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Study on Seismic Performance of Column-To-Column Connection in Prefabricated Structures

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ABSTRACT –

Most projects in India are made of cast-in-situ concrete, even though precast concrete structural technologies are used extensively worldwide. India's rapidly growing population and limited space have created a great demand for multistorey residential complexes. Earthquakes are a type of natural calamity that has caused serious damage to infrastructure and fatalities. The poor performance of the connectors was identified as the cause of the precast constructions' collapse. The precast concrete structure's weakest point is its connections. The goal of the current study is to determine which precast structures function well in seismic zones by analyzing the behavior of column- to-column connections during seismic activity. Investigating thedetails of a half- grunted sleeve in a precast concrete column-to-column connection subject to cyclic loading was the primary goal of the study. A partially grouted sleeve joint was modelled analytically using the ANSYS finite element programmed. To caste prefabricated column to column connection with coupler and half grouted sleeve. To compare both coupler and half grouted sleeve in prefabricated column to column connection.

Keywords: Precast concrete, column-to-column connections, half grouted sleeve, coupler.

1. INTRODUCTION

Inia's infrastructure has grown significantly in the last many years The building industry must always look for ways to improve because of the rising demand for high-quality structures and the growth of infrastructure. The building industry will consequently become more industrialised; precast concrete construction is one technique to achieve this. Concrete is poured into reusable moulds or formwork to create precast concrete components. The concrete is then allowed to cure in a controlled environment before being transported and assembled on the construction site. The global arena sector has seen a remarkable growth in precast concrete use in recent years.. This is because precast concrete provides superior structural elements, effective construction, and overall time and cost savings.

In India, cast-in-situ construction is the most used technique. Building with precast concrete is a relatively recent technology. Flyover construction often uses precast concrete structures. There is much room for development in India's construction industry, particularly in the production and application of factory- made, quality-controlled precast components, which facilitate quicker construction and more rapid economic growth. This can be attributed to India's rapid development.

1.1 Objective

- To compare both the coupler and half grouted sleeve in prefabricated column to column connection.
- To caste the prefabricated column to column connection with coupler and half grouted sleeve.
- To compare both analytical (ANSYS SOFTWARE) and experimental work of half grouted sleeve in prefabricated column to column connection.
- To Examining the behavior of half grouted sleeve in column-to-column precast structure and determine the behaviors by following parameters.
- Ultimate Load Carrying Capacity
- Load-Displacement Hysteretic curve.
- Drift
- Ultimate deflection

1.2 Scope

• To minimize the usage of OPC in order to making sustainable environment

• To minimize the usage of M-sand to avoid the over mining in quarries.

• To find out the chemical composition of foundry sand to avoid the adverse effect on concrete.

• To study the inter molecular arrangement of SCCby Scanning Electron Microscope (SEM), it helps to identifying the bond between the aggregate and cement sand mortar.

2. LITERATURE REVIEW

i) Wang xi Zhang et.al (2018) The paper investigates the tensile behavior of half grouted sleeve connections at elevated temperatures. It examines the compressive behavior of cementitious grout and how it changes with temperature. The bonding length of the rebar may become insufficient at high temperatures. The elastic modulus of both the half grouted sleeve connection and the single rebar decreases rapidly with increasing temperature, with the connection showing a faster decreasing trend. The test results can be used in the design and analysis of half grouted sleeve connections at elevated temperatures.

ii) Huang Yuan et.al (2017) The paper investigates an experimental study on the tensile behavior of half grouted sleeve connections, including failure modes such as rebar tension fracture, bond failure, and thread sliding failure. The tensile capacity of the connections is determined using an analytical model, and good agreement between the test results and predictions is obtained. Strength, yield, and ductility ratios are used to assess the connections' performance. The accuracy of the suggested formula for failure mode prediction is also covered in the study, and it is recommended that more experimental research be done in order to produce a more trustworthy regression formula. The Fundamental Research Funds for the Central Universities and the National Natural Science Foundation of China are funding this research.

