

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 8, August 2017

Performance Based Design of Jetties

P. Venkatalakshmi¹, J. Suma Sree², P. Veerabhadra Rao³

P.G. Student, Department of Civil Engineering, GVP College of Engineering (A), Visakhapatnam, India¹

Associate Professor, Department of Civil Engineering, GVP College of Engineering (A), Visakhapatnam, India²

Professor, Department of Civil Engineering, GVP College of Engineering (A), Visakhapatnam, Visakhapatnam, India³

ABSTRACT: The aim of performance based design is to study damage pattern and to control the damage under earthquake forces. To study the performance of a structure a simplified nonlinear static analysis is used which is popularly known as pushover analysis. It is a simplified non linear technique to observe the deformation of a structure under seismic loads. In pushover analysis load is applied incrementally to plot the force-deformation relationship. Permanent gravity loads are applied along with horizontal loads (i.e. structure is pushed continuously) until it reaches the target displacement or collapse occurs. In this paper, a pushover analysis is carried out to study the performance of jetties. For the study a 2D-Frame of a jetty is considered and designed as per IS: 456-2000 and IS: 1893-2002 and hinges are assigned as per the FEMA-356. The objective of study is run pushover analysis for default hinges and user defined hinges with different dredge levels and to observe the structural behaviour, base shear and deformation at performance point.

KEYWORDS: Jetties, Hinges, Pushover analysis, Capacity curve, Demand curve, Base shear, performance point.

I. INTRODUCTION

In present days pushover analysis is widely used due to its simplicity, but it is mostly applied on RC Buildings, Steel Frames. Pushover analysis on jetties is very much limited. In present days, due to globalization imports and exports are increased. Large volumes of goods are to be handled through water transport since it is Economical. As imports and exports increase the handling capacities of ports are also to be increase (i.e. large capacity vessels are to be handled). Hence it is necessary to design berthing structures to perform well under seismic loads. Non-linear static analysis is popularly known as pushover analysis. It came into practice in 1970's, but it has been developed over the past two decades and become a most preferred analysis procedure for design and seismic performance evaluation purposes because of its simplicity and consideration of post elastic behaviour. Its limitations, weaknesses and the accuracy of its predictions in routine application should be identified by studying the factors affecting the pushover predictions. It is mainly used to estimate the strength and drift capacity of existing structure/new structures and the seismic demand for this structure subjected to a given earthquake. Performance based design has brought the nonlinear static pushover analysis procedure to the forefront. The magnitude of the structural loading is incrementally increased in accordance with a certain predefined pattern. With the increase in the magnitude of the loading, weak links and failure modes of the structure are found. The loading is monotonic with the effects of the cyclic behaviour and load reversals being estimated by using a modified monotonic force-deformation criteria and with damping approximations. Static pushover analysis is an attempt by the structural engineering profession to evaluate the real strength of the structure and it promises to be a useful and effective tool for performance based design. The effectiveness of pushover analysis and its computational simplicity brought this procedure into several seismic guidelines (ATC 40 and FEMA 356) in last few years. In push over analysis the structure can be run for force controlled method or the deformation controlled capacity. In deformation control method the structure is pushed laterally (incremental loads) until a target displacement reached by the structure. Target displacement is the maximum displacement of a structure in elastic and post elastic behaviour. In force control method the structure is pushed laterally (incremental displacements) until a target force reached by the structure. Push over analysis gives estimation of force and displacement capacities of the structure, Sequence of the member yielding and the progress of the overall capacity curve and its effect on the structure. Estimates of axial force, shear force and moment demands on potentially brittle elements and deformation demands on ductile elements.

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 8, August 2017

Estimates of global displacement demand, corresponding inter-storey drifts and damages on structural and non-structural elements expected under the 20 earthquake ground motion considered. It gives clear idea of weaker sections of structure and progress of failure on capacity curve. The progress of failure of the structure can be understood by force-deformation graph. The performance level indicators are shown in fig and explained in table below.

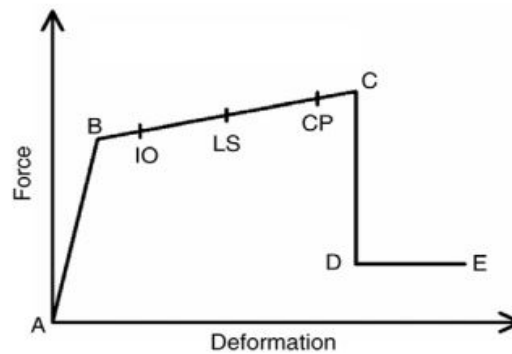


Fig. 1 Force- Deformation graph

A-B = Elastic Zone

B-C = Strain Hardening Zone

C-D = Loss of Strength

D-E = Residual strength

The above graph is plotted between force Vs deformation. From the graph performance of the structure can be observed clearly. They are discussed below.

