Shear Strength of the Groove of Precast Concrete H-Posts

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Abstract

The precast concrete market is increasing globally with an estimated economy of 107.83 billion US dollars in 2018 and a growth rate of 5.7%. Boundary wall is one of the popular applications of precast concrete. H-posts used in boundary walls have plain concrete grooves and their shear strength is not studied well. While theoretical shear resistance of the groove based on concrete codes is greater than the likely wind load, this study experimentally validates the shear strength of such grooves by performing structural testing. Five test series with two repetitions are tested. Two grades of concrete are tested with plain grooves and grooves having reinforcement studs. Shear resistance of the grooves is at least 8 times greater than the maximum wind load. The ultimate failure occurs at the stem of the grooves for the plain concrete grooves, but panels fail in bearing for the specimens with shear studs at grooves.

Keywords: *boundary wall, concrete groove, H-post, precast concrete, shear strength*

Introduction

With an unprecedented growth of infrastructure development, precast concrete elements have been increasingly used all over the world. Precast concrete market size was estimated as 107.83 billion US$ in 2018 and is forecasted to reach 168.17 billion US$ by 2026, maintaining an annual growth rate of 5.7% (Reports and Data, 2019). The Asia Pacific region held the largest market share of 31% in 2018 largely owing to the demand of precast concrete in infrastructure and construction industry in emerging economies, including China and India (Reports and Data, 2019). This has led to substantial investments in the research and development of precast concrete technologies. Both structural and non-structural members are constructed using precast concrete.

Structural elements include large structures such as bridge girders, dam elements, building frame structures, hollow core slabs, road pavements, and soldier pile walls with precast piles and panels. Similarly, minor structures such as boundary (compound) walls are quite popular precast concrete applications. Such walls are made by erecting a series of H-posts (also called intermediate posts) and corner posts at a typical spacing of, say, 1.5 to 3 m, and inserting precast concrete panels on the grooves of the posts. A photograph of a typical boundary wall constructed using H-posts and panels is shown in Figure 1. The walls are primarily designed for lateral forces including wind loads. The load from the panels is transferred to the posts and in doing so, the grooves of the panels are subjected to shear forces.

Shear strength of concrete has been extensively investigated since long. Various codes have provisions about the shear strength of plain and reinforced concrete (e.g., ACI 318-19 (American Concrete Institute, 2019) and IS 456:2000 (Bureau of Indian Standards, 2000)). As the shear strength of plain concrete is relatively low and also the shear failure mode is brittle, structural elements are often designed by using shear reinforcement. Particularly with improved understanding of seismic loads, beams and columns are almost invariably provided with shear reinforcement. However, the groove of boundary walls has no reinforcement, and the situation is that of a plain concrete groove resisting the structural loading. While codes and standards, such as those by American Concrete Institute (2019) and Precast/Prestressed Concrete Institute (2010), include provisions for the shear design of girders, piers, beams, columns or slabs, clear guideline about the design of plain concrete grooves is not available. Even though grooves are common in gates of water retaining and regulating concrete structures, the supporting concrete is usually thick and it is often designed as reinforced concrete with provision of dowel bars and secondary reinforcement (Bureau of Indian Standards, 1984). Therefore, shear resistance of the plain concrete grooves of H-posts should be thoroughly investigated.

