Influence of Horizontal Reinforcement on Ultra High Performance Concrete Wall Panels under Two way in plane action

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Abstract— This paper presents the results of an experimental investigation carried out to determine the influence of horizontal reinforcement on the strength and behavior of Ultra High Performance Concrete (UHPC) wall panels under two way in plane action. The percentage of horizontal reinforcement adopted was 0.25, 0.45 and 0.65. Two wall panels were cast corresponding to each percentage of horizontal reinforcement and were tested under two way in plane loading. The test results show that the increase in ultimate strength is about 14.6% for a increase in horizontal reinforcement from 0.25 to 0.45% and beyond 0.45% of horizontal reinforcement the increase in strength was negligible. The increase in energy absorption capacity was about 48% for an increase in the percentage of horizontal reinforcement from 0.25 to 0.65%.

Index Terms— Crack pattern, Energy absorption, Load- deflection, Horizontal reinforcement, Two way, Ultra high performance concrete, Wall panels

1 INTRODUCTION

ADVANCES in the science of concrete materials have led to the development of a new class of cementitious material composites and Ultra High performance concrete (UHPC) is one among them. It is a material composed of an optimized gradation of granular constituents, a low water cement ratio and a high percentage of internal fiber reinforcement. The mechanical properties of UHPC include high compressive strength and sustained post cracking tensile strength. It has a discontinuous pore structure that reduces liquid ingress and significantly enhancing durability as compared to conventional and high performance concrete [9].

The concrete elements normally used for cladding and curtain wall applications have a substantial structural reserve strength which is not always recognized and utilized. With very little addition to the standard or specially designed shapes, the elements can easily be used as structural components, thus taking full advantage of the concrete section and the embedded reinforcing steel which otherwise is needed only for handling purposes [2],[10].

Architectural precast concrete wall panels that act as load bearing elements in a building are both a structurally efficient and economical means of transferring floor and roof loads through the structure and into the foundation. In building practice, the most economical application of architectural precast concrete is as load bearing structural elements.

Many studies have been conducted to study the strength and behavior of wall panels under one way in plane action [3]. These investigations showed that the different parameters which influence the ultimate strength include aspect ratio, slenderness ratio, and amount of steel in vertical and horizontal direction. Ruzitah Supinyeh and Siti Hawa Hamzah [11] carried out experiments on the structural behavior of steel fabric reinforced concrete wall panels under eccentric loading and described the failure patterns. Pillai and Parthasarathy [4] conducted study on the behaviour of panels with a central single layer of reinforcement and found that the influence of the steel ratios on ultimate strength was negligible. Saheb and Desayi [5],[6] conducted experimental studies on wall panels using two layers of reinforcement meshes in both directions and found that the ultimate strength of the wall panels increases with the increase in the vertical steel. A detailed comparative study on normal and high strength concrete wall panels was carried out by Doh [7]. He conducted studies on the slenderness ratio and aspect ratio of concrete wall panels using a single central layer of reinforcement mesh. Ruby et al. [8] worked on UHPC wall panels with varying thickness using a single central layer of reinforcement. The strength of wall panels depends on the concrete grade and percentage of steel used. This paper presents the results of experimental investigation conducted on six UHPC wall panels with varying percentage of horizontal reinforcement under two way in plane loading.

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2 EXPERIMENTAL PROGRAMME

The experimental investigations were carried out to find the effect of different percentages of horizontal reinforcement on the behavior of UHPC wall panels under two way in plane action. Six numbers of square wall panels of size 750 mm and 35 mm thickness were castand tested.

2.1 Materials

Ordinary Portland Cement (53 grade) conforming to IS 12269-1999 and fine aggregate less than 4.75mm size conforming to grading zone I as per IS 2386 (Part-III) -1973 having a specific gravity of 2.67 were used. Potable water conforming to the requirements of water for concreting and curing as per IS:456-2000 were used for the present investigation. Cement was replaced by the micro filler silica fume with a specific gravity of 2.2. Superplasticizer used was Conplast SP 430. Mild steel bars of 3mm diameter were used as reinforcement for wall panels.

2.2 Mix Proportions

UHPC mix proportion of M80 grade was developed using the modified ACI 211 method suggested by Aitcin [1] and the mix proportions are given in Table 1.

