Seismic Response of Multi-storey Building with Short Core Buckling Restrained Brace System

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Abstract - *An In concentrically braced frames the use of long core buckling restrained braces (LCBRBs) used are expected to yield in both tension and compression considerably without degradation of capacity under seismic ground motions. A new short core buckling restrained brace system on the other hand it could be presented as a system for a conventional long core BRB. The core element is built shorter than usual in a short core BRB. Steel core could have a significant effect on its overall behavior in the short length of BRB since it directly influences the energy dissipation of the member. Moreover, BRB could be utilized effectively as a damper to en route for dissipation of seismic energy input, predominantly when it is used within the brace in a frame as a fuse. This study aimed at measuring more detailed behavior than previous researches of a multi-storey building with short core BRBs by using stainless and carbon steel core element in comparison with multi-storey buildings of conventional steel bracing and long core BRB. For this investigation 8 and 16 storey buildings are modelled, Non-linear analysis of time history method is carried out and results are drawn.*

Key Words: Storey Building friction Damper.

1 INTRODUCTION

In civil engineering, the building is loaded with enormous repeated cyclic forces during seismic forces. These seismic forces affect more economic losses and losses of lives due to damage of structures. Beams and columns which are major structural elements are affected more during earthquake. When large amount of energy is resisted inside the building and it is distributed inside. The sustaining level of damage in a building depends on distribution of the earthquake energy.

In order to minimize the earthquake energy effectively we need to have concern about the designing of earthquake resisting system. For resisting the earthquake bracing system is one of the concerns to resist the lateral load activity.

The bracing system is very common in civil engineering field which is a part of structural system.

1.1Conventional braced frame system (CBFs)

To resist the lateral load impact resulting from earthquake which creates lateral drift, conventional braced frame has more resistible lateral stiffness. V shaped, diametric and X shaped brace frame are the different kinds of conventional braced frame.

The degradation of the conventional braced frame under compression due to buckling of the conventional braced system is the only concern for the building. Due to the ductile behavior of eccentrically braced frames and lower stiffness, conventional braced systems are used. For moment resisting frames, eccentrically braced frames can be used. Based on the location of link beam location eccentrically braced frames can be used. It is composed of main elements like

- Column
- Link beam
- Bracing
- Non link beam

Based on study of many research journals, it is proved that the building do not serve its entire life span in case of high seismic areas. To counteract this, braced system looks like much better choice. It adds more stiffness and stabilize the building. This modification in case of buckling – restrained braced system (BRB) have better advantages when compared with conventional braced system.

It is cost effective, has high value of stiffness, it requires less maintenance and easy to replace it.

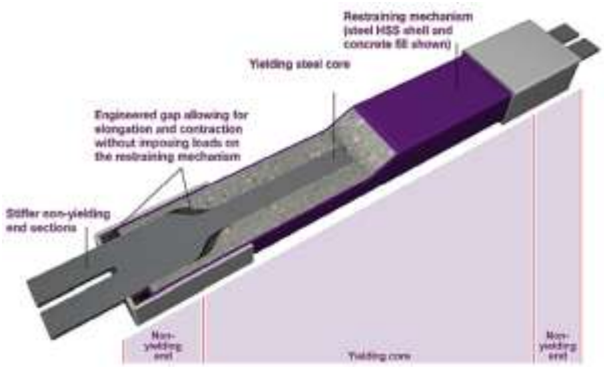
1.2 Buckling restrained braced system

In case of lateral load resisting, the BRBs are recently developed system with more benefits. It is designed in such a way that it is a structural brace in a building and to resist lateral loads. Another interesting thing is that the BRBs are proposed in a way that basic frame work is designed to retain its elastic properties during seismic duration, all the lateral load damage occurs within the braces.

