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NUMERICAL STUDY ON EFFECT OF AREA OF REINFORCEMENT IN CONFINED MASONRY STRUCTURES

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Abstract: Masonry is an assemblage of masonry units and binding materials. The masonry units are brittle in nature. The unreinforced masonry structure undergoes brittle failure during strong earthquake. So it is necessary to increase the seismic resistance of the building. The building materials such as brick and concrete are brittle in nature while steel is ductile in nature. The brittle failure of masonry structures can be changed to ductile failure by introducing confining elements such as vertical tie columns and horizontal tie beams. The confined masonry structures will perform better during earthquake than unconfined masonry structures. The performance of confined and unconfined masonry structures during earthquake are analyzed in TREMURI software, which follows finite element analysis (FEA). The pushover analysis obtained after the global analysis in TREMURI software provide capacity curve. This paper focused on the effect of confining element by varying diameter of reinforcement. By increasing the diameter of reinforcement used in confining element, the seismic resistance of the masonry structures can also be increased.
Keywords: Base shear, Confinement, Masonry, Seismic Analysis, Unconfinement

I. INTRODUCTION

Masonry is an assemblage of mortar and masonry units (Kaushik et al, 2007). The masonry units which are bonded together with the help of mortar to form a masonry element, such as column, pier, buttress and wall. The commonly used masonry units are burnt clay building bricks, sand lime bricks, concrete blocks, burnt clay hollow blocks, gypsum partition blocks, auto claved cellular concrete blocks and stones. The functions of masonry construction are supporting loads, sub dividing space, affording fire and weather protection and providing thermal and acoustic insulation etc. Masonry structures acquires stability from the support offered by roof, cross walls, floors and other elements such as piers and buttresses. Load bearing walls are structurally more efficient when the load is uniformly distributed and the structure is so planned that eccentricity of loading on the members is as small as possible. Avoidance of eccentric loading by providing adequate bearing of floor or roof on the walls providing adequate stiffness in slabs and avoiding fixity at the supports etc. is especially important in load bearing walls in multi storey structures.

Various types of masonry construction systems are unreinforced masonry, reinforced masonry and confined masonry. The various methods used for analyzing the masonry structures are lateral force analysis, modal response spectrum analysis, nonlinear static analysis, nonlinear time history dynamic analysis and q-factor approach.

Confined masonry structures are seismic resisting structures, where masonry walls are confined by reinforced concrete pillars and beams. At the time of construction of a confined masonry structure, masonry walls are used as formworks to build the reinforced concrete elements. The reinforced concrete frame plays the important role of confining masonry walls, and therefore helps in increasing the ductility of the structure. The openings of confined masonry structures are confined by reinforced cement concrete frames. As observed after several severe earthquakes, confined masonry structures showed a reliable anti-seismic behaviour. Earthquake causes ground motions in random fashion, both vertically and horizontally, in all directions radiating from the epicenter. So a building resting on it will experience motion at its base. Confined masonry structures perform well during earthquake than unconfined masonry structures.

This paper mainly focused the anti-seismic effect of confined masonry structures. The effect of confinement can be increased by increasing the percentage of area of steel used in the confining elements. The load carrying capacity of the structure is increased with increase in area of steel but after attaining a particular load, further increase in area of steel will not affect the load carrying capacity of the structure.

II. PREVIOUS STUDIES

A. Benavent-Climent et al. 2012 [20] discuss the effects of confinement on failure mode. The failure modes include out-of-plane buckling, compression failure and bond failure. Two large-scale reinforced concrete structural walls were tested under quasi-static cyclic loading conducted at Purdue University. One of the specimens called W-MC-C herein after had confinement reinforcement while the other called W-MC-N herein after did not have any confinement reinforcement. From this experiment it is clear that the confinement did not affect to the yielding force, confinement reinforcement increased the maximum lateral displacement capacity and the inelastic curvatures are concentrated at the wall base.

