The Application of "Capacity Design" in a RC Building Frame Structure

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ABSTRACT

Many countries throughout the world have accepted the concept for design of RC buildings based on the "capacity design" methology.This has been proved also by the Eurocode-8 that is largerly based on this method.The main idea of this method is to predetermine places at which the occurrence of nonlinear deformations shall be dictated.This critical parts,the so called plastic hinges,are designed and processed separately to enable those places dissipate the total energy.It is desirable that all the inelastic deformations be due to bending,which with the provided previous and necessary conditions,corresponds to ductile behavior of the structure.

This paper presents the application of the "capacity design" in a structure consisting of RC frames in both orthogonal directions.In such structures this method is reduced to elimination of the possibility of formation of plastic hinges in the columns in order to fulfill the basic principle of(weak beams-strong columns) which is included in almost all seismic regulations,this method requires a considerably higher bearing capacity of columns.Such a conservative approach leads to the requirement of larger proportions of columns and a greater amount of longitudinal reinforcement.

As an example, the proposed methodology is applied to an actual reinforced concrete building frame structure.Beams,supporting floors,and columns are continuous and meet at nodes,called rigid joints.Such frames can readily carry gravity loads while providing adequate resistance to horizontal forces ,acting in any direction.We will make the elastic and plastic analysis by the program,according Eurocode 8. The analysis will be performed until the response of the building will reach three conditions. After the final model is reached we will propose the next step to design the structural elements.The final design of elements will be given in the % of required reinforced steel.And finally ,we will make the time-history analysis for an actual earthquake.

Keywords: *capacity design,frame structure,elastic analysis.*

Introduction

A capacity design approach is likely to assure predictable and satisfactory inelastic response under conditions for which even sophisticated dynamic analyses techniques can yield no more than crude estimates.This is because the capacity designed structure can not develop undesirable hinge mechanisms or modes of inelastic deformation,and is,as a consequence,insensitive to the earthquake characteristics,except insofar as the magnitude of inelastic flexural deformations are concerned.When combined with appropriate detailing for ductility,capacity design will enable optimum energy dissipation by rationally selected plastic mechanisms to be achieved.Moreover,as stated earlier,structures so designed will be extremely tolerant with respect to the magnitudes of ductility demands that future large earthquakes might impose.The structure of our example(fig.1) consist of RC frames in both orthogonal directions.

