Comparative Study of Multi-Storey Building with Coupled Shear Wall and Multi-Storey Building with Conventional Shear Wall

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Abstract - *In multi-storey structure where the nations have high seismic activity reinforced concrete shear wall are intensely used the need of optimum modeling of shear walls for linear and non-linear analysis of building is most significant. The coupling beams connected with two or more concrete wall comprised of shear walls will be distributed all over the height of the structure. The structural walls of reinforced concrete walls will be acting as major elements in resisting the earthquake energy. The response of the building will be dominated by the seismic structural wall and it is more required to evaluate the earthquake response of the shear wall in correct method. To achieve a system that has large lateral stiffness a beam is coupled by number of individual wall piers. In shear wall system, the overturning moments will be resisted partially by axial compression-tension couple. It involves formation of plastic hinges for energy dissipation mechanism in almost every coupling beam. In this study the study of conventional and coupled shear walls were analyzed for 10, 20 and 30 storied building for both response spectrum analysis and equivalent static analysis. The results are compared by selecting the parameter like storey displacements, storey drifts, storey shear, overturning moment and storey stiffness. They offer great potential and efficient resisting system for lateral loads. The conclusions show that coupled shear wall has more advantages than conventional shear wall system.*

***Key Words*: multi-storey building, conventional shear wall, coupled shear wall, storey drift, storey shear, over turning moment, storey stiffness.**

1. INTRODUCTION

1.1 General

Resilience or resistance in tall buildings in moderate to highly-seismic areas around the world is one of the increasing concerns because of uncertainties associated with their expected performance in the event of a strong earthquake and the consequences of having damage distributed for overall height of these buildings which require repairing. To avoid associated uncertainties from earthquake, hurricane etc. special lateral load resisting systems has been used like advanced bracing systems (diagrid system, buckling restrained bracing system etc.), shear wall system, damper system(active damping and passive damping), tubular systems (framed tubular system, insitu core tubular system, braced tubular system and bundled tubular system) , advanced diaphragm system etc. Especially for building height greater than 48m, special lateral resisting systems such as a dual system compromised as moment-resisting frame and a reinforced concrete core wall are suggested because of its significant response. In core wall system to improve the efficiency to resist unexpected lateral forces consisting of coupled shear wall system were introduced. The system with coupled shear wall has been showing better performance in both structures and studies. Although, many design engineers have not considered coupled shear wall effect. Hence, in RCC coupled Shear wall to avoid lateral force due seismic forces, frequently walls are coupled with two or more reinforced concrete walls in series in medium to high rise structures. The transfer of force vertically between adjacent walls is by coupling beams which will resists a portion of overturning moments that create a coupling action. The usage of shear walls is one of the most potential options in case of earthquake resistant system when its compared with moment resistant frames and shear wall system in reinforced tall buildings. Shear and flexure behaviour controls the moment resistant and shear wall combination frame, flexure is the only behaviour that controls coupled shear wall system. Shea capacity controls coupling beam provided. In coupling beams the inelastic yielding dissipates energy in coupled shear walls. To avoid lateral resisting force effectively coupled shear wall is thought to have better performance compared with conventional shear wall systems. Most of the building encased with coupled shear wall in recent construction industry has been more efficient for reducing damage uncertainties due to natural calamities etc. in buildings.

