Reduction of PP-band Mesh Connectivity for Masonry Structure Retrofitting

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Masonry construction is very attractive and popular construction for different continents of the world. The risk associated with Unreinforced masonry (URM) construction during the earthquake are vuneráblility and life safety. Number of casualties are always reported in the past for different earthquake related to masonry construction. Enhancing the performance of brick masonry in particular during the earthquake with material which will be cheap and having better performance during the earthquake have been dream of researcher and practicing engineer.

Polypropylene band (PP-band) retrofitting has been used for the retrofitting of masonry structures in many under developing countrie. The PP-band applied on the masonry wall are connected at every intersection of the mesh. Effort was made by reducing the PP-band mesh connectivity for reaching the optimization in manner of time and cost for retrofitting of URM masonry structure. By varying these parameters we can propose a solution of PP-band retrofitting with less work force,cost and time by testing them in ¼ scale model on shake table test. Comparison of PP-band mesh performance having its connectivity at fully connected, non connected and URM have been evulated.

Key Words : *Unreinforced Masonry, Polypropylene, retorofitting and connectivity.*

1. INTRODUCTION

Masonry structure retrofitting for construction have been intiated in the underdeveloping countries to overcome diasterous situation during seismic events. The PP-band (polypropylene) was utilized as retrofitting material for masonry construction has been developed by (Mayorca and Meguro, 2004) [1]. Many different aspects have been studied by Meguro Laboratory, Institute of Industrial Science, The University of Tokyo (Sathiparan, 2008) [2].

Masonry houses with stone, adobe and brick are common material adopted for construction of the house. The single story houses with PP-band mesh have been evaluated on the ¼ scale model with roof on Shake table test. The seismic performance for the PP-band retrofitted model has been enhanced in comparison to Non-retrofitted Model fig-1

a) Non retrofitted Model　　b) PP-band retrofitted Model

Fig.1 Damagaed condition of Model house at Frequency 5 Hz and Acceleration 0.4 g

During current research effect of reduction in PP-band mesh connectivity by varying them from all point of mesh connected with PP-band to non-connected. We will keep the out-plane connectivity with wall and mesh pitch constant for both retrofitted houses. The effect of surface finishing of the houses was done for akk the sample model. Three brick masonry model houses of ¼ scale with URM, PP-band mesh fully connected (PPF) and PP-band non-connected (PPN) were tested on shake table test by varying frequency and acceleration.

2. PREPARATION OF MODEL HOUSES

(1) Shaking Table Description.

Shake table installed in IIS, University of Tokyo have dimension of 1.5 m x 1.5 m having maximum weight of specimens of 2,000 Kg. It has capability of controlling 6 degree of freedom, frequency ranging from 0.1 to 5 Hz and displacement ± 100 mm. Adopted house model with ¼ scale selected in keeping in mind the limitation of shake table.

(2) Construction of House Model.

Concrete foundation were used for building the house and form erected initially. The base dimensions of the house were 930 mm x 930 mm and 720 mm height of the house as shown in Fig.2. Brick of 75 mm x 50 mm x 37.5 mm placed in 18 having wall thickness 50 mm. Mortar having ratio cement, sand, lime ratio as (1:7.9:20) with w/c as 0.4 (water cement ratio). Wooden lintel were placed above the door and window having dimension were 245 mm x 485 mm and 245 mm x 325 mm.

The effort is made to make replica model similar to developing countries masonry houses in terms of strength.. The straw were placed at bottom layer and after every fourth layer for Out of Plane connection of PP-band with brick wall. At the top layers cement bricks with bolt were placed along with brick in same mortar. The form work was removed after 7 days and sprinkled with water for same duration. The 28 days were given to house to gain strength. Wooden piece of 30mm x 50 mm was placed at top layer for providing level surface for placement of wooden roof truss.

(3) Retrofitting Procedure

Retrofitting scheme needs to be simple and easily employed by local people at site. Model with fully connected mesh designated as PPF s was made by Cutting piece of PP-band (6m x 0.5mm) for horizontal and vertical length. The out of Plan connection was made with steel wire through the wall in Fig.3. The horizontal piece at the bottom was attached outside and inside with ultra-sonic pulse welding device and

Fig.2 Model House after completion of brick work

then connected with out of plane connection. The vertical Piece was attached at pitch of 50 mm with bottom piece of PP-band as shown in Fig.4.

