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Experimental investigation on hexagonal steel tubular columns filled with plain and fiber reinforced concrete under eccentric compression load

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ABSTRACT: Due to the advantages of Concrete Filled Tube columns (CFT), their attention is increasingly on the rise. Despite the great research done in these sections, in some cases, as in the case of less frequent sections or using different types of concrete, the need for research to complete the design criteria and guidelines seems necessary. The present study was conducted with an experimental approach to study the behavior of CFT columns under eccentric load. In this study, 8 CFT columns with a hexagonal cross-section of 150 cm in length were tested. Concrete used as the core of the samples was simple concrete and fiber concrete. The displacements in two directions of the longitudinal and lateral has been recorded and the force-displacement diagram for all samples in both directions has been drawn. Parameters such as bearing capacity, ductility index, energy dissipation and effective hardness have been analyzed and compared. Based on the comparison of the results, it was found that in columns that are only under axial load, the increase in concrete core strength significantly increases the bearing capacity of the specimens, so that an increase of about 50% of the concrete core strength causes an increase of about 20% of the loaded capacity of the specimen; However, by increasing the bending moment, the effect of concrete core resistance is greatly reduced. Also, it was found that specimens filled with fiber concrete have a greater ability to maintain effective hardness. It also seems that the presence of fibers in concrete affects the ductility and energy dissipation parameters.

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1. INTRODUCTION

The flood of the rivers are often density currents. Hence, the investigation of these flows can resolve a part of the sedimentation issues. Despite a lot of research that has been conducted to understand better the behavior of the density currents [1 - 5], evaluation of these currents' behavior that have suspended sediment loads and encounter permeable obstacles in their path requires further studies. For this purpose, the process of changes in the sedimentation with different angles of permeable obstacles is investigated in this research. Speed and depth of the density currents affected by permeable obstacles and the process of encounter and passing of them through the permeable obstacles are also evaluated.

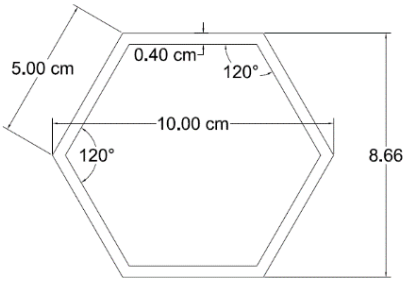

Fig. 1. Details of the section

2. MATERIALS AND METHODS

A flume with a length of 10 m, a width of 30 cm, and a height of 45 cm has been examined in this study, as shown in Fig. 1. Two obstacles with grooves and pits porosity at different percentages of 10, 15, 20, 25 and 30 and in the with an equal slit width and diameter of 3 mm, were mounted respectively.

3. RESULTS AND DISCUSSION

Flow velocity measurement was conducted by lateral imaging of the flume. The vertical profiles of flow velocity and concentration at a distance of 2 meters upstream of the obstacle are shown in Fig. 2.

As shown in Fig. 2, as the density current gets closer to the obstacle, the mean velocity reduces and the depth velocity becomes more dispersed. Also, due to the sedimentation in the path toward the obstacle, the concentration of materials diminishes, and the concentration in the deep parts of the flow increases. Changes of depth in the upstream vicinity of the obstacles are shown in Fig. 3.

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Table 1. Geometric Specifications of samples

Sample	L×B×t (cm)	e (cm)
PC-0	150×5×0.4	0
PC-5	150×5×0.4	5
PC-10	150×5×0.4	10
PC-15	150×5×0.4	15
PSR-0	150×5×0.4	0
PSR-5	150×5×0.4	5
PSR-10	150×5×0.4	10
PSR-15	150×5×0.4	15

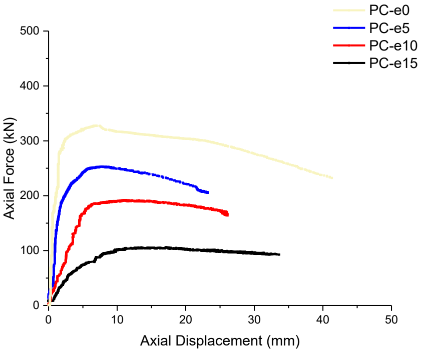

Fig. 2. load-axial displacement diagram for samples filled with simple concrete

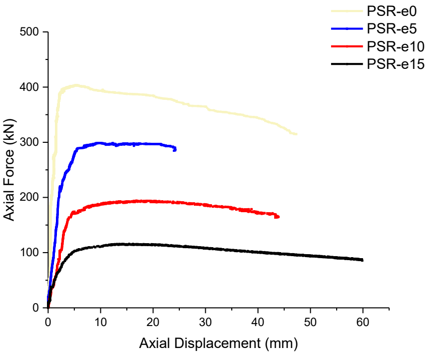

Fig. 3. load-axial displacement diagram for samples filled with fiber concrete

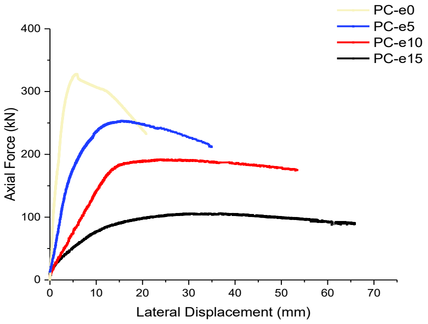

Fig. 4. load-lateral displacement diagram for samples filled with simple concrete