Table1: Performance Levels

Performance level		Description
Immediate Occupancy (IO)	Operational	No significant damage has occurred to structure, which retains nearly all its pre-earthquake strength and stiffness. Non-structural elements are secure and most would function, if utilities were available. Building may be used for intended purpose, albeit in an impaired mode.
Life Safety (LS)	Life safe	Significant damage to structural elements with substantial reduction in stiffness, however margin remains against collapse. Non-structural elements are secured but may not function. Occupancy may be prevented until repairs can be instituted.
Collapse Prevention (CP)	near collapse	Substantial structural and non-structural damage. Structural strength and stiffness substantially degraded. Little margin against collapse. Some falling debris hazards may have occurred.

The performance of a structure at different stages are presented in diagram format is shown in figure below. In operational condition the structure doesn't under go any damage; it can be used for further use. In Immediate occupancy the structural elements undergo less damage but structural elements are functional. In Life safety the structural elements undergo more damage than IO state but they can be serviceable and reused again. In Collapse Prevention stage there is large damage to structural elements and they are not repairable and reusable. At this stage the structural elements are ready to collapse.

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 8, August 2017

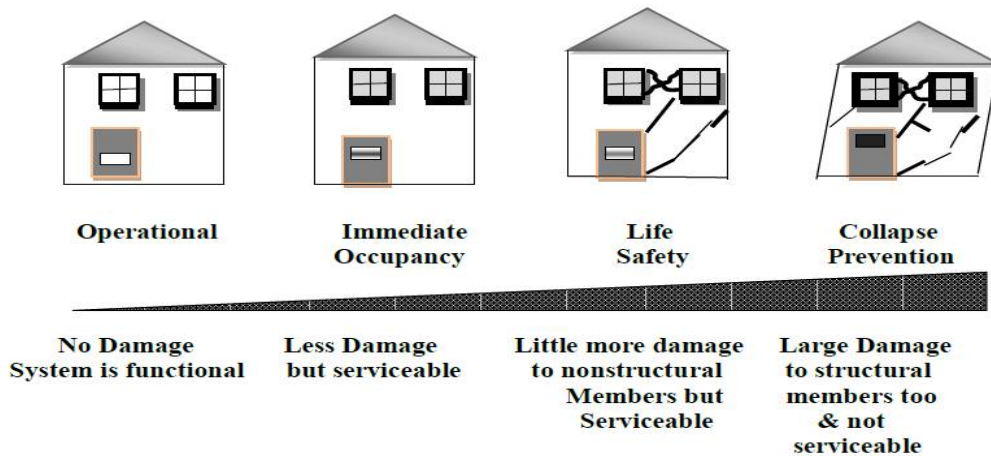


Fig. 2 Performance Level Indicators

II. LITERATURE REVIEW

A study on pushover analysis on different structures are discussed below
Chopra¹ et al, 2004, In this paper a building frame without shear wall and with shear wall is designed as per Indian standard i.e. IS 456:2000 and IS 1893:2002. The objective of this study is to check the performance of a building when designed as per Indian Standards with and without shear wall in a building frame. The pushover analysis is carried by using software SAP 2000. Dimpleben P. Sonwane et al, 2015, In this paper a RC Framed building is considered and designed as per the IS: 456-2000 and pushover analysis was carried out. Then the performance of a structure is observed and the frame is redesigned by changing the main reinforcement for various frames at different story levels. Out of the above the best combination of reinforcement that is economical, effective and less susceptible to damage is considered as performance based design. Neethu² et al, 2015, In this paper a building frame is designed as per IS: 456-2000 and IS: 1893-2002. Pushover analysis is carried out to study the performance point and also the effect of earthquake forces on multi-storey building is checked with a design tool SAP2000. Sowmya⁴ et al, 2015, In this paper, a two bay ten storied moment resisting frame is Designed according to IS: 875 and IS: 1893: 2002 (seismic zone IV). A pushover analysis is carried out to study the performance of steel moment resisting frame designed as per IS 800:2007. For push over analysis, the plastic Hinge Formation is considered according to FEMA 356. The result of the study is reported in terms of Capacity curve, Sequence of formation of plastic hinges, demand curve and performance point.

