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AN EXPERIMENTAL INVESTIGATION AND MODELLING OF SHEAR BEHAVIOUR OF VERTICAL JOINTS BETWEEN PRECAST PANELS

A. Biswal[(1)], A. Meher Prasad[(2)], A. K. Sengputa[(3)]

[(1)] *PhD Scholar, Department of Civil Engineering, IIT Madras, tim.aparup@gmail.com*
[(2)] *Professor, Department of Civil Engineering, IIT Madras, prasadam@iitm.ac.in*
[(3)] *Professor, Department of Civil Engineering, IIT Madras, amlan@iitm.ac.in*

Abstract

Precast concrete multi-storied building systems are classified as framed system, wall (large panel) system and dual system. A wall type building is an assemblage of precast wall and slab panels, with various types of joints. Based on the location and orientation, a joint can be a horizontal joint or a vertical joint. To predict the behaviour of a building under lateral seismic forces, it is necessary to characterise the behaviour of the joints. The present research focuses on the in-plane shear behaviour of vertical joints.

In the experimental part of the investigation, twelve wall assemblage specimens were tested under direct in-plane shear. Parameters affecting the strength and deformability, such as the type of transverse joint reinforcement (U-bars or loops), amount and spacing of transverse joint reinforcement, and configuration of joint (plane, castellated and castellated with edge lips) were investigated. Based on the observed behaviour, analytical expressions were proposed to predict the shear load versus slip behaviour for each configuration of joint. The proposed expressions can be used to model shear springs (links) between the wall elements, in a computational model of a wall type building. To demonstrate the use of the proposed expressions, a stand-alone jointed wall was modelled using multi-layered membrane elements and shear springs. A few models were developed with different options of modelling the vertical joint. A pushover analysis was performed for each model under the action of lateral loads. The observed behaviour of the experimental specimens, proposed expressions and the results of the numerical analysis are reported in this paper.

Keywords: *Castellated Joint; In-Plane Shear Behaviour; Plane Joint; Precast Concrete; Vertical Joint.*

1. Introduction

With high demand for fast construction in housing industry, precast concrete systems are gaining popularity in India. These systems ensure high quality control, reduced time of construction, less pollution at site and cost effectiveness for repetitive construction. Precast concrete systems in multi–storeyed buildings can be categorised into three broad groups: framed system, wall (large panel) system and dual system. In a wall type building, the joints between the wall and slab panels play an important role in the overall behaviour of the building under external loads. Based on the location and orientation, a joint can be classified as a horizontal joint or a vertical joint. Depending on the design philosophy adopted, the connections in the joints are categorised as strong connection and ductile connection [1-2]. In a strong connection, the connections are detailed to be stronger than the precast members. However, in a ductile connection, the connections are weaker than the precast members. In the later type of connections, the precast members are designed to remain elastic under seismic forces. The vertical joints can be further categorised into two broad groups, wet joint and dry joint [2]. The present research focuses on grouted (wet) vertical joints, which are considered to be weak joints. However, they are used in low to moderate seismic regions of India. To achieve the vertical connectivity between two panels, U-bars or commercially available loops are used as transverse joint reinforcement. The intermediate space between the panels is filled with cement–sand grout. The configuration of vertical joints can be categorised into three groups as follows.

a) Plane surface of the joint faces, which is convenient in terms of formwork (Fig. 1b).
b) Castellated (Keyed) surface of the joint faces, to generate strut action at the shear keys (Fig. 2a).
c) Castellated surface of the joint faces with edge lips, to conceal the shear keys for aesthetics (Fig. 2b).

The behaviour of grouted vertical joints under in-plane shear has been experimentally investigated since 1960's. The studies identified the parameters such as the type, amount and spacing of transverse joint reinforcement, width of joint, strength of the joint grout, which affect the strength and deformability of a joint [3-8]. For a plane joint, two stages of the joint behaviour were revealed [3]. In the first stage, the joint resists the load till the initiation of first crack. In the second stage, the joint reinforcement shares the load. For a joint with castellation, the number and dimensions of shear keys affect the shear strength of the joint [6-7]. Joints with reinforcement suitable for construction were also studied [9]. Expressions to calculate the shear strength of a joint, and design recommendations are available in the literature [3-10]. However, any formulation of shear load versus slip behaviour of the joints is not available.

In conventional linear analysis of a wall-type precast building for seismic forces, either the connectivity of the panels is considered monolithic or it is neglected (disjointed walls), or the shear transfer between the panels is partially released. These approaches can be unconservative or conservative in terms of estimating base shear or lateral drift. In a performance based analysis of a building subjected to seismic forces such as to predict the lateral load versus drift behaviour in a pushover analysis, it is necessary to characterise the behaviour of the joints. The study reported in this paper aimed to characterize the in-plane shear behaviour of grouted vertical joints based on tests of jointed panel assemblages.

