IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 12, Issue 2 Ver. VI (Mar - Apr. 2015), PP 34-41
www.iosrjournals.org

Ductility of Outrigger Typologies for Highrise Structures

MSc. Rafael Shehu
Post graduated student, School Fratelli Pesenti, Polytechnic University of Milan, Italy

Abstract: *This research paper focuses on aspects of the building performance designed or retrofited by means of conventional or virtual Outriggers. The purpose of this paper is to highlight the ductil characteristic of the structures, as a way of describing the post elastic phase and their performance during seismic events. Used methodology is the investigation of three buildings with different heights and four type of structural models through nonlinear analysis using finite elements method and their results interpretation in terms of internal forces, deformations, capacity and ductility. The way of result interpretation is done by comparing the behavior of each structure, thus draw strong and relevant conclusions and recommendations on the applicability of these structures. The study of the ductil behavior seems important in the design phase, as well as in the phase of study for restoration purposes of buildings in high seismic activity areas.*
Keywords: *Outriggers, Vierendel , Bracing, Ductility, Capacity curve, Performance point, Drift.*

I. Introduction

Nature of structural systems

The philosophy of design of civil structures especially of high-rise buildings[1], technology and construction materials develops in parallel on basis principles of global and local performance of each element of the structure. Let's take a short view on two main structral elements which are related in some way with the internal forces. An element cantilever "wall" type, which under the action of lateral forces works in bending and its destruction is dominated by bending or shear. Diagonal elements, "Bracing" who conducts a “shear” global behavior but destroyed by axial forces. Combining the above elements to exploit the respective properties receive some types of structures, successfully I would add, resistant to lateral forces. [1][2][3][4]

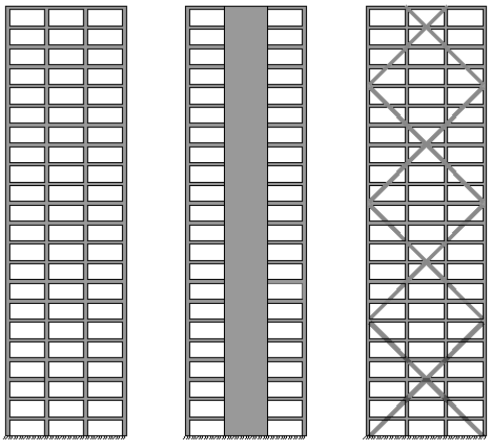

Figure 1. Frame Resistent Structures, Shear Wall Resistent Structures, Bracing Resistent Buildings.

[1] Some design codes refers as “highrise buildings” for structures with more than 15 storeys, but the concept of outrigger is effective for more than 20-25 storeys buildings.

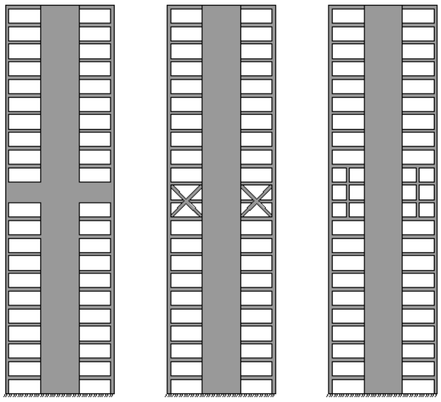

Figure 2. outrigger resistent structures, convecional outrigger, truss outrigger, vierendel.

Nature of ductility

Zones with high seismic activity refer the ductility factor to the same importance with the strength and strength of the entire structure [8]. Ductility, as the main objectiv factor determining the plastic phase behavior of the structure should also be achieved by fulfiling some parameters (not very objectiv), refering the recommendations for anti-seismic designs (destruction scheme or the formation of plastic hinges) which can not be specifically evaluated on the graph of ductility assessment. [1][7] To evaluate the theoretical or practical ductility we refer the force-displacement graph developed for elements or structures. Analzing the structures is raised the issues of idealization the structure behavior through multilinear curves which are mathematical models of real physical models.