iii) Jianwei Chen et.al (2022) This paper investigates two sorts of failure modes were noted. Rebar failure happened when the SR was 50% or less, which happened after the splice rebar reached its maximum strength. Rebar pull-out happened shortly after the splice rebar gave for a 100% SR, demonstrating the effect of rebar strip off ribs on splice. According to the study's failure modes, the ultimate tensile load of a splice is determined by two main factors: the bond strength at the rebar-grout interface and the rebar's ultimate strength, the latter of which would determine the splice's tensile capacity. The splice performance was unaffected by lengthening the rebar strip off ribs of the elastic part of the rebar. On the other hand, when the length of the inelastic portion of the rebar was increased, the splice's ultimate bearing capacity and ductility decreased.

iv) Linlin Xie et.al (2022) This paper investigates a defect-detectable and repairable half-grouted sleeve (DDRHGS) .To address the identification and restoration of inadequate grouting of GSCs, DDRHGS was created. In order to verify the repair method's dependability and examine the impact of inadequate grouting on GSC connection performance, a total of 52 DDRHGS specimens were subjected to two cyclic loading protocols. Analysis was done on the effects of rebar diameter, defect ratio, repair material, and loading procedures, with a focus on the tested specimens' failure mode, loadbearing ability, and deformation capacity.

v) Feng Xu et.al (2018) This paper investigates a experimental bond behavior of deformed rebars in half-grouted sleeve connections with insufficient grouting defect. The risk of PC infrastructures failing too soon can be greatly increased by inadequate grouting of the sleeve connections between RC components. Twenty-one sets of sleeve connection specimens under tensile load were used in a systemic experimental examination to better understand the bond behavior of the sleeve connection with inadequate grouting. To simulate potential inadequate grouting in practice, four types of configurations—uniform, longitudinal, axial, and inclined—have been created for this study. The volume-ratio of the insufficient grouting is meant to range from 0% to 50%. Considering the impact of inadequate grouting, the failure mechanism and the bond stress-slip relation of the specimens have been analyzed.

vi) Wang xi Zhang et.al (2020) The paper investigates an experimental study on the post-fire tensile behavior of half grouted sleeve connections (HGSC) with construction defects. An analysis is conducted on the impact of construction faults and peak temperature on the properties of HGSC. Tested and compared to single rebars under identical conditions is the tensile behavior of sixty-six post-fire HGSCs with construction flaws. The investigation and discussion focuses on the yield strength, ultimate strength, yield elongation, ultimate elongation, and ductile factor of post-fire HGSC with construction faults.

2.1 SUMMARY OF LITERATURE REVIEW

The tensile behaviour of half grouted sleeve connections at elevated temperatures, emphasizing changes in the compressive behaviour of cementitious grout and the potential insufficiency of rebar bonding at high temperatures. The post-fire tensile behaviour of half grouted sleeve connections with construction defects, analysing the impact of faults and peak temperature on properties such as yield strength, ultimate strength, yield elongation, ultimate elongation, and ductile factor in comparison to single rebars. The tensile behaviour of half grouted sleeve connections, identifying failure modes and determining tensile capacity using an analytical model. The study emphasizes the assessment of performance through strength, yield, and ductility ratios, suggesting the need for further experimental research. The failure modes in splice connections, highlighting rebar failure and pull-out. It emphasizes the role of rebar strip off ribs, the bond strength at the rebar-grout interface, and rebar ultimate strength in determining the splice's ultimate tensile load and capacity. Lengthening the inelastic portion of the rebar decreases ultimate bearing capacity and ductility. The study includes 52 specimens subjected to cyclic loading, analysing the effects of rebar diameter, defect ratio, repair material, and loading procedures on failure mode, load-bearing ability, and deformation capacity.

3. MIX DESIGN

Casting M40 grade specimens typically involves precise measurements and strict adherence to concrete mix proportions. M40 grade concrete is a high-strength concrete mix designed to achieve a compressive strength of 40 megapascals (MPa) at 28 days. It contains carefully proportioned ingredients including Portland cement, coarse and fine aggregates, and water.