TABLE1
MIX PROPORTIONS OF UHPC

Particulars	Quantity (kg/m^3)
Cement	675
Sand	1356
Silica fume	75
Water	192
Superplasticizer	22

2.3 Reinforcement

The reinforcement in the form of rectangular grid, fabricated using 3 mm diameter steel bars, was placed in a single layer at mid-thickness of the panel. The yield strength of reinforcement steel was 250 N/mm^2. The percentages of reinforcement and spacing provided in the panels are given in Table 2.

TABLE 2
REINFORCEMENTDETAILS OF PANEL

Designation	% Reinforcement		Spacing (mm)	
	Horizontal	Vertical	Horizontal	Vertical
WP25	0.25	0.15	83	105
WP45	0.45	0.15	46	105
WP65	0.65	0.15	30	105

2.4 Casting of Wall Panels

Cement, sand and silica fume were mixed in dry state in drum type mixer machine. The required quantity of super plasticizer was added along with 50% water. Mixing was continued till a uniform paste was obtained. Then the mould was filled with concrete in two layers. The specimens were cast horizontally on a level floor. The two ends of the specimen were made wider for uniformly distributing the load and to obtain proper seating. The wall panels were moist cured with wet gunny bags for an initial period of three days and were then immersed in the curing tank. After 28 days of curing, the panels were taken out from the curing tank and were white washed and made ready for testing.

2.5 Experimental setup

Wall specimens were tested under two way in-plane loading. For measuring the deflection, dial gauge is positioned at the middle. In order to measure the deformation and to calculate the vertical strain, LVDT was used. The load setup, dial gauge and LVDT positions are shown in Fig. 1(a) and Fig. 1(b).

2.6 Testing of Wall Panels

After marking the positions of LVDT and dial gauge, the specimen was placed vertically on a 300 t compression testing machine. The vertical sides were supported to ensure hinged conditions on all the four sides. In order to transfer the load uniformly, a box section was kept on the top of the specimen.

After applying the seating loading, compressive load was applied at the interval of 50 kN and the dial gauge and LVDT readings were taken. The wall panel was loaded to failure and the first crack load and ultimate load were noted.

Fig. 1(a). Set-up for lateral deformation

Fig. 1(b). Set-up for vertical strain

3 RESULTS AND DISCUSSION

3.1 First crack load and Ultimate load

Table 3 shows the first crack load and ultimate load values for the specimens under two way in-plane loading. First crack load was taken as the load corresponding to the point at which the load-deflection curve becomes nonlinear.

TABLE 3
FIRST CRACK LOAD AND ULTIMATE LOAD

Designation	First crack load in kN	Ultimate load in kN
WP25	400	820
WP45	500	940
WP65	450	950

The ultimate strength of wall panel increases with the increase of percentage of horizontal reinforcement. The increase in ultimate load is about 14.6% for an increase in horizontal reinforcement from 0.25% to 0.45%. The increase in strength could be because of the two way bending in which the horizontal reinforcement resist the bending action. For the percentage of reinforcement above 0.45% the increase in strength was not considerable and was only 1.16% for an increase in horizontal reinforcement from 0.45% to 0.65%.The reduction in strength development with increase in horizontal reinforcement beyond 0.45% may be because of the insufficient reinforcement in the vertical direction to balance the increased resistance offered by the horizontal reinforcement.

3.2 Load - Deflection Behaviour

Based on the observations, the load-deflection graphs and load-vertical strain graphs were plotted for the specimens and are shown in Fig.2 and Fig.3.