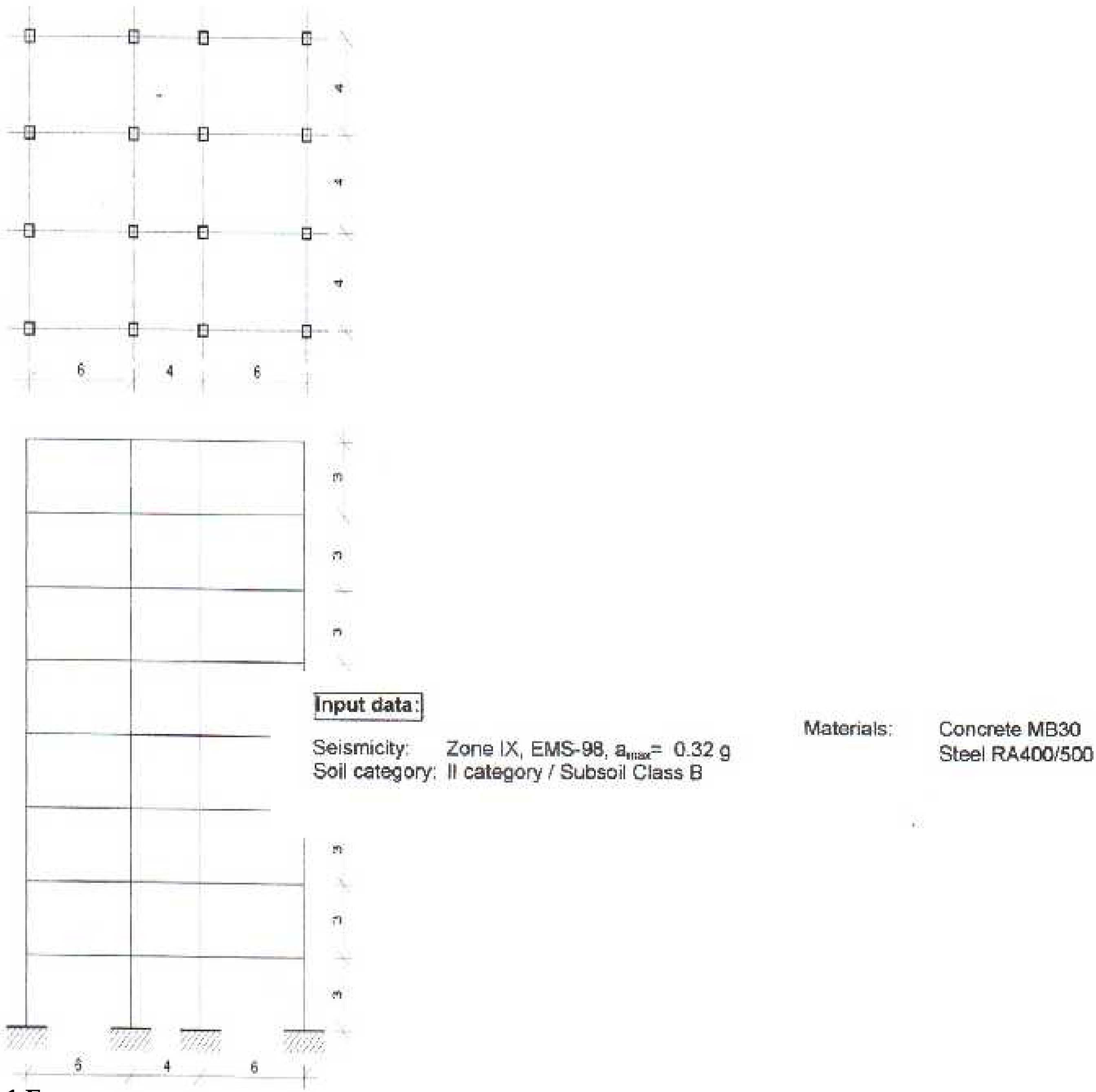

Fig.1 Frame structure

Analysis of the vertical loads
Assuming:

As GRAVITY Loads : $G = 8$ kN/m^2

As LIFE Loads : $Q = 2$ kN/m^2

These are applied in all the area of the floor in all 8 floors.

According to EURONORMS we have chosen the **Preliminary dimensions.**

$$\frac{N_{sd}}{b*h*fcd} \leq 0.55 \quad b*h > \frac{N}{0.55} = 2200\text{m}^2 \qquad (1)$$

- We have fixed the dimensions of columns: *60 x 40*
- For beams we have decided to use as preliminary dimensions: *50 x 30*

For simplicity we keep the same dimensions for all the columns and the beams.

Determination of seismic forces
Based on the Eurocode 8 the natural period should be :

$$T_1 = 0.075 * H^{3/4} = 0.075 * 24^{3/4} = 0.813 \text{ sec.} \quad (2)$$

In our building frame the programe of this period is 0.93 sec.

