	Hi (kN)
15	45	3860.7	0.0011	4.32
14	42	4776.88		5.35
13	39	4776.88		5.35
12	36	4776.88		5.35
11	33	4776.88		5.35
10	30	4776.88		5.35
9	27	4776.88		5.35
8	24	4776.88		5.35
7	21	4776.88		5.35
6	18	4776.88		5.35
5	15	4776.88		5.35
4	12	4776.88		5.35
3	9	4776.88		5.35
2	6	4776.88		5.35
1	3	4776.88		5.35
Σ				79.23

Conclusions

Based on the results obtained in our study, and not only, but also referring to the contemporary literature, we can emphasize that the structural designers shall be based by the designing codes, in particular EN-1992-1 which it pays more attention to the phenomena of imperfection to the constituent elements of structure. It should be recalled that imperfection takes into account a number of errors which could be done during the time of designing, execution and structure maintenance, especially its impact is at the case of flexible structure, so that horizontal shift are evident and have a significant value as it is the case of structural elements type of skeleton, structural elements from steel especially to those of precast type.

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