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Direct Displacement Based Seismic Design of RC Frame Structure

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Abstract

Background/Objectives: In this paper we direct a seismic design of a Reinforce concrete frame building under displacement based design. **Methods/Statistical analysis:** There is a problem with force based design that we can't find a clear relation between forces & cracking, that was drift or displacement is directly related with damage. **Findings:** By this simple design method we consider drift as parameter and can easily design this with given performance level under-code drift limit. In this paper determine maximum deviation from target drift& justified it code limit. **Improvements/Applications:** The approach of our design methodology satisfactorily achieves by inelastic time history analysis as well as push over analysis. In this simple design we get a very successful and a clear predictable seismic response.

Index Terms

Seismic Design, Force &Cracking, Target Drift, Performance level, Time History Analysis

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I. INTRODUCTION

Reinforce concrete frame structures are very regular use in a common buildings, every buildings belongs from types of seismic region. As a structural engineer we have to design a earth quake resistant design. It is hardly possible to design 100% EQ resistant [1] buildings but we can easily design a safe design under some hazard level.

In past the structural designer mostly follow force based seismic design. Some researcher & scholar may found that there is not directly relation between force and damage, that was strain or drift has a clear and effectively related with structural cracking [2]. Due to ground motion or we directly say EQ is main reason for failure of an structural frame. The researchers name this new way to design method is call Displacement Based Design, andit's very effective & simple method. Concept of this method fully based on considering our structure as SDOF system. There is much literature available to describe this proposed design method. In this paper we satisfy our design by our Indian standard maximum code drift limit & also care its performance level. The performance level of a building is divided [1] into three parts first one is immediate occupancy, in this level damage lowest. 2nd one is life safety in this level and life is safe under ground motion, 3rd one is collapse prevention here the structure is highly in damage at near collapse.

Table1.LIST OF SYMBOL AND MEANING

EQ	*Earth Quake*
Θ_y	*Yield Drift*
ε_y	*Yield Strain In Rebar*
L_b	*Length Of Beam*
h_b	*Depth Of Beam*
Θ_d	*Design Drift*
Θ_{yF}	*Yield Rotation Of Frame*
Θ_p	*Plastic Rotation Of Frame*
MDOF	*Multi Degree Of Freedom*
SDOF	*Single Degree Of Freedom*
Δ_d	*Design Displacement*
M_e	*Evaluated Mass*
H_e	*Effective Height*
Δ_c	Critical Storey Displacement
δ_c	Value For Critical Storey
PBD	Force Based Design
Δ_i	Expected Target Displacement At Each Floor
Δ_y	*Yield Displacement*
μ	*Ductility Of System*
ξ	*Damping Of Structure*
T_e	*Effective Time Period*
K_e	*Effective Stifness*
V_B	*Base Shear*
F_i	*For At Floor Level*
F_t	*10% Of Total Base Shear*
NTH	*Nonlinear Time History Analysis*
ISD	*Inter Storey Drift*
LS	*Life Safety*
CP	*Collapse Pretension*
IO	*Immediate Occupancy*
DDBD	*Direct Displacement Based Design*

II. SELECTION OF TARGET DISPLACEMENT

A. Yield displacement

The selecting performance drift limit also call design drift, by strong column weak beam concept [1] we can say our target for local failure occur in beam first that's why we have to consider plastic rotation of beam only. If εy is yield strain in rebar [2]

$$\Theta_y = 0.5\varepsilon_y.\frac{L_b}{h_b} \quad (1)$$

By this equation we get the maximum angular yield rotation. The design drift of a system comes from sum of yield drift & plastic rotation of system.

B. Plastic Rotation

We also say plastic rotation of frame comes from beam because hinges form first in Beam then Column cause of strong column weak beam concept.

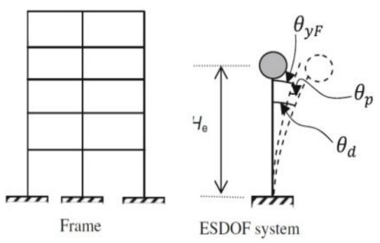

Fig.1. Allowable Design Target Displacement

$$\theta_d = \theta_{yF} + \theta_p \quad (2)$$

We can determine the plastic rotation form [3] FEMA-356.
In this paper we take our target design drift is maximum Indian standard code drift limit 4% and determine respective base shear, and also find our performance level respective base shear for same building frame. It has been always checking that our target drift limit should not cross our code maximum allowable drift limit.

III. DESIGN METHOD

A. Pre-designed

Our main objective of design in this method we take cares only the drift. The design methodology vastly describe in DDBD M.J.N Pristly, G.M Calvi, M.JKowalsky [1]
We have to do a preliminary design of a frame, as per demand we take a column section with predictable design steel 2%-3%. As per recruitment respective beam size adopted from target performance level [1]. As we know yield rotation of beam depended upon Lb/Db & the plastic rotation of beam adopted from average plastic rotation of frame. [4] The beam depth kept from 0.33 to .5 times of beam depth.