$$\mu = \frac{u_m}{u_y}$$

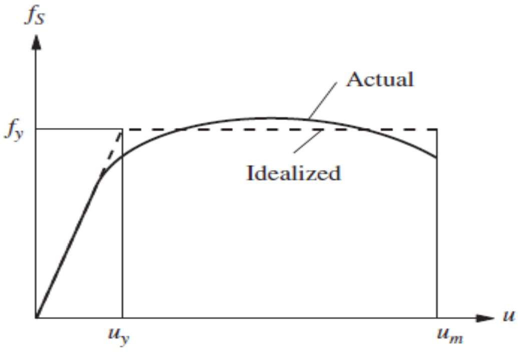

Figure 3. Bilinear Model Of Material/Structure Behaviour [1]

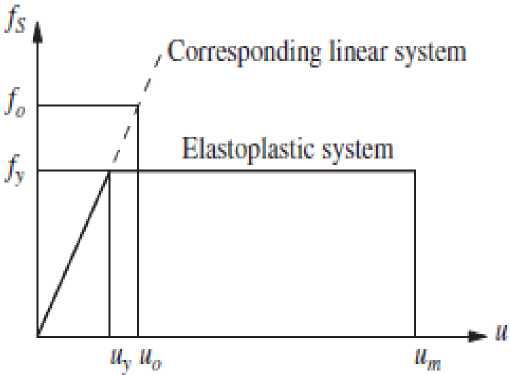

Figure 4. Corresponding Linear System And Elasto-plastic System [1]

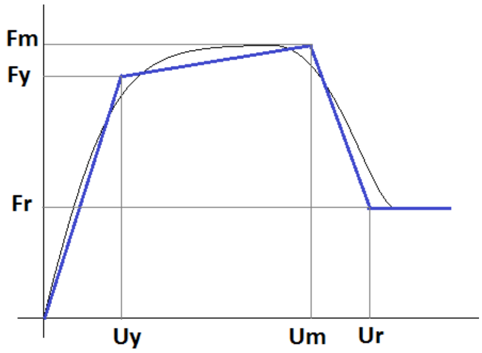

Figure 5. Multilinear System Of Material/Structure Behaviour

In the first two graphs above elasto-plastic ideal curve is bilinear, while in the third graph we are dealing with a multilinear curve which is closer to the real behavior. The most important parameters in terms of safety are: Fy- (strength design of the structure) and Um- (maximum deformation of the structure in the postelactic phase). Fr- represents remainind strength which has no practical interest since it exceeds all expectations from the performance of the structure. Parameter Fm- (actual maximum strength of the structure) which can be translated in overstrength that comes from the materials or as a result of a plastic mechanism which reserves the elements of the structure in the elastc phase ready to face further internal forces which come from the reallocation of internal forces (redundancy).[7]

Theoritcally the bilinear model is correct but practically a pure yielding within a certain segment of deformations doesn't exist. In a practical sense of security we must achieve such a behavior of the structure which meet the following conditions:

1. $\mu = \frac{u_m}{u_y} \geq \mu_{demanded}$
2. $1 < over\ strength = \frac{F_m}{F_y} \leq \frac{Excessed\ action}{F_y}$

In this case, remember that the bendings elements have a safer post-elastic behavior.

Reinforcing intervention strategies

A new or existing structure should be subject of tests which evaluate its performance and based on these results may arise a need to improve the behavior of the structure. Taking into consideration the types of structures mentioned in the first paragraph there is a need to recognize the complex behavior of such structural systems in terms of internal forces, deformations, drifts, ductility etc. The purpose of a reinforcement strategy is to simultaneously achieve several benefits mentioned above.

II. Methodology

The methodology used in this paper is by analyzing the various structures and investigtion of the results to identify the similarities and conclusions. Constructive basic structure will be "wall" combied with outrigger. For each structure will study the data for drifts, capacity curves, plastic hinges, performance point.

