sciendo Ovidius University Annals Series: Civil Engineering, Year 20, 2018
DOI: 10.2478/ouacsce-2018-0008

Determination of the Basic Force-Displacement on the Top in the Case of the Structure with Reinforced Concrete Frames P+6

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Abstract – **The theme of the paper is to design the capacity of a P + 6E construction with reinforced concrete frame structure and determination of the basic force-displacement on the top. Drawing the cutting force - the displacement at the top requires a non-linear bias of the pushover type.**

The non-linear static calculation is used in the displacement-based design methodology, in which lateral displacements are considered the main parameter for characterizing the seismic response of the structures.

Keywords – non-linear static calculation, reinforced concrete frame structure, seismic response

1. INTRODUCTION

The load given by a strong earthquake seeks to create an appropriate mechanism to release earthquake-induced energy through deformation energy. This mechanism is initiated by the appearance of plastic joints in beams and columns.

- the order of appearance of the plastic joints is followed. The appearance of these plastic joints in columns is not acceptable but at the lower ends of the columns at the base of the structure and at the last level.

- by pushing the structure and the appearance of the plastic joints, the structural strength reserve (redundancy) of the structure is followed, the structure is not avoided and the structure remains at the level of the Life Safety(LS)performance.

- the bilinearization of the capacitance curve determines the able lateral force of the structure (Fy) and the overall ductility of the structure $\mu = \alpha u / \alpha 1$.

2. EXPERIMENT DESCRIPTION

The research building is a P + 6E floor structure with reinforced concrete structure, occupying a rectangular surface of 16,50 x 35,00 m in plan. The building is located in Bucharest.

The basic objective of the current type of seismic design is to provide the most advantageous structural energy dissipation mechanism. In the case of a structure with multiple degrees of freedom, not all elements have to highlight a ductile behavior.

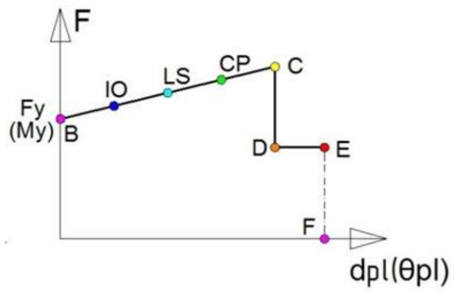

Fig. 1 Force-displacement curve for plastic joints with automatically assigned properties

The properties of the plastic joints are automatically determined by FEMA 356 specialized computing programs. For coupled and non-coupled plastic joints for each degree of freedom / effort, it is necessary to define a force-displacement curve (bending-rotating) with five points : A, B, C, D, E, F (Fig. 1)

The meaning of these points is as follows:

-pointA = the origin of the curve
-point B = plastification limit
-point C = ultimate capacity for static non-linear calculation
-point D = residual capacity for static non-linear calculation
-point E = complete failure

IO= (Immediate occupancy)
LS= (Life safety)
P= (Collapse Prevention)

In order to be able to perform a non-linear calculation in a first phase, a linear calculation was made to determine the moments capable of the sections and, implicitly, the reinforced steel used. These data will be used later in the nonlinear calculation.

The section through the building is shown in Figure 2 and in Figure 3 the calculation model.