Figure 1: Boundary wall constructed with H-post and panels

Posts are mostly designed as cantilever columns resisting bending moment, and panels are designed as one-way slabs supported on the posts. An almost similar structural arrangement exists in soldier pile walls (also called lagging walls) that are used to retain earth mass. Akmilah et al. (2014) recently proposed a cost effective precast concrete soldier pile wall system in which the bending moment and shear strength of the pile section was considered. While studies have focused on the flexural strength and design procedure for the posts, shear strength of grooves is hardly reported in the literature. It should be noted that, Zhang et al. (2016) extensively reviewed the shear transfer mechanism and suggested that most current approaches to predict shear capacity are empirical and should only be used within the bounds of the testing regimes from which they were derived. This indicates that shear strength of plain concrete grooves should be ascertained by experimentally testing the grooves. As the market of precast concrete boundary wall products is expanding in developing countries, clients of the precast manufacturers have shown concerns about the shear strength of the concrete grooves as the grooves are free of any reinforcement. Theoretical calculations alone were inadequate to convince clients and it appeared essential to demonstrate the strength of grooves by performing real scale tests. This study presents an experimental study that tests the grooves of H-posts for their shear capacity. Shear strength of the plain concrete from the test is compared with the theoretical strength calculated based on codes (American Concrete Institute, 2019; Bureau of Indian Standards, 2000). Different grades of concrete and different depths of groove are investigated. Moreover, as a possibility to increase the shear capacity of the groove, grooves with reinforcement studs are studied to shed light on the role of such reinforcement. Failure pattern as observed in the experiment is discussed. This study experimentally demonstrates the adequacy of the grooves to resist the maximum likely wind loads. Moreover, as the H-post and panel system is sometimes used to construct low-cost sheds (Figure 2) for residential and commercial use, this study will provide some guidance towards safe construction practices for such sheds.

Figure 2: A shed constructed using H-post and panels

Materials and Methods

H-Post

Figure 3 shows the geometry of the H-posts considered in this study. For the experimental study, the loaded length of the H-post specimens was 600 mm. The posts were cast in a precast concrete plant and the cross-section used in the plant was chosen for this study. Accordingly, the cross section was 150 mm × 150 mm. The posts were longitudinally reinforced with four 4.75 mm diameter reinforcing steel. The posts comprised two grooves of size 30 mm × 60 mm throughout their length on two opposite faces. While H-posts in the plant are cast (compressive strength of concrete ≥30 MPa) by using an extrusion machine, the posts used for the experimental study were cast manually by using wooden formworks. Therefore, stirrups made of 4.75 mm diameter steel were used at the ends and center of the posts to hold the longitudinal bars in position as shown in Figure 3. Posts were demolded after two days of casting and were cured with wet burlap for 28 days.

Three variations of H-posts were tested. Type A comprised the groove depth of 30 mm. Type B comprised the groove depth of 10 mm, which was attained by partly filling the 30 mm deep grooves. Type C included reinforcement studs projecting to the grooves from the shear stirrups as shown in Figure 4. For the type C H-posts with reinforcement studs, the stirrups were provided at a spacing of 100 mm. They were provided such that the reinforcement studs were spaced at 400 mm center to center. The groove to be tested comprised two studs, which would support the shear force through the dowel action.

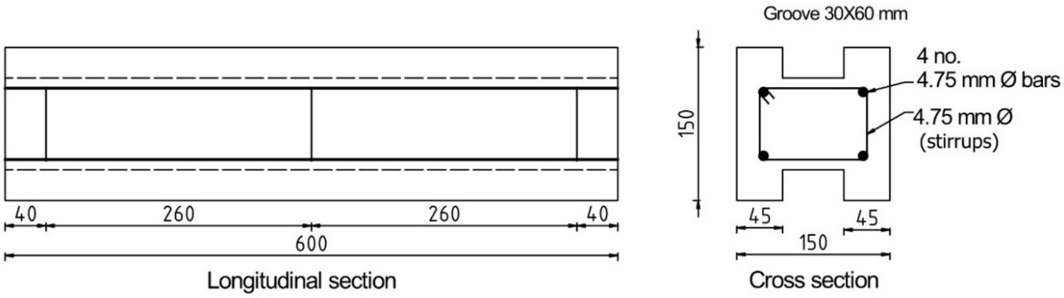

Figure 3: Groove and longitudinal reinforcement in H-posts (all dimensions are in mm)

