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Seismic analysis of beam-column connections in precast structures

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ABSTRACT:

The behavior of wet precast beam-column connections in a progressive collapse scenario is covered in this research. The performance of monolithic and precast wet connections in terms of strength, ductility, and load carrying capacity are compared in this study. In comparison to monolithic connections, the experimental analysis demonstrates that the precast wet connections taken into consideration in the study are more ductile and capable of withstanding greater load.

Keywords: Precast constructions, Wet beam column connections, Progressive collapse, Glass fiber.

INTRODUCTION:

The behavior of wet precast beam column connections in a progressive collapse scenario is covered in this research. It includes experimental research that evaluates these connections' reaction in terms of deflection and ultimate load carrying capacity. The study finds that precast connections are more ductile and capable of withstanding greater loads when comparing the performance of precast wet connections to monolithic connections. A review of the literature on progressive collapse and the principles for creating structures resistant to progressive collapse is also included in this study. A novel precast concrete beam-to-column connection for moment-resisting frames is suggested in the paper. Similar to monolithic connections, the suggested connection is intended to be simple to construct and to have enough earthquake protection. But no tests have been conducted to evaluate its seismic performance under reversal cycle loading. The seismic performance of the suggested connection using tests on a reference monolithic specimen as well as two precast beam-to-column specimens. In comparison to the monolithic specimen, the results demonstrate that the suggested precast system functions effectively under cyclic loading.

OBJECTIVE:

1. The beam column connections is to be analysed in ANSYS software to determine the strength in the beam-column joint.
2.The lap and grouted sleeve joint of precast specimens were cast and tested under reversed cyclic loading.
3.Analytical and experimental studies were conducted on the wet connections and the results were observed.

GLASS FIBRE REINFORECED CONCRETE

Glass fiber reinforced concrete, or GFRC, combines the improved qualities of glass fibers inserted in concrete with the structural strength of concrete, marking a revolutionary advancement in building materials. By addressing challenges including tensile strength, durability, and flexibility, this composite material provides an appealing alternative to the drawbacks of conventional concrete.

EXPERIMENTAL INVESTIGATIONS ON BEAM-COLUMN JOINTS:

The mechanical properties of concrete with glass fiber are mentioned below,

1. Compressive Strength
2. Split tensile strength.

3. Flexural Strength

The optimum percentage of glass fibre used in concrete for the mix proportion of 1:1.9:2.84 for M40 grade concrete is 1.5%.

COMPRESSIVE STRENGTH :

Fig1. Compressive strength

Table1. Compressive strength

MIX TYPE	PERCENTAGE OF GLASS FIBER	COMPRESSIVE STRENGTH (N/mm2)
GF 1.5	1.5	47.5

SPLIT TENSILE STRENGTH:

Fig2. Split tensile strength

Table2. Split tensile strength

MIX TYPE	PERCENTAGE OF GLASS FIBER	SPLIT TENSILE STRENGTH (N/mm2)
GF 1.5	1.5	22.2

FLEXURAL STRENGTH:

MIX TYPE	PERCENTAGE OF GLASS FIBER	SPLIT TENSILE STRENGTH (N/mm2)
GF 1.5	1.5	22.2

DESIGN OF BEAM COLUMN JOINT:

The height of the building is 9m, length of the building is 12m, Breadth of the building is 9m**.**

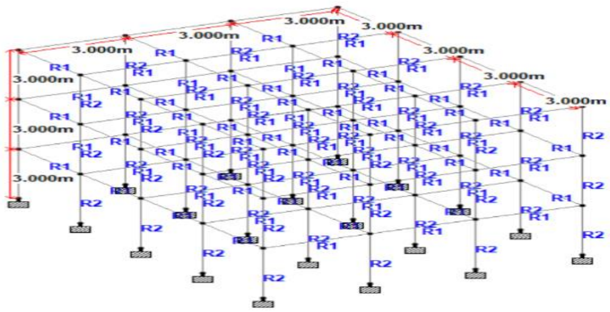

Fig3. G+2 Residential Building

COLUMN DESIGN

Size of the reinforcement – 12mm, Spacing - 100mm, Size of the stirrups – 8mm,Spacing of the stirrups - 100mm

