International Journal of Latest Research in Engineering and Technology (IJLRET)
ISSN: 2454-5031
www.ijlret.com || Volume 03 - Issue 03 || March 2017 || PP. 63-76

STRENGTH AND ELASTIC PROPERTIES OF BRICK MASONRY INFILL AT VARIOUS ANGLES INCLINED TO BED JOINT

Niranjana N[1.a] and Arunkumar A S[2]

[1]*Student, Master of Technology in Construction Technology, BMS College of Engineering,* [2]*Associate Professor, Department of Civil Engineering, BMS College of Engineering (Autonomous College affiliated to VTU Belgaum), Bull Temple Road, Bangalore*

Abstract: Increasing rate of population and land value demands multi-storeyed buildings for their comforts and need. Most of multi-storeyed buildings are designed as masonry in-filled (MI) reinforced concrete (RC) framed structure. However, these structures are safe under normal loading condition; their lateral load resisting capacity is low. Also, it is well known from the past researches that MI does influence the lateral loading capacity of the structure positively. But, the current design method does not include the influence of MI. Several researchers have succeeded to develop a relation using diagonal strut method however, it's accuracy is still a challenge since, the current code considers strength and elastic properties of masonry perpendicular to bed joint. But, the information on the strength and elastic behaviour of MI when loaded at an inclination to bed joint is inadequate. The present experimental investigation attempts to study the strength and elastic properties of brick masonry infill at various loading angles with respect to bed joint which has been presented in detail.

Keywords: MI-RC frame, loading inclination to bed joint, strength and elastic properties of MI.

INTRODUCTION

India being developing country with second highest population in the world demands increased comforts and facilities in the form of housing, commercial buildings, industries and infrastructure. Also, increased land value and density of population caused revolution in the high raised building construction. These high raised buildings are constructed as MI-RC framed structures using bare frame design method. Thus these buildings behaves safe under normal loading condition. However, under influence of lateral forces like forces due to seismic loads, wind loads, undesirable effects are observed MI-RC framed structure which may lead to premature or total collapse of MI or RC framed structure and results in a hazard.Researchers from the past have been succeeded to prove the existence of interaction between MI and frame and indicated its role in adding up stiffness to the structure through macro modelling, in which MI is replaced with equivalent diagonal strut and some of which are discussed below.

Polyakov (1960) was the first researcher to propose MI in a steel frame to be modelled as equivalent pin-jointed diagonal strut. Later Holmes (1962) conducted experiments on steel frame with brick work and concrete infilling and proposed that effective width of diagonal strut is 1/3rd of the diagonal length of infill panel. Smith (1962), indicated that for an infill having side's ratio of 5 to 1 the effective width of diagonal strut varies from d/4(for a square infill) to d/11 where 'd' is the length of masonry infill. Later with considering the interaction between the MI and frame, Stafford Smith (1969) developed a set of empirical curves that relate the stiffness parameters to the effective width of an equivalent diagonal strut, considering the interaction between masonry infill and the frame. Mainstone (1971) proposed an empirical relation between effective width of an equivalent diagonal strut and Stafford Smith's stiffness parameter using Smith's relative stiffness parameters. The results of this relation showed lower value of effective width of diagonal strut than that was proposed by Stafford Smith's model.

Further, Liauw and Lee (1977) conducted experiments on diagonal strut for MI frames with and without openings. They concluded that strength and stiffness of infill masonry are greatly affected by position and size of openings. The equivalent width of diagonal strut proposed by Hendry (1981) was half the width proposed by Smith (1962).Paulay and Preistley (1992) from their studies on seismic design of concrete and masonry buildings showed that higher the width of diagonal strut, higher will be the structure stiffness. Also, indicated that width of diagonal strut would be 0.25 times the diagonal length of strut.

El-Dakhakhni et al (2003), in their research has shown different ways of MI failure as a result of lateral stresses such as corner crushing, sliding shear, diagonal cracking, diagonal compression, and frame failure mode that are shown in fig 1. They proposed three strut model and an analytical technique to predict lateral stiffness up to failure and ultimate load carrying capacity of infill concrete masonry in steel frame. The infill masonry was modelled using ANSYS FE program and effective area of the loaded diagonal region of the infill was distributed to three struts. They concluded that Young's modulus in the inclined direction was 80% and Ultimate strength of masonry panel in the inclined direction was reduced to 70% of the corresponding values as obtained for normal to bed joint.

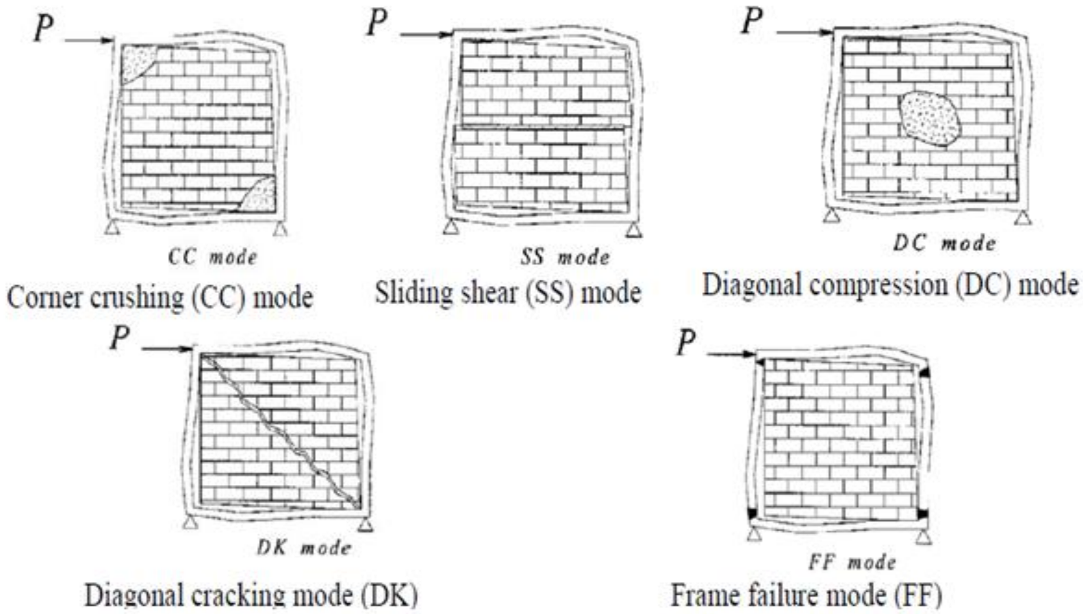


Fig 1 Various Modes of Failure of RC Frame With Infill Masonry Wall (Dakhakhni 2003).