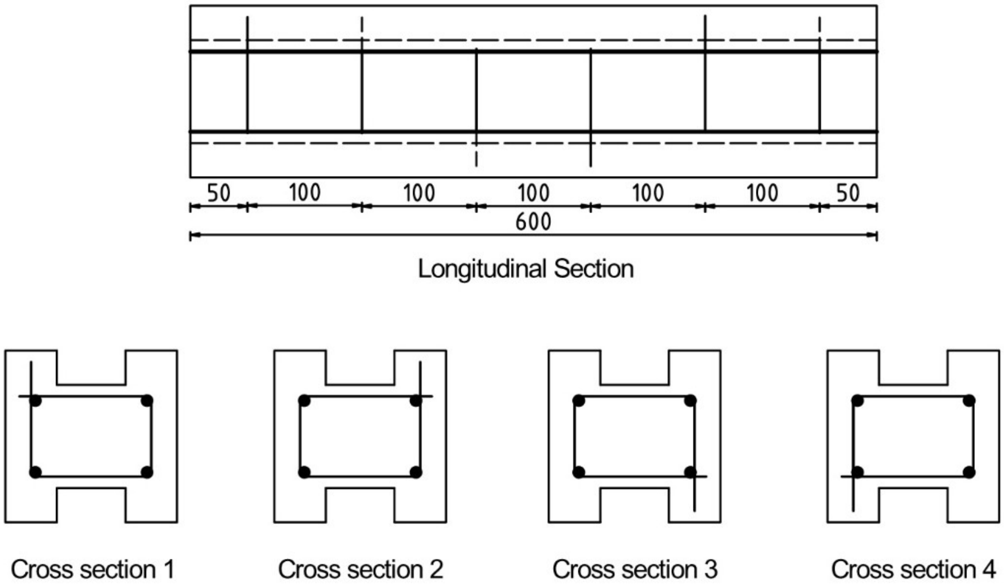

Figure 4: Reinforcement stud arrangement in Type C H-posts (all dimensions are in mm)

Precast Panels

Precast panels considered in this study were 300 mm wide and 50 mm deep as shown in Figure 5. The panels were continuously cast in the precast plant by using an extrusion machine and cut to the desired lengths. Concrete mixture was designed to achieve the concrete compressive strength of 30 MPa. The casting method utilized a dry cast method of mixing with water to cement ratio of 0.3. The casting machine had built-in vibrating and compacting assemblies. The length of the panels for the test was taken as 880 mm. The panels comprised five numbers of 4.75 mm diameter longitudinal reinforcement and no cross-sectional reinforcement. The panels had four 20 mm diameter hollow cores. All the panels were cured with wet burlap for 28 days.

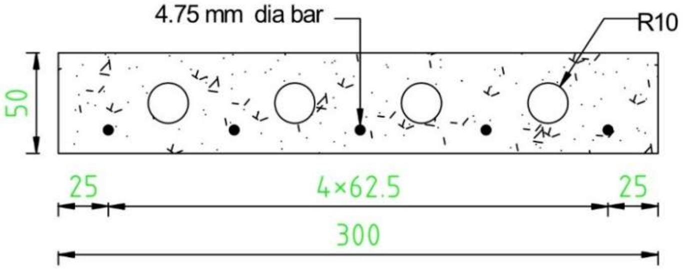

Figure 5: 50 mm thick precast panel (all dimensions are in mm)

Concrete mixture

H-posts were cast by using two strength grades of concrete, namely, M15 and M30 grade concrete with nominal compressive strength of 15 and 30 MPa, respectively. It should be noted that these grades are taken as nominal experimental variables and do not necessarily comply with the structural concrete requirements and the characteristic strength criteria set by concrete standards. Ordinary Portland cement of grade 43 based on Nepal Bureau of Standards and Metrology (2020) was used for the concrete mixture. Locally available river sand and crushed aggregate, supplied by aggregate suppliers, were used. The sand was washed river sand and had particle size finer than 4.75 mm. The coarse aggregate was crushed river boulders and the size was less than 12.5 mm. No supplementary cementitious materials or admixtures were used. Steel with ultimate tensile strength of 500 MPa was used as the reinforcing steel. Table 1 shows the mixture proportions and the compressive strength for the two grades of concrete. Compressive strength was obtained by testing concrete cubes of size 150 mm at 28 days.

