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ANALYSIS AND COMPARISON BETWEEN OMRF AND SMRF MULTISTOREYED RC BUILDING FRAMES

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Abstract: Reinforced concrete special moment frames are used as part of seismic force-resisting systems in buildings that are designed to resist earthquakes. Beams, columns, and beam-column joints in moment frames are proportioned and detailed to resist flexural, axial, and shearing actions that result as a building sways through multiple displacement cycles during strong earthquake ground shaking. Special proportioning and detailing requirements result in a frame capable of resisting strong earthquake shaking without significant loss of stiffness or strength. These moment-resisting frames are called "Special Moment Resisting Frames" because of these additional requirements, which improve the seismic resistance in comparison with less stringently detailed Intermediate and Ordinary Moment Resisting Frames. The design criteria for SMRF buildings are given in IS 13920 (2002). In this study, the buildings are designed both as SMRF and OMRF, and their performance is compared. For this, the buildings are modeled and pushover analysis is performed in SAP2000. The pushover curves are plotted from the analysis results and the behavior of buildings is studied for various support conditions and infill conditions. The behavior parameters are also found for each building using the values obtained from pushover curve and is investigated.

Keywords: SMRF, OMRF, Pushover analysis, Static Non-linear analysis, SAP2000, ductility factor, response reduction factor.

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INTRODUCTION

Reinforced concrete special moment frames are used as part of seismic force-resisting systems in buildings that are designed to resist earthquakes. Beams, columns, and beam-column joints in moment frames are proportioned and detailed to resist flexural, axial, and shearing actions that result as a building sways through multiple displacement cycles during strong earthquake ground shaking. Special proportioning and detailing requirements result in a frame capable of resisting strong earthquake shaking without significant loss of stiffness or strength. These moment-resisting frames are called "Special Moment Resisting Frames" because of these additional requirements, which improve the seismic resistance in comparison with less stringently detailed Intermediate and

OMRF. Moment frames are generally selected as the seismic force-resisting system when architectural space planning flexibility is desired. When concrete moment frames are selected for buildings assigned to Seismic Design Categories III, IV or V, they are required to be detailed as special reinforced concrete moment frames. Proportioning and detailing requirements for a SMRF will enable the frame to safely undergo extensive inelastic deformations that are anticipated in these seismic design categories. SMRF may be used in Seismic Design Categories I or II, though this may not lead to the most economical design. Both strength and stiffness need to be considered in the design of SMRF. According to IS 13920(2002), SMRF are allowed to be designed for a force reduction factor of R= 5. That is, they are allowed to be designed for a base shear equal to one-fifth of the value obtained from an elastic response analysis. Moment frames are generally flexible lateral systems; therefore, strength requirements may be controlled by the minimum base shear equations of the code.

Principles of design for SMRF.

The design base shear equations of current building codes incorporate a seismic force-reduction factor R, that reflects the degree of inelastic response expected for design-level ground motions, as well as the ductility capacity of the framing system. A SMRF should be expected to sustain multiple cycles of inelastic response if it experiences design-level ground motion. The proportioning and detailing requirements for SMRF are intended to ensure that inelastic response is ductile. Three main goals are:

(1) To achieve a strong- column/weak-beam design that spreads inelastic response over several stories;

(2) To avoid shear failure; and

(3) To provide details that enable ductile flexural response in yielding regions.

BUILDIN DETAILS AND MODELLING FOR ANALYSIS

The designed frames are modeled for nonlinear analysis. It is necessary to develop a computational model to perform any kind of analysis. The parameters defining the building models, the basic assumptions and the geometry of the selected buildings for the study are discussed. This includes the development of concentrated plasticity hinges at the critical sections of beams and columns.

The material properties and the geometric parameters considered in the study are listed in

Table 1. M25 concrete is used at the design stages, along with Fe415 steel. The detailed description is given in the Table 1.

Table 1. Material properties and Geometric

Sr	Design Parameter	Value
1	Unit weight of concrete	25kN/m3
2	Unit weight of Infill walls	18kN/m3
3	Characteristic Strength of concrete	25 MPa
4	Characteristic Strength of concrete	415 MPa
5	Compressive strength of strong masonry (*Em*)	5000MPa
6	Compressive strength of weak masonry (*Em*)	350MPa
7	Modulus of elasticity of Masonry Infill walls (*Em*)	750*f'm*
8	Damping ratio	5%
9	Modulus of elasticity of steel	2e5 MPa
10	Slab thickness	150 mm
11	Wall thickness	230 mm

Parameters assumed

Sr No	Design Parameter	Value
1	Seismic Zone	V
2	Zone factor (Z)	0.36
3	Response reduction factor (R)	5
4	Importance factor (I)	1
5	Soil type	Medium soil
6	Damping ratio	5%
7	Frame Type	SMRF