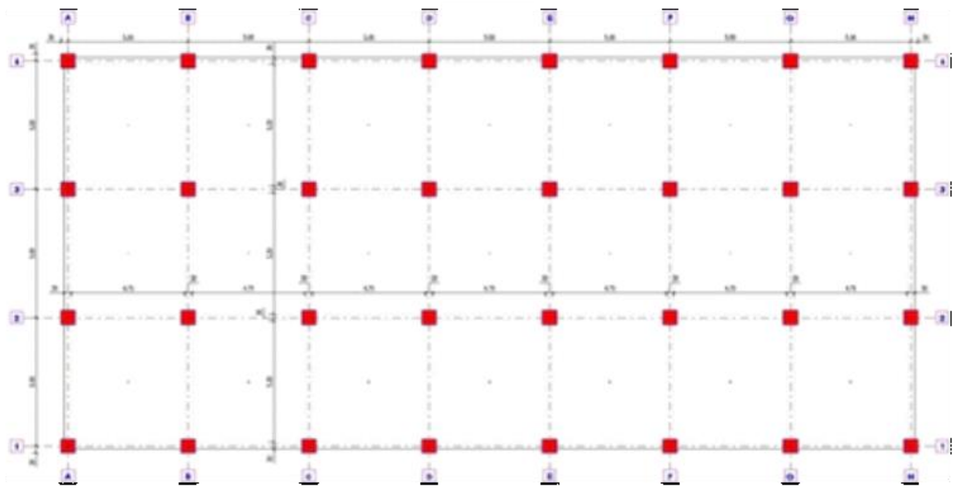

Fig. 2 Building plan

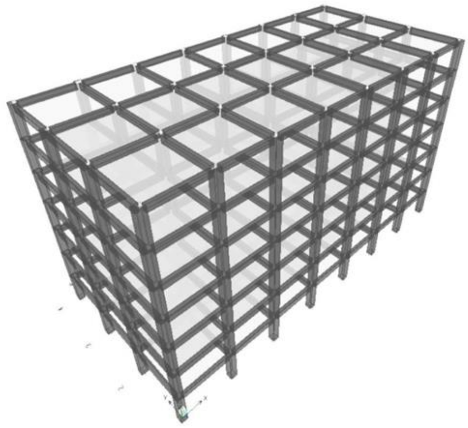

Fig. 3 Structure calculation model

The steps taken in the first phase are the assessment of loads, the pre-dimensioning of the elements, the evaluation of the seismic action, the checking of the lateral displacements, the calculation of the reinforcements. For example, fig. 4 shows the reinforcement areas for a transverse frame.

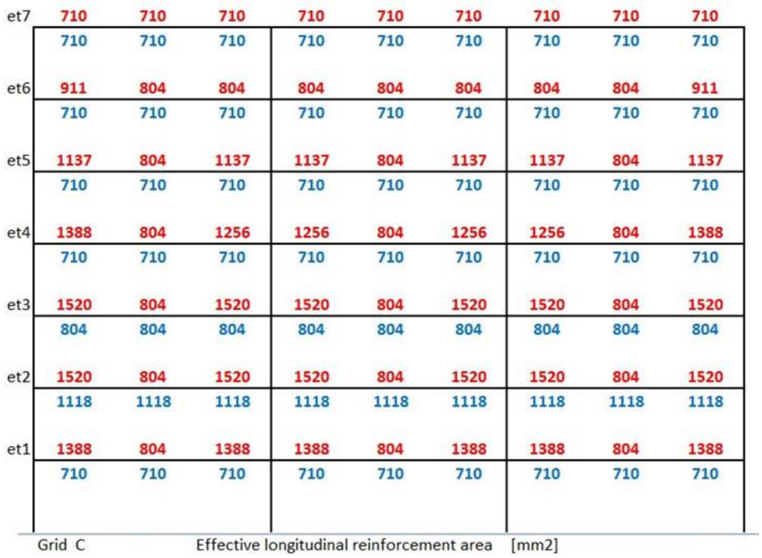

Fig. 4 Longitudinal reinforcement area transversal frame beams C

The value of the longitudinal beam area of the beams and pillars in these tables is the input value in the non-linear calculation of the stress-determining structure (Mrd) according to the average strength of the concrete and steel.

Non-linear static calculation was performed using the ETABS program.

The vertical distribution of lateral forces is made by two different distributions, namely:

-a distribution in which the lateral forces are proportional to the masses (acceleration is constant in height) ip.1.

-a distribution resulting from modal analysis for the predominant vibration mode; a simplified triangular distribution can be accepted.ip.2

Table.1 Determining the displacements imposed on the structure

		T[s]	Sde[m]	c	Sdi[m]	d[m]
IP I	dir X	1.117	0.233	1.3943	0.3242	0.42
	dir Y	1.032	0.198	1.5165	0.3010	0.39
IP II	dir X	1.117	0.233	1.3943	0.3242	0.32
	dir Y	1.032	0.198	1.5165	0.3010	0.30

The steps taken to achieve the calculation model are as follows:

-calculation of moments capable of considering the average strength of steel and concrete.