Also, research conducted by Kashif Mahmud et al (2010) showed that, RC frame parameters like number of bay, story level, span of bay, thickness of masonry infill and presence of soft story plays significant effect on the performance of infill RC frame with respect to strength, lateral stiffness and deformation capacity. Rajesh et al (2014) studied performance of RC frame buildings with and without infill walls through macro modelling and indicated that, strut model buildings are stiffer and safer during earthquake than the bare frame models. Nanjunda Rao et al (2015) studied behaviour of unreinforced masonry prisms at 0^{0}, 30^{0}, 45^{0}, 60^{0} and 90^{0} inclinations to the bed joint with an aim to enhance the deformation capacity of URM structures using different grades of fibre reinforced polymers of glass and carbon type. From their experiments it was found that the masonry elastic parameters such as modulus of elasticity, compressive strength, ultimate strain and failure pattern of URM are influenced by loading axis with respect to bed joint.

There have been scanty experimental studies on the strength and elastic properties of brick masonry infill at different inclination angleswith respect to bed joint.

OBJECTIVES OF THE PRESENT INVESTIGATION

Past studies on MI-RC frames has revealed that MI in these frames can be modelled as a diagonal strut where the width of diagonal strut depends on the inclination of the diagonal, elastic modulus of masonry and the contact length of MI with the frame. During seismic activity, these MI-RC frames will be subjected to lateral forces. The lateral stiffness contributed by MI is very complex to estimate it as a shell and hence it is being visualised as a diagonal strut element in the analysis. The diagonal strut will be subjected to compression forces along the diagonals of the frames. In such cases, MI will be subjected to compression force which acts at some inclination with the bed joint. The present code IS: 1905-1987 (Reaffirmed in 2002) recommends the elastic modulus and compressive strength of masonry based on tests on masonry prisms when the loads are acting perpendicular to bed joint.

However, under lateral loading condition the masonry will be subjected to compressive force at an angle with respect to bed joint. Hence, the compressive strength and the elastic properties along the inclination become necessary to calculate the width of diagonal strut to be used in the analysis of MI-RC frames. Thus, to exploit the use of MI to the maximum extent in the design the following objectives were drawn.

- To evaluate the strength and elastic properties of brick MI along the inclined direction.
- To determine the variation in strength and elastic properties of brick MI along inclination angles 45^{o}, 37^{o}, 31^{o},27^{o} for the frames having column to column spacing of 3m, 4m, 5m and 6m respectively with common floor to floor height of 3m on comparison with strength and elastic properties of brick MI perpendicular and parallel to bed joint.

PRESENT INVESTIGATION

In the present investigation to determine strength and elastic behaviour along different inclinations with respect to bed joint, prism of size 250mm x 450mm was selected in the diagonal angles of the frames chosen. This is indicated in the typical drawing shown below.

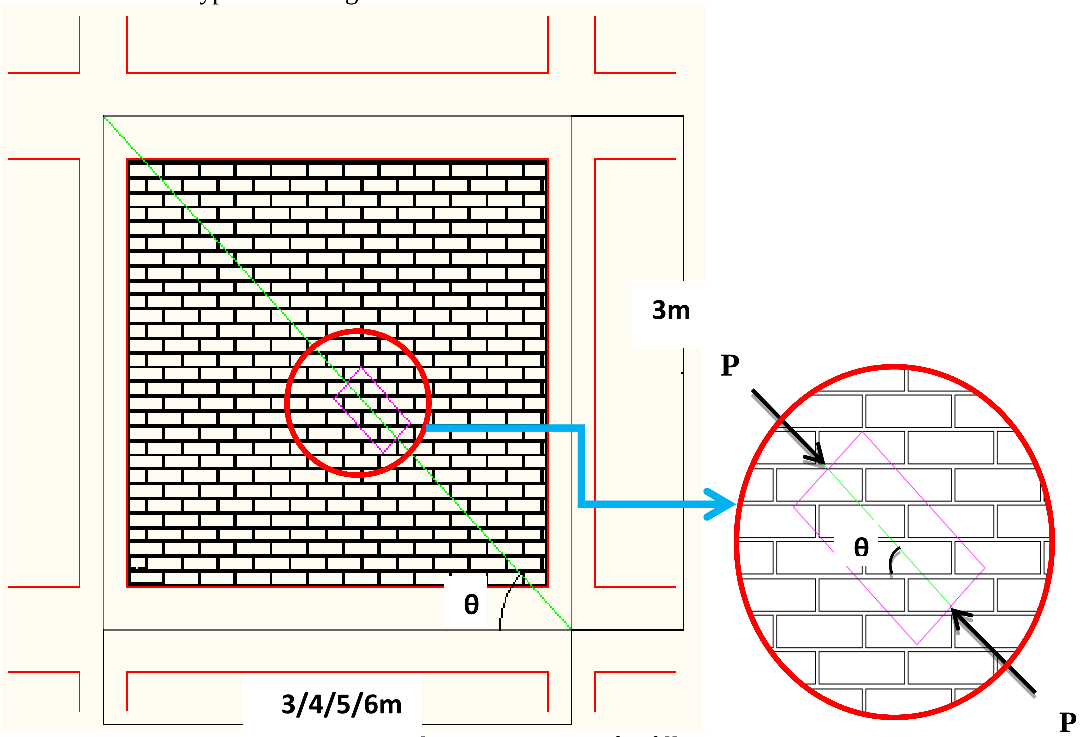


Fig 2 Typical CAD Drawing of Infill RC Frame.

PREPARATION OF SPECIMEN

To prepare prism specimens for testing CAD drawings were prepared for each frame with MI using average sizes of Table moulded bricks and wire cut bricks selected for investigation. The dimensions of each brick in the prism portion were marked in the CAD drawing and bricks were marked as per drawings (fig 3 and fig 4) and cut using cutting machine as shown in fig 5. To hold the cut bricks in position and to achieve good precision in prism dimensions with least deviations, the casting was done using wooden sheet formwork as shown in Fig 6 and Fig 7. Later the gaps between the bricks were filled with mortar of 1:6 (cement: sand) proportion with 1.4 water cement ratio (Fig 8) and care has been taken to ensure that the entire gap was filled with mortar. Prisms were also cast for the loading condition parallel and perpendicular to bed joint which is indicated in fig 9 and fig 10 respectively. Three prisms in each case were cast and were cured for 28 days using jute bags.