Theofanis D. Krevaikas1 and Thanasis C. Triantafillou 2005 [16] discuss the effect of confinement on increasing the axial capacity of masonry. Four series of uniaxial compression tests were conducted, with a total of 42 specimens on model masonry columns with the variables are radius at the corners, type of fibres, cross-section aspect ratio and number of layers. It is concluded that, in general, FRP-confined masonry behaves very much like FRP confined concrete. Confinement increases both the load-carrying capacity and the deformability of masonry almost linearly with the average confining stress. The uniaxial compression test results enabled the development of a simple confinement model for strength and ultimate strain of FRP-confined masonry.

Bryan D. Ewing and Mervyn J. Kowalsky 2004 [3] carried out the experiment for finding out the compressive behavior of grouted clay brick masonry prisms. In this experiment the stress–strain characteristics of unconfined and confined clay brick masonry are determined. In order to achieve this objective, a series of 15 clay brick masonry prisms were constructed, instrumented, and tested. It is shown that confinement plates are extremely effective in enhancing the ultimate compressive strength as well as increasing the deformation capacity of the clay brick masonry prisms. The ultimate compression strength can be increased by 40% with the use of confinement plates. Failure of the confined masonry prisms occurred simultaneously or immediately after yielding of the confinement plates.

Hussein Okail et al. 2014 [8] investigates the behavior of confined masonry walls subjected to lateral loads. Six full-scale wall assembles, consisting of a clay masonry panel, two confining columns and a tie beam, were tested under a combination of vertical load and monotonic pushover up to failure. A numerical model was built using the finite element method in ABAQUS and was validated in light of the experimental results. Confining elements play an important role in maintaining the strength and ductility of the confined walls, higher reinforcement ratios and increased number of confining elements provides the wall with significant strength reserve. The lateral load capacity is inversely proportional to the width of the perforations in the wall whether it is a door or a window opening. Confining the openings with tie columns helps restore the reduced capacity and significantly enhance the wall ductility. Higher aspect ratios drive the wall into a flexure dominated failure mode and consequently enhance the strength and ductility of the walls. Due to diagonal tension failure mode of squat panels, increasing the axial load will result in a considerable increase in the lateral load carrying capacity of the wall assembly.

Sk. Sekender Ali and Adrian W. Page. 1988 [13] developed a Finite Element Model for the analysis of solid masonry subjected to in plane loading. It is particularly suited to cases where high local stresses and stress gradients are present. The parameters needed to define the surface were ultimate compressive stress and the tensile strength. The ultimate compressive stress and the tensile strength are determined from unconfined compression test and the spilling test respectively. The proposed finite element model can be applied to any brick mortar combination, laid in any bond pattern, once the basic material parameters have either been nominated from relatively simple test. Simple four nodded quadrilateral elements with a fine mesh near the loading point was used to simulate the failure pattern that take place under the concentrated load.

III. SEISMIC ANALYSIS OF BUILDING IN TREMURI

Table1 Building Parameters

Sl No:	Description	Value
1	Wall thickness	240mm
2	Height of each floor	3m
3	The live load considered on the slab, Q_k	0.75kN/m^2
4	The dead load considered on the slab, G_k	3kN/m^2

5	Shear modulus, G	200 Mpa
6	The compressive strength of mortar, f_m	2.5Mpa
7	The compressive strength of the brick, f_k	16 Mpa
8	The initial shear strength of the brick, f_{vm0}	0.23 Mpa
9	Final shear strength of the brick,f_{vlim}	3.764 Mpa
10	The young's modulus of brick, E	800 Mpa

The values given in table1 is used to analyse the building in TREMURI software.

The following table gives the values of base shear of unconfined and confined masonry buildings in X and Y direction. In confined masonry construction various diameter of reinforcements are used as longitudinal bars in confining element ranging from 6mm to 20mm.

Table 2 Comparison of value of base shear of confined and unconfined masonry of building.