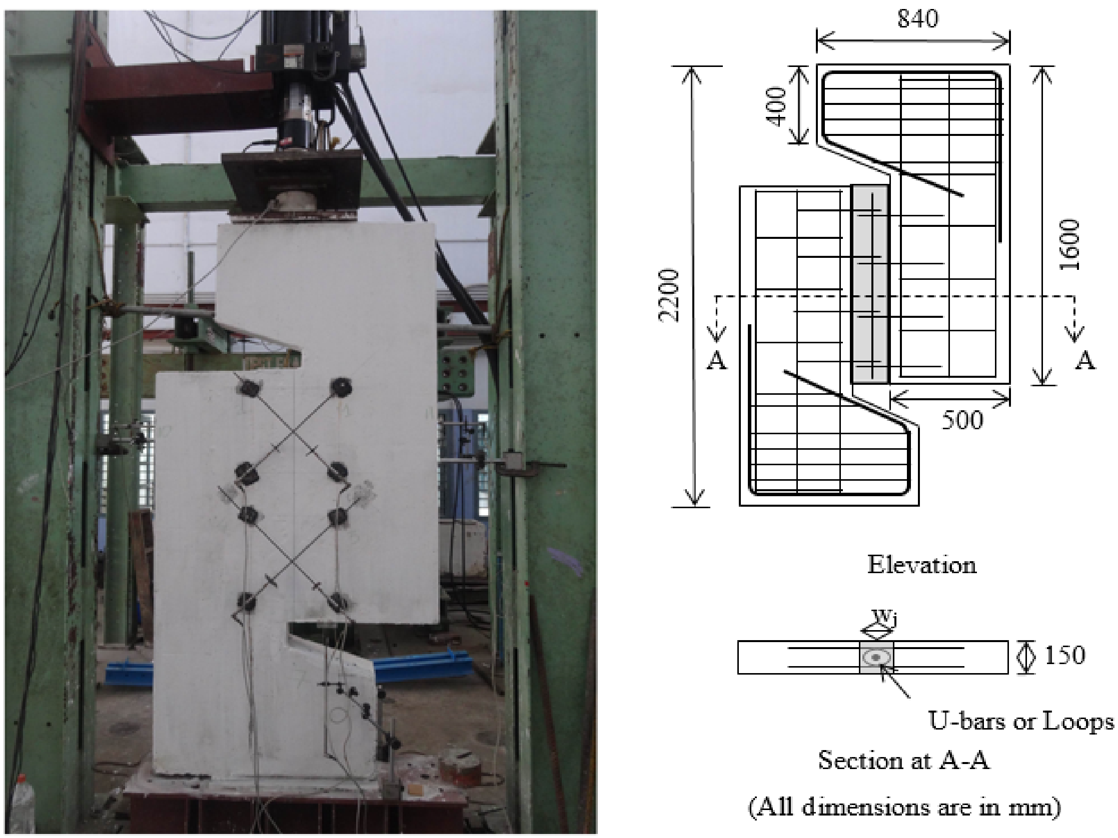
2. Experimental Investigation

To investigate the behaviour of vertical joints under in-plane direct shear, an experimental investigation was carried out. A total of 12 assemblage specimens with different joint configurations were tested. The various parameters affecting the strength and deformability of the joint were investigated. The detailing of the joints was adopted from the current practice in the precast construction industry in India. The specimens were grouped as per the joint configurations (Table 1). To check the repeatability of the results, two specimens were tested in each group.

2.1 Test Setup

The test setups used by previous researchers were either single shear or double shear type. In the single shear type, two panels are assembled to form a specimen. Among the two panels, one panel is supported and the other is subjected to a vertical load. This setup requires an extra support to counterbalance the moment generated due to loading and weight of the hanging panel. In the double shear type, three panels are used and two joints are formed. Among the three panels, two panels are supported and the middle panel is subjected to a vertical load. This setup produces arch action of the concrete, which affects the uniformity of shear stress in the joint region.

In the present study, single shear type test setup was adopted (Fig. 1a). Each specimen consisted of two panels joined by transverse joint reinforcement and grouting. To avoid extra supports, each panel in a specimen consisted of a corbel extension. The corbels were provided to allow the applied vertical load to pass through the centre of the joint region, without generating any moment. Displacement controlled test was performed using a 50 ton capacity hydraulic actuator. To measure the shear deformation of the joint region and vertical slip between the panels, linear variable differential transducers (LVDTs) were used.

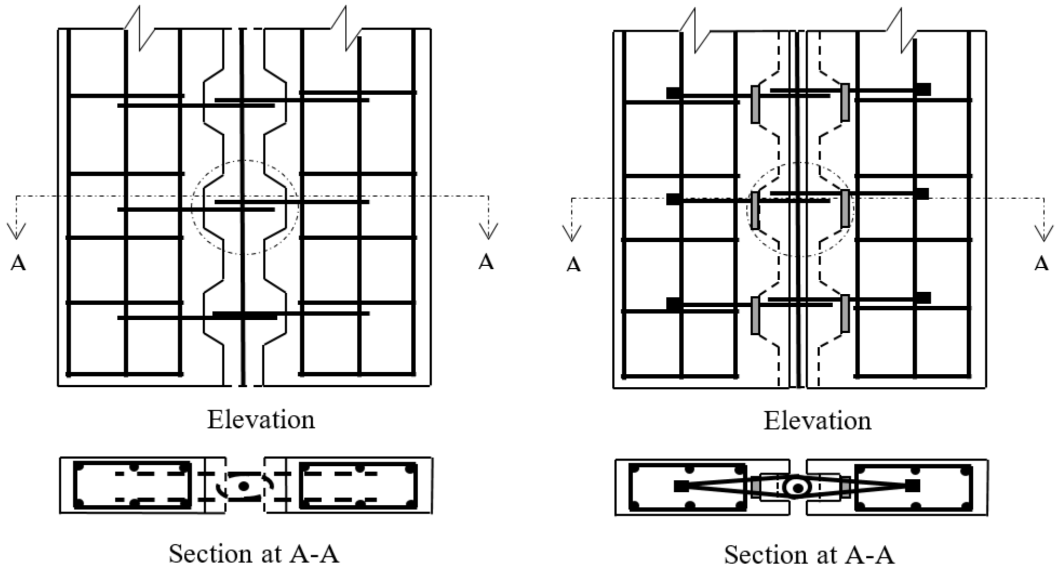


a) Photo b) Sketch (for a plane joint)