Fig 3 View of Marked TMBs. Fig 4 View of Marked WBs. Fig 5 View of Cutting of Bricks


Fig 6 View of Cut TMBs Placed in Position Before Casting.


Fig 7 View of Cut WBs Placed in Position Before Casting.


Fig 8 View of Mortar Filling.


Fig 9 Prisms For Loading Parallel To Bed Joint.


Fig 10 Prisms For Loading Perpendicular To Bed Joint.

CHARACTERISTICS OF MATERIAL USED IN THE EXPERIMENTAL STUDY

The present investigation involves locally available Table Moulded Bricks (TMBs) and Wire Cut Bricks (WBs). The dimensional characteristics of bricks were measured as per IS: 1077:1992 and they had average dimensions of 220x100x75 mm and 225x100x80 mm respectively. These bricks when tested for compressive strength under UTM of 600 KN showed average compressive strength of 3.58 MPa and 9.16 MPa respectively confirming to IS: 3495 (Part 1):1992.TMBs showed water absorption of 11.51% confirming to IS: 3495 (Part 2): 1992 and Initial Rate of Absorption (IRA) of 1.088 Kg/m^2/min. Similarly WBs showed water absorption of 12.13% and IRA of 1.334 Kg/m^2/min. Cement mortar used in this present experimental work includes river sand confirming to IS: 2386 (Part 1): 1963 (Reaffirmed in 1997) with fineness modulus of 2.43 and has water absorption of 0.4% with OPC of 53 grade in 1:6 proportion, with water to cement ratio of 1.4 and showed 110% flow confirming to IS: 2250: 1981 (Reaffirmed 1995). Mortar cubes of 70.6x70.6x70.6 mm were tested for compression as per IS: 2250: 1981 (Reaffirmed 1995) after 28 days of curing and they showed average compressive strength of 7.30 MPa when tested under compression testing machine of 3000 KN capacity. Also, mortar cylinders with 300 mm height and 150 mm diameter were tested of Modulus of Elasticity (Fig 11) which showed average compressive strength of 5.57 MPa and modulus of elasticity of 7835.7 $N/mm^2$from the Stress-Strain graph shown below (Fig 12).

Fig 11 Mortar Cylinder Testing For MOE.

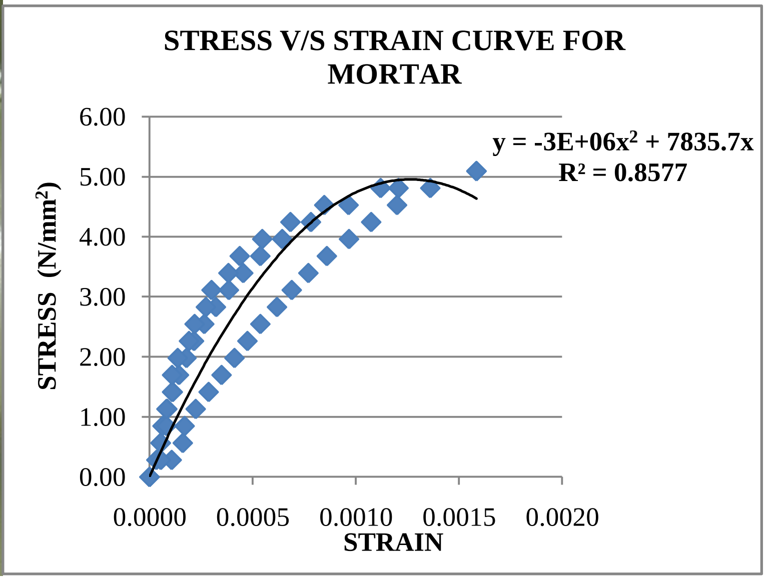


Fig 12 Stress Strain Curve For Mortar Cylinder.

EXPERIMENTAL RESULTS AND DISCUSSIONS

Present investigation involves testing of brick prisms prepared using table moulded and wire cut bricks as indicated above. Three prisms for each loading angle for two type of bricks selected were tested after curing them for 28 days. The typical test arrangements for loading prisms parallel, perpendicular and inclination to bed joint are indicated below.

(i) (ii) (iii)

Fig 13: Typical Test Setup For Loading Condition (i) Parallel to Bed Joint (ii) Perpendicular to Bed Joint (iii) Inclined to Bed Joint.

a) Table Moulded Brick Prisms Loaded Parallel To Bed Joint (TMBP-100-0^0)

Table 1: TMBP-100-0^0 Prism Test Results.

Sl. No	Prism Size (mm)	h/t	Area (mm^2)	Ultimate load (KN)	Prism Strength (MPa)	Corrected Prism Strength (MPa)	Masonry Efficiency (□)	Average Corrected Prism Strength (MPa)
1	250x100x480	4.80		55.00	2.20	2.18	0.61	
2	250x100x480	4.80	25000	58.60	2.34	2.32	0.65	2.19
3	250x100x480	4.80		52.50	2.10	2.08	0.58	

International Journal of Latest Research in Engineering and Technology (IJLRET)
ISSN: 2454-5031
www.ijlret.com || Volume 03 - Issue 03 || March 2017 || PP. 63-76

A. TABLE MOULDED BRICK PRISMS

a) Table Moulded Brick Prisms Loaded 27^0 With Respect To Bed Joint (TMBP-100-27^0)

Table 2: TMBP-100-27^0 Prism Test Results.

Sl No	Prism Size (mm)	h/t	Area (mm^2)	Ultimate load (KN)	Prism Strength (MPa)	Corrected Prism Strength (MPa)	Masonry Efficiency (□)	Average Corrected Prism Strength (MPa)
1	250x100x472	4.72		29.70	1.19	1.17	0.33	
2	250x100x480	4.80	25000	14.00	0.56	0.55	0.15	0.87
3	250x100x480	4.80		22.20	0.89	0.88	0.25	

b) Table Moulded Brick Prisms Loaded 31^0 With Respect To Bed Joint (TMBP-100-31^0)

Table 3: TMBP-100-31^0 Prism Test Results.