-evaluation of the displacement requirement for the system with an equivalent degree of freedom from the seismic response spectrum, depending on its rigidity and strength characteristics

-evaluation of the displacement requirement for the real system based on the requirement to move the system with a degree of freedom

-apply the horizontal load until the travel requirement value is reached

-verification of the plastification mechanism, made evident by imposing the displacement requirement of the structure. It determines the relative displacements of the level, the joints of the plastic joints and verifies their enrollment within the permissible limits. The ratio αu / α1 is also determined and the behavior factor is correctly chosen to design the structure.

3. RESULTS AND SIGNIFICANCES

After performing the calculations by pushing the structure up to the target displacements, the following force-displacement curves were obtained:

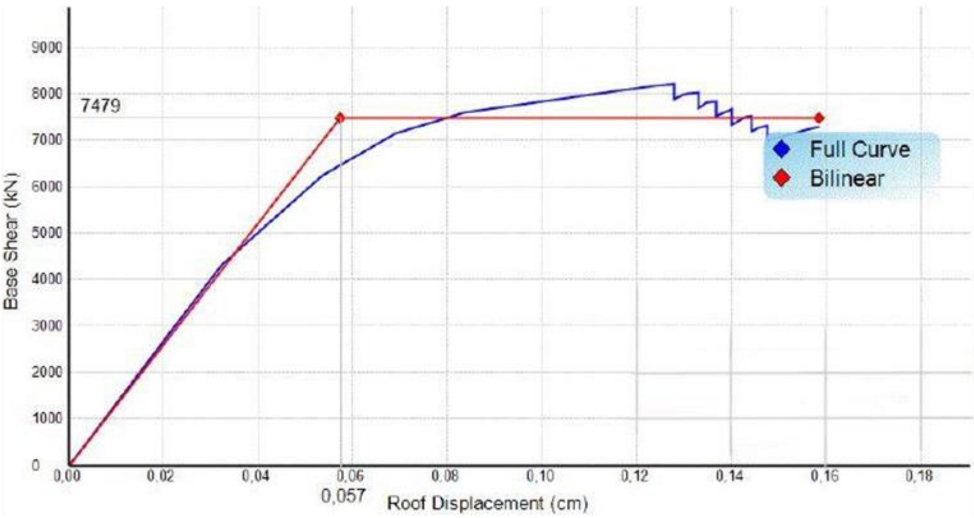

Fig. 5 Pushover curve X direction (hypothesis1)

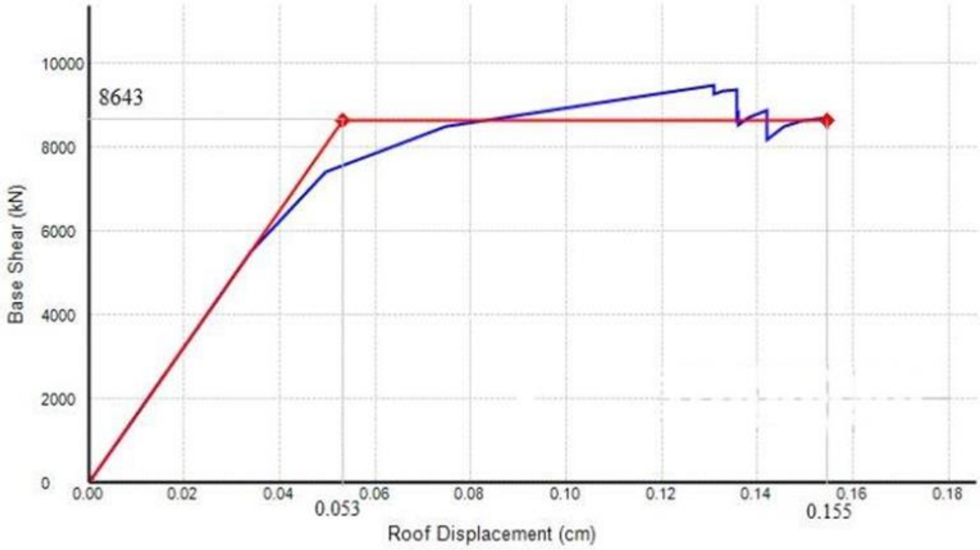

Fig. 6 Pushover curve Y direction (hypothesis 1)

