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Evaluation of Response of Inelastic RCC Frame Structures

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Abstract

In this study, Non-linear response of concrete with differential value of Young's Modulus is determined by the stress strain expression. The modulus of elasticity is varied throughout to evaluate the non-linear response of concrete structure at a constant load. The modeling of structure is done in STAAD PRO Vi8 software. In this study, single storey-single bay frame is modeled which is subjected to dead load and uniform loads, has been considered for the non-linear response of concrete structures. A structural element such as Column is used for evaluation of the non-linear response of concrete material. From this, deflection of the column element is carried out by using STAAD PRO software with different initial tangent modulus of elasticity at a constant loading.
Keywords: Non-linear response of concrete frame, STAAD PRO V8i, Load- deflection curve, material non-linearity, Modulus of Elasticity

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I. INTRODUCTION

In recent year, reinforced concrete has been utilized with expanding modernity in the development of complex structures, for example, multi-story tall structures, long-span bridges, atomic controls, gravity-type offshore plate-forms, and so on. These structures are subjected to a variety of environmental loads including earthquake movements, wind and wave forces, furthermore, drifting ice. Under extreme conditions, a structure might be disfigured well beyond its elastic range, and subsequently a nonlinear analysis gets to be essential [2].

Concrete is a non-homogeneous material and behaves elastically over a small load range initially. Inclusion of reinforcement brings in additional aspects of non-homogeneity because of the involvement of two materials. Any realistic analysis of reinforced concrete structures, should take the effect of these non-homogeneities which reflect in several complexities like cracking, nonlinear material behavior the loss of bond between concrete and steel etc. Concrete by nature cracks at a very low tensile stress and hence cracking of concrete is a major nonlinearity [1].

Nonlinear analysis of concrete structures is expanding regularly with time due to vast use of RCC material and evaluation of finite element procedure. Now-a-days reinforced concrete is widely used structural material with its limitation of linear behavior to small response. When linear elastic analysis is no longer valid under such condition nonlinear analysis is required. It plays an important role in the design of new and existing buildings.

II. LITERATURE REVIEW

A.M. Reinhorn and G. D. Manolls [4] worked on the "Active Control of Inelastic Structures" in this they presented methodology for the structures to control their shape when the structure undergoing nonlinear deformation under the use of an active pulse or force systems. They took these three examples to get over the methodology. (1). A conventional structure subjected to dynamic loading. (2). An off shore platform under wave action. (3) A structure with rubber isolators under earthquake motions. Material non-linearity was accounted iterative procedures. They concluded that an active pulse control decreasing the response of the structure. The algorithm they were used in this research applicable for both linear and nonlinear systems.

M.M. Ali and D.E. Grierson, (1986) [5], studied "Non-Linear Design of Reinforced Concrete Framework", a nonlinear design method had been developed for the RCC framed structures. Designed RCC frame in both cases strength and ductility, satisfied at the described service and ultimate loading condition in which strain- hardening effect of high strength reinforcing steel is also admitted in the design.

Nonlinear programming problem solved by the mathematical solution algorithm. They took a one-storey two bay structure as an example. At last they achieved design method for accounts for the basic strength and deformation criteria for the reinforced concrete structures. Also strain hardening effect of high grade steel reinforcement are utilized to profit as in results and reduced material cost.

III. METHODOLOGY

If the structures are not designed properly and are not constructed with the required quality then they may cause a large deflection due to non-linearity of the reinforced structures and they may get failure. To find out the nonlinearity of the concrete structure are complex but there are such software are used for analyze the structures. In this work, material nonlinearity of concrete of the RCC frame structure has been analyzed by using the software STAAD PRO V8i.

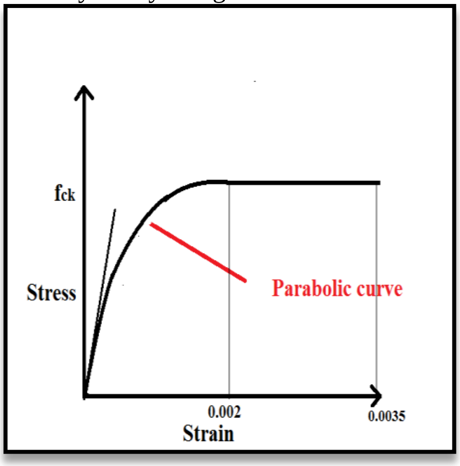

Fig. 1: Non-linear stress- strain curve for concrete

The fig 1 shows the nonlinear behavior of the concrete [7]. In this study I'll verify that the RCC structure got nonlinearities because of the material nonlinearity.

IV. VERIFICATION STUDIES

The selected problems for the evaluation consist of one bay one storey RCC frame. In this study the column is analyzed on the STAAD PRO software with various value of modulus of elasticity to evaluate the response of inelastic RCC frame structure.