Modelling

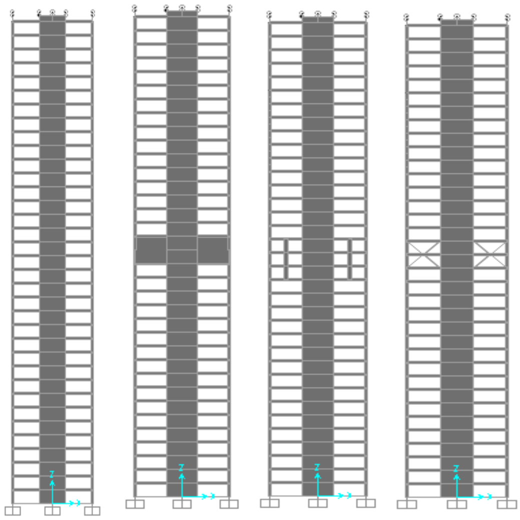

Figure 6. Four Types Of Structural Models, Modeled With SAP2000, A) Dual System B) Outrigger System C) Outrigger Vierendel System D) Outrigger Bracing System

Structures in the study will be a civil building construction 25,30,35 storeys with reinforced concrete dual systems, frame with central wall and the same layout in the plan. They will be calculated for gravital loads (1.35Dead + 1.5Live) and five cases of lateral seismic loads according to EC-8 (PGA = 0:33, 0:34, 0:35, 0:36, 0:37). It would be valid to mention that have been taken five different peak ground acceleration value so that the analysis will be performed within a range of security for the overcome of demanded ground acceleration. Strategy strengthening of these existing structures or the performance of new constructions will be realized in three different structures.

a. Rigid outrigger (MODEL B)
b. Vierendel outrigger [3] (MODEL C)
c. Bracing outrigger (MODEL D)

Structures above will be subject to pushover analysis to evaluate the performance of the structure.

III. Results

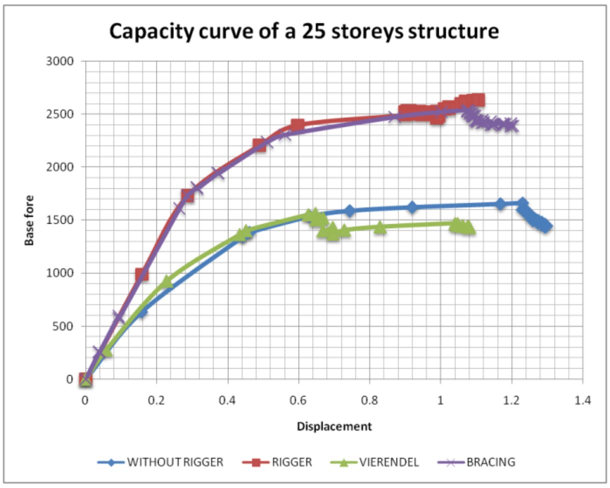

Figure 7. Capacity Curve of a 25 Storey Structure

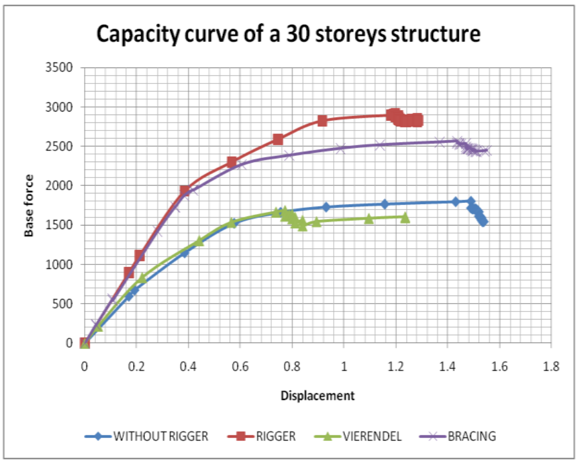

Figure 8. Capacity Curve of a 30 Storeys Structure

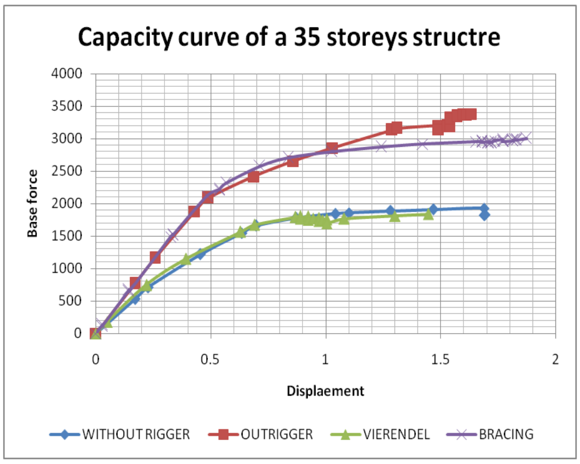

Figure 9. Capacity Curve of a 35 Storey Structure

From the similarity of struture behaviour comes as conclusion that outriggers can harden the structure and increase their capacity. Such behavior was expected refering studies related with the performance of outriger structures, also for their optimal position through the height of the building. Referring to these studies is chosen in our models that these constructions are positioned at half the height of the structure [9].