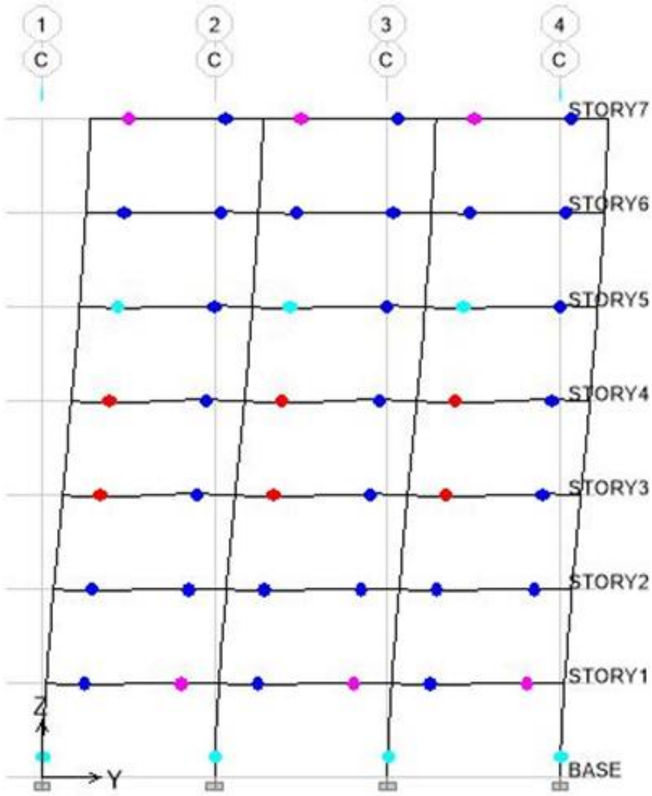

Fig. 7 Plastic joints step 17

The drawing of the plastic joints at the moment of reaching the displacement requirement allows to verify the realization of the design conception of the hierarchy of the resistance capacities of the structural elements according to the mechanism of dissipation of the desired energy.

At step 17, the target node located on the roof, reaches a maximum displacement of 15.5 cm, X direction , hypothesis 1.

At step 24, the target node located on the roof reaches a maximum displacement of 15.8 cm, Y direction, hypothesis 1.

At the capacity curve in the X direction in hypothesis I, it is observed that by bi-linearization of the curve, the first plastic joint (corresponding to the first curvature stiffness reduction) occurs around at a capable lateral force (Fy) of 7479 kN. The design seismic force is 3838.10 kN, so the coefficient of over-resistance due to the design resistances of the materials is 1.94.

The ratio of αu / α1 used for the assessment of seismic forces is 1.35. According to the curve, the αu / α1 ratio (ductility of the structure) results from 2.77, higher than the one evaluated; consequently the behavior factor q will be higher. This can be considered as a safety factor with a suitable value for the earthquake design situation.