Table-1: Parameters for mix design

Grade designation	:M40	
Type of cement	:OPC 43 grade	
Brand of cement	:Dalmia cement	
Fine aggregate	:Zone II	
Exposure condition	:Very severe	**(IS 456-Table 3)**
Minimum cement content	:340 kg/m^3	**(IS 456-Table 5)**
Slump workability	:100 mm	**(IS 456-Cl.7.1)**
Type of concrete	:Pumping	
Standard deviation	:5 N/ mm^2	**(IS 10262-Table 2)**
Maximum cement content	:450 kg/m^3	
Maximum water content	:186 kg/m^3	
Water- Cement ratio	:0.40	**(IS 456-Table 5)**

High-strength concrete blends like the M40 mix design are commonly utilized in structural applications where exceptional durability and load-bearing capacity are necessary. After curing for 28 days, the material—which is precisely composed of cement, aggregates, water, and admixtures—achieves acompressive strength of 40 megapascals (MPa). The M40 mix is ideal for challenging construction conditions and heavy-duty infrastructure projects because of its outstanding resilience to environmental elements like moisture and chemical attack, which is ensured by its thorough attention to proportioning and quality control. The Mix proportion as per IS 10262 – 2019

Table-2: mix proportion for M40

Cement	:443.25 kg/m^3
Water	:177.3 kg/m^3
Fine aggregate	:602.20 kg/m^3
Coarse aggregate	:1188 kg/m^3
Chemical admixture	:2.96 kg/m^3
Water – cement ratio	:0.42

Table-3: mix proportion of M40 grade of concrete

Water	**Cement**	**Fine Aggregate**	**Coarse Aggregate**
0.42	1	1.35	2.68

4. DIMENSION OF PRECAST COLUMN

In order to assist efficient manufacturing and building processes, precast columns are frequently constructed to fit common cross-sectional shapes, such as rectangular, circular, or T-shaped profiles. In order to satisfy specific project needs, special forms and sizes can be produced thanks to advanced manufacturing procedures. The selection of column dimensions is guided by structural analysis and engineering calculations, which guarantee that the columns will minimise construction costs and offer sufficient strength, stiffness, and stability to handle the necessary loads. Precast producers, architects, and engineers work together to ensure that precast columns fit the overall building design while also meeting aesthetic and functional requirements.

Table-4: dimension of precast column

SPECIFICATION	**COLUMN**
Grade of concrete	M40
Grade of steel	Fe 550
Length	1500mm
Breadth	150mm
Depth	180mm
No. of reinforcement	4
Size of reinforcement	12mm
Stirrup size	8mm
Spacing	110mm
cover	30mm

5. CONVENTIONAL COLUMN

A conventional M40 grade column is typically constructed using a high- strength concrete mix designed to withstand a compressive strength of 40 megapascals (MPa) after 28 days of curing. The column's dimensions, reinforcement detailing, and construction methodology adhere to engineering standards and project specifications. Coarse and fine aggregates are meticulously proportioned with Portland cement, ensuring optimal strength and durability. During casting, proper compaction techniques are employed to eliminate voids and ensure uniformity.

Fig 1: Conventional column(m40)

6. COUPLER IN COLUMN-TO-COLUMN CONNECTION

Couplers help to effectively link reinforcing bars in column-to-column connections. By removing the need for time-consuming lap splicing, these mechanical connectors increase construction productivity. Couplers preserve structural integrity by ensuring exact alignment and load transfer between columns. There are several varieties of these systems, such as threaded, welded, or mechanical grip systems, and each has unique benefits for seismic performance and ease of installation. Couplers are a dependable solution for column-to-column connections in reinforced concrete construction, cutting down on construction time and simplifying assembly while also improving the structure's resistance to seismic stresses.

Fig 2: Casting of coupler in column-to-column connection

Fig 3: coupler in column-to-column connection

7. HALF GROUTED SLEEVE

In the building, reinforcing bars are joined together structurally via half- grouted sleeves. Concrete can partially fill the cavity thanks to the sleeve's one open end. For a variety of reinforced concrete applications, including column-to- column connections, this design's efficient load transfer and little material consumption make it appropriate.