Building No:	Type of building	Value of base shear in Y direction (kN)	Value of base shear in X direction (kN)	% increase in base shear in Y direction	% increase in base shear in X direction
1	Unconfined	293.91	144.95	0	0
	Confined (6mm diameter)	387.88	245.63	31.97	69.45
	Confined (8mm diameter)	401.36	247.7	36.56	70.88
	Confined (10mm diameter)	414.72	258.96	41.10	78.65
	Confined (12mm diameter)	430.66	271.42	46.53	87.25
	Confined (16mm diameter)	469.4	284.34	59.71	96.16
	Confined (20mm diameter)	469.4	284.34	59.71	96.16

By analyzing the building number in TREMURI software, with and without confinement, it can be seen that the value of base shear is more for confined masonry than that of unconfined masonry. The value of base shear is increased from 293.91kN to 469.4kN in y direction and 144.95kN to 284.34kN in x direction. In confined masonry various diameter of reinforcements are used ranging from 6mm to 20mm, from that optimum diameter of reinforcement was found to be 16mm because further increase in diameter of steel will not increase the value of base shear. The percentage increase in value of base shear was found to be 31.97 to 59.71% in y direction and 69.45 to 96.16% in x direction.

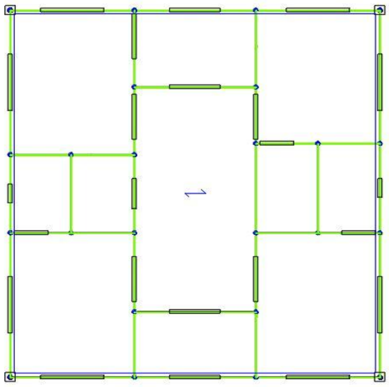

Fig. 2 2D View of the model in TREMURI

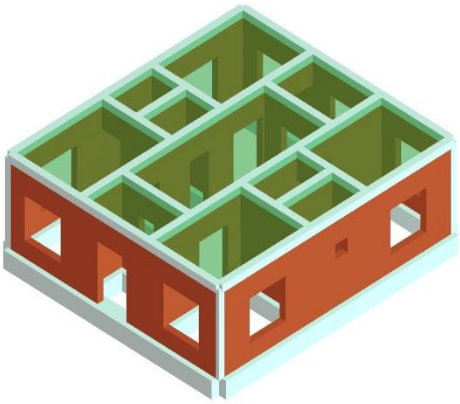

Fig.3 3D View of the model in TREMURI

Following are the graphs obtained by analyzing confined masonry buildings in TREMURI software.

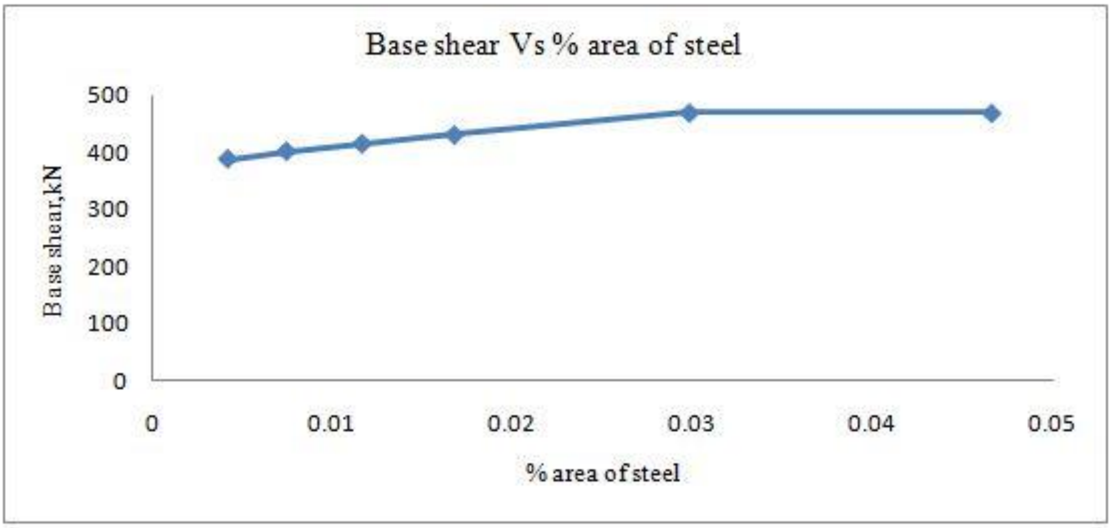

Fig.4 Base shear Vs % area of steel of building in Y direction.

By changing the diameter of reinforcement from 6mm to 20mm, the value of base shear is increased from 387.881kN to 469.403kN. The value of base shear is same for 16mm and 20mm diameter bars. So that 16mm diameter bar is sufficient as a longitudinal reinforcement in confining element.

