Analytical Study on the Effect of Stiffness Modifiers on the Performance of RCC Building Subjected to Seismic Force as per IS 1893(2016)

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Abstract - *Seismic forces are very harmful and damage to building. Due to this, sometimes cracks are formed in structural and non-structural components and so stiffness of the member can be reduced. The stiffness modifiers are used to counter-balance this effect. The concept of stiffness modifiers is introduced for the first time in IS 1893 (part 1) 2016: The clause no. 6.4.3.1 of the code defines requirements for structural analysis. It is mention in the clause that for structural analysis, for column 70% of Igross should be considered and for beam 35% of Igross should be considered. A detail analytical study carried out between building having stiffness modifiers and ordinary building without stiffness modifiers. The response spectrum method is good method can be applied to the models. The mode displacement is acquired by modeling the Structure in the Structure analysis software (ETAB). The main motive was to compare the modified Structure with the ordinary Structure. Parameter has help in comparison of these models. Result of displacement, drift and shear reinforcement were in very higher side when using stiffness modifiers so there is quite scope to classified stiffness modifiers value according to different height of the structure, shape of structure and earthquake zone.*

Key Words*: Stiffness modifiers, Response spectrum method, Structure analysis software (ETAB), Seismic forces, Geometry of the structure.

1. Introduction

Stiffness of the member means rigidity of the member. In general terms It is capacity of the member to resist deformation and deflection under the action of the apply load. If the members have less stiffness, it's become more flexible. A structure that is made up of many different structural elements, those elements will carry load proportionate to their relative stiffness. Therefore, the load an element will attract increases the stiffer it is. Seismic forces which are generating during earthquake heavily affect reinforced concrete sections such as building, bridge etc.

1.1 Importance of Stiffness Modifiers

Generally during ordinary analysis of the structure we are considering 100% moment of Inertia for the element of the structure. So they become very stiff in nature and attract larger amount of earthquake force. Due to this earthquake force, cracks will generate in tension zone of the element. So, the moment of inertia of element will be reducing than gross moment of inertia. If we apply stiffness modifiers on element of the structure, structure behave more flexible in nature and attract lower force of earthquake and got less damage during an earthquake.

2. Aim, Objective and Scope of Work

2.1 Aim of Study

The aim of my study is "Analytical study on the effect of stiffness modifiers on the performance of R.C.C building subjected to seismic force as per IS 1893(2016)"

2.2 Objective of Study

The main objective for the resent study is as follow:-

- To do comparative study on analysis of structure model with stiffness modifiers and structure model without stiffness modifiers for the various earthquake zone up to the building height of 45 m.

- To study the behavior of R.C.C structure element like beam and column under the effect of stiffness reduction factor as per IS 1893(2016) part-1 consider different shape of the building including square shape building, rectangular shape building and C-shape (irregular) building with the different height such as 15m, 30m and 45m.

- To understand the comparison of storey displacement, storey drift, time period, Area of shear reinforcement, axial force in column, span moment and end moment in beam for model with stiffness modifiers and model without stiffness modifiers.

2.3 Scope of Work

- 3D modeling and analysis will be carried out on the structure model with different floor plan such that square floor plan, rectangular floor plan and C-shape floor plan. Each model prepared with stiffness modifiers and without stiffness modifiers.
- Total 54 no. of model will be analyzed of varying height less than 50 m. earthquake zone III , IV and V should be consider for the analysis of structure.
- 3D modeling and analysis should be done by ETAB (2017) software.
- Method of analysis:- Response spectrum method
- Formula and values for various parameters will be taken from the IS 1893(2016) part-1.
- Parameter to be studied,
- Comparison of displacement
- storey drift
- Amount of shear reinforcement
- Time period for various mode
- Span moment of beam.

3. Software Validation

An experimental study has been carried out for Software validation of ETAB for further work in this research.
A reference problem has been taken from the research paper:-"Influence of Aspect Ratio & Plan Configurations on Seismic Performance of Multi storied Regular R.C.C. Buildings: An Evaluation by Response Spectrum Analysis"- International Research Journal of Engineering and Technology.

Data taken for the software validation problem is given in following table:-

Table :-1 model geometry

MODEL GEOMETRY	
Building length (L)	48 meter
Building width (w)	12 meter
Building height (H)	48 meter
No. of floor	16 no.
Height of floor	3 meter
No. of bay in X-dir	8 no.
No. of bay in Y-dir	2 no.