Vierendel construction in above structures exhibit a slight decrease of the capacity and almost no impact on the strength of the structure. This can be explained by the fact that the rigidity of the node where elements are positioned is not so significant to affect the quality of the internal forces of the central wall, which defines the entire dominant behavior of the building. It is clear that if the rigidity of this node would be comparable to the hardness of a rigger, the structure would be more stiff and would have a higher capacity. Structure with diagonal bracing is evaluated as a siff structure and the the above results proves this assertion.

Interpretation of results

Judging on the form of the capacity curve, more deficient in the sense of using plastic properties is what regards Outrigger structures because they have a tendency to increase the capacity considerably. Structure with diagonal connection has a moderate behavior as well as rigidity and plasticy. In this case we would have a quasi-perfect behavior of a structure which has a considerable plastic phase which takes place with a slight increase of strength.

The table below includes the results from all the models, characterized by a tendency of the results despite from the floor number of the structure. Highlighted are the values taken for the mean values ofground acceleratoins. It is worthy mentioning the results regarding the ductilty of the structure. Table 1. is organized into three main columns which represent the structure 25, 30 and 35 storey. For each structure / column have four lines which represent structural typologies as follows: WO- Without Outrigger; O- Outrigger structure; VO- Vierendeel Outrigger; BRAC- Bracing Outrigger. For each row the table reflects the results of: PGA- peak ground acceleration value of the spectrum function refering EC8; V-Base Shear for the performance point refering FEMA 440 (software calculated); D Target displacement for the for the performance point refering FEMA 440 (software calculated); Ductility- Value of ductility achieved for the for the performance point refering FEMA 440 (software calculated). Refering to the basic structure without Outrigger results can be interpreted thus:

	TYPE	PGA	V	D	DUCTILITY		TYPE	PGA	V	D	DUCTILITY		TYPE	PGA	V	D	DUCTILITY
25 STOREYS STRUCTURE	WO	0.33	1438.023	0.523	2.67	30 STOREY STRUCTURE	WO	0.33	1597.048	0.675	2.359	35 STOREYS STRUCTURE	WO	0.33	1775.091	0.865	2.176
		0.34	1447.614	0.534	2.642			0.34	1608.67	0.69	2.335			0.34	1787.155	0.893	2.183
		0.35	1457.03	0.544	2.614			0.35	1620.112	0.704	2.311			0.35	1799.963	0.927	2.21
		0.36	1.466.276	0.555	2.586			0.36	1631.379	0.719	2.288			0.36	1812.993	0.962	2.238
		0.37	1475.356	0.565	2.559			0.37	1642.476	0.733	2.65			0.37	1826.25	0.998	2.266
	O	0.33	1665.586	0.275	1.752		O	0.33	1974.678	0.406	1.804		O	0.33	2191.431	0.552	1.64
		0.34	1726.466	0.286	1.82			0.34	1997.169	0.417	1.794			0.34	2217.722	0.568	1.635
		0.35	1750.259	0.294	1.83			0.35	2019.565	0.428	1.785			0.35	243.968	0.584	1.631
		0.36	1769.751	0.302	1.833			0.36	2041.869	0.439	1.775			0.36	2270.17	0.599	1.626
		0.37	1789.279	0.311	1.837			0.37	2064.081	0.45	1.766			0.37	2296.326	0.615	1.622
	VIE	0.33	1457.338	0.517	3.108		VO	0.33	1643.315	0.707	2.997		VO	0.33	1789.115	0.922	2.798
		0.34	1467.76	0.529	3.086			0.34	1653.519	0.72	2.963			0.34	1758.876	0.923	2.708
		0.35	1478.045	0.541	3.065			0.35	1663.502	0.733	2.93			0.35	1775.601	0.969	2.769
		0.36	1488.195	0.553	3.045			0.36	1676.056	0.753	2.927			0.36	1741.388	0.969	2.684
		0.37	1498.215	0.564	3.024			0.37	1683.053	0.775	2.93			0.37	1735.256	1.004	2.704
	BRAC	0.33	1804.6	0.312	2.647		BRAC	0.33	1956.264	0.426	2.257		BRAC	0.33	2360.334	0.592	2.329
		0.34	1807.001	0.313	2.524			0.34	1976.921	0.438	2.252			0.34	2383.448	0.605	2.304
		0.35	1802.136	0.314	2.426			0.35	1997.509	0.45	2.247			0.35	2406.221	0.618	2.28
		0.36	1799.732	0.315	2.355			0.36	2018.031	0.462	2.241			0.36	2428.658	0.63	2.256
		0.37	1814.364	0.321	2.326			0.37	2038.486	0.474	2.236			0.37	2450.768	0.643	2.232