Fig. 1 –Test setup and dimensions of a typical specimen (All dimensions are in mm)

2.2 Specimen details

Fig. 1(b) shows the dimensions of a typical specimen. The height of the test region was selected to be 1 m. Based on the height of test region, the dimensions of a panel were decided. The parameters considered in this study were the type of transverse joint reinforcement (U-bars or loops), amount and spacing of the joint reinforcement, and configuration of joint (plane, castellated and castellated with edge lips). Fig. 2 shows the schematic diagram of the castellated joint without and with edge lips. Table 1 provides the information of the parameters and specimen designation. Fig. 3 shows the types of transverse joint reinforcement used. The individual panels were cast in the horizontal position (flat). After demoulding, the panels were tilted-up. The joint faces of the panels were hacked to generate proper bond between the grout and panel concrete. After aligning the two panels in respective vertical positions, grouting of the joint was done. The material properties and amount of transverse joint reinforcement are summarised in Table 2. The compressive strength of grout was designed to be less than that of the concrete in the panels.



a) Without edge lips b) With edge lips

Fig. 2 –Schematic diagram of castellated joint

Table 1 –Details of joint configuration

Joint configuration	**Type of transverse joint reinforcement**	**Specimen group**	**Spacing of transverse joint reinforcement (mm)**	**Specimen designation**
Plane joint	U-bars	P-U-250	250*	1A, 1B
	Loop box	P-L-250		2A, 2B
	U-bars	P-U-125	125	3A, 3B
Castellated joint	U-bars	C-U-300	300*	4A, 4B
	Loop box	C-L-300		5A, 5B
Castellated joint with edge lips		CL-L-300		6A, 6B

* These spacings are adopted in practice in India. The dimensions of the U-bar was 8 mm.

The specimen nomenclature is as follows.
For joint configuration: P: Plane joint, C: Castellated joint, CL: Castellated joint with edge lips.
For type of transverse joint reinforcement: U: U-bars, L: Loop box.
For spacing of transverse joint reinforcement: 125/250/300.

3. Test Results

Brief experimental observations from the specimens are reported in this paper. Detailed results of the experimental programme are available in Reference 14. The values of selected response quantities such as cracking load, slip at cracking and ultimate load for each specimen are summarised in Table 2. The ultimate load is defined as the maximum observed load. Fig. 4 shows the typical load versus slip curves for specimens with plane and castellated joints. The average slip between the panels was calculated from the readings of the vertical LVDTs.

3.1 Behaviour of specimens

For a specimen with plane joint, the load versus slip curve is almost linear till initiation of the first crack at any one or both the interfaces of grout and panel concrete. In comparison to specimens with U-bars, about 40 %

higher cracking load was observed for specimens with loop boxes (Fig. 4a). This increase in cracking load was because of mild shear key effect of loop boxes. After the first crack, a sudden drop in load carrying capacity was observed till the formation of dowel action of the transverse joint reinforcement. The reduced load was more or less retained by dowel action up to about 13.0 and 9.5 times the slip at the crack, for specimens with U-bars and loop boxes, respectively. Thus, for a specimen with plane joint and conventional spacing of joint reinforcement, the cracking load is the ultimate capacity. Fig. 5 (a) shows the typical crack pattern observed for specimens with U-bars at 250 mm spacing. It was observed that the cracks were primarily at one or both the interfaces of the joint. For a specimen with closer spacing of transverse joint reinforcement (3A and 3B), the ultimate capacity was slightly higher than the cracking load. A few diagonal cracks were observed in the joint region. The load retention beyond the ultimate was improved.

For a specimen with castellated joint, the load versus slip curve is linear till initiation of the first diagonal crack in the joint. After the first crack, formation of diagonal struts was observed. It leads to increase in load carrying capacity of the joint, till shearing or crushing of the keys. The increases were about 40 % and 45 % beyond cracking, for specimens with U-bars and loop boxes, respectively (Fig. 4b). However, for the specimens with edge lips, due to the reduced thickness of the struts, there was no increase in capacity beyond cracking. Fig. 5 (b) shows the crack pattern observed in specimens with castellated joints without edge lips. There were diagonal cracks followed by the crushing of the struts in the grout and shearing of the keys at their bases.

a) U-bar b) Loop box

Fig. 3 –Types of transverse joint reinforcement used

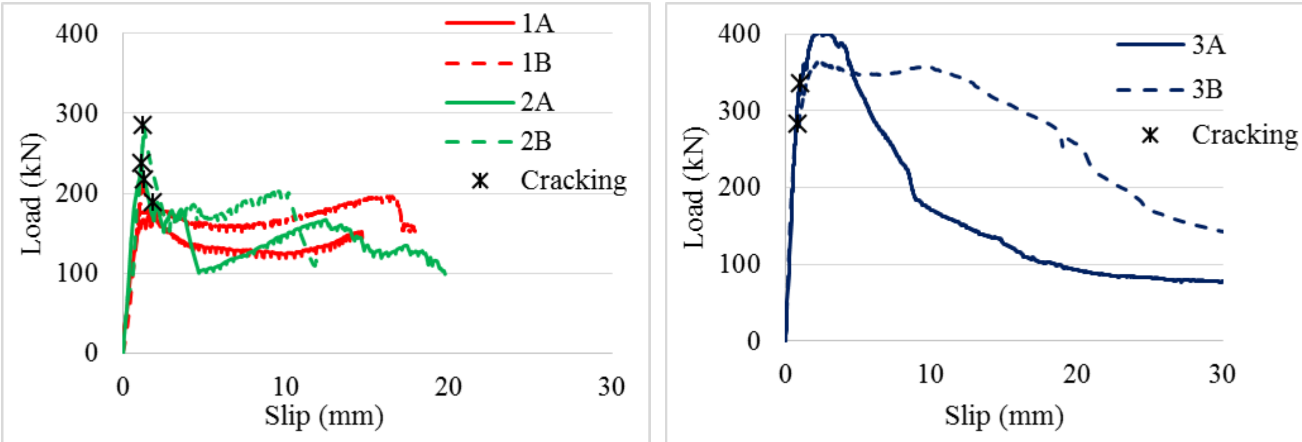
Table 2 –Material properties and selected response quantities for specimens