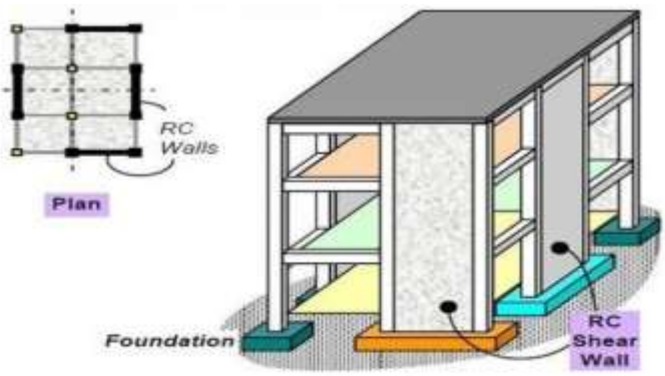


Fig-1.1: Building with Shear Wall

1.2 Investigation of Coupling Beam

In the coupling beams if the yield moment capacity is low then it will undergo beyond the plastic rotation capacities that will lead to the rupture of the members. Therefore the optimum level of yield capacities should be designed and coupling beam should be provided. The plastic rotation capacity available in beams depends on moments directly. The transverse reinforcement and longitudinal flexural reinforcement will be there for conventional reinforcement for lateral shear along the longitudinal axis of the beams there will be longitudinal reinforcement running parallel and transverse reinforcement will consists mostly of closed stirrups across longitudinal axis of the beam. If the strength of these ties > or = to ¾ what actually required for shear strength of the beam then spacing of these ties < or = d/3 over the entire length of the beam, then there is stable hysteresis curves, this is mandatory reinforcement that is been used for construction in present days

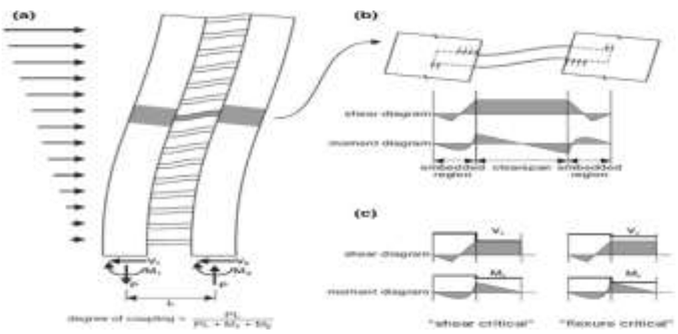


Fig-1.2: Forces acting on Coupled Shear Wall

1.3 Case Study

A 56-storey tower building is considered for case study which is located in Tehran. It has more seismic activity in Iran country. The transverse main walls has an angle of 120 degree and perpendicular to them there are multiple sidewalls. Reinforced concrete main walls are shear walls which has staggered opening regularly. Reinforced concrete sidewalls which are also shear walls are connected with coupling beams. The tower has following general considerations .Construction sequence loading, Time-dependent effects, Overall torsion. In this there is a seismic evaluation of structural system the investigation whether the building has enough ductility to satisfy the seismic assumption mentioned in the codes. The coupling elements behavior of coupled shear wall provides effective contribution to resist lateral loads. The shear walls for both bracing system and gravity load resistant are not recommended because it is neither acceptable conceptually or economically. Here, gravity loads are also resisted by a significant percentage and to carry seismic loads. The primary assumption about gravity, vertical load distribution and ductility level redistribution of these loads according to creep and sequential loading will change eventually.in the mid height of the structure there will be critical demand. Based on height to width ratio shear walls are classified into three groups. When this ratio exceeds 2.0 then shear walls are called high-rise shear walls. When the ratio is less than 1.0, shear walls are referred as low rise shear walls. If the ratio is between 1.0 and 2.0 then they are medium rise shear walls. Flexure is the main reason for the failure in high rise shear walls, for low rise shear walls shear is the main reason. Flexure and shear are the main reason for failure in medium rise shear wall. The orientation of the rebar and principal direction of applied tensile stresses on shear walls are the main reasons because low rise shear wall are not exhibiting ductility property. High performance shear walls have been proposed to improve the seismic behavior of low-rise SW under earthquake loading which has rebar's in principal direction of tensile forces.

2 METHODOLOGY

1. Modelling of 10 storey building with conventional shear wall system and 10 storey building with coupled shear wall system.
2. Modelling of 20 storey building with conventional shear wall system and 20 storey building with coupled shear wall system.
3. Modelling of 30 storey building with conventional shear wall system and 30 storey building with coupled shear wall system.
4. Designing of all above models mentioned according to Indian Standards with considering same lateral resisting section.
5. Analysing models using both linear dynamic analysis (response spectrum analysis) and linear static analysis in latest ETABS software.
6. Comparing results of models with conventional shear wall system and models with coupled shear wall system.
7. Conclusions are drawn.