Table 2 Seismic Design Data assumed for SMRF

Table 3 Seismic Design Data assumed for OMRF

	Frame Name	Frame type	No. of storey	No. of bays	R	Infill Type	Frame Type
1	4S7B-SMRF-I-S-F	Infill	4	7	5	Strong	SMRF
2	8S7B-SMRF-I-S-F	Infill	8	7	5	Strong	SMRF
3	10S7B-SMRF-I-S-F	Infill	10	7	5	Strong	SMRF
4	6S2B-SMRF-I-S-F	Infill	6	2	5	Strong	SMRF
5	6S4B-SMRF-I-S-F	Infill	6	4	5	Strong	SMRF
6	6S6B-SMRF-I-S-F	Infill	6	6	5	Strong	SMRF
7	4S7B-OMRF-I-S-F	Infill	4	7	3	Strong	OMRF
8	8S7B-OMRF-I-S-F	Infill	8	7	3	Strong	OMRF
9	10S7B-OMRF-I-S-F	Infill	10	7	3	Strong	OMRF
10	6S2B-OMRF-I-S-F	Infill	6	2	3	Strong	OMRF
11	6S4B-OMRF-I-S-F	Infill	6	4	3	Strong	OMRF
12	6S6B-OMRF-I-S-F	Infill	6	6	3	Strong	OMRF

Sr No	Design Parameter	Value
1	Seismic Zone	V
2	Zone factor (Z)	0.36
3	Response reduction factor (R)	3
4	Importance factor (I)	1
5	Soil type	Medium soil
6	Damping ratio	5%
7	Frame Type	OMRF

Table 4 Loads considered for designing buildings.

Table 5 Details of all the fixed support bare frames

Sr No	Load Type	Value
1	Self-weight of beams and columns	As per dimensions.
2	Weight of slab	11.25 KN/m
3	Infill weight	11.8 KN/m
4	Parapet weight	2.5 KN/m
5	Floor finish	2.5 KN/m2
6	Live load	3.0 KN/m2

	Frame Name	**Frame type**	**No. of storey**	**No. of bays**	**R**	**Frame Type**
1	4S7B-SMRF-B-H	Bare	4	7	5	SMRF
2	8S7B-SMRF-B-H	Bare	8	7	5	SMRF
3	10S7B-SMRF-B-H	Bare	10	7	5	SMRF
4	6S2B-SMRF-B-H	Bare	6	2	5	SMRF
5	6S4B-SMRF-B-H	Bare	6	4	5	SMRF
6	6S6B-SMRF-B-H	Bare	6	6	5	SMRF
7	4S7B-OMRF-B-H	Bare	4	7	3	OMRF
8	8S7B-OMRF-B-H	Bare	8	7	3	OMRF
9	10S7B-OMRF-B-H	Bare	10	7	3	OMRF
10	6S2B-OMRF-B-H	Bare	6	2	3	OMRF
11	6S4B-OMRF-B-H	Bare	6	4	3	OMRF
12	6S6B-OMRF-B-H	Bare	6	6	3	OMRF

Table 6. Details of all the hinged support bare frames

Sr no	Frame name	Frame type	No. Of storey	No. Of bays	R	Frame type
1	4S7B-SMRF-B-F	Bare	4	7	5	SMRF
2	8S7B-SMRF-B-F	Bare	8	7	5	SMRF
3	10S7B-SMRF-B-F	Bare	10	7	5	SMRF
4	6S2B-SMRF-B-F	Bare	6	2	5	SMRF
5	6S4B-SMRF-B-F	Bare	6	4	5	SMRF
6	6S6B-SMRF-B-F	Bare	6	6	5	SMRF
7	4S7B-OMRF-B-F	Bare	4	7	3	OMRF
8	8S7B-OMRF-B-F	Bare	8	7	3	OMRF
9	10S7B-OMRF-B-F	Bare	10	7	3	OMRF
10	6S2B-OMRF-B-F	Bare	6	2	3	OMRF
11	6S4B-OMRF-B-F	Bare	6	4	3	OMRF
12	6S6B-OMRF-B-F	Bare	6	6	3	OMRF

Table 7 Details of all the fixed support

	Frame Name	Frame	No. of storey	No. of bays	R	Frame Type
1	4S7B-SMRF-I-W-F	Infill	4	7	5	SMRF
2	8S7B-SMRF-I-W-F	Infill	8	7	5	SMRF
3	10S7B-SMRF-I-W-F	Infill	10	7	5	SMRF
4	6S2B-SMRF-I-W-F	Infill	6	2	5	SMRF
5	6S4B-SMRF-I-W-F	Infill	6	4	5	SMRF
6	6S6B-SMRF-I-W-F	Infill	6	6	5	SMRF
7	4S7B-OMRF-I-W-F	Infill	4	7	3	OMRF
8	8S7B-OMRF-I-W-F	Infill	8	7	3	OMRF
9	10S7B-OMRF-I-W-F	Infill	10	7	3	OMRF
10	6S2B-OMRF-I-W-F	Infill	6	2	3	OMRF
11	6S4B-OMRF-I-W-F	Infill	6	4	3	OMRF
12	6S6B-OMRF-I-W-F	Infill	6	6	3	OMRF