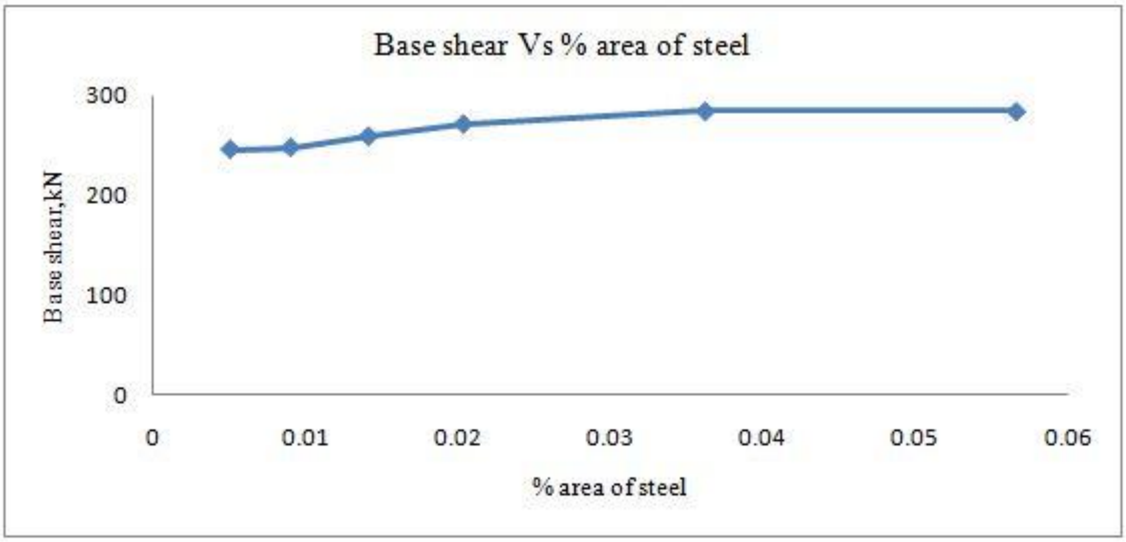

Fig. 5 Base shear Vs % area of steel of building in X direction

By changing the diameter of reinforcement from 6mm to 20mm, the value of base shear is increased from 245.628kN to 284.335kN. The seismic resistance of building was found to be same for 16mm and 20mm diameter bars. So that 16mm diameter bar is sufficient as a longitudinal reinforcement in confining element.

IV. EFFECT OF CONFINEMENT

The seismic resistance of masonry structures can be improved by introducing confining element. The confined masonry structures will perform better than unconfined masonry structures during strong earthquake. And the seismic resistance of confined masonry structure can also be increased by increasing the area of reinforcement. In this project the various diameter of reinforcements are used ranging from 6mm to 20mm and analyzed in TREMURI software. The following graphs shows that the confined masonry structures are more seismic resistant than unconfined masonry structures and it is also concluded that the seismic resistance can also be improved by increasing the area of steel used in confining element