III. DESIGN APPROACH

A single 2-D frame of a berthing structure is considered to verify its performance under seismic conditions. The dimension of a berthing structure is shown in plain view. The frame is located in seismic zone II. The dredge level is considered as -17m and -18m. The lateral resistance of a soil is assigned in the form linear elastic springs. Spring values are calculated using VESIC's Eq

Top spring value:
$$K_1 = \frac{BL}{24}(7K_{s1} + 6K_{s2} - K_{s3})$$

Intermediate spring value:
$$K_2 = \frac{BL}{12}(K_{s(i-1)} + 6K_{si} - K_{s(i+1)})$$

Bottom spring value:
$$K_3 = \frac{BL}{24}(7K_n + 6K_{(n-1)} - K_{(n-2)})$$

Where,

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 8, August 2017

B = Diameter of section in “m”
L = Spacing between springs “m”
K_s = Sub grade modulus “kN/m³”

Sub grade modulus of:
$$K_s = \frac{1.3}{B} \sqrt[12]{\frac{E_s B^4}{E_c I_c}} \left(\frac{E_s}{1-\mu^2} \right)$$

E_s = Elastic modulus of soil in (kN/m²)
E_c = Elastic modulus of concrete in (kN/m²)
I_c = Moment of inertia of pile in (m⁴)
B = Width of section in (m)
μ = Poisson ratio

Tidal range data from VPT. Mean Sea Level (MSL) is at +0.8m.

Table2: Tide levels data

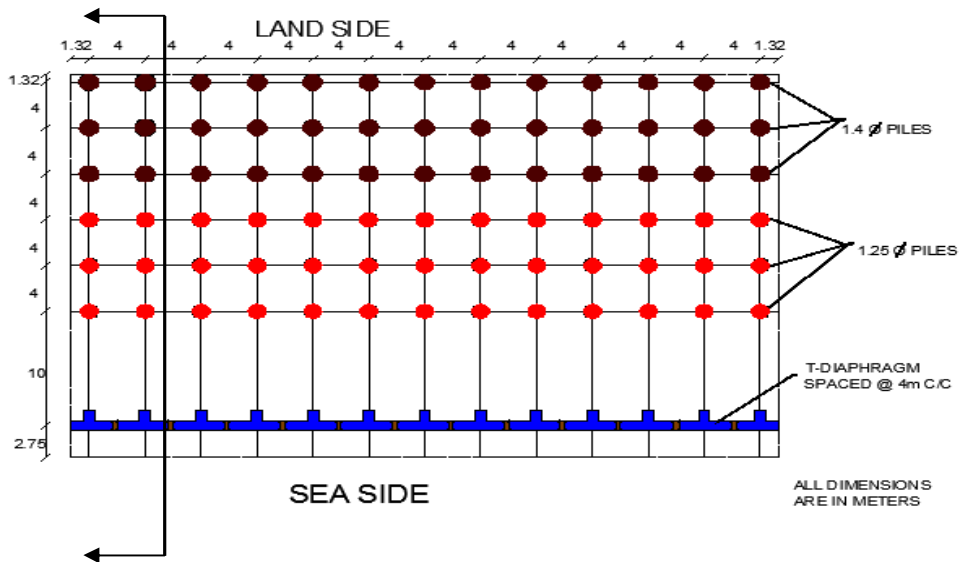
Tide	Level in m
HHW	+ 2.38
MHWL	+ 2.06
MHWL	+ 1.50
MLWL	+ 0.10
MLWL	+ 0.50
LLWL	+ 0.55

Table3: Vessel Parameters

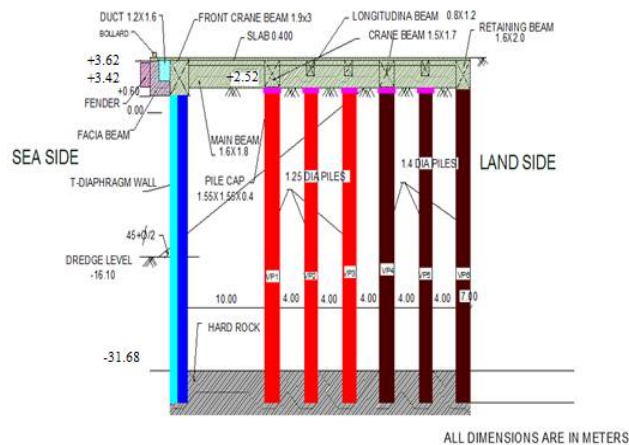
Vessel parameters	Vessel specifications
Size	80,000 DWT
Draft /Draught	14 m
Overall length	230 m
Width	32.50 m
Berthing Velocity (m/sec)	0.15 m/sec
Berthing angle	10 ⁰
Berthing condition	Sheltered and difficult