Specimen designation	**f_{cmg} (MPa)**	**f_{cmp} (MPa)**	**f_y (MPa)**	**A_s (mm^2)**	**Cracking load (kN)**	**Slip at crack (mm)**	**Ultimate load (kN)**
1A	43	56	433	402.1*	189.3	1.8	189.3
1B	48	50	433	402.1*	217.5	1.2	217.5
2A	38	49	1666	120.8	237.6	1.1	237.6
2B	45	58	1666	120.8	285.0	1.2	285.0
3A	48	50	517	703.7**	339.1	0.9	403.5
3B	48	52	517	703.7**	282.9	0.8	364.6
4A	51	53	433	301.6	269.0	1.0	351.9
4B	48	57	433	301.6	283.7	1.2	388.6
5A	61	63	1666	90.6	216.7	0.8	351.0
5B	57	55	1666	90.6	214.7	0.8	264.2
6A	45	48	1333	90.6	284.4	1.1	284.4
6B	55	56	1333	90.6	292.0	1.2	292.0

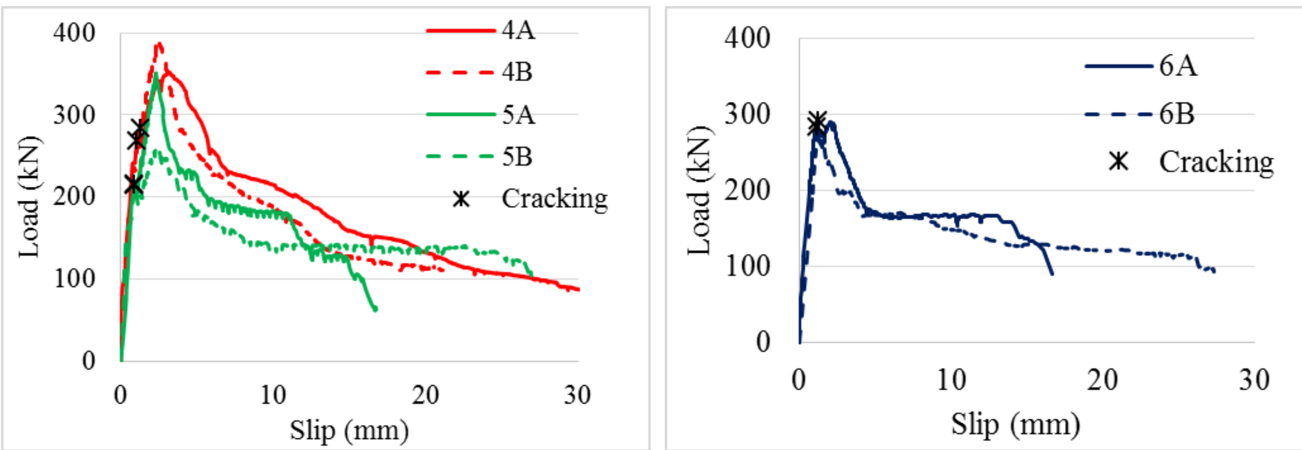
* Four U-bars in a panel, ** Seven U-bars in a panel

Here, f_{cmg}–Mean compressive strength of grout, f_{cmp}–Mean compressive strength of panel concrete

f_y–Yield strength of transverse joint reinforcement, A_s–Total area of transverse joint reinforcement at an interface.

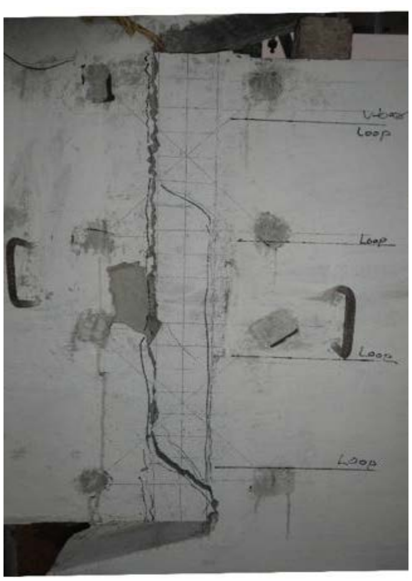


a) Specimens with plane joints

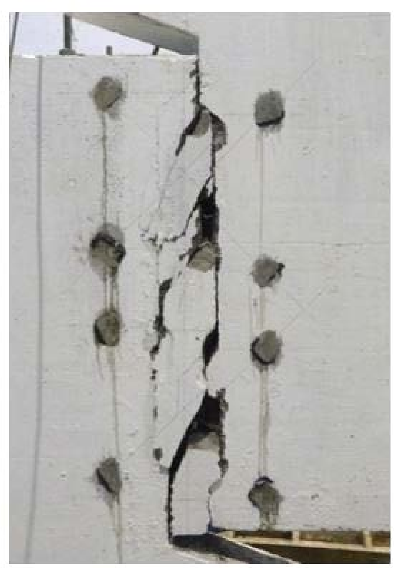


b) Specimens with castellated joints

Fig. 4 –Load versus slip curves



a) Plane joint



b) Castellated joint without edge lips

Fig. 5 –Crack pattern

4. Modelling of Joint Behaviour

The development of the proposed expressions is briefly explained. Fig. 6 illustrates the proposed load versus slip behaviour for plane and castellated joints. In the proposed model, the marginal difference between specimens with U-bars and loops were neglected. The specimens with castellated joints including edge lips are not included here for brevity. The proposed expressions for the selected response quantities are summarised in Table 3. The notations used in the proposed curves are explained below.