2.1 Structural modeling

6 different models are taken into consideration for study. It includes 10, 20 and 30 storeys for both conventional shear wall and coupled shear wall cases with 7x5 bays. The plan is regular/symmetrical plan of 63m x 45m. The height of each storey is 4.0m. 9.0m spacing is maintained between the bays along both sides of the building. Material properties and sectional properties are listed in table 4.1 to 4.4. Considered live load for all the floors is 3.0KN/m^2 and the floor finishing load is 1.3KN/m^2. Modelling was done by ETABS 16.2.0 Software. The modeling parameters considered are described in later sections.

2.2 Input details

Table 1: Material Properties of Concrete

Properties	Values
Material Name	M30
Concrete Compressive Strength	30MPa
Elastic Modulus	27386.13MPa

Weight per Unit Volume	24.9926 kg/m^3
Mass per Unit Volume	2548.538 kg/m^3
Poisson's Ratio	0.2

Table 2: Material Properties of Rebar

Properties	Values
Material Name	HYSD500
Yield Strength (Min)	500 MPa
Tensile Strength (Min)	545 MPa
Elastic Modulus	2x10^5 MPa
Weight per Unit Volume	76.972 kN/m^3
Mass per Unit Volume	7849.047 kg/m^3

Table 3: Structural Elements and Their Material Types

Model Structural Element	Material Type	
	Rebar	Concrete Mix
Column	HYSD500	M30
Slab	HYSD500	M30
Shear wall	HYSD500	M30

Table 4: Section Properties of Structural Elements

Building Types	Basic Elements	Section Property (mm)
For 10 Storey Conventional	Column	800x800
	Beam	500x600
	Slab	200 (Thickness)
	Shear Wall	250 (Thickness)
For 10 Storey Coupled Shear wall	Columns	800x800
	Beam	500x600
	Slab	200 (Thickness)
	Shear Wall	250 (Thickness)
	Spandrel Beam	250x1200
For 20 Storey Conventional	Columns	800x800
	Beam	500x600
	Slab	200 (Thickness)
	Shear wall	250 (Thickness)
For 20 Storey Coupled Shear Wall	Columns	800x800
	Beam	500x600
	Slab	200 (Thickness)
	Shear wall	250 (Thickness)
	Spandrel Beam	250x1200
For 30 Storey Conventional	Columns	800x800
	Beam	500x600
	Slab	200 (Thickness)
	Shear wall	250 (Thickness)
For 30 Storey Coupled Shear wall	Columns	800x800
	Beam	500x600
	Slab	200 (Thickness)
	Shear wall	250 (Thickness)
	Spandrel Beam	250x1200

2.3 LOADS

2.3.1 Dead Loads

Dead loads are stable and permanent loading which acts on a Building. This load directly depends on its self-weight. That weight of the structural elements depends on the specification of materials. The information about self-weight of all construction used for structural elements materials are as mentioned in IS 875-1987 (Part I). These permanent loads are considered according to IS 875-1987 (Part 1). 1.3kN/m^2 is the load considered Floor Finish.

2.3.2 Live Loads

Live loads are unstable and temporarily acting and depend on occupancy and usage of space in the structure. The information about various usage is provided in IS 875-1987(Part II).The models are commercial and the values are taken as mentioned according to IS 875-1987(Part II). 3kN/m^2 is considered Live load.

2.3.3 Earthquake load

Earthquake load is also called as seismic load. It is laterally or horizontally acting load. It is one which is mostly of uncertainty and complexity. It is a type of load that do not occur frequently. The code considered for this model is IS1893-2002(Part I). IS1893-2002 (Part I) refers to general provisions and buildings.