Table 8 Details of all the fixed support frames with weak infill

RESULTS

COMPARISON OF SMRF AND OMRF:

BARE FRAME, FIXED SUPPORT

Fig. shows pushover curves of 4S7B bare frames designed as both OMRF and SMRF, with fixed support conditions. Initially the base shear increases linearly with the roof displacement. After reaching a certain base shear the building yields. The 4S7B frame design as OMRF exhibit a higher capacity of base shear than the 4S7B SMRF frame. However, the 4S7B frame designed as SMRF undergoes higher value of displacement as compared to the 4S7B OMRF frame. Similar behavior is observed for 6S2B, 6S4B, 6S6B, 8S7B and 10S7B buildings.

Performance comparison of OMRF and SMRF buildings with Fixed Support

Building Configuration	BASE SHEAR (KN)		% Increase in Base Shear for OMRF	ROOF DISPLACEMENT (mm)		% Increase in Displacement for SMRF
	OMRF	SMRF		OMRF	SMRF	
4S7B	425	300	41.6%	14	60	328%
6S2B	140	115	21.6%	120	220	83.3%
6S4B	350	250	40%	100	175	75%
6S6B	375	360	4.16%	110	320	199%
8S7B	520	420	23.8%	175	375	114%
10S7B	580	470	23.4%	320	625	96%

COMPARISON OF SMRF AND OMRF: BARE FRAME, HINGED SUPPORT

Performance comparison of OMRF and SMRF building with Hinged Support

Building Configuration	BASE SHEAR (KN)		% Increase in Base Shear for OMRF	ROOF DISPLACEMENT (mm)		% Increase in Displacement for SMRF
	OMRF	SMRF		OMRF	SMRF	
4S7B	425	300	41.6%	14	60	328%
6S2B	140	115	21.6%	120	220	83.3%
6S4B	350	250	40%	100	175	75%
6S6B	375	360	4.16%	110	320	199%
8S7B	520	420	23.8%	175	375	114%
10S7B	580	470	23.4%	320	625	96%

In this comparison, the performance of OMRF and SMRF with hinged support conditions is

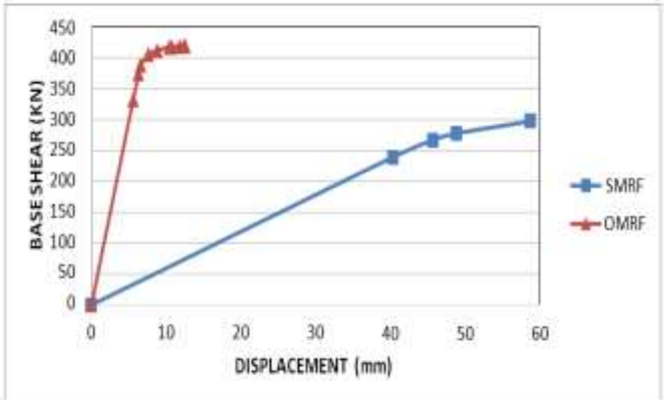

Figure shows the pushover curves of 4S7B OMRF AND 4S7B SMRF with Hinged Support condition and no infill.

considered. The pushover curves for various configurations of buildings are plotted and the building response is observed.

Figure shows pushover curves of 4S7B bare frames designed as both OMRF and SMRF, with hinged support conditions. Initially the base shear increases linearly with the roof displacement. After reaching a certain base shear the building yields. The 4S7B frame designed as OMRF exhibit a higher capacity of base shear than the 4S7B SMRF frame. However, the 4S7B frame designed as SMRF undergoes a higher value of displacement as compared to the 4S7B OMRF frame. This shows that the ductility of the frame designed as SMRF is more compared to that of OMRF.

COMPARISON OF SPECIAL MOMENT RESISTING FRAMES WITH FIXED AND HINGED SUPPORTS.

The pushover curve of SMRF frames with hinged and fixed support condition is plotted and the results are observed. The pushover curve of 6S4B SMRF-B-F and 6S4B

OMRF-B-F is plotted.

The amount of displacement and the ductility ratio of the building is predicted to be same. Hence as like in the case of 6 storey, the same thing can be concluded for other configurations, that the performance of the SMRF buildings under present study is independent of the support condition.