K_0 – Initial stiffness, in kN/mm per meter length of joint

K_{peak} – Secant stiffness at peak, in kN/mm per meter length of joint

s_{cr} – Cracking slip, in mm

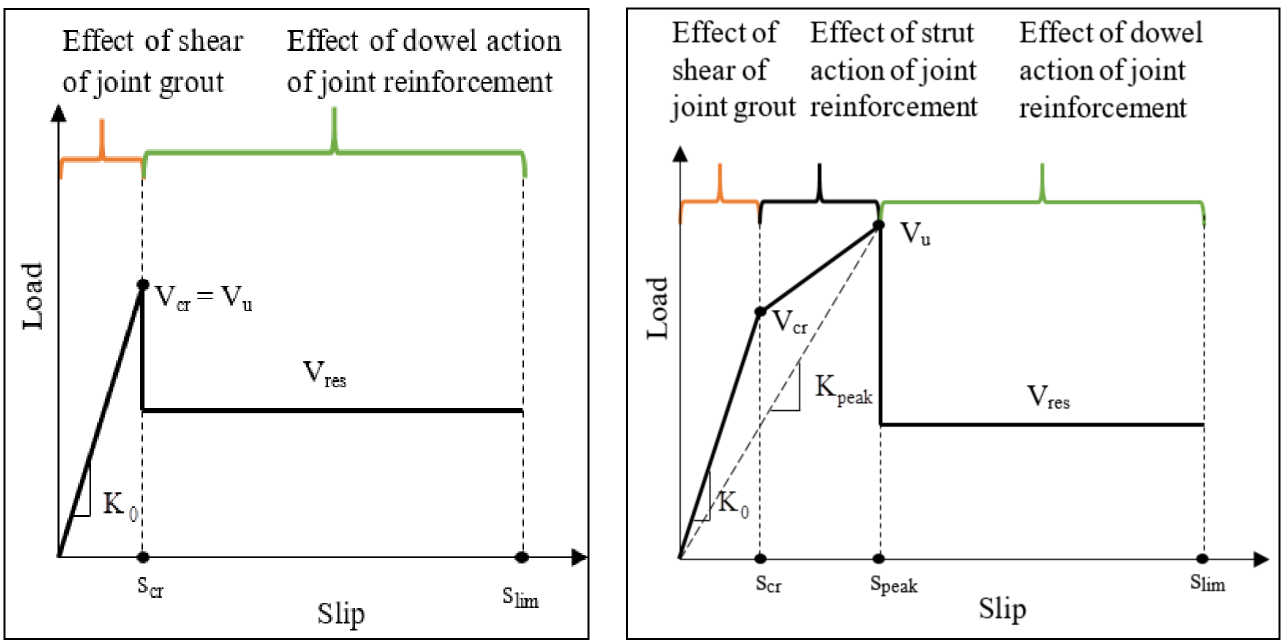
s_{peak} – Slip at peak, in mm

s_{lim} – Limiting slip, in mm

V_{cr} – Cracking load, in kN per meter length of joint

V_u – Ultimate capacity, in kN per meter length of joint

V_{res} – Residual strength, in kN per meter length of joint



a) Plane joint b) Castellated joint without edge lips

Fig. 6 –Proposed load versus slip curves

4.1 Plane joint

The following sub–section explains the development of the proposed expressions.

4.1.1 Initial stiffness

The initial stiffness (K_0) is defined as the ratio of load to slip, at cracking. To model K_0 independent of specimen dimensions, normalised initial stiffness ($K_0^{/} = K_0 w_j/A$) was calculated, where w_j and A are the width and sectional area of the joint, respectively. Based on conventional practice for concrete and observed test results, an estimate of $K_0^{/}$ is expressed in terms of the compressive strength of the grout (f_{cmg}) as follows.

$$K_0^{/} = 25\sqrt{f_{cmg}} \quad (1)$$

Here, $K_0^{/}$ and f_{cmg} are in MPa.

4.1.2 Nominal ultimate capacity

The ultimate capacity was considered to be same as the cracking load, and the effects of the compressive strength of grout and yield strength of joint reinforcement were considered simultaneously. To model the capacity (V_u) similar to the expressions in the literature, two non-dimensional quantities were introduced for the regression analysis, i.e. reinforcement index ($A_s f_y / A f_{cmg}$) and normalised shear strength ($V_u / A f_{cmg}$). It was observed that the values of ($V_u / A f_{cmg}$) for the specimens are more or less linear with respect to ($A_s f_y / A f_{cmg}$). Considering a lower bound estimate, Eq. 2 is proposed.

$$V_u = 0.007 A f_{cmg} + 0.86 A_s f_y \tag{2}$$

4.1.3 Residual strength

Based on dowel action, the residual strength (V_{res}) was considered to be proportional to the area and yield strength of joint reinforcement. Selecting lowest conservative value of the proportionality constant, the following equation is proposed.

$$V_{res} = 0.5 A_s f_y \tag{3}$$

4.2 Castellated joint (without edge lips)

The expressions for initial stiffness, secant stiffness at peak and residual strength were developed in a similar manner as explained in Section 4.1. The expressions for cracking load and nominal ultimate capacity are explained below.