A. Single Storey Single Bay RCC Frame:

The insert fig 2 shows a one bay one storey RCC frame having rectangular beam and column; both ends are fixed, with 6m span and 4.5 m height respectively. The cross sectional area of the element is 0.3 m x 0.5m. The compressive strength of the concrete is f_{ck} = 25 KN/m^2 and the yield strength of the steel is 415 N/mm^2 is used. The frame is subjected to dead load and live loads.

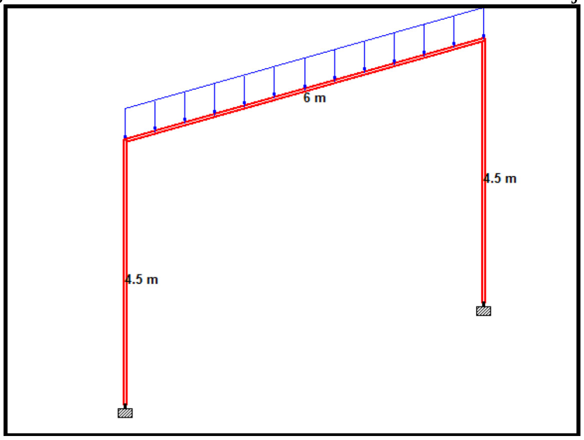

Fig. 2: single storey single bay frame

For the calculation of compressive stress of concrete mentioned expression is used (According to hognestad) [3]:

$$f_C = 0.447\, f_{ck} \left[2 (\varepsilon / \varepsilon_0) - (\varepsilon / \varepsilon_0)^2 \right] \quad \text{[Eq. 1]}$$

For $\varepsilon < 0.002$

$$f_c = 0.447\, f_{ck} \quad \text{[Eq. 2]}$$

For $0.002 \le \varepsilon \le 0.0035$

Where f_{ck} = Compressive strength of the concrete at 28 days

f_c = Compressive stress of the concrete.

ε = Compressive strain of concrete

ε_0 = Strain at the maximum stress fck usually taken as 0.002

And for the calculation of differential Modulus of Elasticity, equation (1) is differentiate with respect to strain then following expression is obtained:

$$E = d\sigma/d\varepsilon = 0.447\, f_{ck} [\, (2 / \varepsilon_0) - (2\varepsilon / \varepsilon_0{}^2) \,] \qquad \text{[Eq. 3]}$$

The above expression is used to determine the differential value of initial tangent Modulus of Elasticity at different interval of strain. The calculated value are given in the following table 1

V. Calculation of Differential Modulus of Elasticity at Different Interval of Strain

Table – 1
Calculation of modulus of elasticity

Sl. No.	*Strain (ε)*	*dσ/dε (E) (kN/m²)*
1	*0*	*11175*
2	*0.0002*	*10057.5*
3	*0.0004*	*8940*
4	*0.0006*	*7822.5*
5	*0.0008*	*6705*
6	*0.0010*	*5587.5*
7	*0.0012*	*4470*
8	*0.0014*	*3352.5*
9	*0.0016*	*2235*
10	*0.0018*	*1117.5*

VI. Result and Discussion

Using Eq.2 the different values of Modulus of Elasticity are calculated and the obtained values are used to calculate the deflection of an INELASTIC FRAME using STAAD PRO.

A. Calculation of Deflection of an elastic Column:

Table – 2
Deflection at constant modulus of elasticity

Sl. No.	*Young's Modulus (E) (kN/m²)*	*Load (kN/m)*	*CUM. Load (kN/m)*	*Deflection (in.)*	*CUM. Deflection (in.)*
1	*2.5×10^7*	*0*	*0*	*0*	*0*
2	*2.5×10^7*	*1*	*1*	*0.001*	*0.001*
3	*2.5×10^7*	*2*	*3*	*0.002*	*0.003*
4	*2.5×10^7*	*3*	*6*	*0.003*	*0.006*
6	*2.5×10^7*	*4*	*10*	*0.004*	*0.010*
6	*2.5×10^7*	*5*	*15*	*0.005*	*0.015*

