International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 12 Issue 05, May-2023

Performance Of 3d Printed Pre Twisted Aesthetic Structural Duplet Columns

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Abstract:- The commercial finite element programme ANSYS is used to create a numerical model in order to examine the structural performance of 3d printing on attractive structural duplet columns. To create three-dimensional shapes, material is consecutively stacked while being controlled by a computer during 3D printing. It is highly useful for creating prototypes and geometrically challenging components. In this study, two I-shaped columns that are set up in series and parallel are taken into consideration. Let's examine the behaviour of the column at various rotational radii in both series and parallel arrangements. The ANSYS software was used to create 18 models (nine parallel and nine perpendicular). After the performance study is completed, strengthen the chosen model to determine which of these models has the best structural performance. Both inside and externally, steel plates and engineered cement concrete can be used to strengthen structures.

Keywords- ANSYS software

I. INTRODUCTION

Three-dimensional concrete printing (3DCP) technology appears to have generated the most attention among the currently available additive manufacturing (AM) techniques for concrete since both its overall technological level and economic value have been established. The implementation of typical demonstration projects has occurred with the advancement of 3DCP technology. The Eindhoven University of Technology printed a concrete structure in 2015 that was 11 metres long, 5 metres wide, and 4 metres high. A 3DCP office established in Dubai opened its doors in 2016. A 7.2-metre-tall, two-story office building was printed in 2019 by China Construction Second Bureau LTD. The office block was constructed on-site using 3DCP technology rather than printed concrete components. In 2017, the Institute of Advanced Architecture of Catalonia (IAAC) printed a 12-meter-long concrete pedestrian bridge. A team from Tsinghua University produced a concrete pedestrian arch bridge in Shanghai in 2019 using 3D printing technology. 44, 68, and 64 precast printing components made up the bridge's arch, railing, and deck, respectively.

However, there are several difficulties in using 3D-printed concrete buildings in actual technical applications. With a strong resistance to compression and a moderate resistance to tensile and flexural pressures, concrete is a common quasi-brittle material. The strengthening technique used when concrete serves as a material for AM is crucial for enhancing its mechanical qualities. To construct a building using 3DCP technology, freshly mixed concrete is extruded from the nozzle along a specified path and layered on top of one another. As a result, installing vertical reinforcement on printed concrete walls is challenging. Additionally, printed plain concrete walls have a low ultimate bearing capacity, limited cracking resistance, and are brittle.

3D printing

3D printing is the process of stacking material gradually while being guided by a computer to create 3D forms. Manufacturing geometrically challenging components and prototyping both benefit greatly from it. It can be accomplished using a number of processes that include layering materials (such as polymers, liquids, or powder grains) before using computers to regulate deposition, joining, or solidification.

Fig 1- 3D Printing [1]

The term "3D concrete printing," sometimes known as "concrete printing," describes digital fabrication techniques for cementitious materials based on a variety of 3D printing technologies. These procedures are used in the building sector to create building components, building elements, civil infrastructure, and street furniture. Concrete printing can be used to create the finished object directly or indirectly by creating the formwork that will hold the concrete while it is being cast or sprayed. address for 3-dimensional formworks

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some of the main difficulties with printing 3D concrete. Conventionally cast or sprayed concrete that incorporates reinforcement bars conforms with building codes. Additionally, concrete's surface quality is far better than that of 3D printed concrete. The 3D-printed formwork can be coated or polished to produce a smooth surface.

II. VALIDATION

A. Description of experiment model

The experimental result obtained from the 3D printed concrete wall under axial compression experiment by researchers [1] was numerically validated. The dimension of 3D printed wall were 240mmx710mmx720mm [1]. Material Properties derived from the experiment were used as a basis for modelling. Material have Ortho tropic property. As concrete has anisotropic mechanical properties, experiments were designed to test the axial compressive strength of the printed concrete in two directions [1]. The filaments cross-section is parallel to D1 [1]. And D2 is parallel to the layers' horizontal interfaces [1]. The printed concrete's axial compressive strengths in D1 and D2 are were 49.3 MPa and 40.8 MPa, respectively [1]. Indicated by
Direction 1
E-30231 Mpa, Poison ratio-0.2
Direction 2
E -33467 Mpa, Poison ratio -0.2
After modelling, the 3D printed wall underwent nonlinear analysis. The outcomes were contrasted with those of the experiments.

B. Finite Element Analysis

Utilising ANSYS Workbench 2022, a concrete wall that was 3D printed was validated.
. The model of the 3D printed concrete wall specimen was developed with the help of design modeller in ANSYS Workbench. Concrete-solid 185 was used to create the specimen; this material possesses the abilities of plasticity, hyper elasticity, stress stiffening, creep, big deflection, and huge strain. The supports' bottom end is fixed, and two points of two-point loading are applied in an axial direction as displacement at the top of the columns. The researchers compared the finite element analysis's results for ultimate load and ultimate deflection to experimental data.