4.2.1 Cracking load

The cracking load is influenced by the tensile strength of grout. Based on conventional practice for concrete, the cracking stress is expressed as a function of $\sqrt{f_{cmg}}$. The cracking load is given as follows.

$$V_{cr} = 0.19 \sqrt{f_{cmg}} A \tag{4}$$

4.2.2 Nominal ultimate capacity

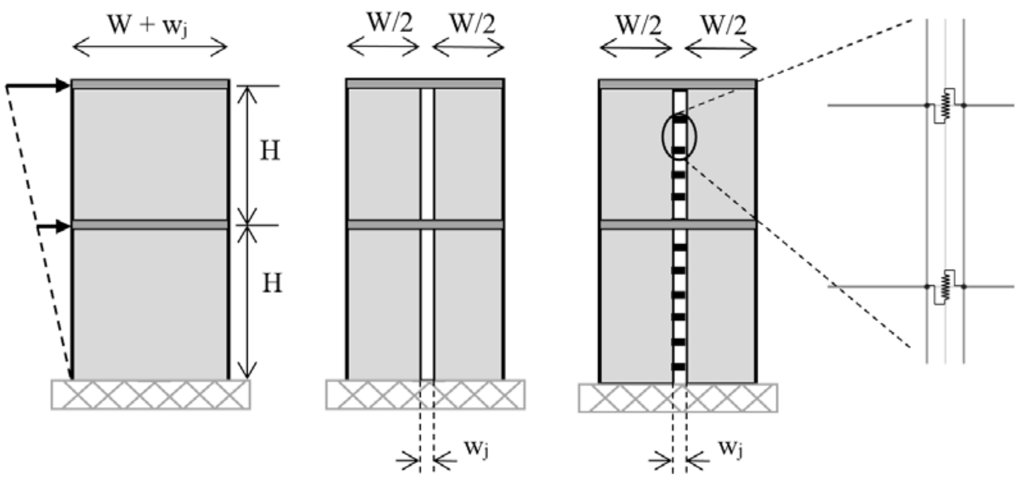
For the capacity, the expression proposed by Rizkalla et al. [11] based on strut action for a horizontal joint, was selected. The following equation is proposed.

$$V_u = 0.33 (n_k - 1) f_{cmg} A_{dk} \sin\varphi \tag{5}$$

Here,
A_{dk} – Average cross sectional area of diagonal strut ½ (w_j+d_s) t/cosθ, based on a prismatic cylinder
θ – Angle of shear key
φ – Angle of strut
d_s – Depth of the shear key, in mm
t – Thickness of shear key, in mm (same as thickness of the joint)
n_k – Number of shear keys per meter length of the joint

5. Numerical Analysis

A numerical analysis is shown to demonstrate the applicability of the proposed expressions in a computational model. A stand-alone wall was modelled, by considering two hypothetical vertical precast panels joined together (Fig. 7). The width of an individual panel (W/2) is 3 m. The height of the wall is 6 m. A squat wall was selected to study the behaviour dominated by shear. The width of the joint (w_j) is100 mm. Fig. 8 shows the dimensions and details of reinforcement in a wall panel.



a) Monolithic b) With gap c) With shear links

Fig. 7 –Loading profile and elevations of wall models

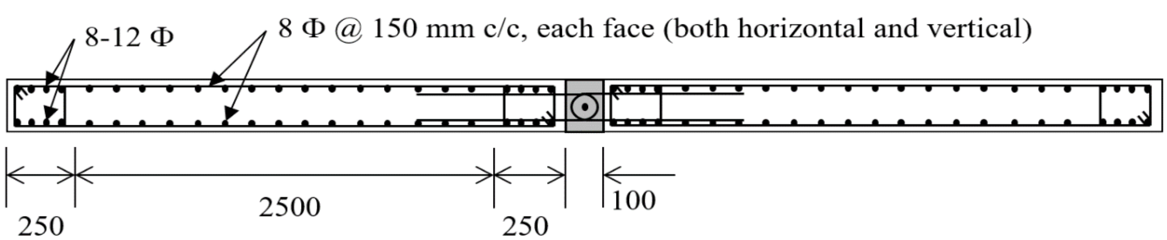


Fig. 8 –Dimensions and details of reinforcement in a wall panel

(All dimensions are in mm)

Three models were analysed as follows: (i) considering monolithic action, (ii) two disjointed walls with a gap in-between, and (iii) two walls with shear links. In the models, only deformability of the vertical joint was considered, and any sliding or rocking at the base was not considered. Multi-layered membrane elements were used to model the walls using SAP2000 (Version 18) [12], where concrete and steel reinforcement are defined as separate layers. Nonlinear stress-strain curves based on the Indian code IS 456:2000 [13] were assigned to the materials. A diaphragm constraint was defined at each floor level. A triangular lateral load profile was selected for the pushover analysis (Fig. 7). A load was applied at the centre of each diaphragm. Shear links were provided at 250 mm spacing, same as the mesh size. The proposed load versus slip behaviour of plane joint or castellated joint (without edge lips) was used to define the property of a shear link. The parameters of the property were calculated for 1 m length and then interpolated for 250 mm spacing (Table 3). Fig. 9 shows the shear link properties for the plane and castellated joints. To avoid numerical instability due to sudden drop in capacity, the softened part of a property was modelled by using a hyperbolic equation till limiting slip. Beyond the limiting slip, the curve is linearly dropped down to zero capacity. The corresponding slip was assumed to be twice that of the limiting slip.