Sl. No	Prism Size (mm)	h/t	Area (mm^2)	Ultimate load (KN)	Prism Strength (MPa)	Corrected Prism Strength (MPa)	Masonry Efficiency (□)	Average Corrected Prism Strength (MPa)
1	250x100x480	4.80		32.00	1.28	1.27	0.35	
2	250x100x480	4.80	25000	15.00	0.60	0.59	0.17	0.85
3	250x100x475	4.75		17.50	0.70	0.69	0.19	

c) Table Moulded Brick Prisms Loaded 37^0 With Respect To Bed Joint (TMBP-100-37^0)

Table 4: TMBP-100-37^0 Prism Test Results.

Sl. No	Prism Size (mm)	h/t	Area (mm^2)	Ultimate load (KN)	Prism Strength (MPa)	Corrected Prism Strength (MPa)	Masonry Efficiency (□)	Average Corrected Prism Strength (MPa)
1	250x100x486	4.86		22.00	0.88	0.87	0.24	
2	250x100x490	4.90	25000	10.40	0.42	0.41	0.12	0.55
3	250x100x478	4.78		8.90	0.36	0.35	0.10	

d) Table Moulded Brick Prisms Loaded 45^0 With Respect To Bed Joint (TMBP-100-45^0)

Table 5: TMBP-100-45^0 Prism Test Results.

Sl. No	Prism Size (mm)	h/t	Area (mm^2)	Ultimate load (KN)	Prism Strength (MPa)	Corrected Prism Strength (MPa)	Masonry Efficiency (□)	Average Corrected Prism Strength (MPa)
1	250x100x480	4.80		25.20	1.01	0.99	0.27	
2	250x100x495	4.95	25000	27.00	1.08	1.07	0.29	0.88
3	250x100x480	4.80		15.00	0.60	0.59	0.16	

e) Table Moulded Brick Prisms Loaded Normal (90^0) To Bed Joint (TMBP-100-90^o)

Table 6: TMBP-100-90^0 Prism Test Results.

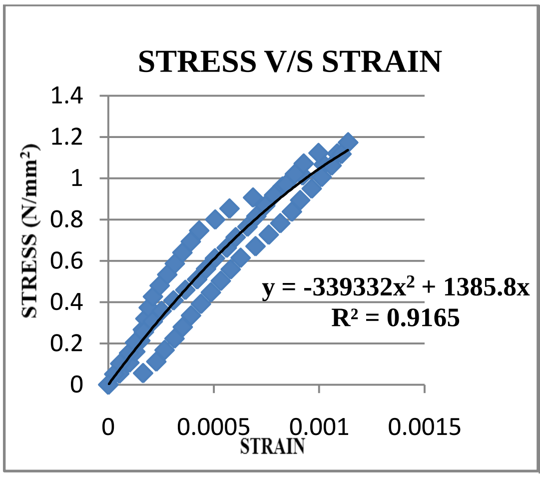
Sl. No	Prism Size (mm)	h/t	Area (mm^2)	Ultimate load (KN)	Prism Strength (MPa)	Corrected Prism Strength (MPa)	Masonry Efficiency (□)	Average Corrected Prism Strength (MPa)
1	220x100x445	4.45		52.60	2.39	2.32	0.65	
2	220x100x445	4.45	22000	38.40	1.74	1.69	0.47	1.96
3	220x100x440	4.40		42.20	1.91	1.85	0.52	

*Correction for prism strength is applied as per IS: 1905: 1987 in all the cases.

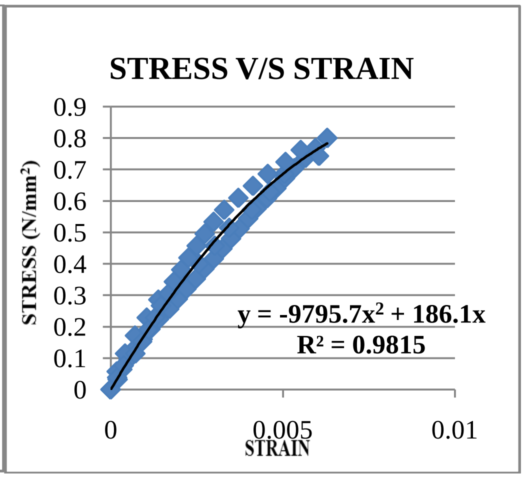
(i) (ii) (iii)

(iv) (v) (vi)

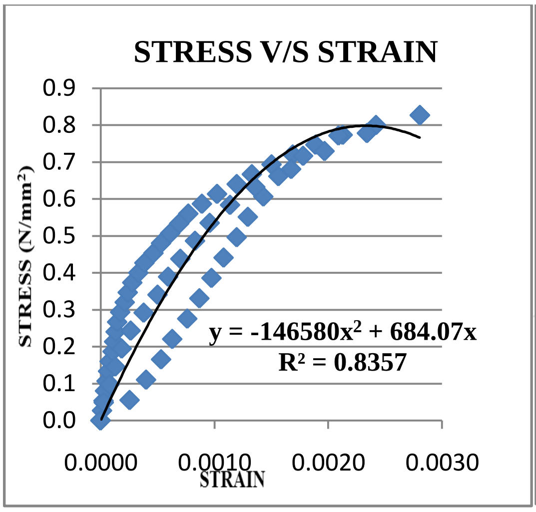
Fig 14: Failure Specimens of TMBPs At Loading Angles (i) Parallel to bed joint(ii) 27^0 to bed joint(iii) 31^0 to bed joint (iv) 37^0 to bed joint (v) 45^0 to bed joint (vi) Perpendicular to bed joint.



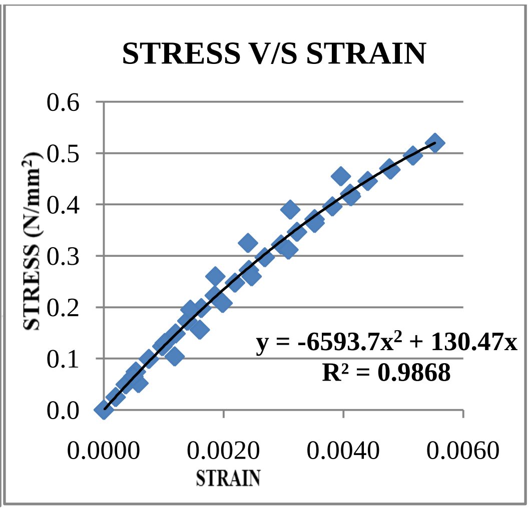
(i)