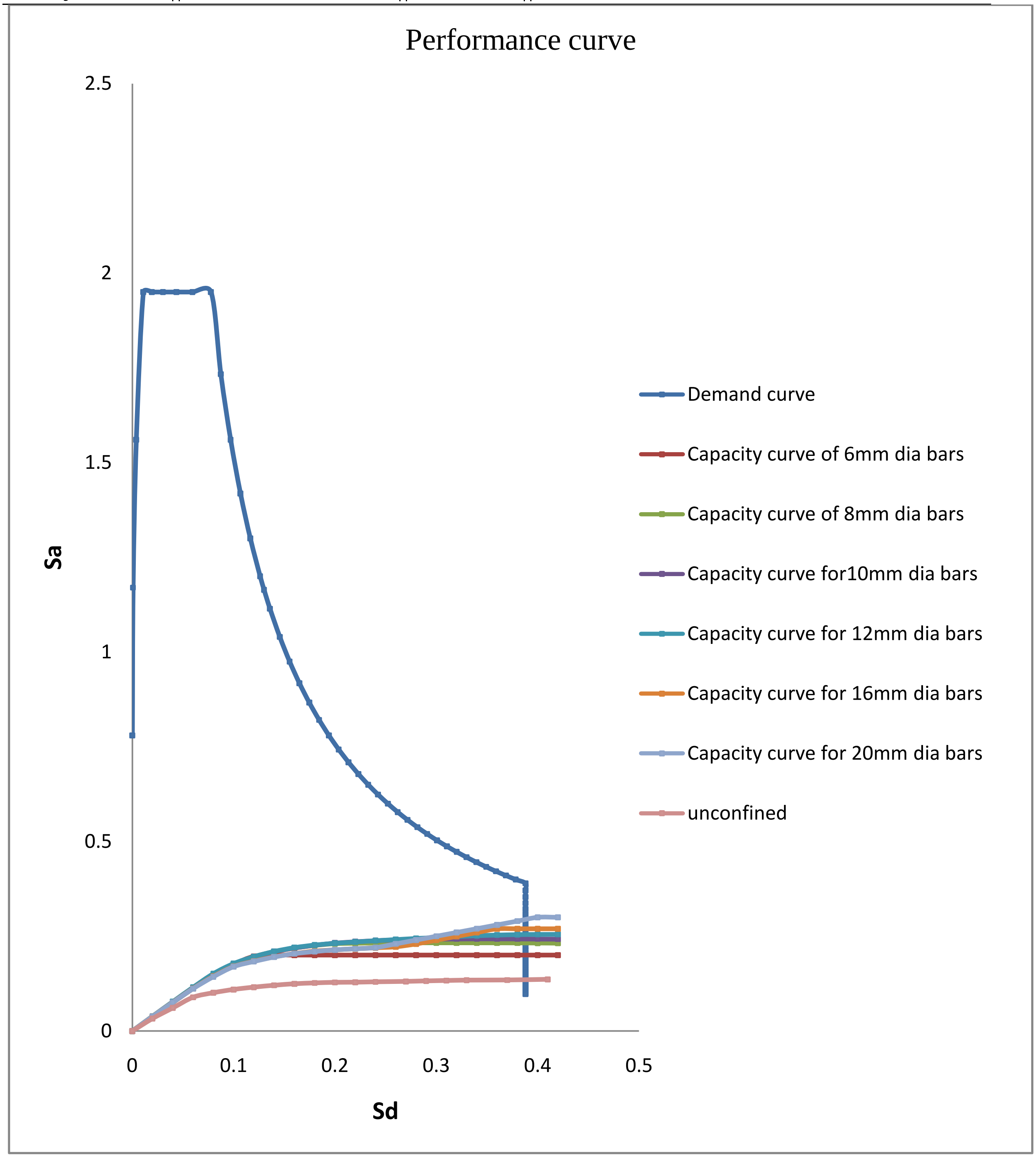

Fig.6 Performance curve of building in x direction.

The demand curve and capacity curve are meeting at a point, and that meeting point is known as performance point. Figure 6. shows that the performance point of confined masonry is higher than that of unconfined masonry. In confined masonry construction various diameters of reinforcements ranging from 6mm to 20mm are used as longitudinal reinforcements in confining element. And by increasing the diameter of reinforcement, the performance point can be improved and there by achieving better seismic resistance.