Table 1 Mixture proportions and compressive strength of concrete

Concrete grade	Mixture proportion (kg per m^3)				28-day cube compressive strength (MPa)
	Cement	Sand	Coarse aggregate	Water	
M15	337	646	1170	186	14.78±0.20
M30	415	620	1123	186	33.79±0.21

Specimen configuration and Preparation

Five series of boundary wall specimens with two repeats (total ten specimens) were tested in this experimental study. Table 2 shows the designations and details of the five-test series. Series 1 and 2 were cast using M15 grade concrete and the remaining three series were cast using M30 grade concrete. Grooves were designated as reinforced and plain depending on whether a stud was projected to the groove or not. While series 1 to 4 had a groove depth of 30 mm, a fifth series was designed with a groove depth of 10 mm to simulate a gap arising from factors such as construction tolerance, misalignment, or settlement of the posts. Therefore, a designation PG-M30-1T indicated a specimen with plain groove and cast with M30 grade concrete. The last number after the hyphen indicated the repeat number and the letter ‘T’ represented ten mm depth of groove instead of the typical 30 mm groove depth.

Each test specimen was prepared as a set of two H-posts supporting concrete panels on their grooves as shown in Figure 6. The test specimens were tested by positioning the boundary wall in a horizontal plane, that is, rotated 90° when compared to the field orientation. The length of H-posts was 600 mm along the direction perpendicular to the plane shown in Figure 6. The loading length of 600 mm was maintained by using two panels. H-posts were placed on the support (flange of an I section) by maintaining the projection of the end of the groove as 45 mm. The H-posts were fixed on the support by using a pair of angle sections connected through two bolts. This arrangement was used to simulate the fixity of H-posts provided by the ground in actual boundary walls. As shown in Figure 6, the specimens were loaded using two-line loads (length 600 mm) with a spacing of 690 mm. The line loads were applied through a pair of steel tubes of cross-section 90 mm × 90 mm × 5.54 mm that distributed the load from the piston of a hydraulic jack on either side. The steel tube was placed 15 mm away from the groove edge of the H-post. Rubber pads were used under the steel tube to uniformly distribute the load along the loading area.

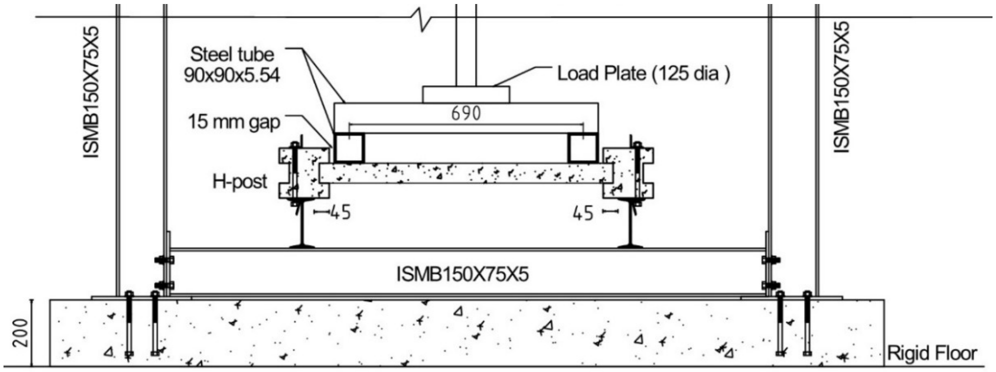

Figure 6: Specimen loading and support condition

Table 2 Specimen designation and details

Test series	**Specimen designation**	**Concrete grade**	**Groove depth**	**Groove type**
1	PG-M15-1	M15	30 mm	Plain

Test series	Specimen designation	Concrete grade	Groove depth	Groove type
	PG-M15-2			
2	RG-M15-1			Reinforced
	RG-M15-2			
3	PG-M30-1	M30		Plain
	PG-M30-2			
4	RG-M30-1			Reinforced
	RG-M30-2			
5	PG-M30-1T		10 mm	Plain
	PG-M30-2T			

Test apparatus and load test set up

The test was performed at the loading frame of a precast concrete plant in Chitwan, Nepal. In order to set up a specimen in the loading frame, initially one H-post was clamped in position atop a flange of the supporting I-section (Figure 6). Another H-post was placed on the opposite flange and partially clamped. Two precast panels were inserted into the grooves from either end of H-posts. The panels were centered and levelled, and the partially clamped H-post was clamped to the desired position.