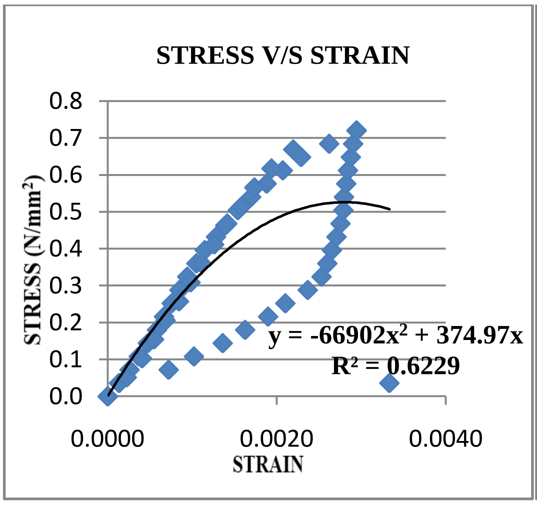
(ii)



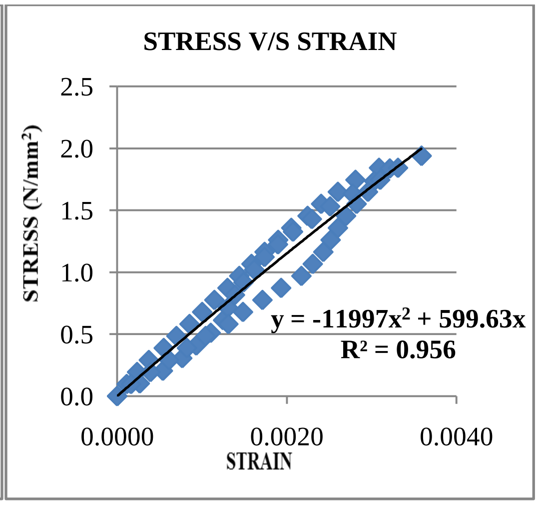
(iii)



(iv)



(v)



(vi)

Fig 15: Stress-Strain Curves of Table Moulded Brick Prisms Tested For Loading Conditions
(i) Parallel to bed joint(ii)27° to bed joint(iii) 31° to bed joint (iv) 37° to bed joint (v) 45° to bed joint (vi)Perpendicular to bed joint.

B. WIRE CUT BRICK PRISMS

a) Wire Cut Brick Prisms Loaded Parallel To Bed Joint (WBP-100-0^0)

Table 7: WBP-100-0^0 Prism Test Results.

Sl. No	Prism Size (mm)	h/t	Area (mm^2)	Ultimate load (KN)	Prism Strength (MPa)	Corrected Prism Strength (MPa)	Masonry Efficiency (□)	Average Corrected Prism Strength (MPa)
1	265x100x490	4.90		124.00	4.68	4.66	0.51	
2	265x100x490	4.90	26500	115.00	4.34	4.32	0.47	4.56
3	265x100x490	4.90		125.00	4.72	4.69	0.51	

b) Wire Cut Brick Prisms Loaded 27^0 With Respect To Bed Joint (WBP-100-27^0)

Table 8: WBP-100-27^0 Prism Test Results.

Sl. No	Prism Size (mm)	h/t	Area (mm^2)	Ultimate load (KN)	Prism Strength (MPa)	Corrected Prism Strength (MPa)	Masonry Efficiency (□)	Average Corrected Prism Strength (MPa)
1	250x100x465	4.65		46.00	1.84	1.81	0.20	
2	250x100x480	4.80	25000	30.00	1.20	1.19	0.13	1.91
3	250x100x485	4.85		69.00	2.76	2.74	0.30	

c) Wire Cut Brick Prisms Loaded 31^0 With Respect To Bed Joint (WBP-100-31^0)

Table 9: WBP-100-31^0 Prism Test Results.

Sl. No	Prism Size (mm)	h/t	Area (mm^2)	Ultimate load (KN)	Prism Strength (MPa)	Corrected Prism Strength (MPa)	Masonry Efficiency (□)	Average Corrected Prism Strength (MPa)
1	250x100x490	4.90		57.20	2.29	2.28	0.25	
2	250x100x465	4.65	25000	47.00	1.88	1.85	0.20	2.10
3	250x100x478	4.78		54.80	2.19	2.17	0.24	

d) Wire Cut Brick Prisms Loaded 37^0 With Respect To Bed Joint (WBP-100-37^0)

Table 10: WBP-100-37^0 Prism Test Results.

Sl. No	Prism Size (mm)	h/t	Area (mm^2)	Ultimate load (KN)	Prism Strength (MPa)	Corrected Prism Strength (MPa)	Masonry Efficiency (□)	Average Corrected Prism Strength (MPa)
1	250x100x486	4.86		50.00	2.00	1.99	0.22	
2	250x100x474	4.74	25000	44.40	1.78	1.75	0.19	2.00
3	250x100x477	4.77		57.00	2.28	2.25	0.25	

e) Wire Cut Brick Prisms Loaded 45^0 With Respect To Bed Joint (WBP-100-45^0)

Table 11: WBP-100-45^0 Prism Test Results.

Sl. No	Prism Size (mm)	h/t	Area (mm^2)	Ultimate load (KN)	Prism Strength (MPa)	Corrected Prism Strength (MPa)	Masonry Efficiency (□)	Average Corrected Prism Strength (MPa)
1	250x100x478	4.78	25000	55.00	2.20	2.18	0.24	1.74
2	250x100x470	4.70		57.40	2.30	2.26	0.25	
3	250x100x468	4.68		40.00	1.60	1.57	0.17	
4	250x100x498	4.98		23.40	0.94	0.94	0.10	

f) Wire Cut Brick Prisms Loaded Normal (90^0) To Bed Joint (WBP-100-90^0)

Table 12: WBP-100-90^0 Prism Test Results.

Sl. No	Prism Size (mm)	h/t	Area (mm^2)	Ultimate load (KN)	Prism Strength (MPa)	Corrected Prism Strength (MPa)	Masonry Efficiency (□)	Average Corrected Prism Strength (MPa)
1	225x100x468	4.60		61.00	2.71	2.66	0.29	
2	225x100x470	4.70	22500	82.40	3.66	3.61	0.39	3.18
3	225x100x475	4.70		75.00	3.33	3.28	0.36	

*Correction for prism strength is applied as per IS: 1905: 1987 in all the cases.