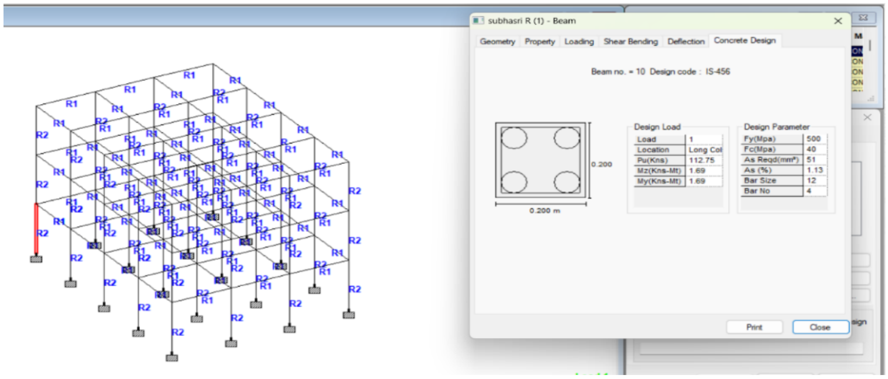

Fig4. Column Design

BEAM DESIGN

Size of the reinforcement – 12mm, Spacing - 100mm, Size of the stirrups – 8mm, Spacing of the stirrups - 100mm

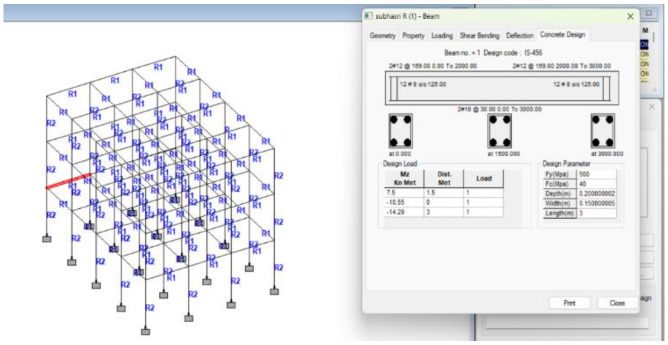

Fig5. Beam Design

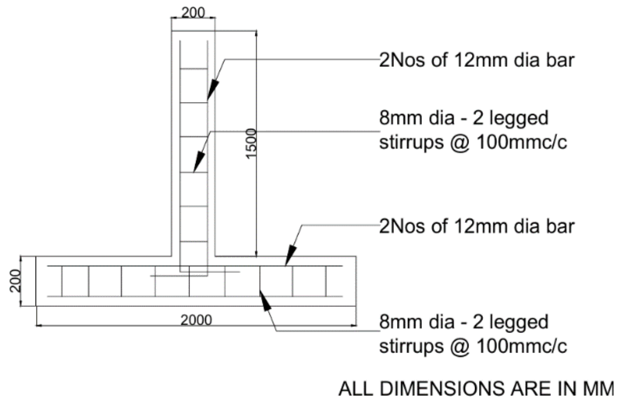

Fig6. Details of the Reinforcement

Tab 4. Dimension of the mould

SPECIFICATION	BEAM	COLUMN
Length	1500mm	2000mm
Breadth	150mm	150mm
Depth	200mm	200mm
Size of reinforcement	12mm	12mm
Spacing	100mm	100mm

GROUTING MATERIAL:

Grout is frequently used to seal joints and fill gaps, such as those found between tiles. Grout bridges those spaces, keeping the tiles from shifting or chipping at the edges over time. For high strength, corrosion-resistant anchoring of bolts and bars with a diameter of 12 to 25 mm into concrete, rock, masonry, or brickwork where quick installation and early load application are necessary, use Bostik Anchor Grout.

