Experimental Investigation of Precast Horizontal Wall Panel Connection using Reinforcement by Push off Test

M Ashok Kumar[1] J S Princes Thangam[2] Dr. V Govindharajan[3]
[1]P.G Student [2]Assistant Professor [3]Chief Engineering Manager
[1,2]Easwari Engineering College, Ramapuram, Chennai-600089
[3]L&T Construction Pvt. Ltd, Chennai-600089

Abstract— The precast concrete shear wall system is very important for construction due to economic advantages in the speed of construction. The connections between panels are extremely important since they affect both the speed of the erection and the overall integrity of the structure. This project deals with the experimental study of shear transfer in precast concrete wall panels using dowel action and shear friction concept. The horizontal connection of the wall panels is considered in this project. This project is completely done referring to Indian Standard Codes. This paper describes the analytical and experimental behavior of precast wall panel with the horizontal connection. Dimension of the panel is 500mm x 400mm x 100mm and M35 grade of concrete has to be used. The primary purpose of this project is to derive an equation relating the transfer of loads through shear friction action to dowel action, to obtain a connection to resist both gravity loads and lateral shear and to validate the wall panel connection using dowel bar by conducting push off test. The dowel bar is provided with a diameter of 12 mm is used to connect the two panels. The development length (Ld) of the bar is provided with varying in size as 300 mm, 400 mm, 600mm and the behavior of the connection is studied. Analytical study will be done using ABAQUS 6.12 software.
Key words: Precast concrete shear wall, Shear transfer, Dowel action and Shear friction concept, Horizontal connection, Gravity loads and Lateral shear, Development length

I. INTRODUCTION

Precast concrete walls provide an excellent envelope for low-rise commercial and industrial buildings. They are relatively easy to manufacture, structurally efficient, durable, and attractive. Precast concrete walls are also extremely energy efficient when built with insulation. In addition, their desirability to the owner and design professionals can be increased tremendously if they provide lateral-load resistance. The focus of this paper is to develop a connection by using the reinforced bar connection of the two panel in the concept of dowel action and shear friction.

Precast load bearing shear wall panels are used extensively for high rise building construction, due to the high quality control that can be achieved with off-site fabrication, the reduction of construction time and consequently reduction in cost. In addition, precast concrete construction is seldom interrupted by adverse weather condition. The precast concrete load bearing shear wall panels arranged in both the longitudinal and transverse directions of the building is to resist the lateral loads.

The major difference between the longitudinal and transverse shear walls is mainly the type of horizontal connection. Transverse shear wall are normally used to support the hollow core slab of the floor system, whereas the longitudinal shear walls run parallel to the hollow-core slab and do not include the hollow-core slab at their connection. The connections between the panels are extremely important. A well designed simple connection normally minimizes construction time, requires minimal false work and maintains the overall integrity of the structure.

II. BENEFITS OF PRECAST WALLS

The use of precast concrete in the construction of structure is beneficial in many ways. Since precast concrete is cast in a factory- like setting, the quality of construction is much higher than cast-in-place construction in which the concrete is cast at the job site. This is primarily attributed to the controlled setting in which the construction and the quality control takes place. The setting also increases the ability of the construction workers to accurately follow the design specification with a supervisor present, which is more readily available than an on-site inspector may be, to assist with quality control. The manufacturing process used for precast concrete also makes pre-stressing and placement of post-tensioning ducts more convenient. The equipment necessary for pre-stressing in precast plant is already set up for this type of operation to be performed easily and accurately while placement of the post-tensioning ducts is further simplified by casting walls horizontally and due to the improved quality in the construction of the reinforcement cages. Another more obvious advantage of precast concrete is the reduction in site formwork and site labor, caused by off-site pouring, which in turns increases the speed of on-site construction. Also, the availability of crane with increased capacity, new construction technique and off-site fabrication has made it easy for contractors to adapt to precast construction. There also many less obvious advantages of precast construction such as a decrease in traffic congestion, air pollution and noise pollution.