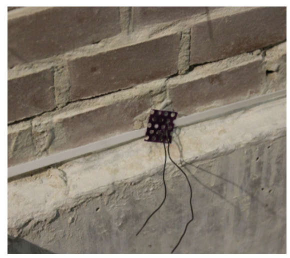

Fig.3 Out of Plane connection with wall

Fig.4 Attachment of Vertial PP-band with horizontal

After attaching all the vertical pieces and then remaining horizontal pieces are placed at pitch of 50 mm. Then connected with out of plane for remaining connections. Around door and windows were warped for better holding of PP-band and mesh fully connected at all intersection Fig.5

Fig.5 Fully Connected PP-band house (PPF)

Model house with non-connected PP-band designated as PPN made by attaching horizontal piece inside and outside at bottom level with out of plane connection shown in Fig.3. Attaching the vertical piece with bottom PP-band horizontally pitch of 50 mm. Attaching horizontal band by waving through vertical PP-band as shown in Fig.6. Connecting PP-band mesh at level of out of plane of connection to make have better grip with vertical band. Attach remaining horizontal PP-band mesh inside and outside at pitch of vertical 50 mm as showin in Fig.7.

Fig.6 Waving Horizontal band

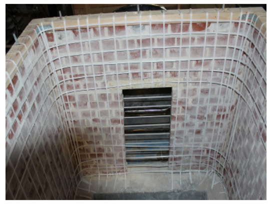

Fig.7 Inside view during retrofitting

Warp the mesh around doors and windows opening as shown in Fig.8. The PP-band mesh is not connected with ultra-sonic welding device and only waving has been done to make the mesh.

Fig.8 Non Connected PP-band house (PPN)

After the completion of retrofitting the houses was surfaced finished with mortar cement, sand, lime ratio as (1:7.9:20) with w/c as 0.4 (water cement ratio) and cured for 7 days. Wooden roof connected after surface finishes was hardened.

3. EXPERIMENTAL SETUP

To study the global and local behavior of building during shaking accelerometer and laser are used to record the acceleration and displacement for the test. There were 24 one dimensional accelerometer attached to the specimen among which 13 in direction of shaking, 7 in transverse direction and 4 in vertical direction. There were total 5 laser attached among which 3 for top wall displacement, 1 for mid height and 1 for base level. The location can be seen from Fig.9. The measured data is recorded continuously at sample rate of 1/500 seconds in all the runs.

Simple Sinusoidal motions with frequency ranging from 2 Hz to 35 Hz by varying amplitude from 0.05 g to 1.4 g were applied to Model houses. The simple input shall be used because for numerical simulation model house.

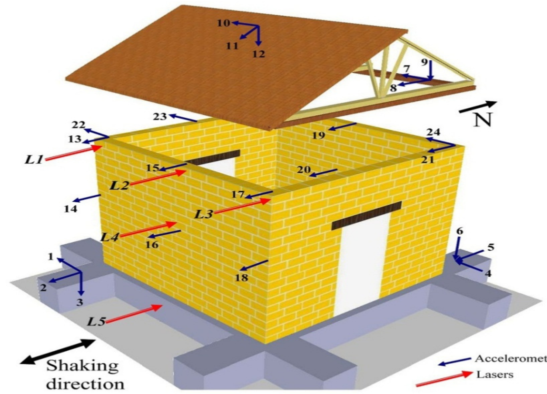

Fig.9 Location of Accelerometer and Lasers

Loading sequence were given in the Table 1 showing loading started from sweep motion and starting from 0.05 g amplitude varying frequency from 35 Hz to 2 Hz. The number of cycles were constant for all frequency Amplitude from 1.0 g higher frequency were ignored and lower frequency 5 Hz and 2 HZ have been used for testing. The number described in the table is the run number for dynamic loading applied.

Table 1 Loading Sequence

Amplitude	Frequency(Hz)							
	2	**5**	**10**	**15**	**20**	**25**	**30**	**35**
Duration (sec)	**20**	**10**	**8.0**	**5.3**	**4.0**	**3.2**	**2.7**	**2.3**
1.4g		53						
1.2g	54	52						
1.0g		51						
0.8g	50	49	43	40	37	34	31	28
0.6g	48	45	42	39	36	33	30	27
0.4g	47	44	41	38	35	32	29	26
0.2g	46	25	24	23	22	21	20	19
0.1g	18	17	16	15	14	13	12	11
0.05g	10	09	08	07	06	05	04	03
sweep	01,02							

4. CRACK PROPOGATION

(1) Non Retrofitted House (URM).