Table 4: Loads and study details

Loads considered	Study details
Dead load Live load Earth pressure Differential water pressure Mooring force Berthing force Seismic Force Temperature raise and fall	Seismic weight of =16940 kN Zone value = 0.1 Importance factor = 1.0 Response reduction factor = 5(SMRF) Time period = 1.06sec T-Diaphragm wall on sea side with six vertical piles behind it. Depth of sub structure 34.5m



(a)



(b)

Fig.3. Plan & Cross Section (a) Plan view of berthing structure (b) Cross - Section

The above figure shows the plan and cross section of berthing structure. It consists of T-Diaphragm wall on sea side and six vertical piles behind it. The sub structure is terminated at a level of -31.68 m. The berthing structure consists of facia beam, duct, front crane beam, rear crane beam, longitudinal beam, retaining beam and deck slab. Top level of berthing structure starts at a level of +3.62m.

Structure modelling:

A 2-D frame of a berth is modelled using Sap-2000. The lateral resistance of soil is assigned in the form of linear elastic springs at a level of -17m and -18m in T-Diaphragm wall. Non-linear static analysis is performed using dead load and live load with a reduction factor of 1.0 and live load with reduction Factor of 0.5. Hinges were defined at the ends of beams, Columns according to FEMA 356 as default hinges and user defined hinges. M3 hinges are assigned to beams and P- M2-M3 hinges are assigned to the column. Displacement control analysis is used for target displacement of

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 8, August 2017

150mm. User defined hinges properties are calculated based on the moment-Curvature data of structural members. Length of hinges is 0.1 and 0.9.

Base shear = 240kN (As per IS: 1893-2002)

Dimensions of T-Diaphragm wall

Thickness of flange	= 800mm	Overall depth of flange	= 3400mm
Width of flange	= 4000mm	Thickness of web	= 800mm

IV. RESULTS AND DISCUSSIONS

Plastic Hinges:

Plastic hinges formation for the berthing structure is obtained at various deck and pile joints. The first hinge is formed in vertical pile 3 at deck and pile joint level for a dredge level of -17m where as in -18m dredge level first set of hinges are formed in vertical pile 2, 3 at deck level. Subsequent hinges are formed at the joints until the target displacement is reached or collapse occurred. The first set of hinge is formed in vertical pile since the joint is weak (soft).

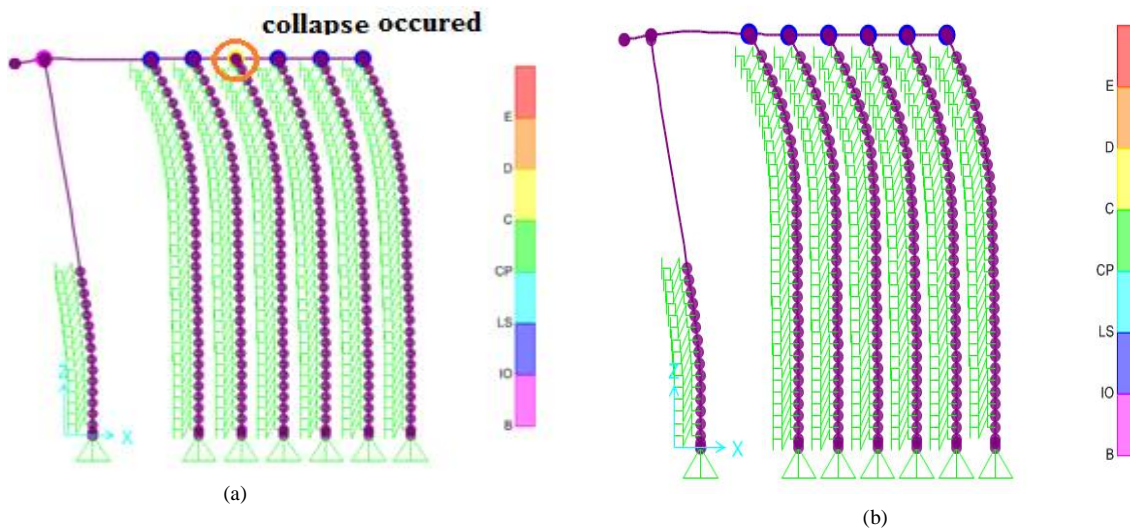


Fig.4. Hinge formations (a) Default hinges (b) User defined hinges for -17m dredge level.