Fig7. Grouting material

CASTING OF TESTING OF SPECIMEN:



Fig8. Casting of lap joint


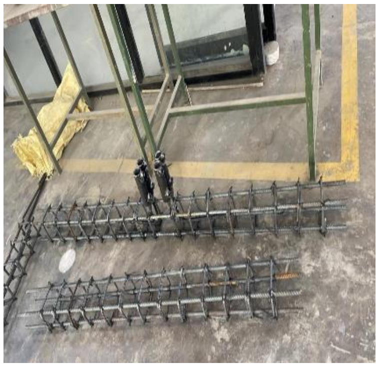


Fig9. Casting of grouted sleeve joint

Fig10. Test Setup for lap joint and grouted sleeve joint

TEST RESULTS:

ULTIMATE LOAD AND DEFORMATION:

Fig11. Cracks developed in lap joint and grouted sleeve joint

Table 5. Ultimate load

SL.NO.	TYPE OF JOINT	ULTIMATE LOAD(KN)
1	**Lap Joint**	**16**
2	**Grouted Sleeve Joint**	**20**

By applying the cyclic loading, the ultimate load for the lap joint is 16KN and for the grouted sleeve joint is 20KN as shown in table5.

Table 6. Maximum Deformation

SL.NO.	TYPE OF JOINT	MAXIMUM DEFORMATION (mm)
1	**Lap Joint**	**50**
2	**Grouted Sleeve Joint**	**39**

Cracks were formed in the joint. The maximum deformation of the lap joint is 50mm and for the grouted sleeve joint is 39mm as shown in table 6.

HYSTERESIS CURVE:

Precast beam-column connections' hysteresis curve serves as a basic illustration of the structure's reaction to cyclic loads and is especially important for seismic design. The hysteresis curve shows how applied loading and subsequent deformation are related to one other as seismic forces expose structures to alternating cycles of tension and compression.

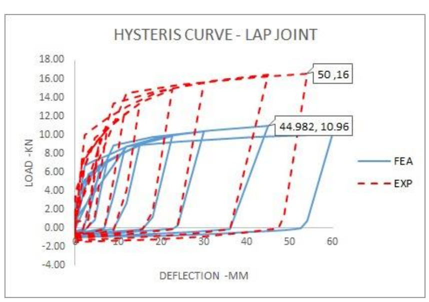

Fig12. Hysteresis curve for lap joint

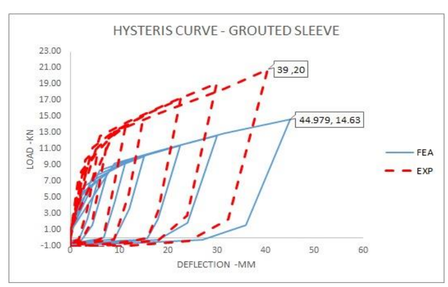

Fig13. Hysteresis curve for grouted sleeve

FINITE ELEMENT ANALYSIS:

Precast structure design and analysis are being revolutionized by the potent computational technique known as Finite Element Analysis (FEA). Precast components provide quality, speed, and efficiency in the field of building. By simulating how precast components would react to different forces and circumstances, FEA, a numerical technique, improves our understanding of the structural behavior of these components.

ANALTICAL STUDY OF BEAM COLUMN CONNECTIONS IN WET JOINTS:

GEOMETRY:

ANSYS's user-friendly tools are used to define solid models to create 3D geometry. Within the ANSYS Geometry interface, users may create and edit geometric surfaces, volumes, and forms. Effective design variant research is made possible by parametric design capabilities.