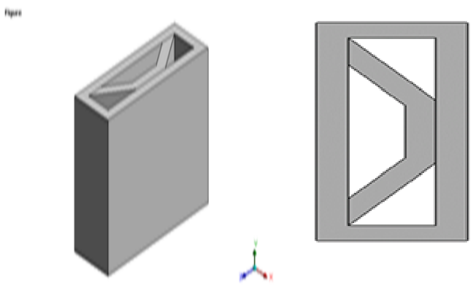

Fig 2: Modelling of Wall

In the modelling of wall 'solid 185'element type is used. The size of the element is 85mm and element shape of meshing is Hexahedron.

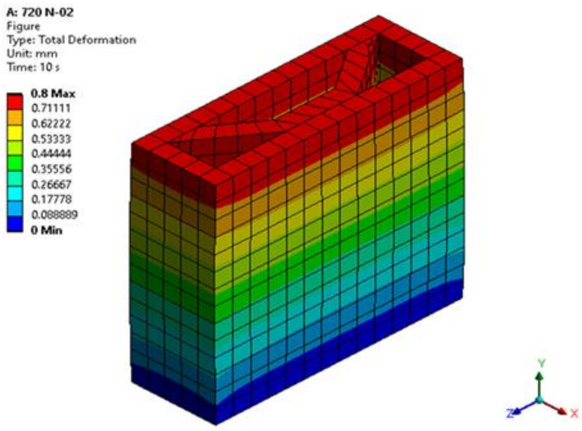

Fig : 3 Total Deformation

C. *Validation results*

At the time of maximum displacement, the axial compressive load applied to the wall specimen was 3352kN. At the same time, the axial compressive load applied to the wall specimen was 3561.2kN. The Percentage of difference is 6.24%. Percentage of difference is less than 10%, hence validation is successful

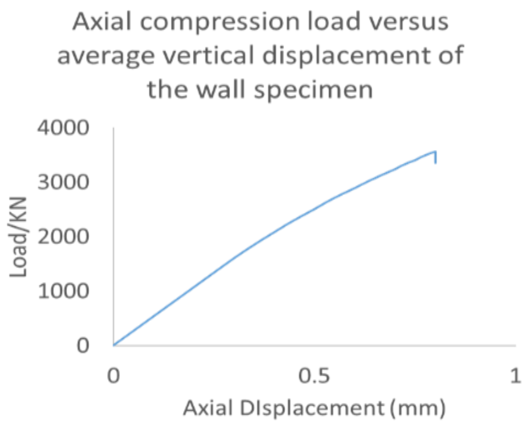

Fig 4: Validation Results

Table 1 Comparison of Results

	Load(kN)
EXP	3352.0
FEA	3561.20
%	6.24

III. PARAMETRIC STUDY

The study was conducted by considering various parameters. In that first one is the analysis of 3D printed parallel I shaped duplet columns with different degrees of rotation and checking the axial capacity of the columns and comparing it with the 3D printed duple column with zero-degree rotation. Another study was, introducing strengthening methods in 3D printed duplet parallel I columns. In this study 45,90,135,180,225,270,315,360 Degrees of rotations are considered and three strengthening methods are considered such as insertion of steel, external plating and infilling by Engineered Cement Concrete(ECC). For conducting the finite element analysis, I shaped duplet concrete column was

International Journal of Engineering Research & Technology (IJERT)
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chosen. The size of the column chosen was 250mmx400mm with a height of 3000mm (fig4). The column was fixed at the bottom without reinforcement. The grade of concrete was M25, and grade of steel used for strengthening is Fe415.The columns are loaded with two-point loading. The load points were defined based on the shear span to effective depth ratio. There are 9 models were considered.

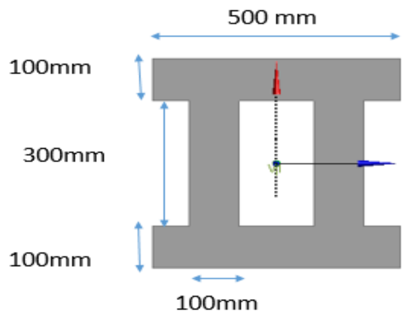

Fig-4: Duplet I Section

A - Modelling and analysis

The Fig 5 shows zero-degree rotation of 3D printed aesthetic structural duplet column drawn in ANSYS software. After analysing ultimate load and ultimate deflection of the column is noted.

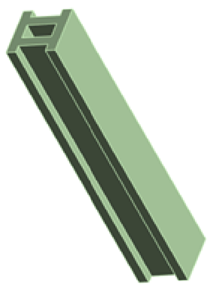

Fig-5 zero-degree rotation

The Fig 6 shows 45-degree rotation of 3D printed aesthetic structural duplet column drawn in ANSYS software. After analysing ultimate load and ultimate deflection of the column is noted. The ultimate load is less than that of the column with zero-degree rotation.