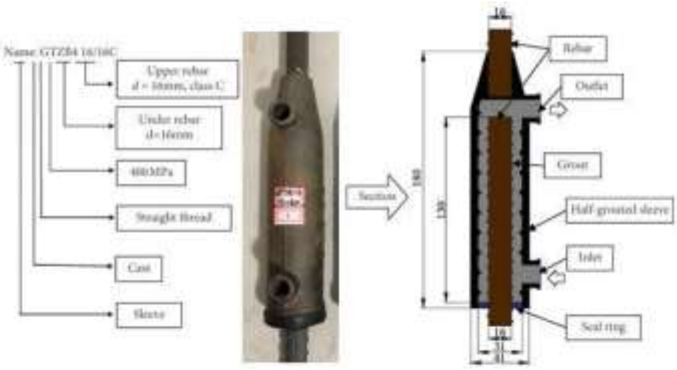

Fig 4: simplified diagram of half grouted sleeve

8. PROPERTIES OF GROUTING MATERIAL

Anchor grout materials possess crucial properties for anchoring applications, including high strength to withstand loads, excellent flowability for complete substrate contact, and minimal shrinkage to prevent voids. They exhibit durability against environmental factors like moisture and chemicals, ensuring long-term stability. Fast curing times expedite installation, while strong adhesion to both anchors and substrates resists pull-out forces. Chemical resistance enhances longevity, and compatibility with various substrates allows versatile use. These combined properties make anchor grout materials essential for secure and reliable anchorage in construction, offering efficiency, strength and durability in diverse application.

Fig 5 Grouting material

9. HALF GROUTED IN COLUMN-TO-COLUMN CONNECTION

Half-grouted sleeves offer a workable way to link reinforcing bars in column-to-column connections. These sleeves have one open end, which lets some concrete seep into the cavity. This design minimises material use while facilitating effective load transfer. In reinforced concrete construction, the half-grouted sleeve improves structural integrity and makes strong column-to- column connections easier.

Fig 6: casting of Half grouted sleeve in column-to-column connection.

Fig 7: Half grouted sleeve in column-to-column connection.

10. SPLIT BOND TEST

The strength of the bond between concrete and reinforcing bars can be assessed using the split bond test. A portion of concrete is cut around a reinforcing bar, and the concrete is subsequently separated from the bar by applying tensile tension. The bond strength can be determined by measuring the highest force needed to remove the concrete from the bar. This test evaluates the quality of the concrete, its surface preparation, and the existence of any additives that strengthen bonds. Verifying that the connection between concrete and reinforcement satisfies design requirements for structural performance and longevity is essential for evaluating the integrity of reinforced concrete structures.

Fig 8: M40 grade Cubes for split bond test

11. TESTING OF CUBE FOR SPLIT BOND TEST

A concrete cylinder with an imbedded reinforcing bar is prepared for the split bond test. The bar is visible due to the longitudinal split of the cylinder. The split spreads along the bar's interface with the concrete when a tensile load is applied to it. The strength of the bond is indicated by the load at which this happens. The quality of the concrete, surface preparation, and surface condition of the bar all affect the outcome. In order to ensure structural integrity in applications like beams, columns, and other reinforced concrete elements, this test assesses how well the concrete and reinforcement connect.

Fig 9: Testing of M40 grade Cubes for split bond test

Table 5. Result of split bond test

SPECIMEN NO	WEIGHT (KG)	LOAD (kN)	COMPRESSIVE STRENGHT (N/mm^2)	AVERAGE COMPRESSIVE STRENGHT (N/mm^2)
1	8.55	685	29.2	
2	9.26	733	32.3	30.06
3	8.64	670	28.7	