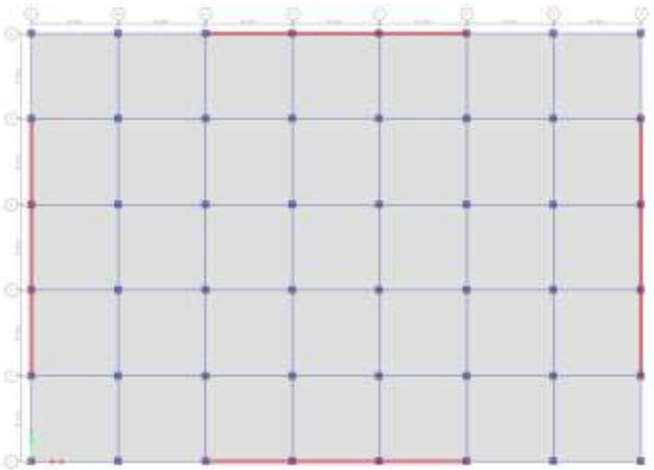
2.3.4 Models Classification

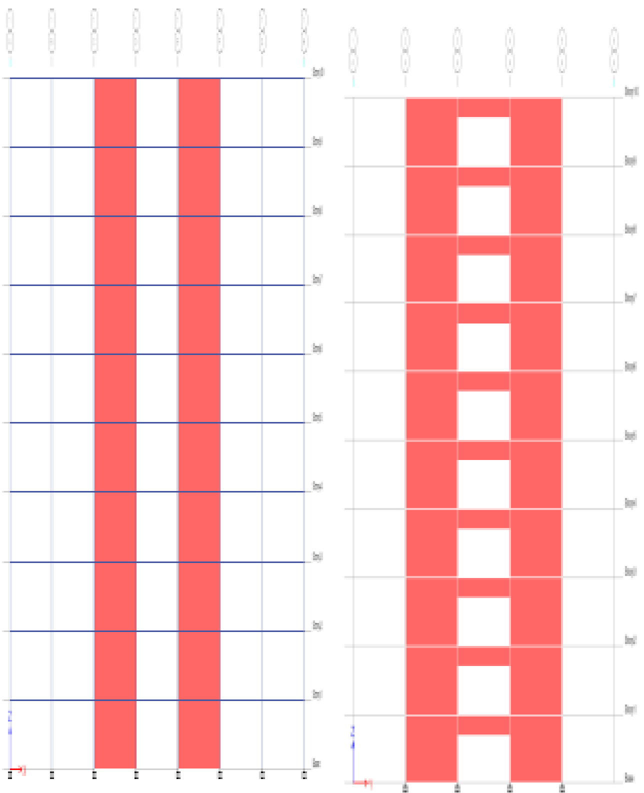
Model 1:10 Storey model Building with Conventional Shear Wall System.
Model 2:10 Storey model Building with Coupled Shear Wall System.
Model 3:20 Storey model Building with Conventional Shear Wall System.

Model 4:20 Storey model Building with Coupled Shear Wall System.
Model 5:30 Storey model Building with Conventional Shear Wall System.
Model 6:30 Storey model Building with Coupled Shear Wall System.