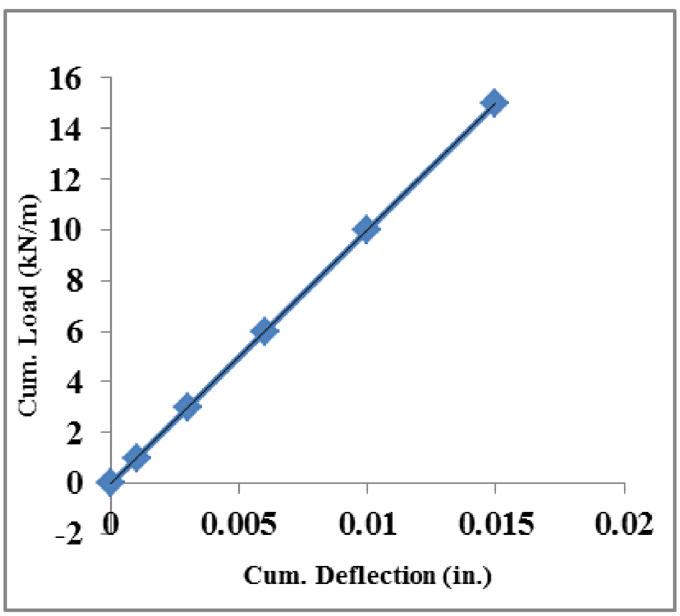

Fig. 2: (a) Linear Graph B/W Load –Deflection

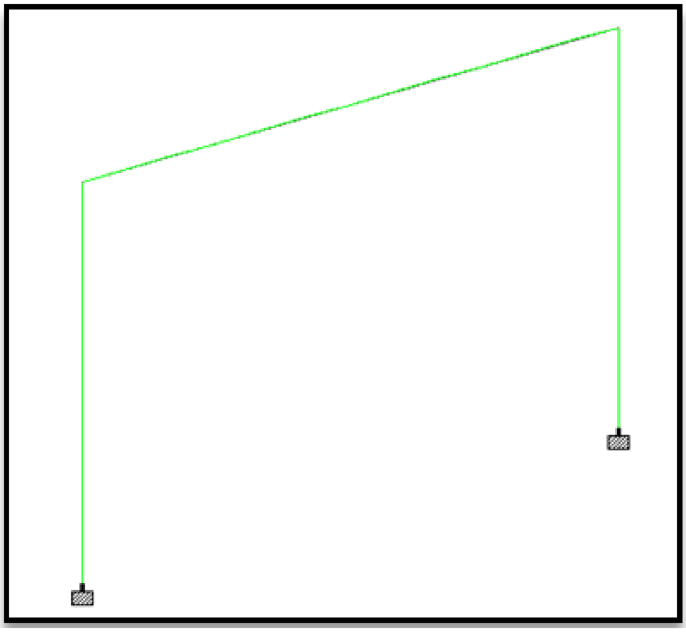

Fig. 2: (b) Elastic Frame

The table 2 shows the deflection of an elastic column at a constant modulus of elasticity and fig 2(a) shows the linear elastic load- deflection graph ,it has seen in fig 2(b) that the frame is elastic that means it is within the limit, when is loaded at 5kN/m at a constant modulus of elasticity.

Calculation of deflection of an inelastic column:

Table – 3
deflection of column at varying initial modulus of elasticity

Sl. No.	***Load (kN/m)***	***CUM. Load (kN/m)***	***Initial Tangent Modulus (kN/m^2)***	***Max. Deflection (in.)***	***CUM. Max. Deflection (in.)***
1	*0*	*0*	*11175*	*0*	*0*
2	*5*	*5*	*11175*	*9.169*	*9.169*
3	*5*	*10*	*10057.5*	*10.188*	*19.357*
4	*5*	*15*	*8940*	*11.462*	*30.819*
5	*5*	*20*	*7822.5*	*13.099*	*43.918*
6	*5*	*25*	*6705*	*15.282*	*59.200*
7	*5*	*30*	*5587.5*	*18.339*	*77.539*
8	*5*	*35*	*4470*	*22.923*	*100.462*
9	*5*	*40*	*3552.5*	*30.564*	*131.026*
10	*5*	*45*	*2235*	*45.846*	*176.872*
11	*5*	*50*	*1117.5*	*91.693*	*268.565*