12. TEST SETUP

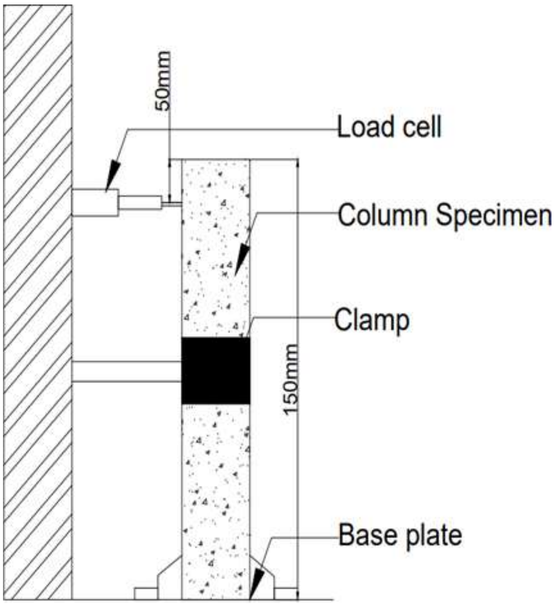

Fig 10: Geometry view of test setup

Fig 11: Laboratory test setup

13. CONVENTIONAL COLUMN SPECIMEN

Place the column specimen into a testing device that can apply lateral loads. Make sure the configuration is reliable and capable of faithfully simulating actual conditions. To guarantee precise measurement of applied loads and column responses, calibrate the testing apparatus. Gradually apply lateral weights to the column specimen while keeping an eye on its response. Increase the load gradually until it reaches the intended maximum or fails.

Fig 12: Test setup of conventional column specimen

Fig 13: Crack on conventional column specimen

14. COUPLER COLUMN SPECIMEN

Fig 14: Test setup of coupler column specimen

Fig 15: Crack on conventional column specime

15. HALF GROUTED SLEEVE COLUMN SPECIMEN

Set the column specimen into a test apparatus that is capable of applying lateral loads. Verify that the configuration can accurately replicate real-world conditions and is dependable. Calibrate the testing apparatus to ensure accurate measurement of applied loads and column reactions. Apply lateral weights to the column specimen progressively while monitoring its reaction. Gradually increase the load until it fails or achieves the targeted maximum.

Fig 16: Test setup of Half grouted sleeve column specimen

16. RESULT AND DISCUSSION

In precast concrete constructions, a type of column-to-column connection known as a half-grouted sleeve connection occurs when only a section of the sleeve is filled with grout. The balance between structural integrity and installation simplicity is provided by this connecting approach.A steel sleeve is inserted into the precast column in this connection, and the top of the sleeve is either left empty or partially filled with grout. The reinforcing bars of the connecting column are then placed into this sleeve. Grout strengthens the connection between the steel sleeve and the reinforcing bars, facilitating better load transmission and adding strength.The following is a summary of the findings for the half-grouted sleeve utilised in a column-to-column junction that were examined using ANSYS and a real experiment: ultimate deformation refers to the maximum displacement or deformation a structure experiences before reaching its failure point.

Table -6: Result of maximum deformation

TYPE OF JOINT	MAXIMUM DEFORMATION
Half grouted sleeve	22.53 mm

Table -7: Result of maximum load

TYPE OF JOINT	MAXIMUM LOAD
Half grouted sleeve	21.3 kN

Table -8: Test Result of half grouted sleeve column connection

LOAD (tone)	DEFLECTION L/3 (mm)
0	0
0.5	2.5
1	4.6
1.5	17.21
2	19.43
2.5	21.65

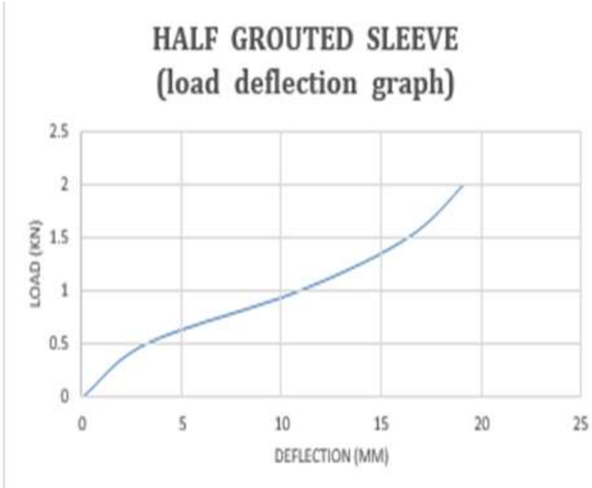

Fig 17: Half grouted sleeve (load deflection graph)