Note: For default hinges collapse occurred in VP3 at 150mm displacement in Fig 4 (a) but no collapse seen in Fig 4(b).

Table5 : Analysis Results

Performance Point	-17m Dredge Level		-18m Dredge Level	
	Default Hinges	User Defined Hinges	Default Hinges	User Defined Hinges
Base Shear(kN)	1835	1904	1855	1865
Displacement (mm)	2.15	2.156	2.5	2.5

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 8, August 2017

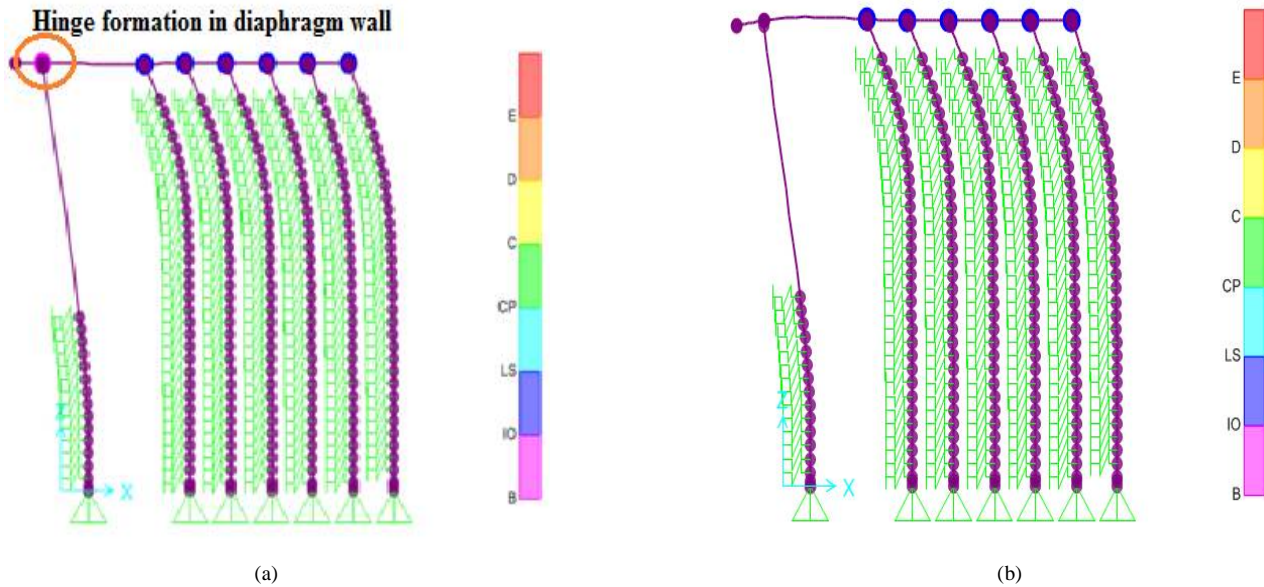


Fig.5. Hinge formations (a) Default hinges (b) User defined hinges for -18m dredge level.

Note: Hinge is formed in diaphragm wall at 150mm displacement in Fig 5(a) but no hinge formation is seen in fig 5(b). Static non-linear (pushover) analysis of a berth is carried out using SAP2000. The target displacement of 0.15 m is chosen to be applied on the berthing frame. For non linear static analysis the various pushover cases are considered such as gravity load (non linear), push X (i.e. loads are applied in +ve X direction). The various load combinations are also used for this purpose. The performance point of frame is obtained as per ATC 40 capacity spectrum method depend on C_a and C_v values. The intersection of capacity curve and demand curve is the performance point. The base shear for PUSH X load case for -17 m dredge level is 1835kN and 1904kN for user defined hinges. The base shear for PUSH X load case for -18 m dredge level is 1855kN and 1865kN for user defined hinges. Since at the performance point base shear is greater than the design base shear the building frame is safe under the earthquake loading. All the hinges are formed in between IO-LS means there is considerable damage to the structure but safe to use which indicates good structural behaviour. The demand curve intersects the capacity curve near the elastic range; the structure has a good resistance because of more stiffness, better soil property and reinforcement more than the required one.