2. Components of BRB

- Steel core
- Casing
- Un-bonded material

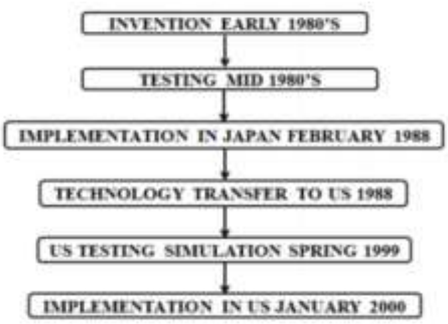
Steel core act as major component or element which is inside the concrete and a grease coating or may be any non-bonding material is applied outside the steel core to resist it from bonding to concrete. Steel core is main element in that resists load and buckling of core system is resisted by outer case (concrete) provided.



1.1 Background of buckling-retrained braced frame

The BRB conception was produced or developed in Japan By a company named Nippon Steel in 1980s and known by its trade mark by the name of in-boned brace system. In the year 1999 the U.S applied and installed it to Plant and Environment Science buildings. An engineer named by Wakabayshi first made the concept of BRB; it was made up of flat steel plate which was sandwiched between RCC panels.

It was first accepted as energy dissipation system and with a philosophy of “damage control” even before it was adopted by North America a force resistant element. Watanabe et.al made the experiment on foundation concepts of BRB programme. It demonstrated better energy dissipation capacity and ductility and they suggested the basic requirements for stiffening the restraining mechanism.



1.2 Advantages of BRBs

- BRBs have much better dissipation of energy when compared with other braced frame systems
- The BRBs resists lateral loads significantly in a structure. Therefore it leads in reducing the member size, connections are much simpler, it requires small foundation demands considerably.

1.3 Disadvantages of BRBs

- In case of steel tube filled with grout or concrete, it has more weight, which makes it difficult in transporting and installation which needs more manpower for installation.

- The BRBs have much less pot-yield stiffness and they don’t have mechanism of re-centering because of this at high seismic loading it has large residual deformation.

3 Modelling

1.1 Material Property

Material Name	M30
Directional Symmetric Type	Isotropic
Weight per Unit Volume	24.9926kg/m^3
Modulus of Elasticity, E	27386.13MPa
Poisson’s Ratio, U	0.2
Coefficient of Thermal Expansion, A	0.0000055C^{-1}
Shear Modulus, G	11410.89MPa
Compressive Strength, f_{ck}	30MPa

Rebar Property of 8 and 16 storey building

Material Name	HYSD500
Directional Symmetry Type	Uniaxial
Weight per Unit Volume	76.9729kN/m^3
Modulus of Elasticity, E	200000MPa
Coefficient of Thermal Expansion, A	0.0000117C^{-1}
Minimum Yield Strength, F_y	500MPa
Minimum Tensile Strength, F_u	545MPa

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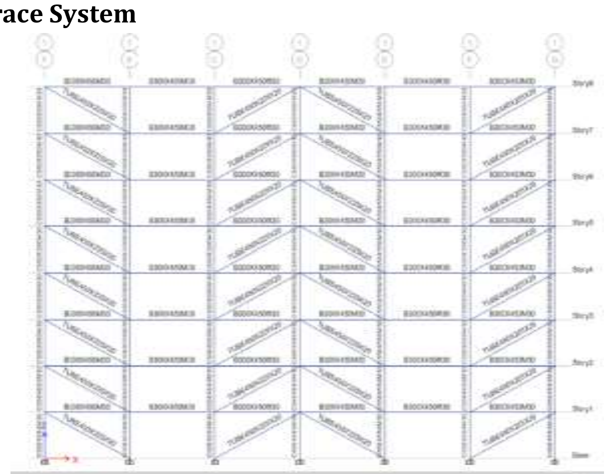
Expected Yield Strength, F_{ye}	550MPa
Expected Tensile Strength, F_{ue}	599.5MPa