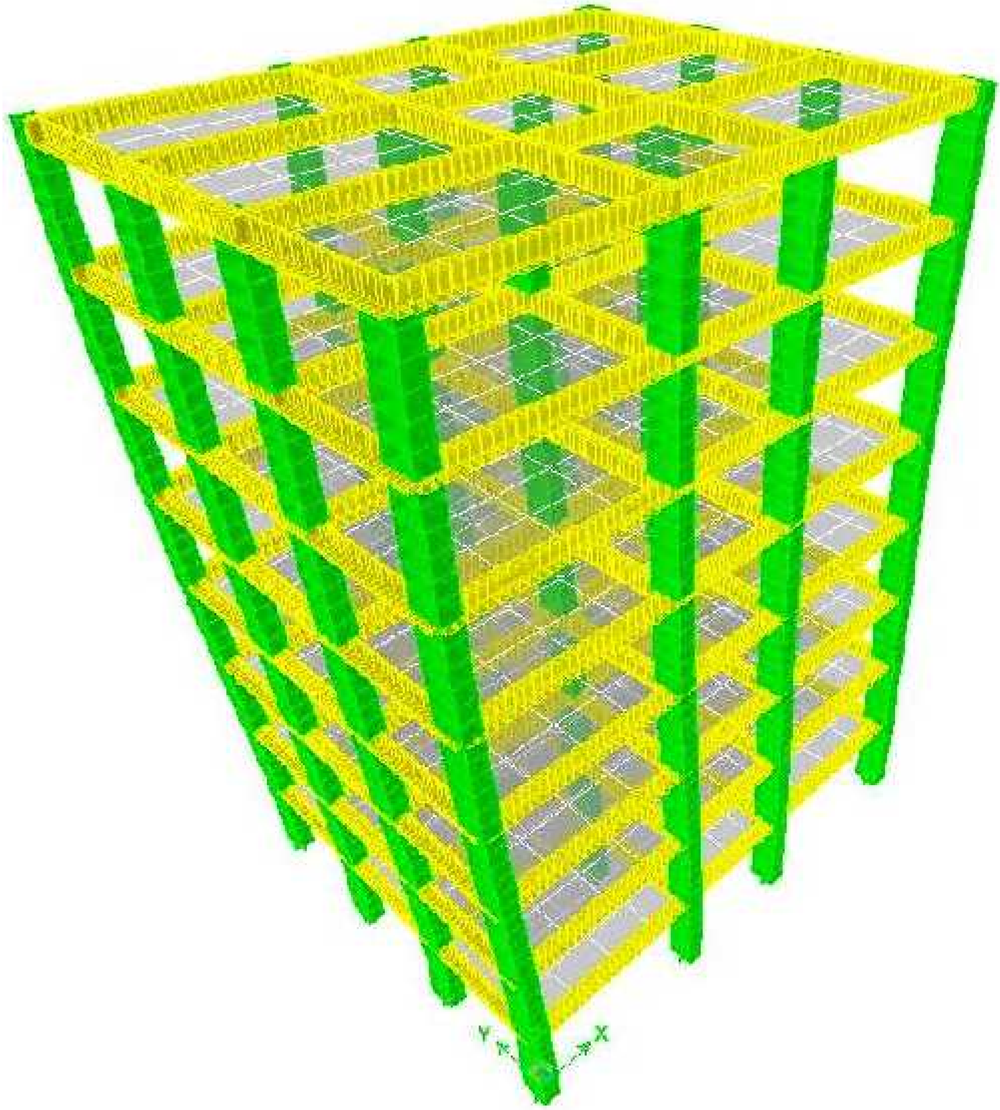

FIG.2 View mode 1 Period 0.9300 seconds

DEFINITION OF BEHAVIOR FACTOR

$$q = q_o \cdot kw \quad (3)$$

$$q_o = 4.5 \cdot \frac{\alpha n}{\alpha 1} = 4.5 \cdot 1.3 = 5.85 \quad (4)$$

$$Kw = 1 \quad (5)$$

$$q = q_o \cdot kw = 5.85 \cdot 1 = 5.85 \quad . \quad (6)$$

We will accept q=5.5 for construction of design response spectrum.Based on seismology, soil conditions and the behavior factor directly from the program is constructed the design response spectrum.

Table 1 Response Spectrum Accelerations

Spec	Mode	Period	DampRatio	SpecFactor	U1
X	1	0.9300047	0.05	1	1.565992
X	2	0.7667445	0.05	1	1.899767
X	3	0.6842608	0.05	1	2.147218
X	4	0.295012	0.05	1	2.4
X	5	0.2348326	0.05	1	2.4
X	6	0.2132108	0.05	1	2.4
X	7	0.1625847	0.05	1	2.4
X	8	0.1229337	0.05	1	2.024681
X	9	0.1144126	0.05	1	1.906522
X	10	0.1058317	0.05	1	1.787532
X	11	0.07662588	0.05	1	1.382545
X	12	0.07534017	0.05	1	1.364717
Y	1	0.9300047	0.05	1	0.4697975
Y	2	0.7667445	0.05	1	0.56993
Y	3	0.6842608	0.05	1	0.6441653
Y	4	0.295012	0.05	1	0.72
Y	5	0.2348326	0.05	1	0.72
Y	6	0.2132108	0.05	1	0.72
Y	7	0.1625847	0.05	1	0.72
Y	8	0.1229337	0.05	1	0.6074042
Y	9	0.1144126	0.05	1	0.5719565
Y	10	0.1058317	0.05	1	0.5362598
Y	11	0.07662588	0.05	1	0.4147637
Y	12	0.07534017	0.05	1	0.4094151