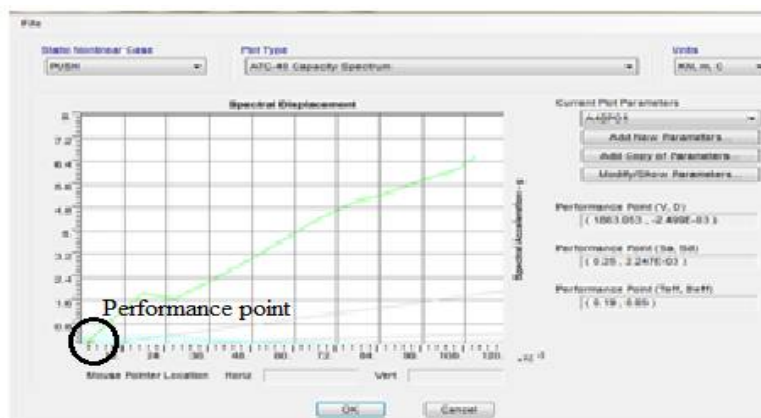


Fig 10 Performance point

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 8, August 2017

V. CONCLUSION

The performance of berthing structure is investigated using pushover analysis. From the analysis results the following conclusions were made:

- At performance point the base shear for default hinges is less than the user defined one.
- The formation of default hinges are occurred at early stages than the user defined hinges. In default hinges collapse occurs at displacement of 150mm where as in user defined hinges collapse is not observed at same displacement.
- From the results obtained the berthing frame used for pushover analysis is seismically safe, because of the performance point base shear is greater than design base shear.
- Since the demand curve intersects the capacity curve near the elastic range, the structure has a good resistance and high safety against collapse.
- The structural behaviour of the berth proved better even though the dredge level is increased
- With better soil properties and by adopting stiff geometry the structural behaviour of a structure is improved.

VI. ACKNOWLEDGEMENT

These authors are thankful to the Visakhapatnam port Trust for providing necessary data and granted permission to publish the same.

REFERENCES

- [1] Chopra A.K, Vasanwala S.A, "Designed as per Indian Standards and also to Determine the Effect of Providing Shear wall to Building Frame", International Journal of Science, Technology & Management (IJSTM), Volume No.03, Issue No. 09, September 2014.
- [2] Neethu K. N, Saji K. P, "Pushover Analysis of RC Building", International Journal of Science and Research (IJSR), Volume 4 Issue 8, August 2015.
- [3] Nivedita N. Raut & Ms. Swati D. Ambadkar, "Pushover Analysis of Multi-storeyed Building", Global Journal of Researches in Engineering Civil and Structural Engineering, Volume 13 Issue 4 Version 1.0 Year 2013.
- [4] Rajkumar. M, Satyanarayana G. V, Veerabhadra Rao. P, "Structural System Evaluation of Jetties", IJEST, vol. 3, ISSN. 2349-784X, Sep – 2016.
- [5] Sowmya. R, Saravanan. M, Marimuthu.V, Surendran.M, Prabha.P, Palani G.S, Sakthieswaran.N, "Seismic Performance Evaluation of Steel Moment Resisting Frames", International Journal of Innovative Research in Science, Engineering and Technology(IJIRSET), Vol. 4, Special Issue 6, May 2015.
- [6] Shinde, Nair Veena V, PudaleYojana 2014 "Pushover analysis of multistory building" International Journal of Research in Engineering and Technology, Vol. 03 (03), 691-693, 2015.
- [7] Tuttoni. S, F. Stochino, "Collapse of prestressed reinforced concrete jetties: durability and fault analysis", Case Studies in Engineering Failure Analysis, vol. 1, pp. 131-138, May 2013.
- [8] Yajnheswaran B, Akshay P. R, Rajasekaran C, SubbaRao, "Effect of Stiffness on Performance of Diaphragm Wall", 8th International Conference on Asian and Pacific Coasts, vol. 116, pp. 3435-349, 2015.
- [9] IS: 456-2000, Plain and Reinforced Concrete-Code of Practice, Fourth revision Bureau of Indian Standards, New Delhi, 2007.
- [10] IS 1893 Part 1 (2002), "Indian Standard Criteria for Earthquake Resistant Design of Structures", Bureau of Indian Standards, New Delhi.
- [11] Applied Technology Council, ATC-40. Seismic evaluation and retrofit of concrete Buildings, California, 1996; Vols. 1 and 2.
- [12] Federal Emergency Management Agency (FEMA 356), "Prestandard and commentary for the Seismic rehabilitation of buildings", November, 2000.