(i) (ii) (iii)

(iv) (v) (vi)

Fig 16: Failure Patterns of Wire Cut Brick Prisms Tested For Loading Conditions
(i) Parallel to bed joint (ii) 27^o to bed joint (iii) 31^o to bed joint (iv) 37^o to bed joint (v) 45^o to bed joint (vi) Perpendicular to bed joint.

International Journal of Latest Research in Engineering and Technology (IJLRET)
ISSN: 2454-5031
www.ijlret.com || Volume 03 - Issue 03 || March 2017 || PP. 63-76

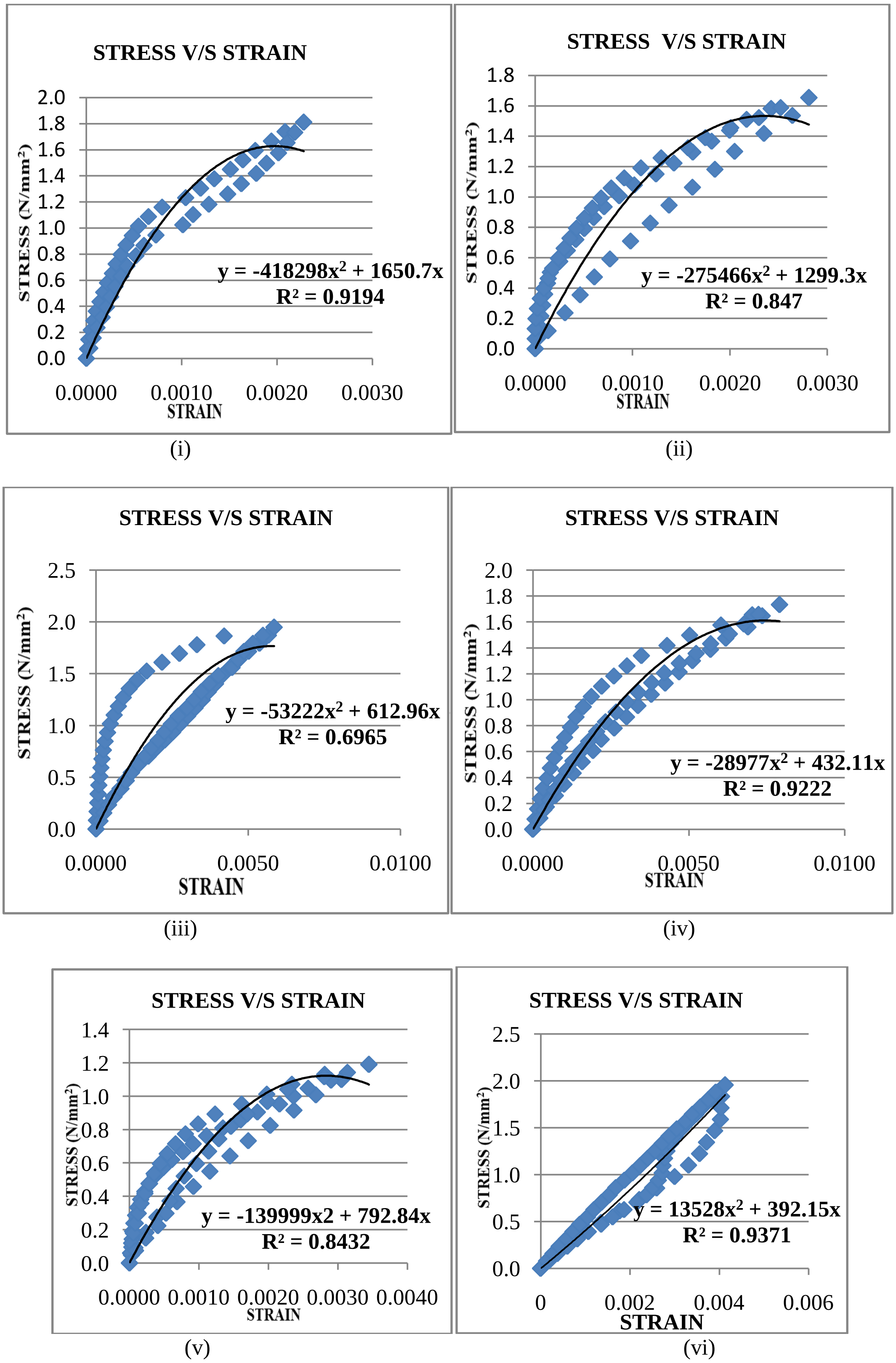


Fig 16: Stress-Strain Curves of Wire Cut Brick Prisms Tested For Loading Conditions
(i) Parallel to bed joint(ii)27° to bed joint(iii) 31° to bed joint (iv) 37° to bed joint (v) 45° to bed joint
(vi)Perpendicular to bed joint.