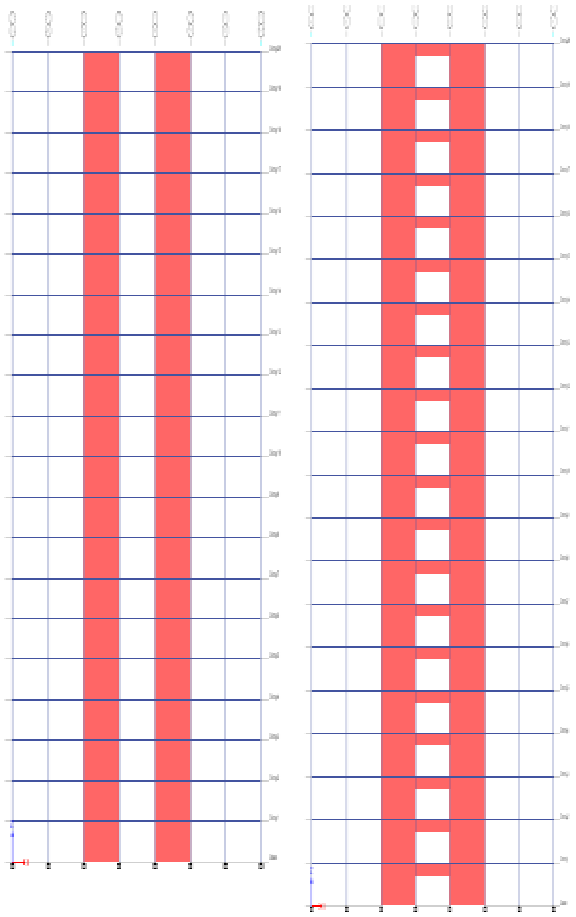
The models with 10, 20 and 30 storeys are considered as shown below. For this linear static and linear dynamic (Response Spectrum) analysis is done for both conventional and coupled shear wall cases separately and analyzed.

Fig-2.3.4: Plan of 7x5 Storey Structure





(Elevation of 10 Storied Building with Conventional Shear Wall Structure and Coupled Shear Wall structure)



(Elevation of 20 Storeyed Building with Conventional Shear Wall and Coupled Shear Wall)

3 Results and Discussions

The main aim of this work is to analyze and study the performance of conventional shear wall system and coupled shear wall system in building. Here all the models are designed according to IS 875-1987 (PART-5). The members are designed for lateral, gravity and combination of loads. Lateral load analyses are carried out and the outcomes are tabularized. The results obtained are in terms of axial force and moments. The results of these models in this work are studied by analyzing in terms of Storey displacement, Storey Drift, Base shear, overturning moment and storey stiffness of building by subjecting the model or structure to lateral forces.

3.1 Maximum Storey Displacement

Model	Maximum Storey Displacement(mm) , (EQX)		
	10-storey	20 storey	30-storey
Building with Conventional Shear Wall System	35.951	89.407	176.045
Building with Coupled Shear Wall System	20.299	55.97	108.2636

Model	Maximum Storey Displacement(mm), (EQY)		
	10-storey	20 storey	30-storey
Building with Conventional Shear Wall System	36.161	90.801	186.887
Building with Coupled Shear Wall System	20.388	56.376	110.9892

model	Maximum Storey displacement (mm), (RSX)		
	10-storey	20 storey	30-storey
Building with Conventional Shear Wall System	26.679	54.524	122.003
Building with Coupled Shear Wall System	17.212	37.328	64.418

Model	Maximum Storey displacement (mm), (RSY)		
	10-storey	20 storey	30-storey
Building with Conventional Shear Wall System	26.777	54.633	129.067
Building with Coupled Shear Wall System	17.28	36.818	65.0314

3.2 Storey Drift

model	Maximum Storey Drift (EQX)		
	10-storey	20 storey	30-storey
Building with Conventional Shear Wall System	0.001	0.0013	0.0018
Building with Coupled Shear Wall System	0.0006	0.0008	0.001103

Model	Maximum Storey Drift, EQY		
	10-storey	20 storey	30-storey
Building with Conventional Shear Wall System	0.0011	0.0014	0.0019
Building with Coupled Shear Wall System	0.0006	0.0008	0.001135

Model	Maximum Storey Drift, RSX		
	10-storey	20 storey	30-storey
Building with Conventional Shear Wall System	0.0008	0.0008	0.0013
Building with Coupled Shear Wall System	0.0005	0.0005	0.00068

Model	Maximum Storey Drift (RSY)		
	10-storey	20 storey	30-storey
Building with Conventional Shear Wall System	0.0008	0.0008	0.00138
Building with Coupled Shear Wall System	0.0005	0.0005	0.000692

3.3 Maximum Storey Shear

Model	Maximum Storey Shear (KN) , (EQX)		
	10-storey	20 storey	30-storey
Building with Conventional Shear Wall System	16218	14546	13416
Building with Coupled Shear Wall System	26873	22983	17507