Table :-2 Loading and section property

SECTION PROPERTY	
Beam dimensions	300 x 600 mm
Column dimensions	800 x 800 mm
Slab thickness	125 mm
Support conditions	Fixed
LOADING	
Live load	4.00 kN/m^2
Floor finish	1.00 kN/m^2
Water proofing	2.500 kN/m^2
Specific wt.of R.C.C	25.00 kN/m^2

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Table:- 3 Seismic Parameters

SEISMIC PARAMETERS	
Seismic zone	III
Earthquake load	As per IS 1893-2002
Type of soil	Type – II, Medium soil
Dynamic analysis	Response spectrum analysis
Zone factor (Z)	0.16 (Zone III)
Damping	5%
Response reduction factor	5.0 (SMRF Structure)
Importance factor	1.00

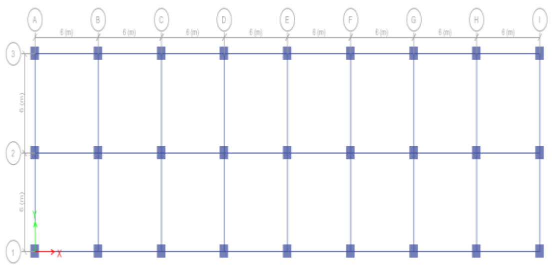

Fig 1 :Grid Data

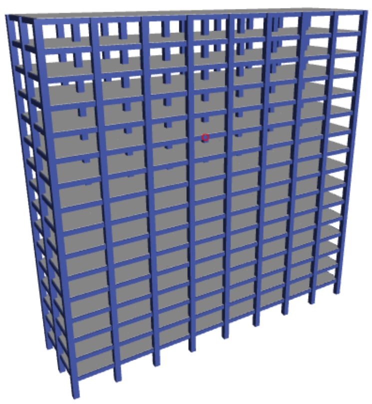

Fig 2: G +16 3D view

4. Analysis of Structural model

In the present study total 54 no. of model was prepared by using ETab software. For this study mainly three types of floor plan are consider.1) square floor plan 2) rectangular floor plan 3) C-shape floor plan. For each floor plan 18 no. of model was prepared in which different height and different earthquake zones are consider. The models are prepared as per the given flow chart. The response spectrum method is consider as per the IS 1893 part-1 (2016). Medium soil should be considered for all the models.

Model number and model specification should be same for all three type floor plan (square floor, rectangular floor and C-shape floor) model which is given in following table.

Table:- 4 Model Details

Model No.	With modifier / Without modifier	Building Height	Earthquake zone
1	Without modifier	15 m	III
1a	With modifier	15 m	III
2	Without modifier	15 m	IV
2a	With modifier	15 m	IV
3	Without modifier	15 m	V
3a	With modifier	15 m	V
4	Without modifier	30 m	III
4a	With modifier	30 m	III
5	Without modifier	30 m	IV
5a	With modifier	30 m	IV
6	Without modifier	30 m	V
6a	With modifier	30 m	V
7	Without modifier	45 m	III
7a	With modifier	45 m	III
8	Without modifier	45 m	IV
8a	With modifier	45 m	IV
9	Without modifier	45 m	V
9a	With modifier	45 m	V

4.1 Modeling And Analysis Of Structure

G+5, G+10, G+15 storey building with square floor plan, rectangular floor plan and C-shape floor plan of R.C.C frame designed by ETAB software and optimization should be done for each model.

To prepared different model in ETAB, following data should be considered. And this primarily data should be same for all the models.

Height and earthquake zone should be changed for different model. According to height of the structure time period for seismic data should be calculated as per as IS 1893- part 1 (2016). Ta=0.09h/√ (d), where h = height of building and d= base dimension along the direction of the earthquake force.

Table:- 5 material & section parameters

MATERIAL PROPERTY	
Concrete grade	M20
Steel grade	Fe500
SECTION PROPERTY	
Beam dimension	300 x 600 mm
Column dimension	600 x 600 mm
Slab thickness	150 mm
Type of support	Fixed support
METHOD OF ANALYSIS – Response spectrum analysis method	

Table:- 6 Loading data

LOADING DATA	
Live load at typical floor	3 Kn/m²
Wall load (outer beam)	13.8 Kn/m²
Wall load (intermediate beam)	9 Kn/m²
Floor finish at typical floor	1 Kn/m²
Floor finish at top floor (including waterproofing load)	3 Kn/m²
Earthquake load	As per IS code
	1893 – part 1