PLASTIC ANALYSIS

Plastic analysis is made by the program according Eurocode 8 for two principal constructions:

$$1.356G + 1.5Q \qquad (7)$$

$$1.6 + 0.45\,Q + 1\,E \qquad (8)$$

The analysis will be performed until the response of the building will reach the above conditions:

a)Natural period of the range : $T_1 = 0.075 * H^{3/4}$ (9)

b)Interstory drifts : ds ≦ (0.05*h)/(q*v) = (0.05*300)/(5.5*0.5) = 0.54545 m (10) c)For ductility requirements: $\frac{N}{b*h} \le 0.55$ (11)

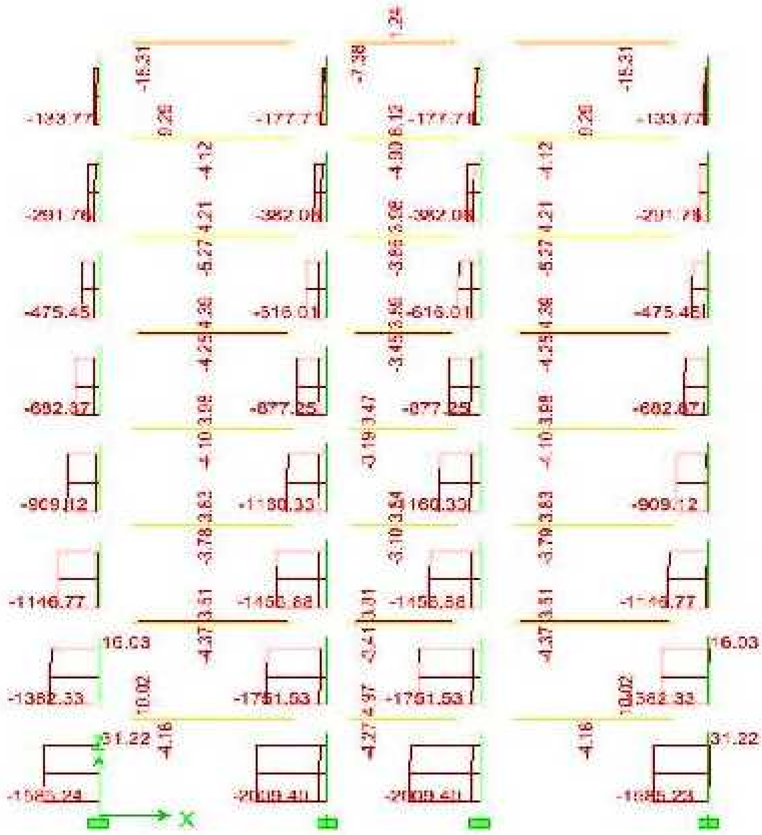

FİG.3 Axial force diagram

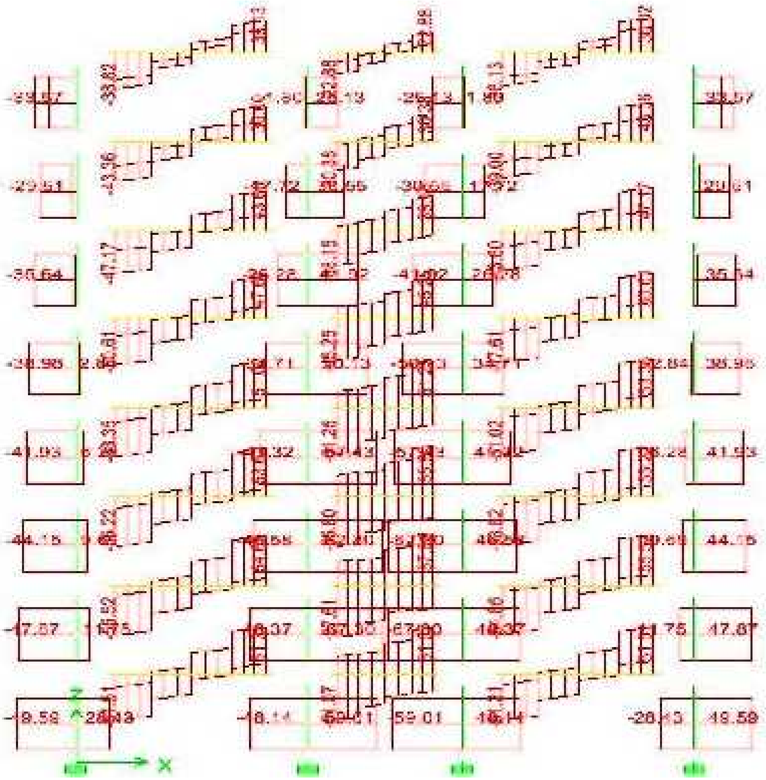

FİG.4 In plane shear diagram

After the final model is reached we propose the next step to design the structural elements.The final design of elements is given below in the % of required reinforced steel.