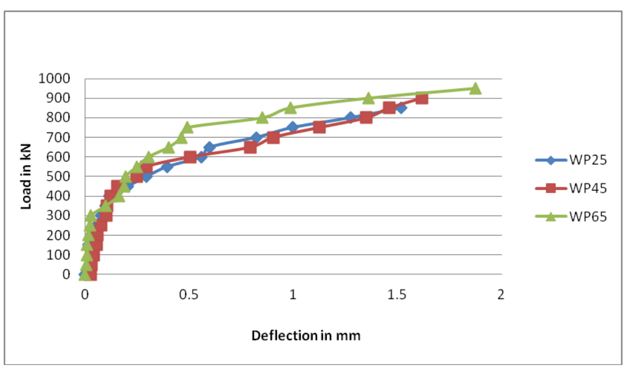


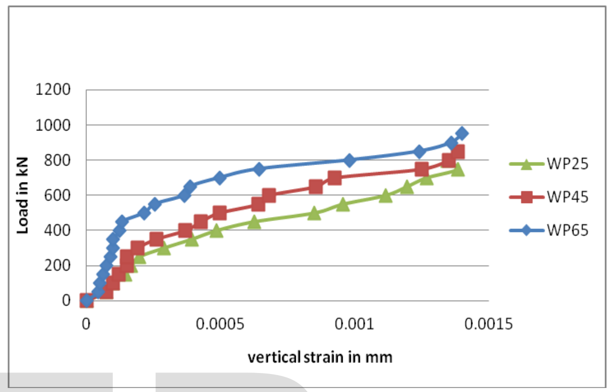
Fig. 2. Load - Deflection Curve at mid point

The lateral deflection and vertical strain increases with the increase of percentage of horizontal reinforcement under two way in plane loading. A maximum deflection of 1.95mm is obtained for the ultimate load of 950 kN in the case of the panel WP65.The maximum deflection for the panel WP 25 and WP45 were 1.51mm and 1.65mm respectively. That means the addition of horizontal reinforcement increases the ductile behavior of wall panels under two way in plane loading.

3.3 Load-strain behaviour

The vertical strain in the middle portion of wall panels was calculated from the deformation values observed using LVDT which was fixed within a gauge length of 120 mm c/c marked at the centre of the specimen. Fig. 3 shows the load-strain behaviour for the vertical strain at middle point for the specimen. For a given load, vertical strain increases with increase in percentage of horizontal reinforcement. That means the capacity to deflect laterally and vertically increases with increase in the percentage of horizontal reinforcement indicating considerable improvement in the ductile property.

Fig. 3. Load- Vertical strain curve



3.4 Crack pattern

The crack pattern for three panels is shown in Figs. 4(a) to 4 (c). For the specimen WP25, one large vertical crack and one or two diagonal cracks were formed when the load reached near the ulti mate load. Four or five small diagonal and vertical cracks were noticed in the panel WP45 before failure while the specimen WP65 showed large number of fine cracks. Thus it can be observed that as the horizontal reinforcement increases the number of cracks increases, but the width of cracks and propagation of cracks decreased.

Fig. 4(a). Crack pattern for the specimen WP25

Fig. 4(b). Crack pattern for the specimen WP45

Fig. 4(c). Crack pattern for the specimen WP65

3.5 Energy absorption capacity

Energy absorption capacity was calculated from the area under load deflection graph. Fig. 5 shows the energy absorption capacity of various wall panels. The energy absorption capacity increases with the increase in the percentage of horizontal reinforcement. The increase in energy absorption capacity was 20% when horizontal reinforcement increased from 0.25 to 0.45%. As the horizontal reinforcement increased from 0.25 to 0.65% the increase in energy absorption capacity was about 48%.

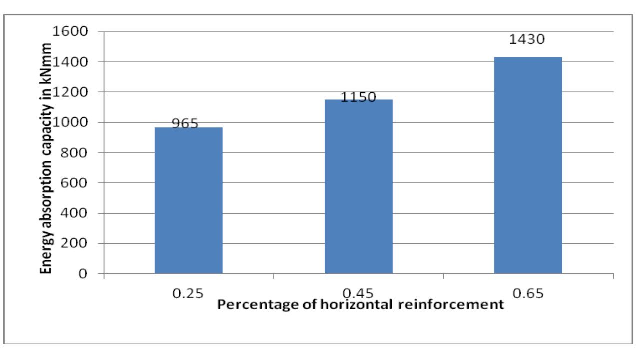


Fig.5. Energy absorption capacity of panels

4 CONCLUSIONS

- From the studies conducted, it can be observed that, the ultimate strength of wall panel increases with the increase of percentage of horizontal reinforcement under two way in plane action. The increase in ultimate load is about 14.6% for an increase in horizontal reinforcement from 0.25% to 0.45% . The rate of increase in ultimate strength diminishes as the percentage of horizontal reinforcement increased beyond 0.45% to 0.65% .
- The lateral deflection and vertical strain increases with the increase in the percentage of horizontal reinforcement indicating considerable improvement in the ductile property.
- The energy absorption capacity increases with increase in the percentage of horizontal reinforcement. About 50% increase in energy absorption capacity can be achieved by increasing the horizontal reinforcement to 0.65%.

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