Specimens were tested under a monotonic load. A manually controlled hydraulic jack of load capacity 500 kN was used for loading. The jack comprised a piston, a hydraulic oil drum and an analog dial gauge with a least count of 2 kN. At every loading interval of 2 kN, specimens were carefully observed for any visible cracks and the cracks were marked. Load corresponding to the initial crack and the ultimate failure were recorded.

Experimental results

Ultimate load capacity

Table 3 shows the ultimate load capacity for the five series (with two specimens per series) as obtained from the test. The load capacity of an individual specimen was within 4% of the average value for the two specimens of a given series, thus ensuring good repeatability. Table 3 also shows the nominal shear stress experienced by the groove of the H-posts corresponding to the ultimate loads. The nominal shear stress (τ) was calculated as,

$$\tau = \frac{P}{2\times b\times d} \qquad (1)$$

where b is the width of the two loading panels (600 mm) and d is the depth of the groove (45 mm). Factor 2 in Eq. (1) represents the two loading lines that shared the total applied load (*P*).

Table 3 shows that the ultimate load capacity for the PG-M15 (average concrete compressive strength of 14.8 MPa) and PG-M30 (average concrete compressive strength of 33.8 MPa) series are approximately identical indicating no influence of the grade of concrete for this particular comparison. With the provision of reinforcement studs, RG-M15 series showed 15% improvement in the load capacity when compared to PG-M15 series. Similarly, RG-M30 series showed 86% increase in the load capacity when compared to the PG-M30 series. While load capacity was improved due to the provision of reinforcement studs for both M15 and M30 grades of concrete, a larger increase was observed for M30 grade concrete. For the specimens with reinforcement studs, the improvement in strength for M30 grade concrete (RG-M30 series) was 59% when compared to M15 grade (RG-M15 series). For the fifth series PG-M30-T with the depth of groove as 10 mm, the ultimate load capacity was approximately 8% higher compared to the PG-M30 series.

Table 3 Ultimate load capacity of the specimens

Test series	**Specimen**	**Ultimate load of individual specimen (kN)**	**Ultimate load of test series (average of two specimens) (kN)**	**Nominal shear stress at the groove (MPa)**
1	PG-M15-1	62	60	1.11
	PG-M15-2	58		
2	RG-M15-1	70	69	1.28
	RG-M15-2	68		
3	PG-M30-1	60	59	1.09
	PG-M30-2	58		
4	RG-M30-1	114	110	2.04
	RG-M30-2	106		
5	PG-M30-1T	68	66	1.22
	PG-M30-2T	64		

Apart from the estimation of ultimate load and nominal stress at the groove, displacements were recorded for each monotonic load application. The recorded displacements at each load increment are shown in Figure 7.