Precast construction has been described as the building process of the future. This is because the materials are relatively inexpensive, the method of construction, involving factory manufacture of component and rapid construction, lends itself to innovation in design and construction, and advanced technology including robotics and use of computer aided manufacture can be easily adapted to increase efficiency of the construction practice and erection procedures, ultimately reducing building costs.

III. OBJECTIVES

- The primary purpose of this project is to derive an equation relating the transfer of loads through shear friction action to dowel action.
- To obtain a connection to resist both the gravity loads and lateral shear.
- To validate the wall panel connection using dowel bar by conducting push off test.

IV. INFERENCE OF THE LITERATURES

The following inferences are made from the literature:

- The Dimensions of precast panels: 500mm x 400mm x 100mm
- The dowel bar is provided with a diameter of 12 mm is used to connect the two panels.
- The length of the bar is provided with varying in size as 300 mm, 400 mm and 600mm
- The behaviour of the connection is studied.
- The Spacing between the bars are 150 mm.
- Distance between the two panels are 20 mm

Cement	Fine Aggregate	Coarse Aggregate
383.3 kg/m³	682 kg/m³	1288kg/m³
1	1.78	3.36

Table 1: Mix Proportion

Mix Design for M35 Control Concrete = 1: 1.78: 3.36

V. CONCEPT OF THE CONNECTION

A. Dowel Action:

Dowel action occurs when a steel bar in a crack is subjected to a shear displacement. If there is sufficient cover on the reinforcing bar, a complex tri-axle state of stress occurs in the adjacent concrete to the bar. The ultimate resistance of this mechanism results essentially in yielding of the steel due to bending.

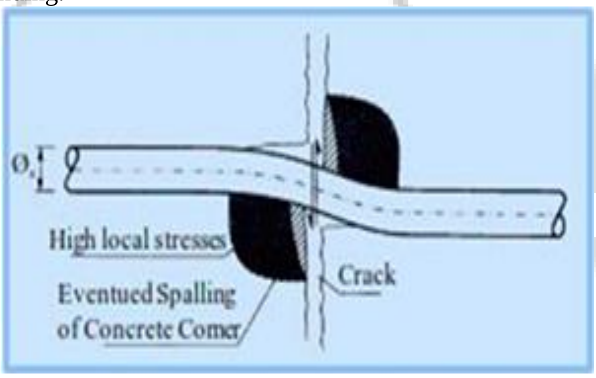

Fig. 1: Dowel Action

According to Cavaco, the shear strength of dowel action can be approached based on the analogy of a laterally loaded beam on a cohesive soil. Often, the crack associated to this mechanism generates tensile forces in the reinforcement bars, due to external actions or friction effect. The interaction of tensile forces and bending leads to a reduction of the maximum possible dowel action.

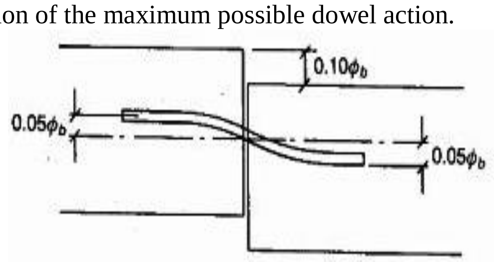

Fig. 2: Displacement of Panels

B. Shear Friction:

The mechanism of shear friction develops with the appearance of the first cracks and the consequent slip between interfaces. The friction force is a function of the normal force across the joint. To analyse and quantify this mechanism, one may use the shear friction model, original developed by Birkeland, or the aggregate interlock model, developed by Walraven and Reinhardt.