URM house there were no crack before Run-26 (35 Hz and 0.4g) and small cracks appear near openings and base of the house which further grows upon successive runs. Diagonal cracks appear on all the side opening which become prominent and visible after run 31 (30 Hz and 0.8g). The house condition can seen at Run-40 (15 Hz and 0.8g) in Fig.10 showing visible diagonal cracks near the opening and horizontal crack on the other face.

The cracks at the base are extend near diagonal cracks up-to Run-43 (10 Hz and 0.8g). Furthermore, horizontal crack appear on the 6th layer from base and

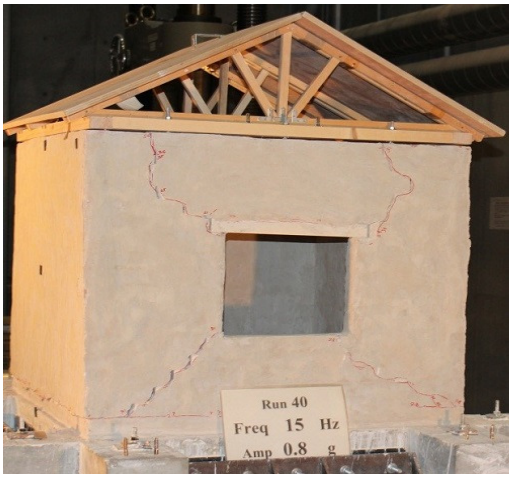

Fig.10 URM house at Run-40 15 Hz and 0.8g

vertical crack extended from base at the run. House collapsed on run-44 (5 Hz and o.4g) by separating itself from the opeinenigs and falling of roof.

(2) Fully Connected PP-band (PPF)

Fully connected PP-band house was not showing any significant damage before Run-28 (35 Hz and 0.8g) but cracks from top around opening have initiated.Small diagonal cracks appear after Run-32(25Hz and 0.4g) near openings. Run 37(20 Hz and 0.8g) there were diagonal cracks and horizontal crack at the base. Diagonal have been extended to base cracks Run-41(10Hz and 0.4g) and falling of plaster is also taking place. The cracks at this point were visible and prominent on the house. At Run-45(5Hz and 0.6g) out of plane crack were observed and condition of house was become worse. Run-50 (5Hz and 1.0g) the top part of near the opening has been damaged and plaster has fallen as shown in Fig.11.House is cracked but due to PP-band result it creats of new cracks.The PP-band was broken at base and near openings, house is out of proportion. The Run-54 (2Hz and 1.2g) was last on which house collapsed by detachment of PP-band from the base.

(3) Non Connected PP-band (PPN)

Non-connected PP-band house was not cracks before Run-27 (35 Hz and 0.6g) and small cracks appear near the opening at this point. Run-28 (35 Hz and 0.8 g) horizontal crack appear at the base. Cracks keep on extending near the opening for Run-33 (25 Hz and 0.6 g). At Run-39 (15Hz and 0.6 g) there were horizontal and diagonal cracks on the house. Out of Plane cracks observed at Run-46(2 Hz and 0.2g) for the house.

The cracks are prominent and visible at the point this point and plaster is falling from the crack parts of

Fig.11 PPF house at Run-50 2 Hz and 0.8g

structure from the base. At Run-51(5Hz and 1.2 g) the mostly house was damaged at the base and remaining structure not showing damaged as shown in Fig.12. The base suffered damaged due to the connection of PP-band at the base only. The house collapsed at the Run-54 (2Hz and 1.2 g) similar to the fully connected PP-band house.

Fig12 PPN house at Run-51 5 Hz and 1.0g

5. PERFORMANCE EVULATION.

Performance of the houses were assessed based on the performaces: Immediate occupancy, Life safety and Collapse prevention based on the damaged level described in the FEMA 356, 2000[3)]. The Equivalent JMA intesnities are calualted based on-frequency and and acceleration used for the dynamic loading.Table 2 shown the performace of the non-retrofitted (URM) model house with different JMA intensity.

Table 2 Performace of URM House Model with JMA Intensities

Amplitude	Frequency(Hz)							
	2	5	10	15	20	25	30	35
1.4g								
1.2g								
1.0g								
0.8g			PC	LS	LS	LS	IO	IO
0.6g		TC	LS	LS	LS	IO	IO	IO
0.4g		PC	LS	LS	LS	IO	IO	IO
0.2g		IO	IO	IO	IO	IO	IO	IO
0.1g	IO	IO	IO	IO	IO	IO	IO	IO
0.05g	IO	IO	IO	IO	IO	IO	IO	IO

IO: Immediate occupancy PC: Partially Collapsed
LS: Life Safety TC: Totally Collapsed

Index	JMA~4	JMA5-	JMA5+	JMA6-	JMA6+	JMA7

Lower frequency are more devasting and JMA intensity is not affected by the duration of loading. Intially crack are observed at Run-26 and Partially collapsed at Run-43 and totally collapsed at Run-44 at JMA intensity 5-.