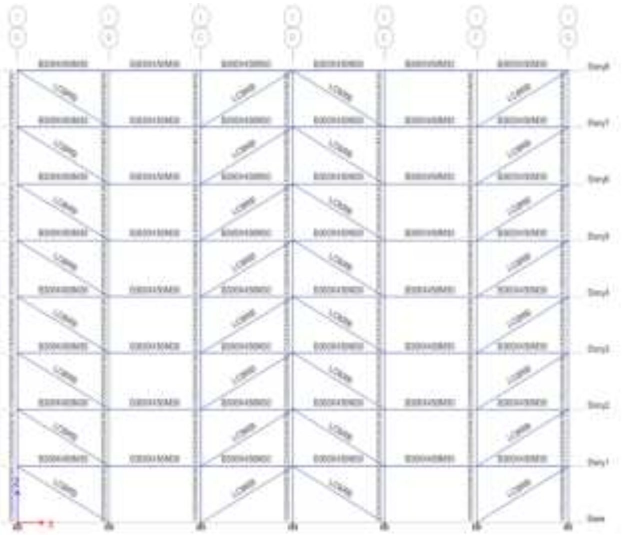
Steel Property of 8 and 16 storey building

Material Name	Fe250
Directional Symmetry Type	Isotropic
Weight per Unit Volume	76.9729kN/m^3
Modulus of Elasticity, E	210000MPa
Poisson's Ratio, U	0.3
Coefficient of Thermal Expansion, A	0.0000117C^{-1}
Shear Modulus, G	80769.23MPa
Minimum Yield Stress, F_y	250MPa
Minimum Tensile Strength, F_u	410MPa
Effective Yield Stress, F_{ye}	275MPa
Effective Yield Strength, F_{ue}	451MPa

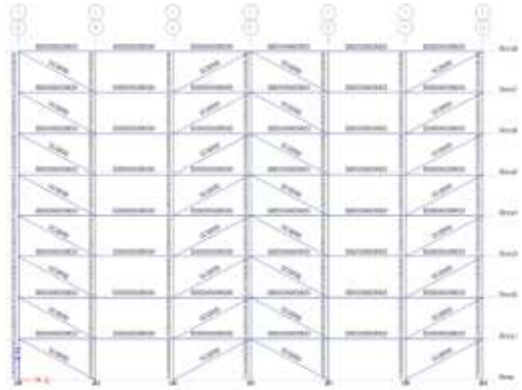
Models of Multi-Storey Building with Conventional Brace System



Frames with Conventional Brace System

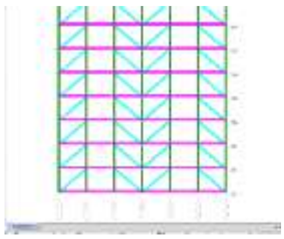


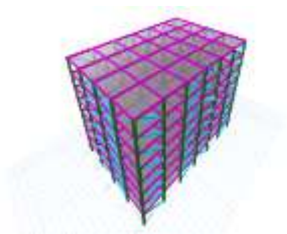
Frames with Long Yielding Core System



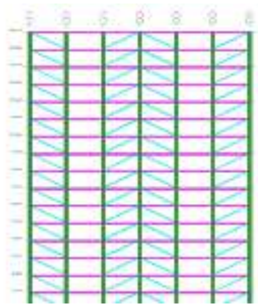
Frames with Short Yielding Core System

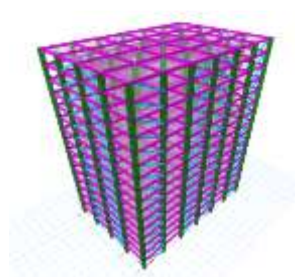
Elevation of 8 Storey **3D View of 8 Storey**





Elevation of 16 Storey **3D View of 16 Storey**





Load Details

PROPERTY NAME	MATERIAL	SECTION SHAPE	DEPTH	WIDTH
C550X550 M30	M30; Fe500	SQUARE	550mm	550mm

Dead Load

These are the natural permanent loads that are acting on the assembly and are dependent on the material properties used for unalike structural elements. IS 875-1987(Part I) affords the detail of unit weights for those materials used in structural elements.

Live Load

The live load on a structure or building is determined by the habitation or usage of that particular structure. IS 875-1987(Part II) defines the detail about the Live Loads for different usage of the structure. Since, the values of live loads for floors and roof are taken as 3kN/m2 and 1.3kN/m2 respectively.