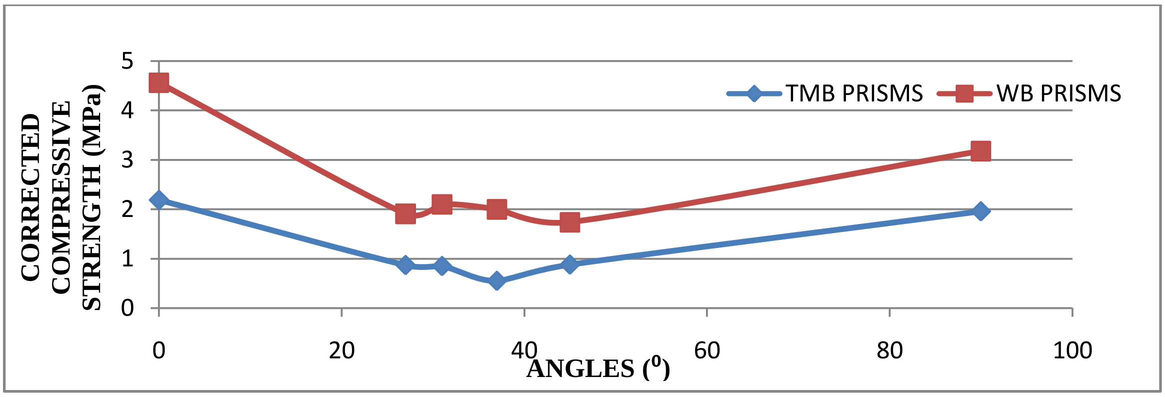


Fig 17: COMPARISION OF AVERAGE CORRECTED COMPRESSIVE STRENGTH WITH LOADING ANGLES

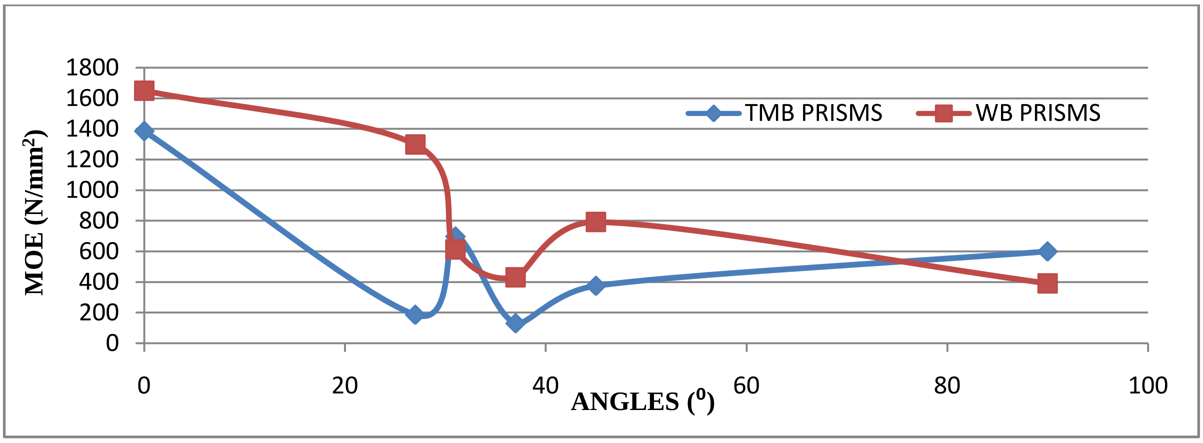


Fig 18: COMPARISION OF AVERAGE MODULUS OF ELASTICITY WITH LOADING ANGLES.

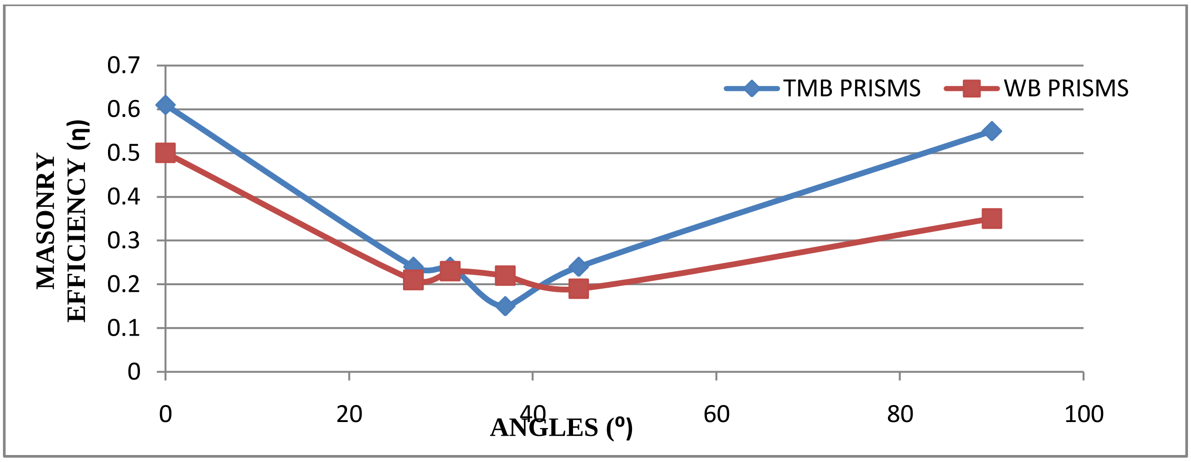


Fig 19: COMPARISION OF MASONRY EFFICIENCY WITH LOADING ANGLES.

From the experimental investigation it was observed that for table moulded brick prisms,

- The elasticity along the masonry parallel to bed joint was 230% that of the value observed perpendicular to bed joint. Further at 27^0 inclination angle huge drop in the elasticity value was observed 31% of the value obtained at normal to bed joint. At 27^0 there was a true shear failure indicating masonry modulus is mainly contributed by mortar (fig 14.ii).

- There was an increase in the elasticity observed at loading angle 31^0on comparing with the previous inclination angle due to participation of bricks along with mortar in handling loading stress and it was 114% of that of value obtained at normal to bed joint.
- At 37^0 loading angle, elasticity value reached lowest of all the values obtained at other loading angles i.e. 0^0,27^0,31^0,45^0 and 90^0. At this angle there was true shear failure and the elasticity obtained was 21% of the value observed at normal to bed joint shown in fig 14(iv).
- Further there an increasing trend was observed till loading angle of 90^0 with respect to bed joint. At 45^0 loading angle, the masonry elastic modulus was contributed by both bricks and mortar since failure of prisms occurred along joints and through bricks which is indicated in fig 14(v). It was 62% of the elasticity value that obtained at normal to bed joint.
- TMBPs when loaded normal to bed joint showed elasticity of 599.63 N/mm^2 and failure was occurred mainly in bricks indicating masonry modulus at 90^0 loading angle was mainly due to brick as the stresses were mainly received by bricks (fig 14.vi).
- Test results revealed that, the compressive strength of TMBPs at 27^0,31^0,37^0 and 45^0 inclinations vary from 25% to 45% of that observed at perpendicular to bed joint. However it reached least value of 28% of compressive strength that of TMBPs tested normal to bed joint and similarly the masonry efficiency.
- Test results of TMBPs at parallel to bed joint showed higher in values with respect to all other loading conditions considered, in parameters like corrected compressive strength, elasticity and masonry efficiency. Their failure pattern is shown in fig 14(i).