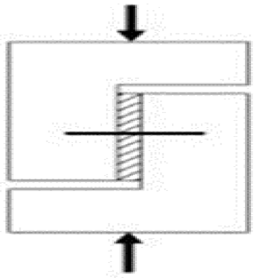

Fig. 3: Load Acting on Test setup

Both models are based on the same principle when two crack surfaces are forced to slide each other, a separation will occur. This separation causes the reinforcement to be stressed in tension, and thus a resisting compression force is developed. Thus, the shear will be resisted by friction between the two materials. The compression may be also due to an external force.

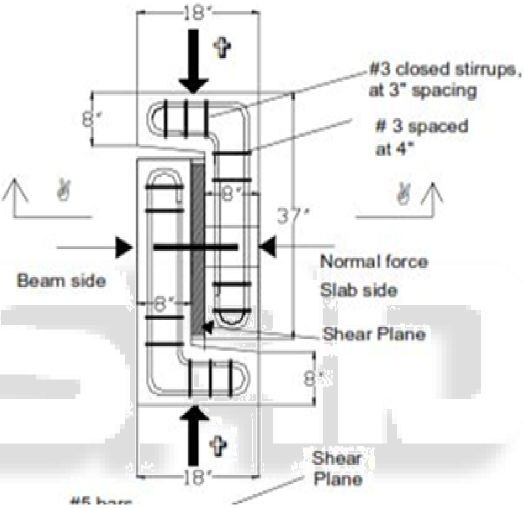

Fig. 4: Reinforcement details in panels

VI. DIMENSIONS OF PANELS

Dimensions of Precast Panels and Connection:
Size of precast panel – 600mm x 400mm x 100mm

A. Connection Parameters:

The dowel bar is provided with a diameter of 12 mm is used to connect the two panels. The length of the bar is provided with varying in size as 300 mm, 400 mm, 600mm and the behaviour of the connection is studied.

Diameter of Dowel bars - 12mm
Spacing between the bars - 150 mm
Distance between the two panels - 20 mm

B. Grouting Materials:

Fosroc Conbextra GP 2 is a ready mix dry power is used a grouting material to connect the panels.

Fosroc Conbextra GP 2 is a ready to use dry powder. The addition of a controlled amount of clean water produces a free flowing, non-shrink grout for gap thicknesses up to 100mm. Conbextra GP2 (T) is a blend of Portland cement, graded fillers and chemical additives which impart controlled expansion in the plastic state whilst minimising water demand. The low water demand ensures high early strength.

The graded fillers are designed to assist uniform mixing and produce a consistent grout.

Fresh wet density	2220kg/m^3
Young's modulus	28 kN/mm^2
Coefficient of thermal expansion	11 x 10^{-6}/ °C
Unrestrained expansion	2 - 4 % in the plastic state
Pressure to restrain	0.004 N/mm^2

Table 2: Properties of Grouting Material

VII. RESULTS AND DISCUSSIONS

A. *Compressive Test Of Concrete Cube:*

Test results of compressive strength of M35 grade concrete with a dimensions of 100mm x 100mm x 100mm concrete cube

Sample	Weight (Kg)	Yield Load (kN)	Strength (N/mm^2)
1	2.469	221.6	22.16
2	2.579	176.24	17.62
3	2.576	224	22.4

Table 3: 3rd Day Compressive Strength Of M35 Grade Cube

Sample	Weight (Kg)	Yield Load (kN)	Strength (N/mm^2)
1	2.570	330	33
2	2.558	332	33.2
3	2.525	332.8	33.30

Table 4: 7th Day Compressive Strength Of M35 Grade Cube

Sample	Weight (Kg)	Yield Load (kN)	Strength (N/mm^2)
1	2.532	457	47.5
2	2.57	442	44.2
3	2.466	468.8	46.80

Table 5: 28th Day Compressive Strength of M35 Grade Cube

B. *Compressive Test of Grouting Material:*

Test result of compressive strength of grouting material with the dimension of cube 40mm x 40mm x 40mm.