Super Dead Load

These are dead loads which comprise of floor finishes and roof finish, these loads also depends on the unit weight of the materials used for the surfaces. The various material surfaces used and their weight per square meter are described in IS 875-1987(Part I). Since, the values of floor finishes and roof finish loads are taken as 1.3kN/m2.

Earthquake Load

Earthquake forces are generated by the inertia of buildings as the buildings dynamically respond to ground motion. The dynamic nature of the earthquake loadings which makes it different from other building loads. The procedure to calculate the earthquake are described in IS 1893 (Part- I) because to calculate earthquake/ seismic force IS 1893 (Part- I) is used.

Table 4.5: The loading combinations are

FLANGE THICKNESS	WEB THICKNESS	WEIGHT
20mm	20mm	15.31kN

DESIGN OF STRUCTURAL MEMBERS

Column Section Design

The program calculates required longitudinal steel or if longitudinal steel is defined, in design of the columns, the condition of column stresses is reported in terms of a column capacity ratio which is a factor that gives a suggestion of stress condition of the column with respect to capacity of the column.

Shear reinforcement design procedure for columns is very similar to that for beams except that the effect of axial force is considered on the concrete shear capacity. For certain special seismic cases, the design of columns for shear is based on the shear capacity. Design of columns were done according to code IS 456: 2000 and columns section details are provided in below table.

Table.6.1 Columns Section Details of 8-storey building

Sl.No	Load Combination Details
a	1.5DL
b	1.5DL+1.5LL
c	1.2DL+1.2LL+1.2EQX
d	1.2DL+1.2LL-1.2EQX
f	1.2DL+1.2LL+1.2EQY
g	1.2DL+1.2LL-1.2EQY
h	1.5DL+1.5EQX
i	1.5DL-1.5EQX
j	1.5DL+1.5EQY
k	1.5DL-1.5EQY
l	0.9DL+1.5EQX
m	0.9DL-1.5EQX
n	0.9DL+1.5EQY
o	0.9DL-1.5EQY

PROPERTY NAME	MATERIAL	SECTION SHAPE	DEPTH	WIDTH
C850X850 M30	M30; Fe500	SQUARE	850mm	850mm

Table.6.1 Columns Section Details of 16-storey building

Table.6.2 Beams Section Details of 8-storey building

PROPER TY NAME	MATERIAL	SECTION SHAPE	DEPTH	WIDTH
B300X45 0 M30	M30; Fe500	RECTANGULAR	450mm	300mm

Table.6.2 Beams Section Details of 16-storey building

PROPERTY NAME	MATER IAL	SECTION SHAPE	DEPT H	WIDT H
B400X500 M30	M30; Fe500	RECTANGULA R	500m m	400m m

Table.6.3 Slabs Section Details for both 8 and 16 storey building

PROPERTY NAME	MATERIAL	THICKNESS
S200M30	M30; Fe500	200mm

Table.6.4 Braces Section Details of 8 and 16 storey building

PROPERTY NAME	MATERIAL	SECTION SHAPE	TOTAL DEPTH	TOTAL WIDTH
TUBE450X225X20	Fe250	STEEL TUBE	450mm	225mm

Table.6.5 BRB of Long Core Yielding Length of 8 and 16 storey

PROPERT Y NAME	MATERIA L OF YEILDING	OVERALL SECTION	ELASTIC SEGMENT SECTION	YIELDING SEGMENT SECTION
Long Core Yielding Length	Fe250	220mmX390m m	80mmX440m m	80mmX290m m