The following material properties and joint reinforcement were assumed for calculation of shear link properties.

f_{cmg} = 40 MPa, f_{cmp} = 40 MPa, f_y = 500 MPa
Reinforcement for plane joint:– 8 mm U-bars at 250 mm c/c
Reinforcement for castellated joint: 8 mm U-bars at 300 mm c/c.
The width of joint and shear key details were considered to be same as those of the tested specimens.

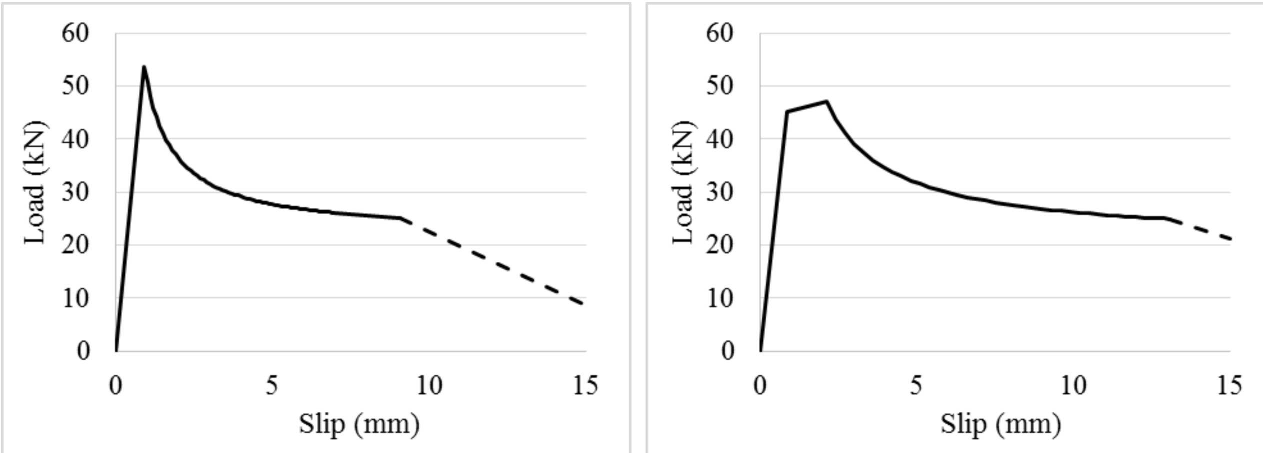
Table 3 –Proposed expressions and calculation of properties for shear links

Property	**Proposed expressions**	**For 1 m length of joint**	**Individual spring**
Plane joint			
Initial Stiffness (kN/mm)	$K_0 = 25\sqrt{f_{cmg}}\dfrac{A}{w_j}$	237.2	59.3
Nominal Ultimate Capacity (kN)	$V_u = 0.007Af_{cmg} + 0.86A_s f_y$	214.9	53.7
Residual Strength (kN)	$V_{res} = 0.5A_s f_y$	100.5	25.1
Limiting Slip (mm)	$s_{lim} = 10s_{cr}$	9.0	9.0
Castellated joint			
Initial Stiffness (kN/mm)	$K_0 = 12\sqrt{f_{cmg}}\, A/w_j$	206.9	51.7
Cracking Load (kN)	$V_{cr} = 0.19\sqrt{f_{cmg}}A$	180.2	45.1
Stiffness at Peak (kN/mm)	$K_{peak} = 0.82f_{cmg}\, A/w_j$	89.4	22.3
Nominal Ultimate Capacity (kN)	$V_u = 0.33(n_k - 1)f_{cmg}A_{dk}\sin\varphi$	188.04	47.0
Residual Strength (kN)	$V_{res} = 0.76A_s f_y$	99.6	24.9
Limiting Slip (mm)	$s_{lim} = 15s_{cr}$	13.1	13.1

5.1 Results

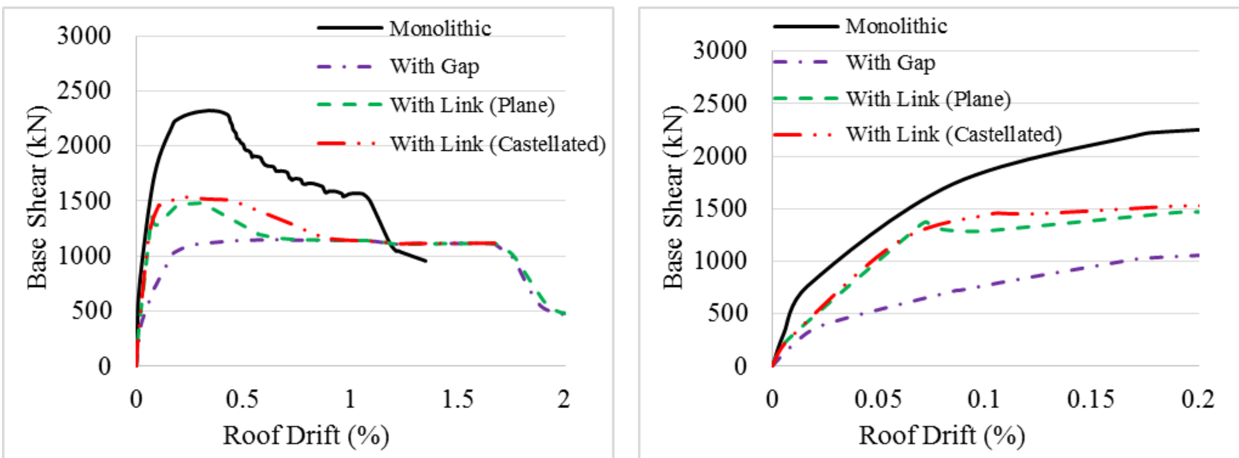
Fig. 10 (a) shows the base shear versus roof drift curves for the wall models. The zoomed–in view in Fig. 10 (b) is shown to observe the differences in the initial stiffness. From the pushover curves, it is observed that the models with shear links lie in between the model with gap and monolithic model. The models with gap and with shear links showed 50 % and 36 % reduction in strength, respectively, in comparison with the monolithic model. The reductions in the initial stiffness were about 63 % and 40 %, respectively. The difference in link properties for castellated and plane joints showed little difference in the behaviour of the models with shear links.