Table:- 7 Material & Section Parameters

MODEL GEOMETERY			
	SQUARE BUILDING	RECTANGULAR BUILDING	C-SHAPE BUILDING
No of bay in X-direction.	4 no.	6 no.	5 no.
No of bay in Y-direction	4 no.	3 no.	3 no.
Length of each bay in X-dir	6m	6m	6m
Length of each bay in Y-dir	6m	6m	4m
Storey Height	3m	3m	3m

Table:- 8 Seismic parameter

SEISMIC PARAMETERS			
	SQUARE BUILDING	RECTANGULAR BUILDING	C-SHAPE BUILDING
Seismic zone	III , IV , V	III , IV , V	III , IV , V
Soil type	Type II (medium soil)	Type II (medium soil)	Type II (medium soil)
Importance factor	1	1	1
Response reduction factor	5	5	5
Damping	5%	5%	5%

5. Conclusions

The important conclusions which can be derived from this research work are as follow:-

- Displacement of the structure, after the application of stiffness modifiers to the structure element was increased by around **50%** of all type of building structure like square shape, rectangular shape and C-shaped (Irregular) building.

- A structure model with stiffness reduction modifiers has a **50%** higher storey drift value than ordinary structure model. And from the graphs we concluded that drift value of the square building is relatively higher than the rectangular building and C-shape (irregular) building.

- Due to application of stiffness modifiers to the structure element like beam and column, overall stiffness of the structure was reduced because after the application of stiffness modifiers natural fundamental period was increased around **30%** as compared to structure model without having any stiffness modifiers. Natural time period was also increased with height of the structure.

- For the square floor plan building, when the stiffness of the beam and column are decreased as per IS 1893-Part 1(2016), shear capacity of building is decreased around 15-25% which may also depend on the building height and beam-column shape and their location. For square building shear capacity of building up to height 15m, 30m and 45m was decreased by about 15%, 20% and 23% respectively.

- In case of rectangular, C-shape or irregular floor plan, after the application of stiffness modifiers to structural members, shear capacity of building is decreased around 30- 40% and during designing of this members, required amount of shear reinforcement is higher than the codal permissible value so it saw over stressed member in ETAB. So we need to increase cross section area of the structural member which leads to increase overall cost of the structure.

- Under the analysis of factored load combination, Span moment of structure with stiffness modifiers was reduced by 15 to 30%. For the square and rectangular structure, span moment was reduced by 25 and 28% respectively. In the case of irregular shape of structure(C-shape), span moment was reduced by 15 to 20%.

- From this study we conclude that, the most resistant floor plan was the square floor plan after the application of stiffness modifiers. We know that, value of displacement and drift of the square floor plan were excessive than permissible value but we can reduce or overcome these effect by replacing stiffness modifiers value for beam is **0.5** instead of 0.35 which is given in IS 1893-Part 1 (2016). We can also reduce displacement and drift by providing rectangular column in reciprocal direction.

- The value of stiffness modifiers for beam and column given in IS 1893-Part 1(2016), must be classified according to different height, shape of the structure and earthquake zone instead of single value.

6. REFERNCES

- IS 1893 –Part 1(2016), "Criteria for earthquake resistant design of structure part 1 general provision and building", Bureau of Indian standard, 6th revision, 2016.

- IS 456-2000, "plain and reinforced concrete code of practice", Bureau of Indian standard, 4th revision, 2000.

- D-P. N. Kontoni, a. A. Farghaly, "stiffness effects of structural elements on the seismic response of r.c.c high-rise buildings", Archives of civil engineering , vol. L XIV

- Mustafa E. Mithaiwala, "A review on effect of different set of stiffness modifiers varying through height of structure on analysis of multi-story R.C.C structure", International research journal of engineering and technology, vol-07

- John-Michal Wong, "Effective stiffness for modelling reinforced concrete structures".

- J.R Pique and M.Burgos, "Effective rigidity of reinforced concrete element in seismic analysis and design", the 14th world conference on earthquake engineering.

- Philip C. Perdikaris, Said Hilmy, "Extensional stiffness, of precracked R/C panels", Journal of Structural Engineering, Vol. III, No. 3 (1985).

- Tom Paulay, "Re-definition of the stiffness of reinforced concrete elements and its implications in seismic design", Structural Engineering International Vol. 1 (2001).

- Bhavinshah, https://www.linkedin.com/pulse/stiffness-modifiers-per-1893-part-1-2016-bhavin-shah