Table-9: Test Result of coupler column connection

LOAD (kN)	DEFLECTION L/3 (mm)
0	0
0.5	7.3
1	11.9
1.5	18.5
2	20.62

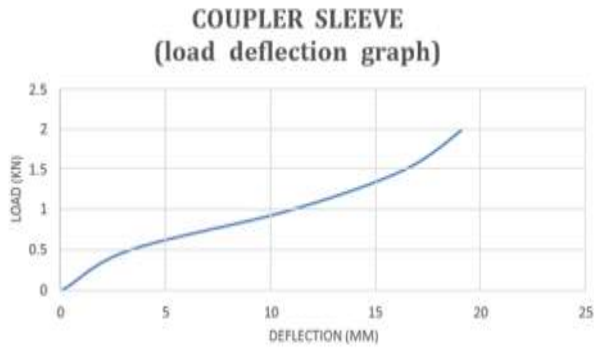

Fig 18: coupler (load deflection graph)

Table -9: test result of conventional column specimen

LOAD (kN)	DEFLECTION L/3 (mm)
0	0
0.5	3.21
1	10.9
1.5	16.32
2	19.1

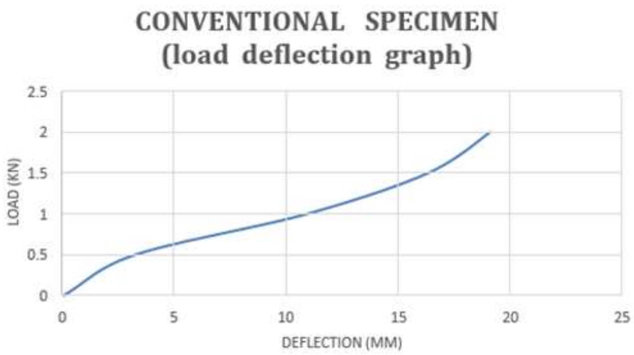

Fig 19: conventional specimen (load deflection graph)

The half-grouted sleeve exceeded the coupler, which underwent fewer deformations under the same load circumstances, with a deformation of 21.23 mm and a load of 2 kN.

The half-grouted sleeve showed an analytical deformation of 22.53 mm when subjected to a pressure of 21.3 kN, but an experimental deformation of 21.65 mm was observed when subjected to a force of 25 kN. This comparison highlights significant differences in load-bearing capacity and deformation between experimental findings and theoretical expectations.

CONCLUSION.

- The half-grouted sleeve in the column-to-column connection was subjected to a cyclic load on the top of the column during the analytical investigations, which were conducted using ANSYS software. The findings came from the examinations of the precast specimens. The analytical study conducted to investigate the behavior of half-grouted sleeves in precast column-to-column connections under cyclic loads yielded the following conclusions.
- Half-grunted sleeve joints were used in this study. The ANSYS program was used to carry out analytical research. Cyclic loading was applied to the specimens, and data on the hysteresis curve, plastic strain, and deformation were noted.
- Because of its practical and structural advantages, half-grouted sleeves are expected to be used in construction more often in the future. They are appealing for a variety of applications due to their increased load transfer efficiency, decreased stress concentrations, and streamlined installation and inspection procedures. Half-grouted sleeves provide an adaptable solution that supports the objectives of efficiency and sustainability when construction techniques change to emphasize these factors. In the years to come, more research and development work is probably going to help them become even more efficient and applicable, solidifying their position as the industry's top option for structural connections.

- The result shows the seismic behavior of a half-grouted sleeve in a column- to-column connection under cyclic stress and the plastic strain damage result using ANSYS software.

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