B. Convert into SDOF system

By considering our system as SDOF we got some properties from DDBD M.J.N Pristly, G.M Calvi , M.J Kowalsky[1] we got

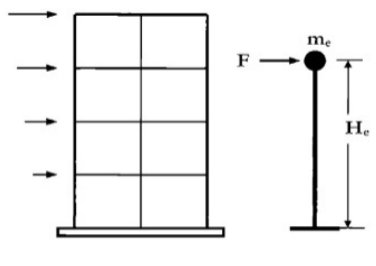

Fig. 2.MDOF to SDOF REPRESENT.

C. Design Parameter Determination:

Design Displacement (Δ_d), Equivalent Mass (M_e), Effective Depth (H_e)

$$\Delta_d = \frac{\sum m_i \Delta_i^2}{\sum m_i \Delta_i} \quad (3)$$

$$m_e = \frac{\sum m_i \Delta_i}{\Delta_d} \quad (4)$$

$$H_e = \frac{\sum m_i \Delta_i h_i}{\sum m_i \Delta_i} \quad (5)$$

From table 1 we see symbol meaning
Here mi is mass of each floor and hi height of floor Δ_i are displacement at each floor [5,6].

For $n \leq 4$
$$\delta_i = \frac{H_i}{H_n} \quad (6)$$

For $n > 4$
$$\delta_i = \frac{4}{3} \cdot \frac{H_i}{H_n} \cdot \left(1 - \frac{H_i}{4H_n}\right) \quad (7)$$

$$\Delta_i = \delta_i \cdot \frac{\Delta_c}{\delta_c} \quad (8)$$

D. Damping and Ductility:

From PBD [1] we determine system ductility & by this we get our damping, it will bring our design to the next level. Respect to design displacement [5] and damping we find period (T) of our system

$$\Delta_y = \theta_{YF} H_e \quad (9)$$

$$\mu = \Delta_d/\Delta_y \quad (10)$$

$$\xi = 5 + 120\left(\frac{1 - \mu^{-0.5}}{\pi}\right)\% \quad (11)$$

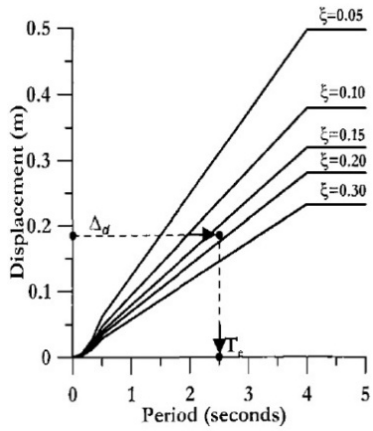

Fig. 3. Displacement and period relation respect to damping of system

E. Base Shear, Stiffness , Force Distribution:

$$K_e = 4\pi^2 \frac{m_e}{T_e^2} \quad (12)$$

Multiplying design displacement and stiffness we also find our base shear, and force distribution at each floor[7,8].

$$V_b = K_e \Delta_d \quad (13)$$

$$F_i = V_b \frac{\Delta_i m_i}{\sum_i^n m_i \Delta_i} \quad (14)$$

The base now distributed at each floor level. At roof level the total base shear 10% is add[9]

$$F_i = F_t + V_b \frac{\Delta_i m_i}{\sum_i^n m_i \Delta_i} \quad (15)$$

IV. Method Apply on Symmetrical Building

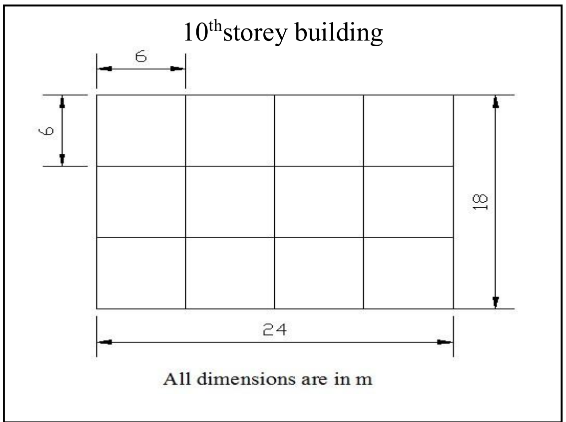

Fig. 4. x-y layout of building

Table 2. Cross Section Detail:

BEAM	650 MM X 1300MM
COLUMN	900 MM X 900 MM
SLAB	220 MM

Table 3. Property of Material:

Concrete grade	M 20
Rebar grade	Fe 415
Strain of Rebar	0.002

Table 4. Total Allowable Rotation For Performance Level

Yield rotation	**IO**	**CP**	**LS**
0.0046	0.005	0.01	0.015
Total rotation	0.0096	0.0146	0.0196

Table5. Mass of storey

n storey	2800KN
(n-1) storey	3200KN

Table 6. Ground motion detail

Artificial ground motion	GM1	GM2	GM3	GM4	GM5
Record no	Centro 1940	Kobe 1995	Whitter 1987	Loma Prieta	Koccaceli
Duration (s)	40	48	40	40	28