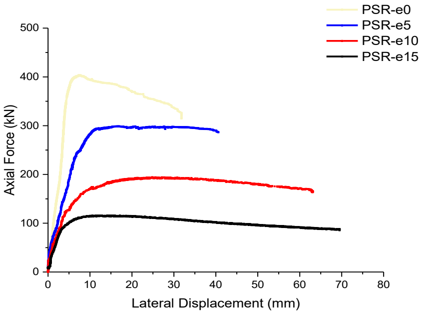

Fig. 5. load-lateral displacement diagram for samples filled with fiber concrete

Table 2. Bearing capacity of samples

Parameters	The most bearable force (kN)	Percentage of strength reduction compared to pure compressive load (%)
PC-e0	327.7	-
PC-e5	253	22.72
PC-e10	191.6	41.48
PC-e15	105.8	67.69
PSR-e0	403.7	-
PSR-e5	298.5	33.44
PSR-e10	216.5	56.72
PSR-e15	115.7	74.20

As shown in Fig. 3, the more the porosity of obstacle is, the less the rate of depth reduction gets. Studies have shown that the flows containing the obstacles with pits have a less upstream depth (4.14%) and a more velocity (3.62%), due to easier passing of the flow. In addition, the mean velocity of the head and back of the current density mass was estimated to be 10.7 and 4.6 cm/s, being 37% more and 30.2% less than the mean velocity of flow, respectively. The analysis of time of the test from the beginning of the injection of density current to the base flow to the last particle of suspended load passing through the obstacle shows that the distribution and changes in the test duration are more at the concentration of 10%

Table 3. Energy absorption of the samples

samples	μ	Energy absorption	Percentage of energy absorption changes based on concrete type compared to simple concrete (%)
PC-e5	5.54	7450	-
PSR-e5	5.28	10789	44.8
PC-e10	4.39	8725	-
PSR-e10	9.46	10943	25.4
PC-e15	5.41	5520	-
PSR-e15	18.06	6835	23.8

Table 4. Effective hardness of the samples

Samples	(N/mm) Effective hardness
PC-e5	40100
PSR-e5	37800
PC-e10	15750
PSR-e10	29100
PC-e15	8687.5
PSR-e15	29750

compared to that of 20%. Moreover, the process of changes in the test duration at the concentration of 20% is more balanced compared to that at the concentration of 10%. Fig. 4 shows how the flow passes through the obstacle and the sedimentary materials accumulate upstream it.

The amount of materials passing through the obstacles is shown in Fig. 5 for two different concentrations and five various porosities.

The results showed that in all cases, the trapping performance of the obstacles with pits is better than those with grooves. The mean trapping of the obstacles with pits was reported to be more than those with grooves by 0.14 and 0.13% at the concentrations of 10 and 20%, respectively. At low concentrations, the performance of the two types of obstacles is relatively similar. At high concentrations, however, the obstacles with pits have been effective with a better rate of trapping. Accordingly, at the porosities of 20 and 25% the lowest trappings were observed for the concentrations of 10 and 20%, respectively. Optimum porosity, which has the highest amount of passing materials, was estimated at 22 and 19% for the obstacles with grooves and pits, respectively.

To examine the effect of the angle of installation, the obstacles were rotated by 90, 105, 120 and 135 degrees relative to the horizontal direction of the floor in the flow direction. The trend of changes in the passing materials through the obstacles for different angles is presented in Fig. 6.

Studies have shown that by increasing the angle of installation, the trapping by both types of obstacles decreases. The amount of trapping reduction in the obstacles with pits was observed to be more than those with grooves. The correlation coefficients in the obstacles with grooves and pits were obtained 0.961 and 0.937, respectively. This can result from easier passing of the flow and evacuation of the materials caused by the pressure on the obstacles with pits.

The results approved the obstacle's efficiency in controlling the density current. It was found that permeable obstacles, due to their capacity to transmit a part of the flow and higher pressure reduction compared to impermeable ones, require smaller dimensions and have higher stabilities.

4. CONCLUSIONS

A review of experimental results showed that the optimum porosity for obstacles with pits and grooves are 22 and 19%, respectively. By increasing the porosity, the trapping reduces up to the optimal porosity and then increases. Evaluation of various angles of the obstacles relative to the direction perpendicular to the floor of the flow showed that by increasing the angle, the amount of trapping decreases. The amount of reduction in trapping for the obstacles with grooves was more compared to those with pits. The mean velocity of flow by using the obstacles with pits was 3.62% more compared to those with grooves. Totally, at the same conditions, the obstacles with pits have always shown a better performance than those with grooves.

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