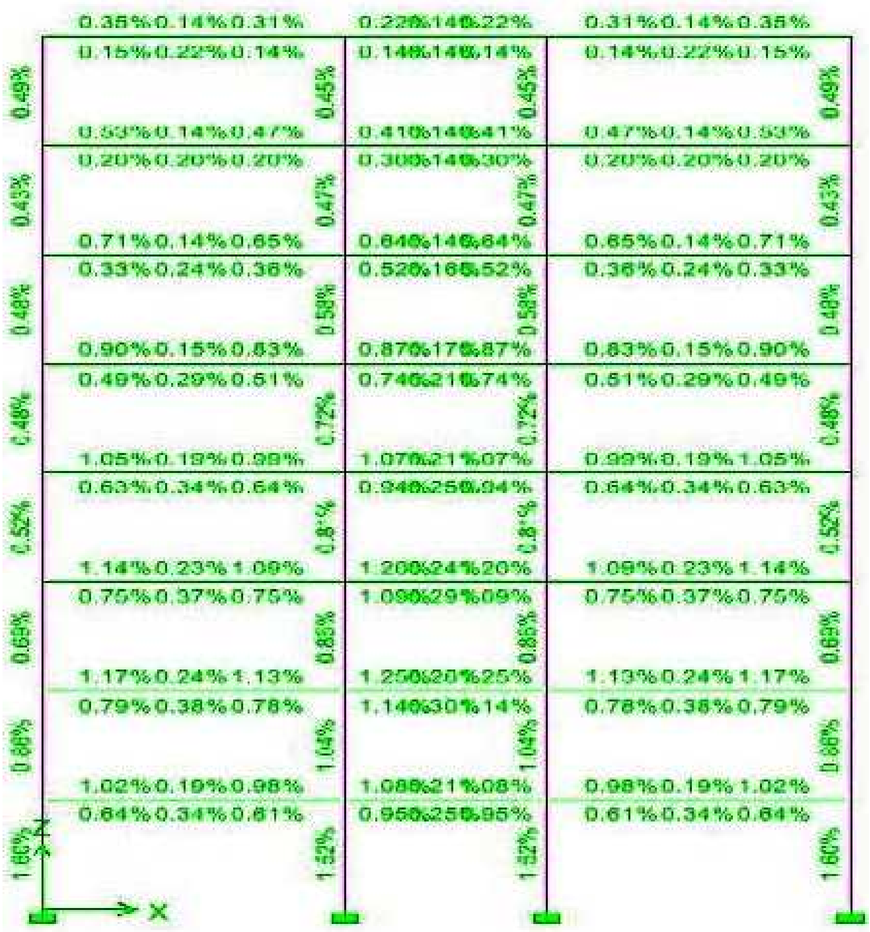

FIG.5 The % of required reinforced steel

TIME-HISTORY ANALYSIS FOR AN ACTUAL EARTHQUAKE

The history analysis is performed due the RC- center earthquake with : q_{max} = 0.32 g.
As e linear analysis for any required history displaced , velocity, acceleration , internal focus, the program can construct directly the result due to the real excitation.

Time history analysis for the preliminary defined dimensioning is performed for El-Centro accelerogram normalized for maximum ground acceleration (Peak Ground Acceleration) PGA=0.32g,time duration t=10 sec,time step for each value Δt=0.02 sec.