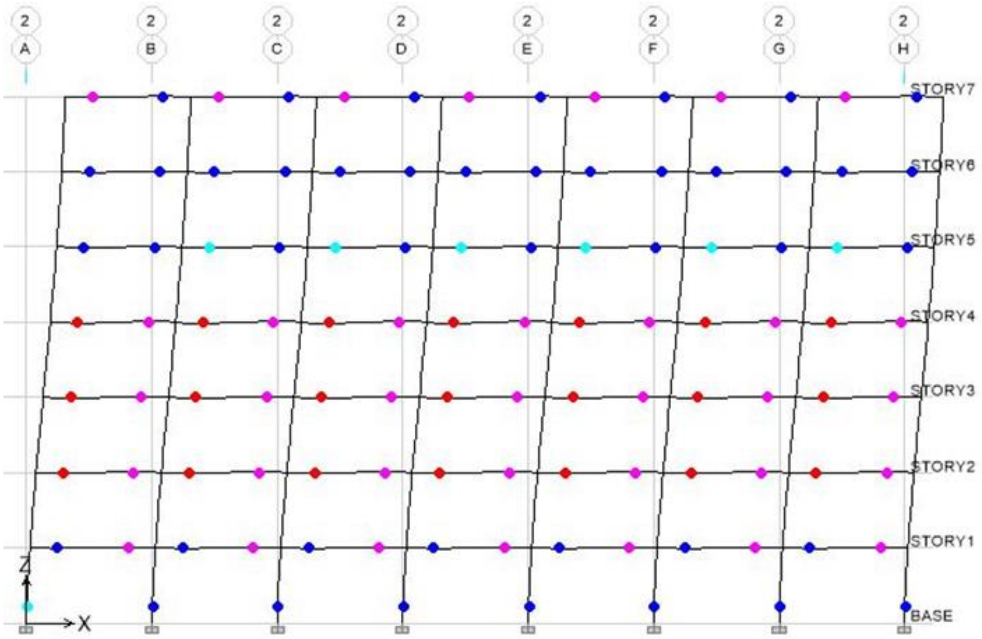

Fig. 8 Plastic joints step 24

At the Y curve in hypothesis I, it is observed that by bi-linearization of the curve, the first plastic joint (corresponding to the first curvature stiffness reduction) occurs around a 8643.20 kN basic force. The design seismic force is 3838.10 kN, so the coefficient of over-resistance due to the design resistances of the materials is 2.25. The ratio of αu / α1 used for the assessment of seismic forces is 1.35. According to the curve the ratio is 2.90, higher than the one evaluated; consequently the behavior factor q will be higher. This can be considered as a safety factor with a suitable value for the earthquake design situation.

4. CONCLUSIONS

The general safety requirement is: *requirement <capacity* and can be expressed in different sizes: displacements and deformations, efforts.

Table 2 Rotation

	I-X	II-X	I-Y	II-Y
STORY7	0.0019	8.31E-04	0.0018	0.0006
STORY6	0.0023	1.19E-03	0.0023	0.0010
STORY5	0.0029	1.66E-03	0.0029	0.0014
STORY4	0.0030	2.12E-03	0.0030	0.0019
STORY3	0.0030	2.40E-03	0.0029	0.0022
STORY2	0.0027	2.33E-03	0.0025	0.0022
STORY1	0.0016	1.61E-03	0.0015	0.0015
			θra	0.03

In all cases the values of the rotation at the floor are below the 3% code value.

From the paintings presented that the structure is of the "low beams-strong columns" type, the plastic joints in the columns only appear at their base, which is allowed by normative.

It is noticed that the structural mechanism of seismic energy dissipation operates according to the norms in the sense that it releases the accumulated energy from the earthquake, by the plastic deformations reaching the level of performance "immediate occupation" and "life saving".

It is noted that in hypotheses II in both directions the force cutter is higher exactly as in the procedure described by the normative P100; in the hypotheses I, the basic moment at the base of structure is higher, on the bouth directions.

From the analysis of capacity curves, it can be noticed that the structure has large reserves and can receive a severe earthquake.

It is noted that the P100-1 / 2013 rotation evaluation procedure consisting of the amplification of displacements obtained from a linear elastic calculation under the design seismic forces, amplified by c * q, leads to higher values, in some cases, much higher than the specific seismic requirements.

An expected and desirable behavior is observed in the direction of forming the plastic joints at the end of the beams. There are no plastic joints that do not lead to progressive collapse.

Only a few plastic joints exceed the CP (collapse Prevention) limit, but the structure has enough reserves to redistribute the efforts that can not be taken up by the dissipative elements that have come out of work.

5. REFERENCES

[1] *Cod de practică seismică* P100-1/2013

[2] T.Postelnicu, I.Damian, D.Zamfirescu (2012), *Proiectarea structurilor de beton armat în zone seismice* ,Editura MarLink, Bcureşti

[3] T.Paulay,H.Bachman,K.Moser (1997), *Proiectarea structurilor de beton armat la acţiuni seismic*e, Editura Tehnică,Bucureşti
[4] I.G.Craifăleanu (2016), *Introducere în calculul neliniar al structurilor la acţiuni seismice cu programul SAP2000*,Matrixrom
[5]SR-EN1992-1-1 Eurocod *2Proiectarea structurilor de beton armat partea 1-1. Reguli generale pentru clădiri.*

Note:

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