Sample	Weight (Kg)	Strength (N/mm^2)
1	0.291	68.125
2	0.294	64.38
3	0.303	78.75

Table 6: 7th Day Compressive Strength of Grouting Material

Sample	Weight (Kg)	Strength (N/mm^2)
1	0.296	82.5
2	0.294	93.5
3	0.303	94

Table 7: 14th Day Compressive Strength Of Grouting Material

Sample	Weight (Kg)	Strength (N/mm^2)
1	0.282	107
2	0.288	100
3	0.300	101.5

Table 8: 28th Day Compressive Strength of Grouting Material

C. *Non-Destructive Testing:*

The non-destructive testing are done for the same sample of cubes with M35 grade concrete with a dimensions of 100mm x 100mm x 100mm concrete cube The Rebound hammer test and the Ultra sonic Pulse Velocity test are done for the specimen to determine the Quality and Strength of concert

An ultrasonic pulse velocity test is an in-situ, nondestructive test to check the quality of concrete. In this test, the strength and quality of concrete is assessed by measuring the velocity of an ultrasonic pulse passing through a concrete structure. This test is conducted by passing a pulse of ultrasonic wave through concrete to be tested and measuring the time taken by pulse to get through the structure. Higher velocities indicate good quality and continuity of the material, while slower velocities may indicate concrete with many cracks or voids.

Rebound hammer test is done to find out the compressive strength of concrete by using rebound hammer as per IS: 13311 (Part 2) – 1992. The rebound of an elastic mass depends on the hardness of the surface against which its mass strikes. When the plunger of the rebound hammer is pressed against the surface of the concrete, the spring-controlled mass rebounds and the extent of such a rebound depends upon the surface hardness of the concrete. The surface hardness and therefore the rebound is taken to be related to the compressive strength of the concrete. The rebound value is read from a graduated scale and is designated as the rebound number or rebound index. The compressive strength can be read directly from the graph provided on the body of the hammer.

Test results for M35 grade concrete with a dimensions of 100mm x 100mm x 100mm concrete cube.

Sample	Density (Kg/m^3)	Rh	UPV (Ultra Pulse Velocity) (m/s)
1	2469	24.9	4729
2	2579	25.4	4729
3	2576	28.13	4729

Table 9: 3rd Day Test of M35 Grade Concrete Cube

Sample	Density (Kg/m^3)	Rh	UPV (Ultra Pulse Velocity) (m/s)
1	2750	31.17	5155
2	2558	33.25	5223
3	2525	31.1	5090

Table 10: 7th Day Test of M35 Grade Concrete Cube

Sample	Density (Kg/m^3)	Rh	UPV (Ultra Pulse Velocity) (m/s)
1	2532	31.17	5155

2	2570	33.25	5223
3	2466	31.1	5090

Table 11: 28th Day Test of M35 Grade Concrete Cube

D. Testing Of Panel with Horizontal Connection:

The precast wall panel with horizontal connection is done in a loading frame which has a hydraulic jack with a capacity of 50 tons. The push off test specimen casted with a connection dimension of 500mm x 400mm x 100mm. Strain gauges are placed in a connection to determine the strain values occur in the connection during the testing process. The LVDT is placed in the side of the panel to determine the deflection occur in the connection and the slip between the two panels are determined.