Fig -6: 45-degree rotation

The Fig 7 shows 90-degree rotation of 3D printed aesthetic structural duplet column drawn in ANSYS software. After analysing ultimate load and ultimate deflection of the column is noted. The ultimate load is less than that of the column with 45-degree rotation.

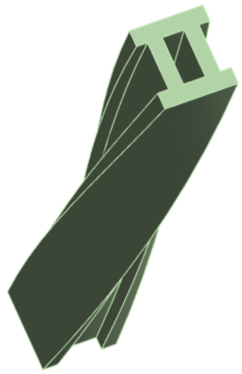

Fig-7: 90-degree rotation

The Fig 8 shows 135-degree rotation of 3D printed aesthetic structural duplet column drawn in ANSYS software. After analysing ultimate load and ultimate deflection of the column is noted. The ultimate load is less than that of the column with 90-degree rotation.

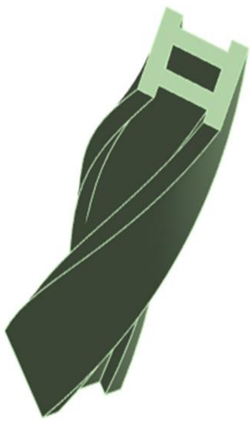

Fig-8 :135-degree rotation

The Fig 9 shows 180-degree rotation of 3D printed aesthetic structural duplet column drawn in ANSYS software. After analysing ultimate load and ultimate deflection of the column is noted. The ultimate load is less than that of the column with 135-degree rotation.

Fig-9:180-degree rotation

The Fig 10 shows 225-degree rotation of 3D printed aesthetic structural duplet column drawn in ANSYS software. After analysing ultimate load and ultimate deflection of the column is noted. The ultimate load is less than that of the column with 180-degree rotation.

Fig-10:225-degree rotation

The Fig 11 shows 270-degree rotation of 3D printed aesthetic structural duplet column drawn in ANSYS software. After analysing ultimate load and ultimate deflection of the column is noted. The ultimate load is less than that of the column with 225-degree rotation.

Fig-11:270-degree rotation

The Fig 12 shows 315-degree rotation of 3D printed aesthetic structural duplet column drawn in ANSYS software. After analysing ultimate load and ultimate deflection of the column is noted. The ultimate load is less than that of the column with 270-degree rotation.

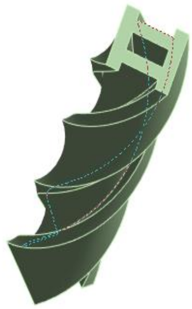

Fig-12:315-degree rotation

The Fig 13 shows 360-degree rotation of 3D printed aesthetic structural duplet column drawn in ANSYS software. After analysing ultimate load and ultimate deflection of the column is noted. The ultimate load is less than that of the column with 315-degree rotation.

Fig-13:360-degree rotation

Parametric study result

- The angle of twist increases, the load carrying capacity decreases.
- when the twist is applied in the case of parallel shaped twisted columns, the ultimate strength is obtained at an angle of 45 degree
- Strengthening methods (Insertion of steel, External plating, Infilling by ECC) are provided to improve the structural performance of the column

Table 2 Result of Parallel twist

model	ultimate load	ultimate deflection	% dec load
P 0	7449.6	7	100
P 45	7396.8	7	0.70876289
P90	7206.6	7	3.2619201
P 135	6875.3	7	7.70913875
P180	6450.9	7	13.4060889
P 225	5886.1	7	20.987704
P 270	5413	6	27.3383806
P 315	4696.4	6	36.957689
P 360	4257.1	6	42.8546499

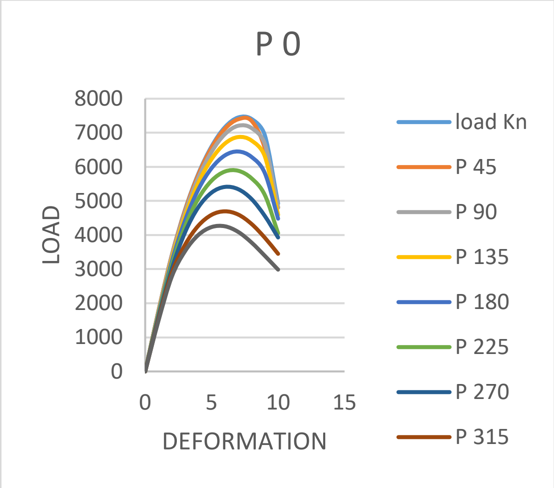

Fig 14 result graph

B - Strengthening

1.*Insertion of steel*- Insertion of steel is done by using 6mm and 8mm bars in parallel. Inorder to print 3 metre long 3DP column, 10 numbers of Fe415 steel bar is used.While comparing with table3 there is no improvement in strength.so this insertion method is not benificial for strengthening 3D printing columns.