Fully connected and Non-connected PP-band retrofitted house have shown damaged level which are similar in term of the damaged level shown in Table 3. Both houses maintained level of Immediate occupancy where the URM partially collapsed. The Drift limit criteria specified say that life safety maintained at 0.6 % and collapse prevention at 1.5 % which have been exceeded by the both PPF and PPN however the damaged level was not as described by the FEMA. The life safety maintained by the both model retrofitted upto JMA intensity 6+. Both house were collapsed at JMA 7 Intensity at Run 54 (2Hz and 1.2g) with finally collapsing after bearing shaking of 10 sec during the application of test.

Table 3Performace of PPF & PPN House Model with JMA Intensities

Amplitude	Frequency(Hz)							
	2	5	10	15	20	25	30	35
1.4g		LS						
1.2g	TC	LS						
1.0g		LS						
0.8g	LS	LS	IO	IO	IO	IO	IO	IO
0.6g	LS	LS	IO	IO	IO	IO	IO	IO
0.4g	LS	LS	IO	IO	IO	IO	IO	IO
0.2g	LS	IO	IO	IO	IO	IO	IO	IO
0.1g	IO	IO	IO	IO	IO	IO	IO	IO
0.05g	IO	IO	IO	IO	IO	IO	IO	IO

IO: Immediate occupancy LS: Life Safety
TC: Totally Collapsed

Index	JMA~4	JMA5-	JMA5+	JMA6-	JMA6+	JMA7

Stiffeness degredation for all the house have been calculated based on the data recorded during the experiment.For the safety of the equipment the data is recorded for the 36 Run for URM and whereas for the PPF & PPN were recorded upton Run-51.

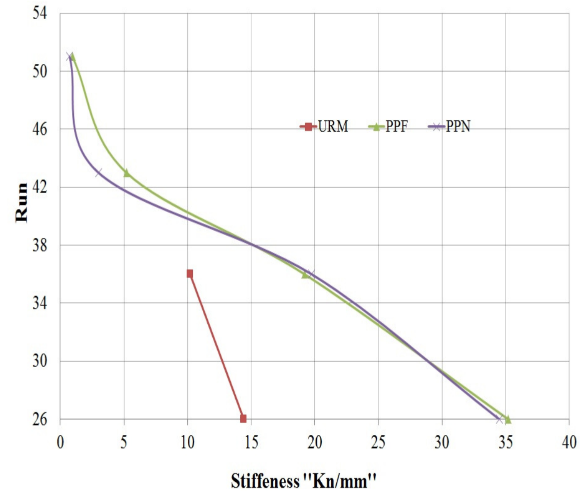

Fig.11 Stiffness Degradation curve of Houses.

The stiffeness curve corresponding to the three model is presented in the Fig.11 which shows that at the intial crack of URM house at Run-26 there was 2.30 times more stiffeness of the retrofitted that URM. Whereas the difference of stiffness of the both PPF and PPN is follow the same trend of degradation but during later stages loading corresponding to Run have small difference of stiffness of both model have been found.

6. CONCLUSION

The brick masonry single story house with similar construction technique for PP-band retrofitting with fully connected and non-connected house have been made. The study gives appropriate solution for retrofitting with PP-band by which we can save the time and cost for retrofitting whole house. URM house collapsed at JMA5- where as both retrofitted house were collapsed at JMA 7 showing increases performance in comparison. Furthermore, retrofitted houses with fully connected and non-connected PP-band collapsed at JMA 7 on similar RUN-54.

Although the performance during the dynamic test for fully and zero connectivity of PP-band gives similar Life safety and stiffeness degradation but non-connected is little damaged at the base. Thus life safety can be maintained with non-connected PP-band mesh and human casualties reductioncan be achieved during sever ground shaking. Furthermore, surface finish has helped in keeping PP-band in contact until the Plaster is fallen. Thus we can Suggest that single story house having wooden Truss roof and surface finish can be retrofitted with non-connected PP-band mesh giving appropriate seismic retrofitting solution in term of cost and time.

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