Also, investigation of wire cut brick prisms indicated,

- The elasticity of WBPs tested parallel to bed joint showed 420% of the corresponding value obtained for set of prisms loaded normal to bed joint. These set of prisms failed clearly along the horizontal joints as shown in fig 16(i).
- At 27^o loading angle, there was some decrease in the elasticity value compared to prisms loaded parallel to bed joint. It was 331% when compared to elasticity value obtained for prisms tested loading normal to bed joint. A clear sliding shear failure occurred at 27^o loading angle which is clearly indicated in fig 16(ii).
- At 31^o loading angle, decrease in the value of elastic modulus was noted compared to loading angles discussed above. It showed an elastic modulus of 156% of that of corresponding value that was observed at normal to bed joint. Failure of this set of prisms was observed along both horizontal and vertical joints with some cracks on bricks (fig 16.iii).
- The elasticity parameter of WBPs continued its decreasing trend and reached lowest value when prisms loaded at 37^oinclination with respect to bed joint. However, it showed an elastic modulus of 110% of the value observed at loading condition normal to bed joint. These set of prisms failed in both vertical and horizontal joints with some cracks in the bricks which is indicated in fig 16(iv).
- At 45^oinclination, prisms showed increase in value of elastic modulus and reached a value of 202% of the value obtained at normal to bed joint loading condition. These set of prisms failed mainly along the horizontal joints and in the vertical joints at the corners as indicated in fig 16(v).
- The compressive strength of WBPs at 27^o,31^o,37^o and 45^o inclinations varied from 50% to 70% that of the corresponding value at perpendicular to bed joint loading condition. It reached least value i.e. 54% of the corrected compressive strength value, with that observed for WBP set loaded normal to bed joint.
- From the test results it was noticed that, the masonry efficiency for 0^o,27^o,31^o,37^o and 45^o inclinations were 178%, 75%, 82%, 78% and 67% of masonry efficiency value with respect to WBPs set loaded perpendicular to bed joint.

CONCLUSIONS

The present investigation focussed on determining strength and elastic properties of MI in the diagonal inclination angles of RC frames with column to column spacing of 3m, 4m, 5m and 6m with common floor to floor height of 3m (i.e. at 45^o,37^o,31^o and 27^o) and also with parallel and perpendicular to bed joint. Based on the studies a comparative study is done with respect to properties of MI perpendicular to bed jointand following conclusions are high lightened;

a) WBPs showed higher in compressive strength compared to TMBPs at all corresponding inclination angles.
b) For the corresponding inclination angles considered for frame sizes 3X3m, 4X3m, 5X3m and 6X3m (i.e. 45^o,37^o,31^o and 27^o) elasticity of,
    - The modulus of elasticity of TMBPs varied from 20% to 115% with that of elastic modulus for the prisms loaded perpendicular to bed joint.

- The modulus of elasticity of WBPs varied from 110% to 335% with that of elastic modulus for the prisms loaded perpendicular to bed joint.

c) Wire cut bricks should be preferred as masonry infill in RC framed structures, especially in the earthquake prone zones.

d) TMBPs, masonry infill of the frame with diagonal angle 37° i.e. 4X3m(LXH) is more critical under lateral loading condition since the results of MOE, compressive strength and efficiency was least and it was nearly 20% of the corresponding values obtained for normal to bed joint loading condition for same type of brick prisms.

e) WBPs, the frame with size 4X3m (LXH) having diagonal angle of 37° indicated least MOE when compared with frames of 3X3m, 5X3m and 6X3m sizes, making it more critical under lateral stresses. However it showed high in compressive strength and efficiency than other loading angles.

f) The masonry efficiency at loading angles 27°,31°,37° and 45° varied from 65% to 85% for WBPs and was 25% to 45% for TMBPs when compared with respective efficiency values of corresponding brick material loaded normal to bed joint.

REFERENCES

[1]. Niranjana N, "Strength and Elastic Properties of Brick Masonry Infill at Various Angles Inclined to Bed Joint", MTech thesis, BMS College of Engineering, Bangalore, Submitted to VTU Jul-2015.
[2]. W.W.El-Dakhakhni, M.Elagaaly, and A.A.Hamid, "Three Strut Model for Concrete Masonry-Infilled Steel Frames", Journal of Structural Engineering, 129(2), 2003, 177-185.
[3]. KashifMahmud,Md.Rashadul Islam and Md.Al-Amin, "Study the Reinforced Concrete Frame With Brick Masonry Infill due to Lateral Loads",International Journal of Civil &Enviornmental Engineering, Vol:10 No:04 August 2010.
[4]. K.S.Nanjunda Rao and G.S.Pavan, "FRP-Confined Clay Brick Masonry Assemblages under Axial Compression: Experimental and Analytical Investigations", Journal of Composites for Construction, ASCE, Feb-2015.
[5]. S.V.Polyakov, "On the interaction between masonry infill walls and enclosing frame when loaded in plane of the wall", Earthquake Engineering, Earthquake Research Institute, San Francisco, 1960.
[6]. M.Holmes, "Steel Frames with brick work and concrete infilling",Proc. of ASCE, 114,1962,183-199.
[7]. B.S.Smith and C.Carter, "A Method of Analysis for Infilled Frames", Proc.ICE, 44, 1969, 34-48.
[8]. R.J. Mainstone, "On the stiffness and strength of Infilled Frames", Proc. ICE, 1971, 51-90.
[9]. T.C.Liauw and S.W. Lee, "On the behaviour and analysis of multi-storey infilled frames subject to lateral loads", Proc. ICE, part 2, 1977, 641-656.
[10]. A.W. Hendry, "Structural brick work", Macmillan, London, 1981.
[11]. T. Paulay and M.J.N. Priestley, "Seismic Design of Concrete and Masonry Buildings", John Wiley and Sons Inc., New York, USA, 1992.
[12]. C.Rajesh, Ramancharla Pradeep Kumar and Suresh Kandru, "Seismic Performance of RC Framed Buildings With & Without Infill Walls", International Journal of Engineering Research and Technology, Vol.3, Issue 10, Oct-2014.
[13]. Catherin Jeselia M, Jayalekshmi.B.R,KattaVenkataramana " Modelling of Masonry Infill- A Review", American Journal of Engineering Research, Vol-2, pp 59-63.
[14]. "Code of Practice For Structural Use Of Unreinforced Masonry", IS: 1905-1987 (Reaffirmed 2002).
[15]. "Common Burnt Clay Building Bricks-Specification", IS: 1077: 1992 (Reaffirmed 1997).
[16]. "Specifications for Sand for Masonry Mortars", IS: 2116: 1980 (Reaffirmed 1998).
[17]. "Code of Practice for Preparation and Use of Masonry Mortars" IS: 2250-1981(Reaffirmed 1995).
[18]. "Method of Tests of Burnt Clay Bricks" IS: 3495 (Part 1): 1992.
[19]. "Methods of Tests for Aggregate for Concrete", IS: 2386 (Part 1): 1963.
[20]. "Code of practice for preparation and use of masonry mortars" IS: 2250: 1981 (Reaffirmed 1995).