Table 7. DDBD Calculated Design Parameter:

Target drift	Code limit	IO	LS	CP
Ѳd (%)	4	0.96	1.46	1.96
Δd (M)	1.045	0.188	0.286	0.384
Me	26032.2	26032.2	26032.2	26032.2
He (m)	23.6	23.6	23.6	23.6
μ	7.18	1.173	2.62	3.52
ξeff	28.95	7.93	19.6	22.84
Te	8.22	1.3	2.56	3.51
Ke (KN/M)	1522	60844	15690	8346
Vb	1191.6	11434	4484	3202

V. Justification of Proposed Method

In DDBD method we have to clear that a response of building only for beam sway mechanism [2], it's possible to design a soft storey but the design displacement of soft storey is very low. Now run NTH [10] analysis building and evaluated the result with our design data, both compares

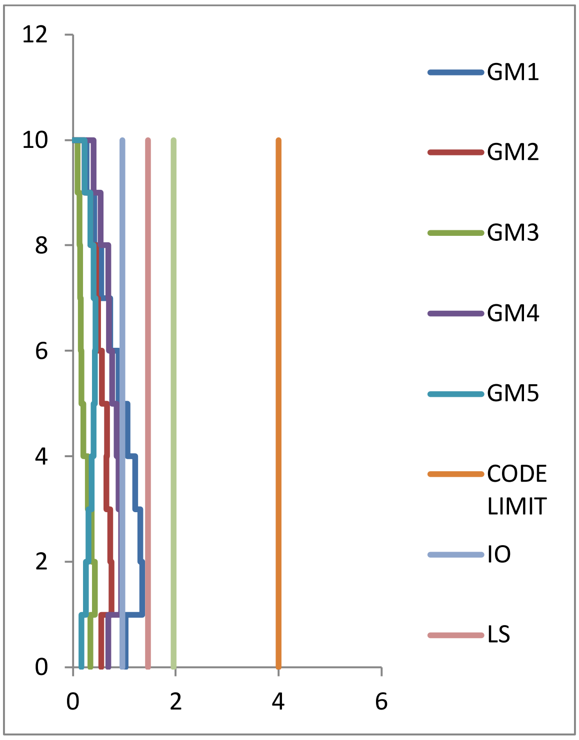

Fig. 5. Inter Storey Drift Response under Ground Motion

Due to ground motion maximum ISD found 1.024%, in fig 5 that was less from LS CP level displacement that means building satisfy under this performance level. Here we compare with target drift level shear force distribution & target displacement. Here we find that at IO level our design Base shear is maximum and we get less displacement at the same time when our RC frame response [6]. Five types ground motion detail given in table 6.

All sectional & material property describe in table 2 , 3 respectively. By this we got our allowable rotation given in table 4 and building mass shown in table 5. All calculated parameters given in table 7.

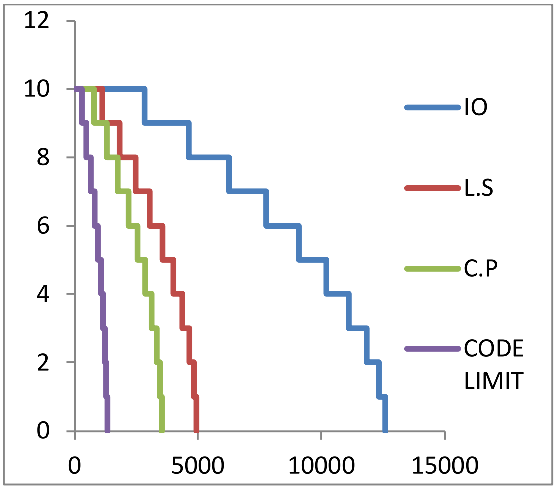

Fig. 6. Force Distribution at Floor Level

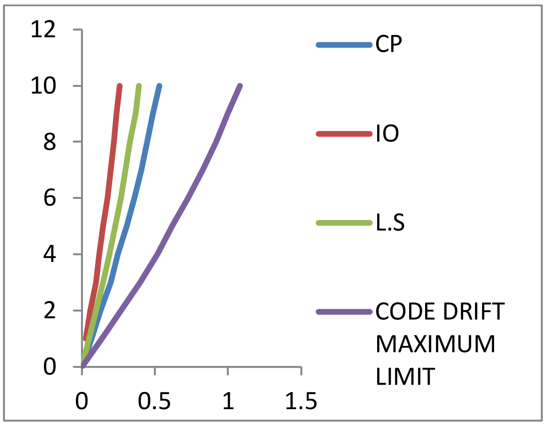

Fig. 7. Expected Displacement Profile

VI. Conclusion

By this proposed design method has been applied to an rc frame with 10thstorey building in different performance level as well as maximum Indian Standard code drift limit. Here we conclude that analyzing our whole structure in manually by DDBD method and did a TH analysis [10] compare with our target displacement with NTH result with different hazard level we conclude that the posed method satisfy its target objective for its all member. According tobuilding impotency we have to select our objective performance level that we can design that with target performance level achieves drift[1].

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