Model	Maximum Storey Shear (KN) ,(EQY)		
	10-storey	20 storey	30-storey
Building with Conventional Shear Wall System	16135	14366	13146
Building with Coupled Shear Wall System	26823	22838	17164

Model	Maximum Storey Shear (KN), (RSX)		
	10-storey	20 storey	30-storey
Building with Conventional Shear Wall System	16217.99	14546.02	13146
Building with Coupled Shear Wall System	26872.99	22982.991	17507.018

Model	Maximum Storey Shear (KN), (RSY)		
	10-storey	20-storey	30-storey
Building with Conventional Shear Wall System	16135	14365.976	13416
Building with Coupled Shear Wall System	26822.99	22837.986	17168.93

3.4 Maximum Overturning Moment

Model	Maximum Overturning moment(KN-m), (EQX)		
	10-storey	20 storey	30-storey
Building with Conventional Shear Wall System	506868	890059	1224249
Building with Coupled Shear Wall System	839825	1406258	1597566

Model	Maximum Overturning moment (KN-m), (EQY)		
	10-storey	20 storey	30-storey
Building with Conventional Shear Wall System	504246	879027	1224249
Building with Coupled Shear Wall System	838243	1397417	1566266

Model	Maximum Overturning moment (KN-m) (RSX)		
	10-storey	20 storey	30-storey
Building with Conventional Shear Wall System	387566	559544	872712
Building with Coupled Shear Wall System	733418	962187	983314

Model	Maximum Overturning moment (KN-m), (RSY)		
	10-storey	20 storey	30-storey
Building with Conventional Shear Wall System	384897	548459	870175
Building with Coupled Shear Wall System	731683	937585	952178

3.5 Maximum Storey Stiffness

Model	Maximum Storey stiffness (KN/m) , (EQX)		
	10-storey	20 storey	30-storey
Building with Conventional Shear Wall System	14710739	16284798	13067060
Building with Coupled Shear Wall System	24697740	25798903	21887086

Model	Maximum Storey Stiffness (KN/m), (EQY)		
	10-storey	20 storey	30-storey
Building with Conventional Shear Wall System	14623988	16083392	12836378
Building with Coupled Shear Wall System	24617098	25670078	21606317

Model	Maximum Storey Stiffness (KN/m), (RSX)		
	10-storey	20 storey	30-storey
Building with Conventional Shear Wall System	16974569	19895695	14779933
Building with Coupled Shear Wall System	25575842	28688955	24688035

Model	Maximum Storey Stiffness (KN/m), (RSY)		
	10-storey	20 storey	30-storey
Building with Conventional Shear Wall System	16904888	19790909	14607998
Building with Coupled Shear Wall System	25443232	28857028	24560764

4 CONCLUSION

The storey displacement in the coupled shear wall building is reduced by maximum amount of 43.61% when the height of the building is less in case of linear static analysis and it is reduced by maximum amount of 49.61% as the height of the building increases in case of linear dynamic analysis when compared to conventional shear wall building. The storey drift of the coupled shear wall building is reduced by maximum of 45.45% when the height of the building is less in case of linear static analysis and it is reduced by maximum amount of 49.85% as the height of the building increases in case of linear dynamic analysis when compared to conventional shear wall building. The Storey shear of the coupled shear wall building is increased by maximum of 66.24% as the height of the building is decreased in both linear static and linear dynamic analysis. The Overturning moment of the coupled shear wall is increased by maximum amount of 66.23% when the height of the building is less in case of linear static analysis and it is increased by maximum amount of 90.09% as the height of the building is less in case of linear dynamic analysis when compared to conventional shear wall building. The Stiffness of the coupled shear wall is increased by maximum amount of 68.33% when the height of the building is less in case of linear static analysis and it is increased by maximum amount of 68.81% as the height of the building is increases in case of linear dynamic analysis when compared to conventional shear wall building.

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