Table 1. Table of The Resuls for all the Modeled Structures Refering to Performance Point and the Ductlity

- Outriggers significantly increases the performance of the structure in terms of strength and stiffness but however in the same time brings a significant reduction in the achieved ductility.
- Vierendel outriger has a smaller effect on the stiffnes and strength of the structure (in some cases it is negative) but there is a notable increase in ductilty achieved.
- Outrigger with diagonal bracing has a considerable influence on the stiffnes and strength of the structure and was not associated with major changes in the structure ductility.

In terms of design it is advisable that structure should posses a high ductilty while in the case of reinforcements along ductility should be increased the stength and rigidity. These principles will classify the structure of the Outrigger as the unrelevant against other choice. These models have another element that is not stated above, which are the dimensions of constructive elements. Basically if a structure's stiffness and resistance is higher than another for the same constructive elements means that we can realize the same performance by elements in smaller dimensions. We have the right also establish a assumption that the structures with outrigger and smaller elements shall have a strength and stiffnes smaller than that above, and in a way its ductility will increase. Results of the analysis show that this happens but in practical cases of high buildings dimensions are fuction also of other factors which may limit the possibility to change them, and in this case engineers should seek new ways of improving the performance.

A very important factor are also the drifts which are taken from the application of lateral seismic forces. To create a complete idea about these structures, studying the drifts provides important information on the rigidities of the storeys and potential soft storeys in the building.

In the graphs above it is clear that structures with bracing carries a pronounced hardening which increases the potential for the formation of soft storeys in the adjacent floors. Favorable structures towards drifts are vierendel structures, by providing a moderate jump in the drifts values.

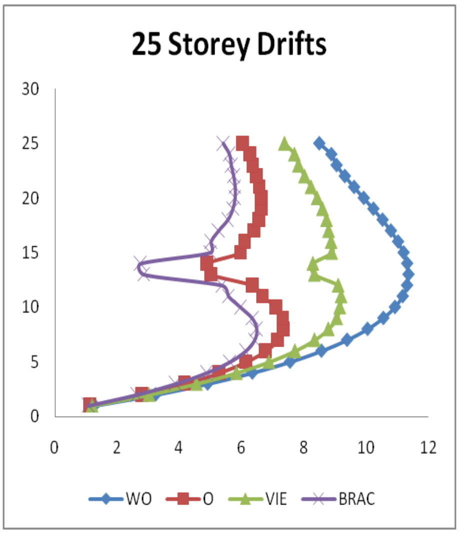

Figure 10. Drifts in the 25 Storey Structure (multiplied by 1000)

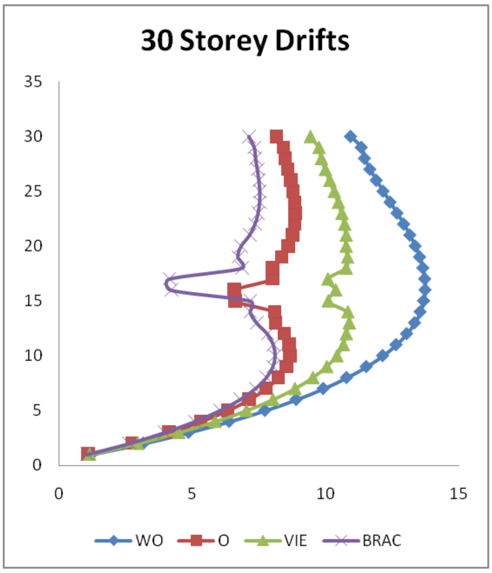

Figure 11. Drifts in the 30 Storey Structure (multiplied by 1000)