Thus, it is observed that assuming monolithic behaviour in a model of vertically joined precast wall panels, will lead to considerable overestimation of the lateral stiffness and strength. On the contrary assuming disjointed walls will lead to substantial underestimation of the lateral stiffness and strength. However, the actual difference in a building will depend on the number of walls, as well as redistribution of forces with other members.



a)Plane Joint b) Castellated Joint

Fig. 9 –Load versus slip properties for shear links



a) Complete behaviour b) Initial behaviour

Fig. 10 –Base shear versus roof drift (for aspect ratio 2)

6. Conclusions

Based on the experimental investigation, the conclusions are as follows.

- For a specimen with plane joint (with 250 mm spacing of transverse joint reinforcement), the cracking load was the observed ultimate capacity.
- About 80 % and 60 % of the cracking loads were retained beyond the peaks by dowel action of the transverse joint reinforcement, for specimens with U-bars and loops, respectively.
- For a specimen with castellated joint without edge lips, diagonal cracks were observed leading to strut action. Also, about 45%increase in shear capacity was observed beyond cracking.
- The effect of castellation was reduced for a specimen with edge lips, and the cracking load was the observed ultimate load.

Based on the numerical analysis, the conclusions are as follows.

- The behaviour of the model with shear links lies in-between the models with monolithic wall and walls with gap. The later behaves like twin cantilevers connected at the floors. The model with shear links behaves as a single cantilever with slip at the vertical joint.
- The models with gap and with shear links showed 50% and 36% reduction in strength, respectively, in comparison with the model with monolithic wall.
- The difference in link properties (castellated and plane) showed little difference in the behaviour of the models with shear links.

Thus, it is recommended to consider the behaviour of the transverse joint reinforcement, especially for squat walls governed by shear deformation. The provision of edge lips leads to reduced strength, and hence not recommended in high seismic areas.

7. References

[1] Priestley, M. J. N., (1991), "Overview of PRESSS Research Program", *PCI Journal*, July/Aug, 50-57.

[2] Englekirk, R. E., (1982), "Overview of ATC Seminar on Design of Prefabricated Concrete Buildings for Earthquake Loads", *PCI Journal*, Jan/Feb, 80-97.

[3] Cholewicki, A., (1971). "Loadbearing Capacity and Deformability of Vertical Joints in Structural Walls of Large Panel Buildings", *Building Science Journal*, 6(4), 163-184.

[4] Abdul-Wahab, H. M. S., and Sarsam, S. Y. H., (1988). "Strength of Vertical Plane Joints between Large Precast Concrete Panels", *The Structural Engineer*, 66(14), 211-215.

[5] Rossley, N., Aziz, F. N. A. A., Chew, H. C., and Farzadnia, N., 2014. "Behavior of Vertical Loop Bar Connection in Precast Wall Subjected to Shear Load", *Australian Journal of Basic and Applied Science*, 8(1), 370-380.

[6] Chakrabarti, S.C., Nayak G.C., and Paul D.K., (1988). "Shear Characteristics of Cast in Place Vertical Joints in Story High Precast Wall Assembly", *ACI Structural Journal*, 85(S4), 30-45.

[7] Chatveera, B., and Nimityongskul, P., (1994). "Vertical Shear Strength of Joints in Prefabricated Loadbearing walls", *J. Natl. Res. Council Thailand.* 66(1). 11-36.

[8] Ciuhandu, G., and Stoian, V., 1991. "Design of Vertical Joints in Precast Reinforced Concrete Shear Walls", IABSE Reports, 62, 778-784.

[9] Sørensen, J. H., Hoang, L. C., Fischer, G., and Olesen, J. F., 2015. "Construction-Friendly Ductile Shear Joints for Precast Concrete Panels", *Proceedings of the Second International Conference on Performance-based and Life-cycle Structural Engineering.*

[10] Abdul-Wahab, H. M. S., and Sarsam, S. Y. H., (1991). "Prediction of Ultimate Shear Strength of Vertical Joints in Large Panel Structures", *ACI Structural Journal*, 88(2), 204-213.

[11] Rizkalla, S. H., Serrette, R. L., Hevel, J. S., and Attiogbe, E. K., (1989). "Multiple Shear Key Connections for Precast Shear Wall Panels", *PCI Journal*, Mar/April, 104-120.

[12] SAP 2000, Version 18, CSI Analysis Reference Manual (2015), Computers and Structures, Inc., USA.

[13] IS 456: 2000, "Indian Standard Code of Practice for Plain and Reinforced Concrete", Bureau of Indian Standards, New Delhi.

[14] Biswal, A., (2015). "Experimental Investigation and Prediction of Shear Behaviour of Vertical Joints between Precast Concrete Wall Panels", M. S. Thesis, Department of Civil Engineering, Indian Institute of Technology Madras, Chennai.