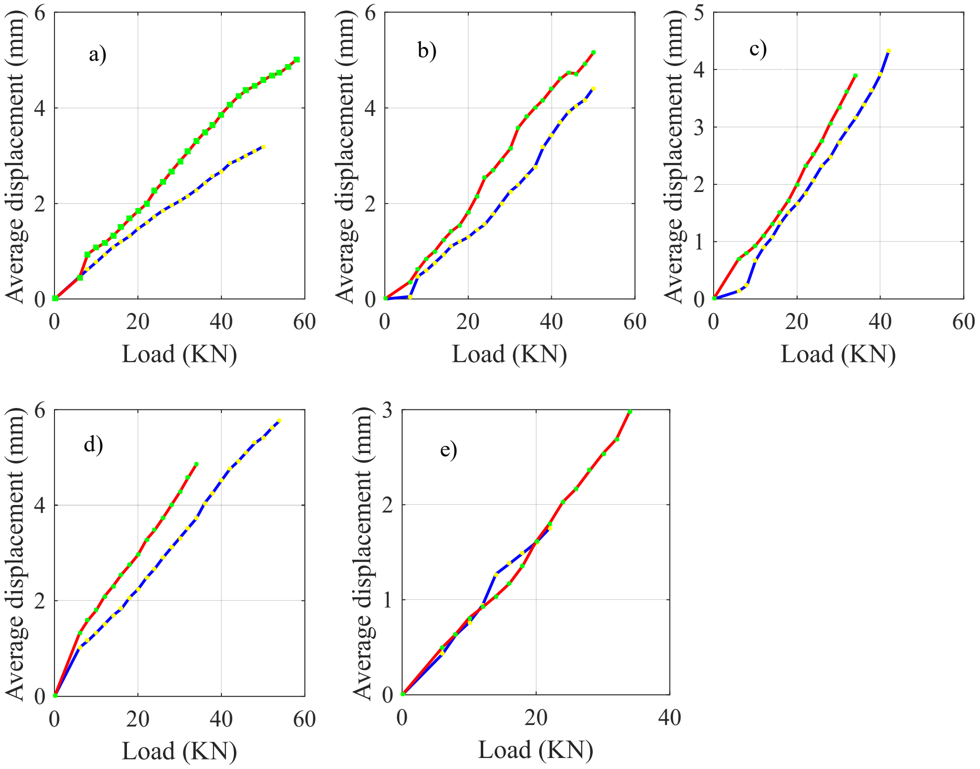

Figure 7: Load displacement plots for: a) PG-M15-1 (blue) and PG-M15-2 (red), b) RG-M15-1 (blue) and RG-M15-2 (red), c) PG-M30-1 (blue) and PG-M30-2 (red), d) RG-M30-1 (blue) and RG-M30-2 (red), e) PG-M30-1T (blue) and PG-M30-2T (red)

In Figure 7, displacements for both specimens are presented, and the trend is mostly similar. While decreasing the depth of the groove from 30 mm to 10 mm, displacement was reduced by 12% in average. This indicated that the shorter groove depth showed larger stiffness as anticipated. Displacement was not very much controlled by the concrete grade.

Failure modes

Figure 8 (a-j) shows photographs of the 10 test specimens after failure. In PG-M15 specimens, no initial crack was observed before the groove failed in shear. The failure was sudden, and the failure plane was at the stem of the groove as shown in Figure 8 (a and b). The failure surface was rough and occurred in one of the H-posts.

With shear studs, RG-M15 specimens exhibited an initial crack in panels before the specimens completely collapsed. The initial crack in the panel was observed at 80% to 85% of the ultimate load. The specimen collapsed with the failure of panels as shown in Figure 8d. Cracked surface was inclined at an angle of about 500 with the horizontal surface. Upon removal of the failed panel after the test, a longitudinal crack was observed on the H-post approximately 10 mm from the stem of the groove (Figure 8c).

Similar to the PG-M15 specimens, PG-M30 specimens exhibited the failure of groove from the stem as shown in Figure 8e and 8f. No initial crack was observed, and the failure was brittle. The rupture occurred throughout the length of the H-post groove. However, the rupture surface was smoother when compared to the PG –M15 and RG-M15 specimens.

With shear studs, the RG-M30 specimens exhibited the maximum value of the ultimate load among the test specimens. At approximately 90% of the ultimate load, an initial crack was observed in the test panels for both specimens of this series. It occurred approximately 140 mm from the stem of the groove. The ultimate failure was observed in the form of panel failure for RG-M30-1 specimen and in the form of groove failure for RG-M30-2 specimen`. Moreover, local failure was observed in the edge of the panels in an arch shape at a distance of 60 mm.

For the shallower (10 mm) depth of groove, PG-M30-T specimens exhibited no cracks of the grooves, and the specimens failed in the form of panel failure. The initial crack was observed at approximately 80 to 85% of the ultimate load. No slippage was observed before the panel failure even though the groove was relatively shallow, and slippage could have happened.

a. PG-M15-1

b. PG-M15-2

c. RG-M15-1

d. RG-M15-2

e. PG-M30-1

f. PG-M30-2

g. RG-M30-1

h. RG-M30-2

i. PG-M30-1T

j. PG-M30-2T

Figure 8: Photographs of test specimens at failure

Discussions

Failure modes

The ultimate load value and the failure pattern suggest that PG-M15 (average concrete compressive strength of 14.8 MPa) and PG-M30 (average concrete compressive strength of 33.8 MPa) specimens failed owing to the relatively lower shear strength of the plain concrete of H-posts. The panels remained intact. The failure pattern was similar in PG-M15 and PG-M30 specimens except that the latter exhibited a relatively finer failure surface. The rough failure surface in PG-M15 specimens is attributed to the relatively larger quantity of coarse and fine aggregates in ordinary grade M15 concrete as shown in Table 1.