LENGTH OF YIELDING SEGMENT	LENGTH OF ELASTIC SEGMENT	TOTAL BRB WEIGHT
6264mm	783mm	42.695kN

Table.6.9 BRB of Short Core Yielding Length of 8 and 16 storey

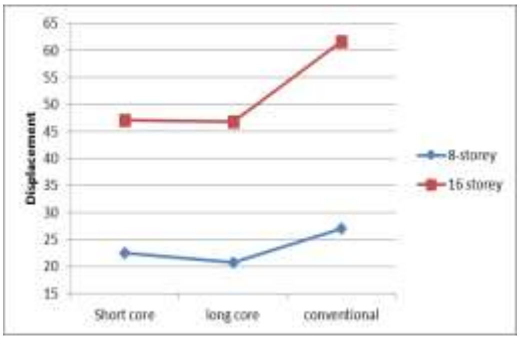
PROPERTY NAME	MATERIAL OF YEILDING	OVERALL SECTION	ELASTIC SEGMENT SECTION	YIELDING SEGMENT SECTION
Short Core Yielding Length	Fe250	220mmX390mm	80mmX340 mm	80mmX290 mm

LENGTH OF YIELDING SEGMENT	LENGTH OF ELASTIC SEGMENT	TOTAL BRB WEIGHT
1258.8mm	3288.6mm	22.136kN

RESULTS AND DISCUSSION

Storey Displacement:

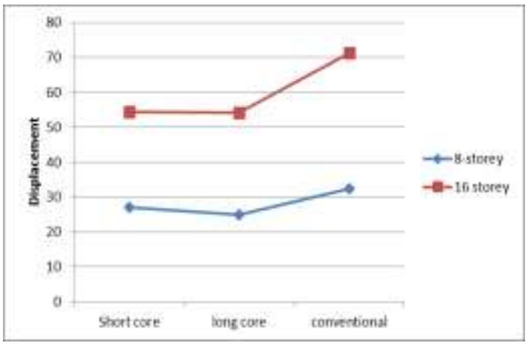
model	Displacement (EQX), (mm)	
	8-storey	16 storey
Short core	22.5	47.153
long core	20.766	46.782
conventional	27.068	61.654



The storey displacement is reduced by 16.8% in SCBRB and 23.28% in LCBRB of 8-storey building where as the storey displacement is reduced by 23.51% in SCBRB and 24.12% in LCBRB in 16-storey building when compared to conventional building.

Table 8.4: Storey Displacement (mm), (EQY)

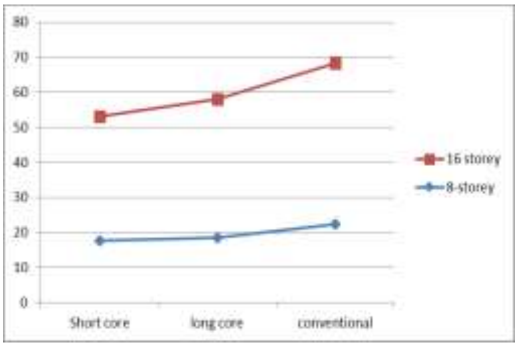
model	Displacement (mm) , (EQY)	
	8-storey	16 storey
Short core	26.969	54.42
long core	24.832	54.115
conventional	32.31	71.331



The storey displacement is reduced by 16.5% in SCBRB and 23.14% in LCBRB of 8-storey building where as the storey displacement is reduced by 23.71% in SCBRB and 24.13% in LCBRB in 16-storey building when compared to conventional building.

Table 8.5: Storey Displacement (Time X), (mm)

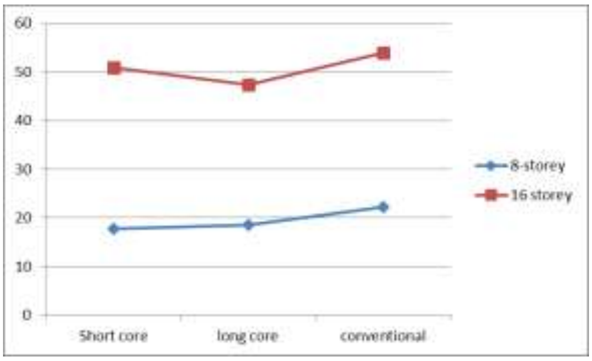
model	Displacement (Time X), (mm)	
	8-storey	16 storey
Short core	17.734	35.493
long core	18.59	39.391
conventional	22.281	45.926



The storey displacement is reduced by 20.40% in SCBRB and 16.56% in LCBRB of 8-storey building where as the storey displacement is reduced by 22.71% in SCBRB and 14.23% in LCBRB in 16-storey building when compared to conventional building.