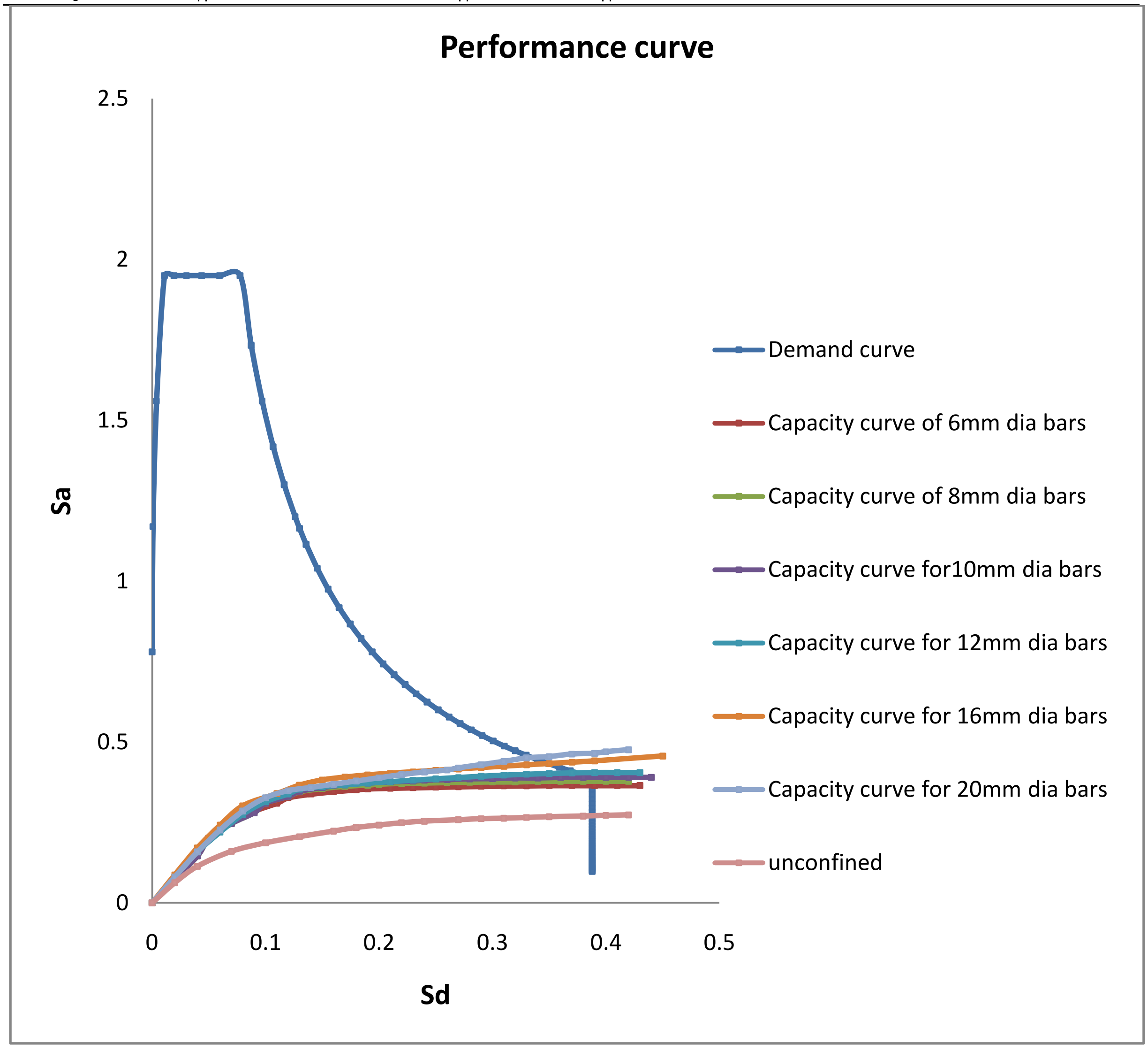

Fig.7 Performance curve of building in y direction

Figure 7 shows that the performance point of confined masonry construction with 20mm diameter longitudinal bar is higher than that of unconfined and other lesser diameter bars. The rise in position of performance point indicates the improvement in seismic resistance.

V. CONCLUSION

Masonry is an assemblage of building units like brick, stone etc. and the binding material such as cement mortar, lime mortar etc. Steel is a ductile material while masonry is a brittle material. The unconfined masonry structure undergoes brittle failure when it is subjected to seismic action. Ductility of the masonry structure can be improved by inserting reinforcements in the structure. Due to the application of confining element such as vertical tie columns, the seismic resistance of the building can be improved. During earthquake, the unconfined masonry structure undergoes brittle failure which will not provide any warning about this failure and may cause damage to human and their properties. But the confined masonry structure undergoes ductile failure when it is subjected to earthquake and it provides warning about the failure and get sufficient time to escape from this location. In this study, a masonry building with and without confinement are analyzed in TREMURI software. The parameter varied in the confined masonry structure is the area of reinforcement. The percentage increase in base shear depends upon wall density, eccentricity, configuration of the building etc. The percentage increase in base shear increases with increase in wall density.

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