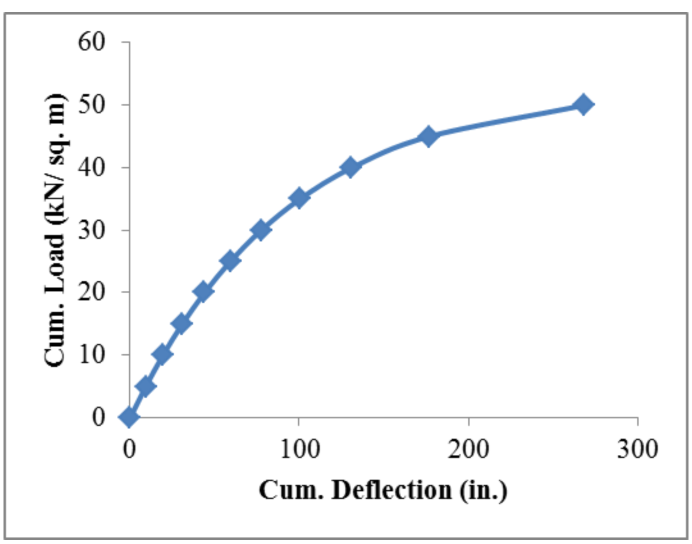

Fig.3.(a) Non-Linear Load –Deflection Curve for Inelastic Frame

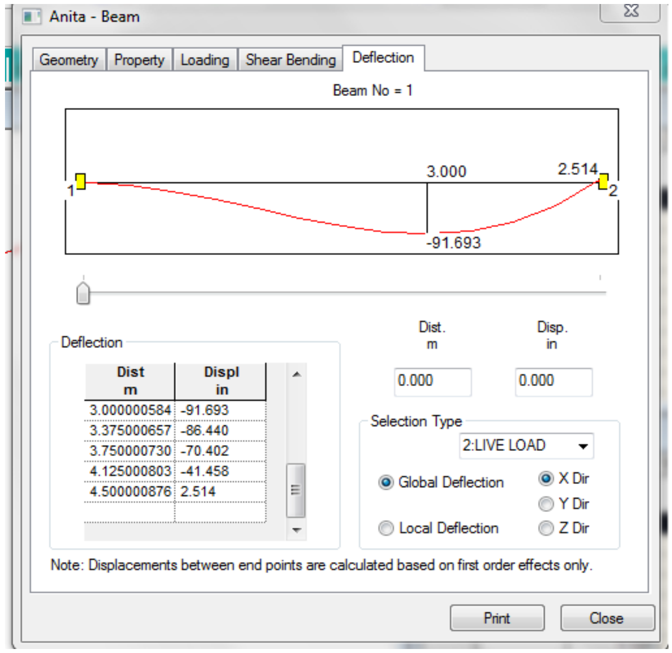

Fig. 3: (b) Deflection of Element

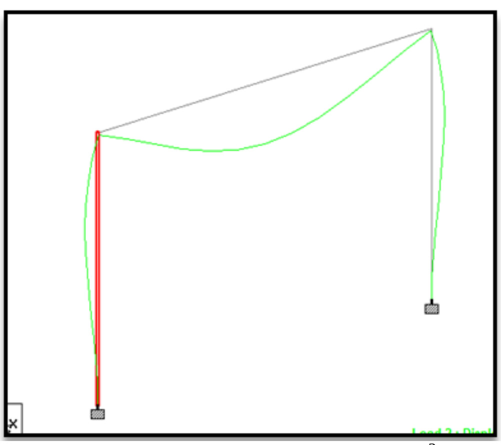

Fig3.(c) Inelastic Frame at 11175kN/m^2

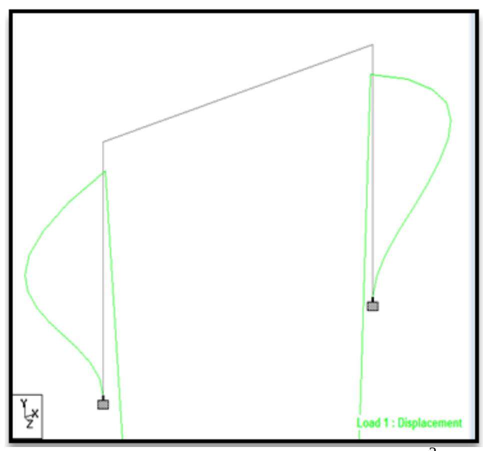

Fig3.(d)Inelastic Frame at 1117.5kN/m^2

The table.3 shows the defection of the column at varying modulus of elasticity. Fig 3(a) shows the cumulative load – cumulative deflection of concrete. Fig 3(b shows the deflection of column at 5KN/m with minimum value of E. fig 3(c) shows the deflection of the frame at 5 KN/m with the 11175KN/m^2 and fig 3(d) shows the deflection of the frame at 5 KN/m with the initial modulus of elasticity 1117.5KN/m^2 (minimum). It means the inelastic structure is gone beyond its elastic limit of the concrete that means it will not got its previous position.

The whole analysis is completed by using STAAP PRO software.

VII. Conclusion

On the basis of the study carried out in this research, the objective is to determine the load deflection curve of an inelastic concrete frame i.e. E and to find out the deflection in concrete structure because of material non-linearity.

The various conclusion achieved in this research are as follows-

1) If the Young's Modulus of the concrete is decreased then the deflection of the structures is increased. It is seen in the analysis the frame is reached beyond its elastic limit.
2) As Modulus of Elasticity (E) is increased, deflection goes on decreasing at a constant loading.
3) At any value of Modulus of Elasticity (E) with different values of load deflection tends to increase.
4) From this work it is seen that if we reduce the value of the young's modulus of concrete, the RCC frame got to maximum deflection at a small loading.
5) From this study we concluded that the parameters i.e. Modulus of elasticity plays important role in the concrete structure.

Non-linearity of the material can't be completely eliminated but its value can be reduced by controlling the various parameters of the material which are used.

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