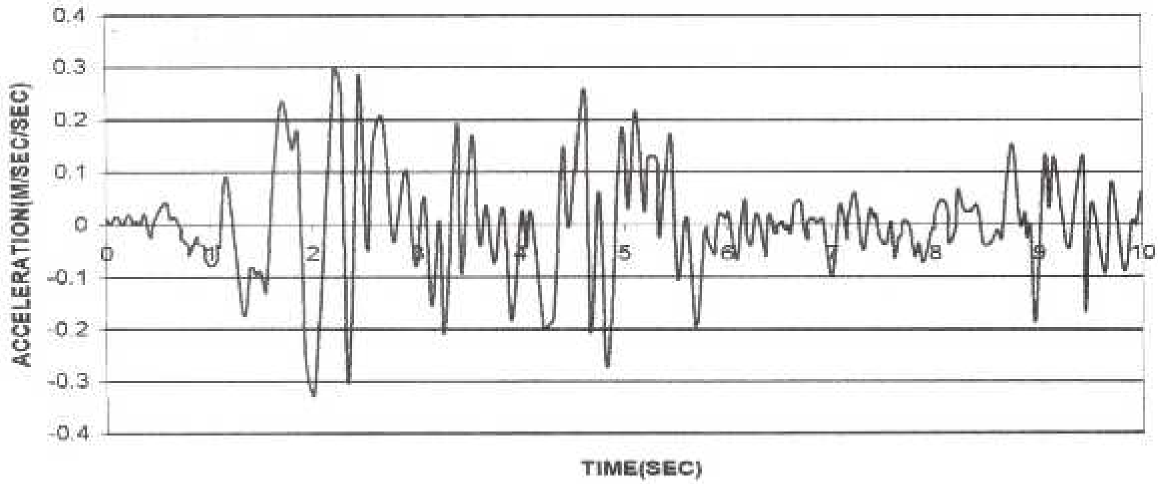

FIG.6 EL CENTRO

Results are given for the same elements already dimensioned:

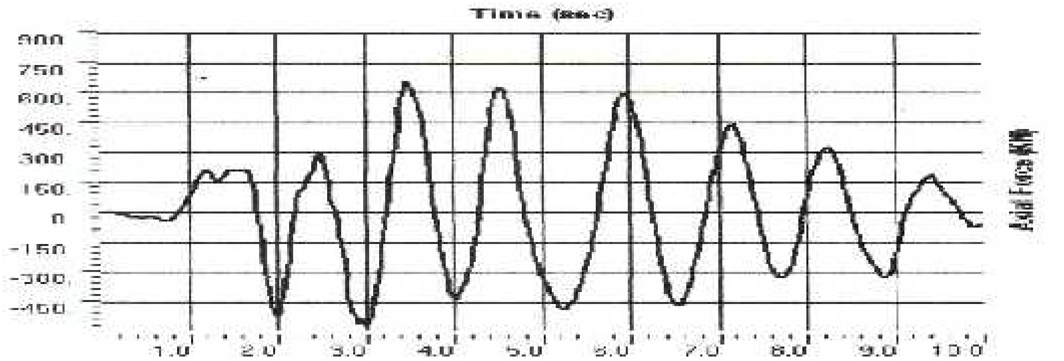

FIG.7 Column (Element 19)Bottom section

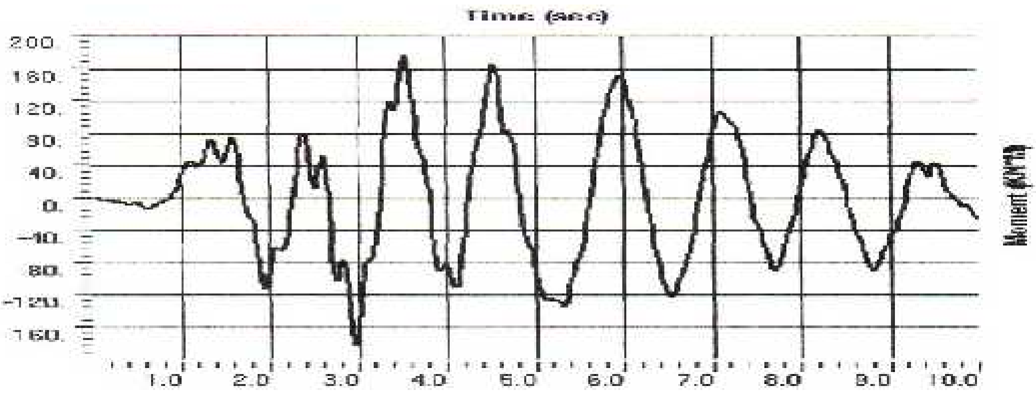

FIG.8 Beam (Element 1)Left section

Conclusions

The capacity design approach explicitly considers the problem of determining the failure mechanism of members. The basic idea is to force the member to fail in a ductile manner by making the capacity of the member in other possible failure modes greater. It involves the simple application of plastic analysis on an element-wise basis.

Plastic hinges are ‘placed’ in the beams.

This procedure works well for designing the beams in a strong-column/weak beam design and for joints.

There is a requirement of larger proportions of columns and a greater amount of longitudinal reinforcement.

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