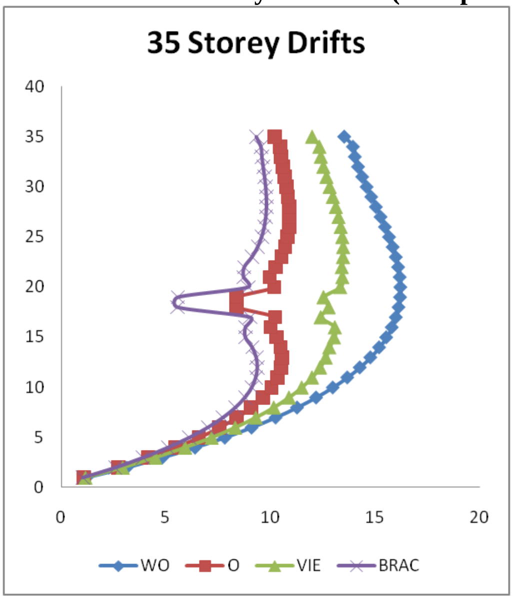

Figure 12. Drifts in the 25 Storey Structure (multiplied by 1000)

IV. Conclusions

Conclusions can be summarized in three issues. The issue of comparing the structures:

- Dutility is an essential structure parameter versus anti-seismic requirements, and should be said that it is the third capacity parameter.
- Performance of Outrigger structure is higher than without Outrigger structures, but their ductility is reduced.
- Structures with diagonal bracing contribute to the performance of the structure without reducing ductility.
- Structures with vierendel have a higher ductility compared with other structures to the same level of strength as well their drifts are more moderated for soft storeys.

For design purposes:

- For new structures is highy recommended the use of outriger typology as a structure performance improvers but recommended to be realized in the form of diagonals or vierendels in order to get plastic behavior from the structure.

For retrofiting purposes :

- According to the strategy defined, we must bear in mind that vierendel structures increase the ductility, meanwhile diagonal structures increase the performance.

References

[1]. A.Chopra – Dynamic Of Structures ,Theory And Aplications To Earthquake Engineering, Third Edition ,1995

[2]. Bunghale S. Taranath - Structural Analysis And Design Of Tall Buildings, Mcgraw Hill, 1988

[3]. Bunghale S. Taranath - Reinforced Concrete Design Of Tall Buildings, Mcgraw Hill, 2000

[4]. Bunghale S. Taranath ,"Wind And Earthquake Resistant Building - Structural Analysis And Design" Mcgraw Hill, 2000

[5]. Gerasimidis S. , Efthymiou E, Baniotopoulos - Optimum Outrigger Location Of High-Rise Buildings For Wind Loading, Eacwe 5, 2009

[6]. Ioana Olteanu, Ioan Petru Ciongradi, Mihaela Anechitei, M. Budescu , - The Ductile Design Concept For Seismic Actions In Miscellaneous Design Codes, Buletinul Institutului Politehnic Din Iaşi, 2009

[7]. N. Pojani – Inxhinieria Sizmike (Seizmic Engineering) , 2003

[8]. P. C. Vasani, Bhumika B. Mehta - Ductility Requirements For Buildings

[9]. P.M.B. Raj Kiran Nanduri, B.Suresh , MD. Ihtesham Hussain -Optimum Position of Outrigger System for High -Rise Reinforced Concrete Buildings Under Wind And Earthquake Loadings, American Journal of Engineering Research, 2013

[10]. R.Shankar Nair - Belt Trusses And Basements As "Virtual" Outriggers For Tall Buildings, Wiley Interscience, 2007

[11]. S. Fawzia, T. Fatima - Deflection Control In Composite Building By Using Belt Truss And Outriggers Systems, World Academy Of Science, Engineering And Technology Vol:4 2010-12-22