The reinforcement studs were quite effective in enhancing the load capacity of the grooves. Ultimate load capacity of RG-M15 specimens was increased by 15% when compared to the PG-M15 specimens and that of RG-M30 specimens by 86% when compared to the PG-M30 specimens. After concrete cracking, the shear force carried by a member without shear reinforcement is resisted as a combination of three factors, namely, concrete compression zone (V_c), aggregate interlocking (V_a), and dowel action (V_d) provided by the longitudinal reinforcement (American Concrete Institute, 2019). Kim & Park (1997) concluded that the contribution of V_d, V_a and V_c was, respectively, 15-25%, 33-50% and 20-40%. The main factors influencing the dowel action are flexural rigidity of longitudinal bars and the strength of the surrounding concrete (Kim & Park, 1997). For the groove, the reinforcement stud designed in this study served as a longitudinal bar of a typical beam. The stud enhanced the shear resistance of the groove through the dowel action as shown by the experimental results. Furthermore, the higher strength of M30 grade concrete compared to the M15 grade concrete was seen to increasingly enhance the dowel action of the studs (Kim & Park, 1997).

Increased shear strength of the grooves caused the panels to crack. Particularly for the RG-M15 specimens (and also for the RG-M30-2 specimen), it should be noted that the groove of the H-posts was also damaged along with the damage of the panels. Due to the presence of reinforcement studs, the groove in RG-M15 specimens failed not at the stem but approximately 10 mm away from the stem. The outer portion of the groove failed to provide any bearing to the panel and only the end part of the panel was subjected to a concentrated bearing stress. This stress caused the panels to fail in bearing. Therefore, the panels, which resisted a larger load of say 100 kN in RG-M30 specimens, failed in bearing at a load of approximately 60 kN.

PG-M30-T specimens with a shallower groove resisted a larger load compared to the PG-M30 specimens. While shear deformation at the joint and the bending deformation of the panel were not measured experimentally, the shallower groove was free from flexural tensile stress at the top part (inner corner) of the groove and hence the capacity of the PG-M30-T specimens was larger compared to the PG-M30 specimens. Because of the relatively narrow bearing area, the panels failed in bearing following the mechanism similar to the RG-M15 specimens explained above. This study aimed to check whether the groove was too short for the panels to slip from the H-posts. However, no slippage was observed. Thus, when the panels do not experience any substantial bending, even a depth of 10 mm appears adequate to support the panels. Moreover, the condition of no slippage validated the loading arrangement of this study that it would not introduce any significant bending of the panels. Nevertheless, from practical considerations of construction, 30 mm groove is safer.

Load capacity

Exposure to wind load

Boundary walls are subjected to wind loads in the lateral direction. As an example, a boundary wall is considered in the Indian sub-continent and the extreme wind load is estimated based on the Indian standard (Bureau of Indian Standards, 1987). The design wind pressure (p_z) is calculated as:

$$p_z = 0.6 \times (k_1 k_2 k_3 V_b)^2 \qquad (2)$$

where k_1, k_2 and k_3 are the multiplication factors that can be taken as 1.0, 1.05 and 1.36, respectively, by considering terrain category as 1, class of structure as *A* and the slope of terrain such that the factor will become the maximum. V_b is the basic wind speed and is taken as 55 m/s, which is the maximum among the available options. This gives the design wind pressure of 3.7 kN/m2. For a boundary wall with H-posts spaced at 3 m, each panel will apply a lateral load of 1.67 kN to the groove of a H-post. The load of 1.67 kN is equivalent to a nominal shear stress of 0.12 MPa. Since all the specimens resisted a nominal shear stress of at least 1.09 MPa as shown in Table 3, the groove of the H-post is safe to be used for boundary walls with a large factor of safety (> 8.8).