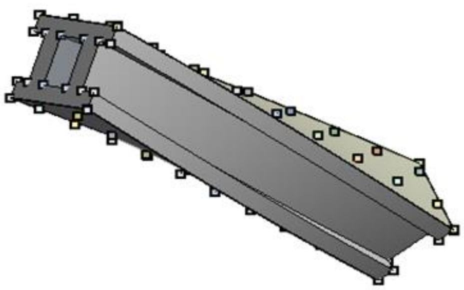

Fig- 15 strengthening by insertion of steel

Table 3: Result of Insertion of Steel

Parallel Twist 45 degree		
model	ultimate load (kN)	ultimate deflection
P 45	7396.8	7
Insertion parallel 8mm	7396.8	7
Insertion parallel 6mm	7396.8	7

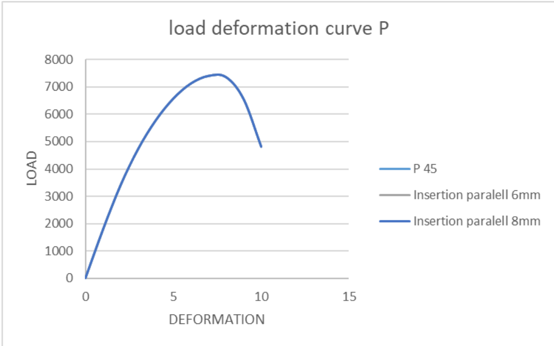

Fig- 16 Deformation curve of infilling

2. *External plating* – External plating is done by using 2.5mm and 5mm thick steel plate. The plate is fixed externally at four sides of the duplet column. The concrete and steel plate was connected by shear connectors. By increasing the thickness of the external plate, the strength is also increasing.

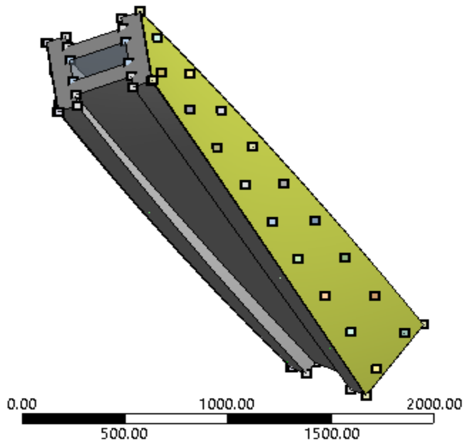

Fig- 17 strengthening by external plating

Table 4: Result of External Plating

Parallel Twist 45 degree		
model	ultimate load (kN)	ultimate deflection
External plate 2.5mm parallel	8121.2	7.1752
External plate 5mm parallel	9002.5	7.1736

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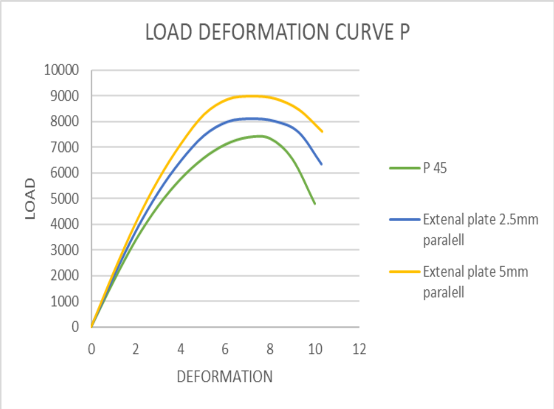

Fig-18 deformation curve of external plating

3.Infilling by ECC –Infilling is done by using Engineered Cement Concrete. ECC is filled in the central vacant portion of the duplet columns. Even though infilling is an effective method, it doesn't provide enough strength while compared to external plating

Table 5: Result of Infilling

Parallel Twist 45 degree		
model	ultimate load (kN)	ultimate deflection
ECC	8880.5	8

Fig -19 Deformation Curve of Infilling

IV. CONCLUSION

- when the twist is applied in the case of parallel shaped twisted columns, the ultimate strength is obtained at an angle of 45 degree
- In this study, the strengthening of column with insertion of 6mm and 8mm bars, the load carrying capacity remains the same as that of column without insertion.
- Strengthening of column with external plating of size 2.5mm, increases the load carrying capacity to 8.91% and with external plating of size 5mm increases the load carrying capacity to 17.86%
- Strengthening by using Engineered Cement Concrete, the load carrying capacity increases to 16.7%
- Therefor Maximum strength is obtained by placing 5mm plate externally

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