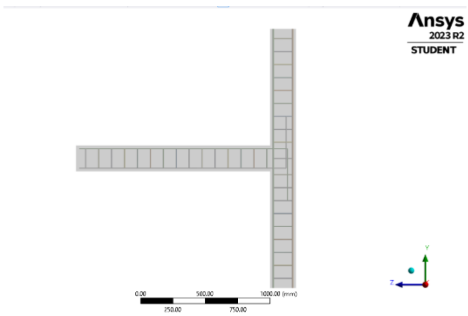

Fig14. Geometry for lap joint

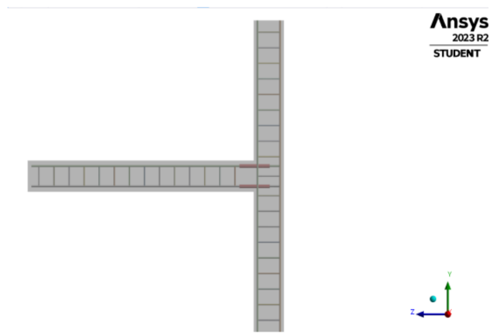

Fig15. Geometry for grouted sleeve

MESHING:

Divide the geometry into discrete pieces in ANSYS for a beam-column connection to make structural analysis easier. Realism in representing the many relationships inside a mesh is essential for these kinds of connections. Refinement in crucial areas and more control over element sizes are made possible by ANSYS's tools for creating structured or unstructured meshes. To ensure realistic simulation results, proper meshing captures potential failure spots, load transfers, and stress concentrations. Achieving a balance between computational economy and accuracy is crucial when creating the mesh for a beam-column connection in ANSYS, as the mesh quality has a direct impact on the precision of structural analysis.

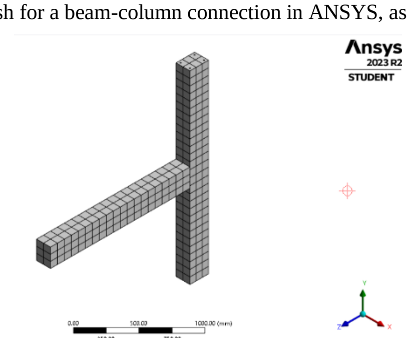

Fig16. Meshing for lap joint

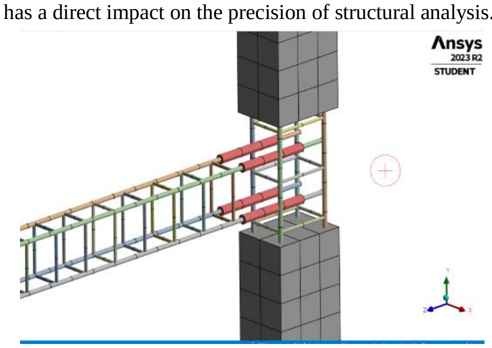

Fig17. Meshing for grouted sleeve

BOUNDARY CONDITIONS:

The column is pinned at support BC. Load A is applied on end of the beam (i.e., cyclic loading).

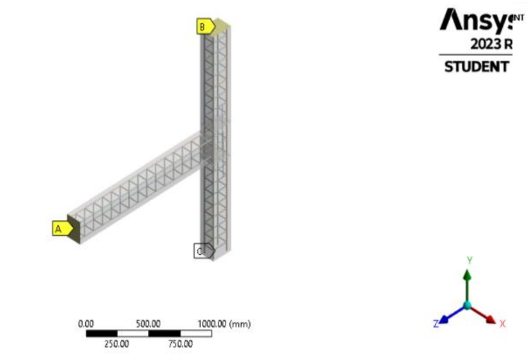

Fig18. Boundary conditions for lap joint

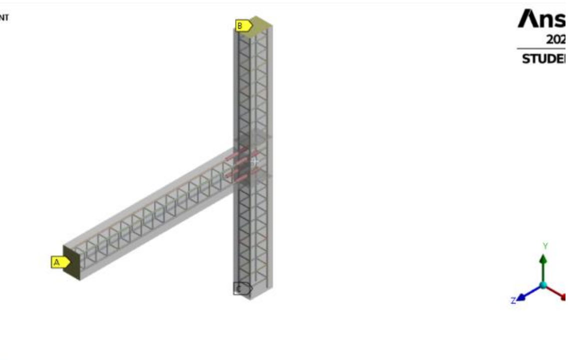

Fig19. Boundary conditions Meshing for grouted sleeve

FEMA PROTOCAL:

The Federal Emergency Management Agency (FEMA) in the United States has produced several standards and procedures that are collectively referred to as "FEMA protocol". For drift displacement under cyclic loading in ANSYS or any other seismic analysis software, only use the FEMA protocol. Drift limitations and displacement assessments during seismic events may be included in the seismic design and analysis guidelines and papers that the Federal Emergency Management Agency (FEMA) offers.

Table 7. FEMA PROTOCAL

AISC / FEMA PROTOCAL			
LENGTH (m)	**DRIFT(Radian)**	**DRIFT (%)**	**DRIFT DISPLACEMENT (mm)**
1.5	**0.00375**	**0.375**	**5.63**
1.5	**0.005**	**0.5**	**7.5**
1.5	**0.0075**	**0.75**	**11.26**
1.5	**0.01**	**1**	**15.01**
1.5	**0.015**	**1.5**	**22.51**
1.5	**0.02**	**2**	**30.02**
1.5	**0.03**	**3**	**45.04**
1.5	**0.04**	**4**	**60.06**

DEFORMATION:

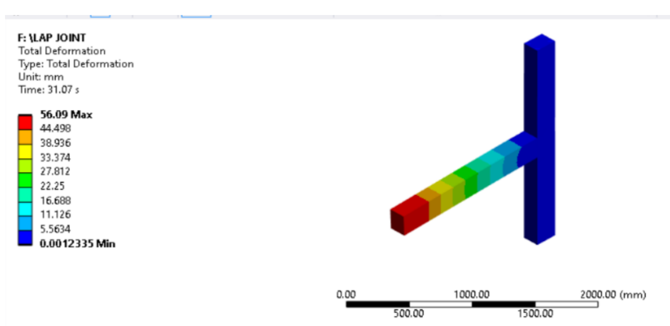

Fig20. Deformation for lap joint

Maximum deformation in lap joint – 56.02mm

Maximum deformation in grouted sleeve joint – 45.23mm

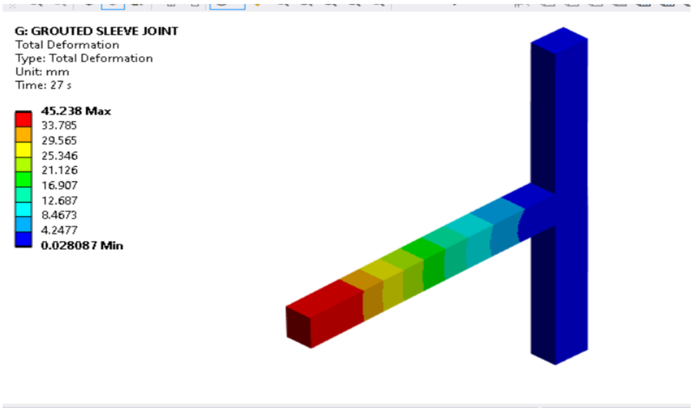

Fig21. Deformation for Grouted sleeve joint

HYSTRESIS CURVE:

LAP JOINT

Ultimate Load – 10.96 KN
Ultimate Deformation – 56.09mm

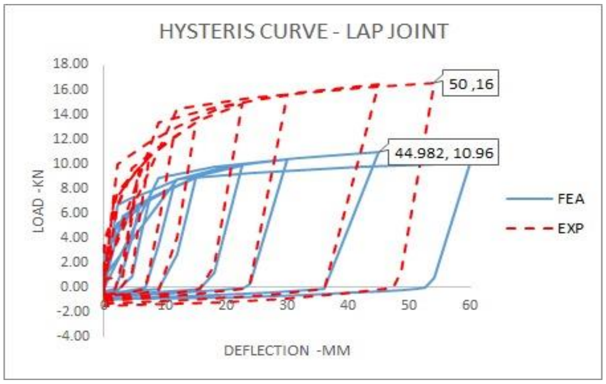

Fig22. Hysteresis curve for lap joint

GROUTED SLEEVE JOINT

Ultimate Load – 14.63 KN
Ultimate Deformation – 45.23mm

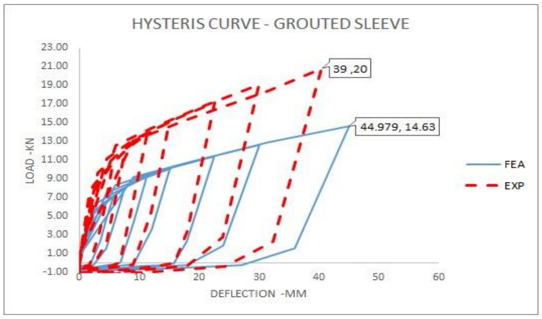

Fig23. Hysteresis curve for Grouted sleeve joint

RESULT AND DISCUSSION:

GEOMETRY:

1. The lap joint connection involves overlapping the beam and column, creating a flush surface.

2. The grouted sleeve connection involves machining a groove in the beam and column, allowing for a more precise fit.

CYCLIC LOADING:

1. The joint should be subjected to cyclic loading to simulate the expected loading conditions during seismic events.

2. Load-displacement curves can be obtained to analyze the joint's response under different loading cycles.

DEFORMATION:

The lap joint connection may exhibit larger deformations compared to the groove connection due to its inherent flexibility.

Table 8. Deformation

SL.NO.	TYPE OF JOINT	MAXIMUM DEFORMATION (ANSYS)	MAXIMUM DEFORMATION (EXPERIMENTAL)
1	**Lap Joint**	**56.09mm**	**50mm**
2	**Grouted Sleeve Joint**	**45.23mm**	**39mm**

ULTIMATE LOAD:

By comparing the ultimate load carrying capacity of lap joint and grouted sleeve joint. The grouted sleeve joint has less high load carrying capacity compared to lap joint as shown in the table 9.

SL.NO.	TYPE OF JOINT	ULTIMATE LOAD(ANSYS)	ULTIMATE LOAD (EXPERIMENTAL)
1	**Lap Joint**	**10.96KN**	**16KN**
2	**Grouted Sleeve Joint**	**14.63KN**	**20KN**

SUMMARY AND CONCLUSION:

Precast concrete constructions are the most widely used versatile form of construction throughout the World for its potential advantages. Though precast concrete is utilized most prevalently Worldwide, there is still hesitancy in using precast concrete structures in high seismic zones, especially in India. This is because of damages caused to precast concrete structures during past earthquakes. The primary reason for damage is the lack of connectivity between the load carrying elements. The connections constitute the weakest link in the structure. Hence there is a need for more research in understanding the behavior of connections under seismic.

Following are the conclusions drawn based on the experimental and analytical investigations carried out to study the behaviour of exterior precast beam-column connections under cyclic loading.

The joints taken for this study are lap joint and groove joint. Analytical investigations were done in ANSYS software. The specimens were subjected to cyclic loading and the results for deformation, ultimate load and energy dissipation was recorded.

The result shows that the performance of groove joint under cyclic loading is more when compared to lap joint, the hysteresis curve got from both the specimen shows that the groove joint specimen has a slightly wider curve when compared to the lap joint, thus the energy dissipation of the groove joint specimen is greater than the lap joint specimen.

Comparing the specimen, it is seen that the groove joint specimen is more suited in seismic prone areas.

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