Theoretical capacity based on code provisions

Concrete standards such as ACI 318-19 (American Concrete Institute, 2019) and IS 456:2000 (Bureau of Indian Standards, 2000) do not have specific provisions for the shear strength of a concrete groove typical to the H-posts. Since the groove does not have shear reinforcement, it may be assumed as a concrete beam with no shear reinforcement. For this condition, according to the ACI 318-19 (American Concrete Institute, 2019), concrete sections can be waived for shear reinforcement when the shear force (V_c) satisfies the following condition:

$$V_c \leq 0.083\Phi\lambda\sqrt{f_c}\ b_w.d \qquad (3)$$

where V_c is the factored shear force (in N), b_w and d are, respectively, the width and the effective depth of the member in mm, and fc is the specified compressive strength of concrete in *MPa*. For high-strength concrete, the term $\sqrt{f_c}$ is limited to a value of 8.3 *MPa*. Factor Φ is the strength reduction factor recommended as 0.75 for shear, and λ is the modification factor that is taken as 1 for normal weight concrete.

As per IS 456:2000 (Bureau of Indian Standards, 2000), concrete sections of minor structural importance can be waived for shear reinforcement when the shear force satisfies the following condition:

$$V_c \leq 0.5\,\tau_c * (b_w * d) \qquad (4)$$

where τ_c is the design shear strength of concrete taken as 0.28 MPa and 0.29 MPa, respectively for M15 and M30 concrete.

For the test specimens with b_w taken as 600 mm and d taken as 45 mm, maximum permissible shear force calculated using Eq. (3) and (4) are presented in Table 4. It should be noted that the force taken by two panels on both ends of the panels is shown in Table 4 for comparison with the experimental load.

Table 4 shows that theoretical shear capacity is greater than the maximum likely wind load, and hence, the grooves of H-posts are safe against wind loading. Moreover, the minimum experimental load capacity obtained from the test is at least 3.2 times larger than the code-based theoretical shear capacity specified for design context. Hence, shear force of grooves should not be a concern in the design of boundary walls using concrete H-posts as investigated in this study.

Table 4: Comparison of experimental capacity, theoretical capacity, and the maximum likely wind load in the test series

SN	**Test series**	**Experimental capacity (kN)**	**Theoretical capacity (kN)**		**Maximum probable wind load (kN)** (Bureau of Indian Standards, 1987)
			IS 456:2000	**ACI 318, 2019**	
1	PG-M15	60	7.56	13.02	6.66
	RG-M15	69	7.56	13.02	
3	PG-M30	59	7.83	18.41	
4	RG-M30	110	7.83	18.41	
5	TPG-M30	66	7.83	18.41	

Conclusions

This study conducted structural testing of boundary walls constructed using precast concrete panels and H-posts. Five test series with two sample repetitions were tested to investigate the shear resistance of the concrete grooves of the H-posts. In order to check the possibility of strengthening the grooves, plain grooves and grooves with reinforcement studs were tested. Furthermore, a series was tested with a shallower groove depth (10 mm instead of the typical 30 mm). The following are the major findings:

- Theoretical shear resistance of the groove based on concrete codes was larger than the maximum likely wind load, and the experimental shear resistance of the groove was at least 8.8 times larger than the maximum likely wind load. Therefore, shear strength of grooves is not a concern in the design of boundary walls as investigated in this study.
- Ignoring other performance requirements, adequate shear resistance of grooves was provided even by the weaker grade of concrete (M15).
- When compared to the plain concrete grooves, reinforcement studs improved load capacity by 15% and 86%, respectively, for M15 and M30 grade concrete. However, sufficient strength of plain grooves suggested that reinforced studs are not necessary.
- For the test series with plain grooves, the ultimate failure occurred at the stem of the grooves. However, for the grooves with reinforcement studs, the failure pattern was changed: bearing failure of the panels was observed.

- The groove depth of 30 mm was found sufficient. Even a shallower groove depth of 10 mm did not cause any slippage. Nevertheless, from practical considerations of construction, 30 mm groove is safer.
- It is concluded that displacement is less likely to be affected by the variation of concrete grade. However, reduction in groove depth is found to be effective in checking displacement.

Conflict of interest

Authors declare no conflict of interest.

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