D-1.1 TEST RESULTS FOR PANEL HAVING Ld = 600 mm

Fig. 6: Failure in Connection

S.No.	Load	Deflection
1	0	0
2	58.4	2
3	100.5	10
4	150.4	16
5	175.5	24
6	179.2	25

Table 12- Load Vs Deflection Values

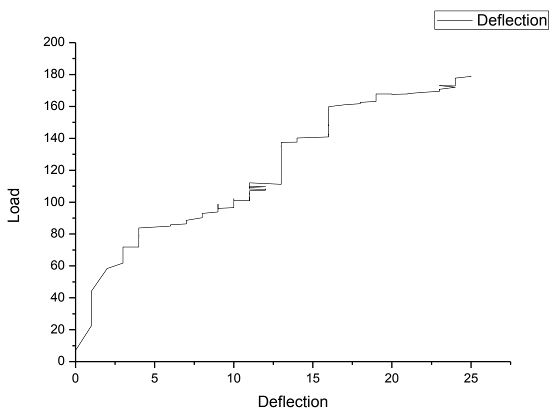

Fig. 7: Load Vs. Deflection Curve

VIII. Analytical Study

A. Abaqus-Introduction:

Abaqus / CAE, or "Complete Abaqus Environment" is a software application used for both the modelling and analysis of mechanical components and assemblies (pre-processing) and visualizing the finite element analysis result.

B. Analysis of Precast Panels

The concrete panel has been analysed by using Finite Element Software Abaqus CAE. The output diagrams are shown below.

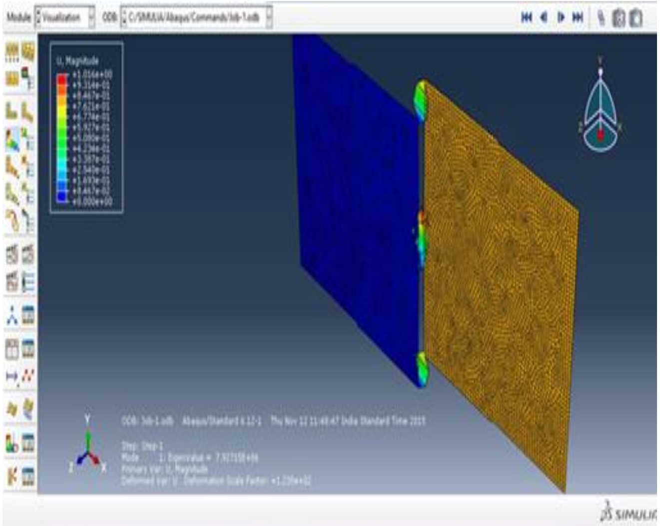

Fig. 8: Failure Pattern – Connection

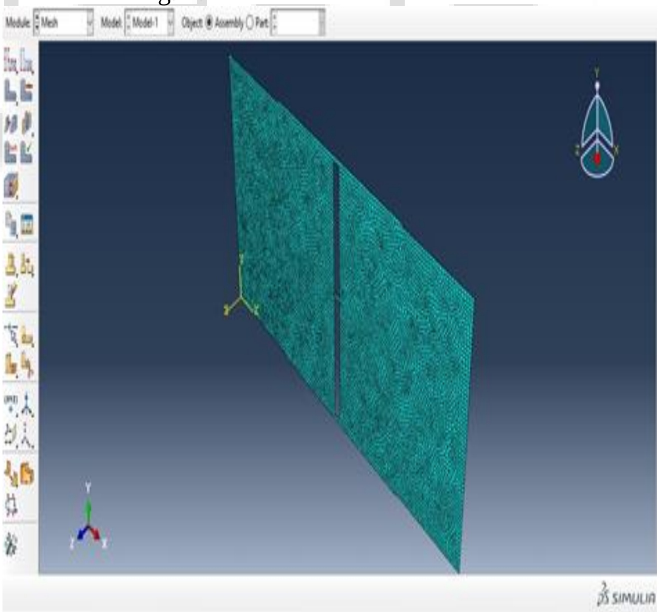

Fig. 9: Quad – dominated meshing

IX. Conclusion

Prototype Horizontal connections used for precast load bearing shear wall panel connections was casted and tested. From our study, the connections are not prone to loads above 200 kN for common buildings since only seismic forces alone affects the integrity of the horizontal connection. The provided dowel length for the connection is found to be more than the adequate and only a crack is found along the connection, which may be due to the bond failure between the grouting material and the panel material.

X. SCOPE AND FUTURE STUDY

This project can be carried out further:

- By reducing the dowel length.
- By reducing the reinforcement.
- For the different grades of concrete.
- By reducing the thickness of the panel.

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