BEAHAVIOUR PARAMETERS OF THE BUILDINGS

A number of performance parameters may govern the capacity of a structure. In order to carry out an inelastic pushover analysis, one or a number of these parameters should be considered for determination of the displacement limit state (Δmax).

Figure shows the pushover curves of 6S4B SMRF with both fixed and hinged support condition and no infill.

Building Config.	Base Shear (KN)	Rdes	Rμ	Rs	μ
6S6B SMRF-B-F	94.2	5	11.5	1.5	5.5
6S6B OMRF-B-F	155.0	3	3.9	1.3	1.8
6S4B SMRF-B-F	63.6	5	12	1.3	10.5
6S4B OMRF-B-F	106.2	3	4.5	1.2	8.4
4S7B SMRF-B-F	94.4	5	16.4	1.3	28.1
4S7B OMRF-B-F	157.3	3	4	1.2	1.7
6S2B SMRF-B-F	33.4	5	5.77	1.6	2
6S2B OMRF-B-F	54.35	3	2.9	1.3	1.1
8S7B SMRF-B-F	120	5	24.57	2.1	7
8S7B OMRF-B-F	199.5	3	17.57	2	4.5
10S7B SMRF-B-F	129.6	5	6.5	1.3	2.14

COMPARISON OF SMRF BUILDINGS WITH STRONG AND WEAK INFILL: FIXED SUPPORT CONDITION.

The performance of SMRF buildings with strong and weak infill is compared. For strong infill condition the value of modulus of elasticity of brick is taken as 5000 MPa whereas for weak infill it is taken as 350 MPa.

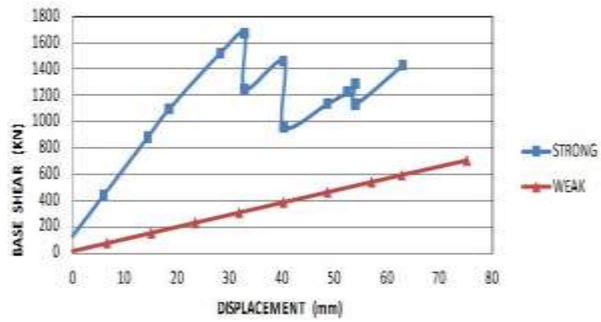

Fig. Showing the comparison of 6S4B SMRF building with strong and weak infill and fixed support conditions.

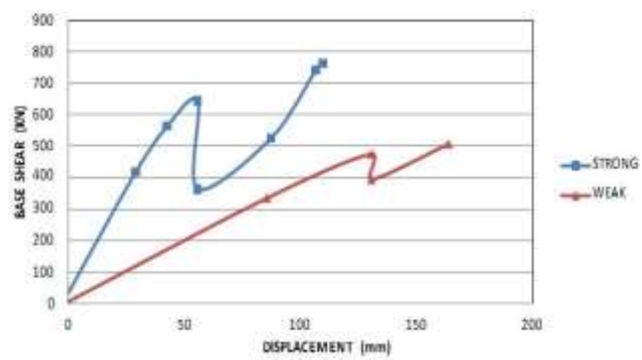

Fig. showing the comparison of 6S2B SMRF building with strong and weak infill and fixed support conditions.

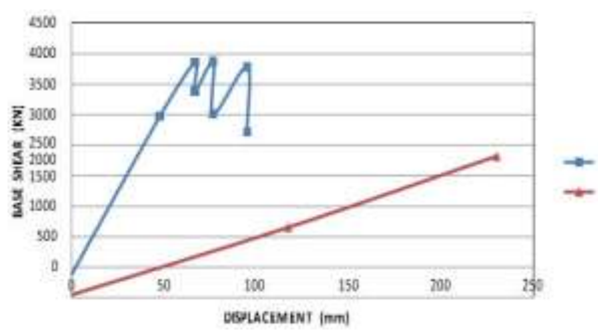

Fig. showing the comparison of 10S7B SMRF building with strong and weak infill and fixed support conditions.

CONCLUSION:

The performance assessment of buildings designed as Special Moment Resisting Frame (SMRF) and Ordinary Moment Resisting Frame (OMRF) is studied for different building configurations, infill conditions and support conditions.

- It is found that the buildings designed as SMRF perform much better compared to the OMRF building. The ductility of SMRF buildings is almost 75% to 200% more than the OMRF buildings in all cases.
- The ductility of SMRF is more in all cases which goes about 75-200% than that of OMRF buildings. But OMRF buildings resist 20-40% more base shear than that be resisted by SMRF buildings.
- It is found that performance of SMRF buildings under fixed and hinged support condition is the same.
- It can be concluded that the SMRF buildings with nstronger infill have base shear capacity of about 1.5 to 2.5 times more than that of SMRF buildings with weak infill.

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