Table 8.6: Storey Displacement (Time Y), (mm)

model	Displacement (Time Y), (mm),	
	8-storey	16 storey
Short core	17.734	50.882
long core	18.59	47.412
conventional	22.281	53.925



The storey displacement is reduced by 20.40% in SCBRB and 16.56% in LCBRB of 8-storey building where as the storey displacement is reduced by 5.64% in SCBRB and 12.07% in LCBRB in 16-storey building when compared to conventional building**.**

Storey Drift:

model	Drift (EQX)	
	8-storey	16 storey
Short core	0.0009	0.001
long core	0.0008	0.0009
conventional	0.0011	0.0013

model	Drift (EQY)	
	8-storey	16 storey
Short core	0.0011	0.0011
long core	0.001	0.0011
conventional	0.0013	0.0015

model	Drift (Time X)	
	8-storey	16 storey
Short core	0.0011	0.0008
long core	0.001	0.0006
conventional	0.0013	0.0009

model	Drift (Time Y)	
	8-storey	16 storey
Short core	0.0009	0.0011
long core	0.0012	0.001
conventional	0.0015	0.0011

model	Base Shear (EQX) ,KN	
	8-storey	16 storey
Short core	6747.866	7456.528
long core	7365.294	8295.971
conventional	10190	11423

model	Base Shear (EQY), KN	
	8-storey	16 storey
Short core	5484.299	6284.424
long core	6002.432	6971.43
conventional	8325.75	9603.784

model	Base Shear (Time X), KN	
	8-storey	16 storey
Short core	6747.842	7456.756
long core	7475.341	8296.078
conventional	10190.01	11423

model	Base Shear (Time Y), KN	
	8-storey	16 storey
Short core	5484.295	7456.556
long core	7309.649	6971.827
conventional	10974	9603.784

model	Overturning moment (EQX), KN-m	
	8-storey	16 storey
Short core	150615	326014
long core	164026	322935
conventional	227074	499400

model	Overturning moment (EQY) KN-m	
	8-storey	16 storey
Short core	122990	276578
long core	134184	307122
conventional	186168	422567

model	Overturning moment (Time X), KN-m	
	8-storey	16 storey
Short core	121116	248355
long core	150837	250259
conventional	189533	389138

model	Overturning moment (Time Y), KN-m	
	8-storey	16 storey
Short core	105939	256448

long core	154736	266025
conventional	215565	327373

CONCLUSIONS

- The value of storey displacement decreases with increase of yielding segment length of BRBs in case of earthquake analysis. Building with LCBRB system has average of 23.21% in 8 storey building and average of 24.125% in case of 16 storey in earthquake analysis for both X and Y direction.
- The value of storey drift decreases with increasing of yielding segment length of BRBs in case of earthquake analysis. Building with LCBRB system has average of 25.28% in 8 storey building and average of 28.77% in case of 16 storey in earthquake analysis for both X and Y direction.
- The value of Base shear decreases with decreasing of yielding segment length of BRBs in case of earthquake analysis. Building with SCBRB system has average of 33.945% in 8 storey building and average of 34.64% in case of 16 storey in earthquake analysis for both X and Y direction.
- The value of overturning moment decreases with decreasing of yielding segment length of BRBs in case of earthquake analysis. Building with SCBRB system has average of 33.805% in 8 storey building and average of 34.63% in case of 16 storey in earthquake analysis for both X and Y direction.

From the above,

- It is known that the storey displacement and storey drift is reduced in LCBRB in both 8 and 16 storey building.
- The base shear and overturning moment is greatly reduced by including SCBRB in both 8 and 16 storey building.

The authors can acknowledge any person/authorities in this section. This is not mandatory.

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