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Behavior of Hot Rolled Steel Section Casings as Composite Column

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ABSTRACT

Larger bearing capacities and superior deformability of steel reinforced concrete (SRC) columns make them a popular choice for high-rise structures. At this time, there are no design codes that specifically cover this sort of structural structure.This study focuses on ISRC (isolated steel reinforced concrete) columns in an effort to better understand their special features. Based on a typical mega column in an ultra-high rise building, scaled ISRC columns were submitted to two-phase testing. In Phase 1, six 1/4-scaled ISRC columns with eccentricity ratios of 0, 10, and 15% are subjected to static stresses. During Phase 2 of the experiment, four 1/6-scale ISRC columns under quasi-static stresses were used for each specimen, which was subjected to simulated seismic loads of 10 percent and 15 percent, respectively. In addition to the physical testing, a FEA was carried out to get a better understanding of the behavior of "mega columns. To determine the specimens' carrying capacity, an enhanced Plastic Distribution Method has been developed. Simplicities comparable to those in EC4 [1] form the basis of the technique. This standard's scope is restricted to a single steel profile. Using modern finite element algorithms, the approach has been shown to be accurate in comparison to both experimental and numerical simulations.

Keywords:steelconcretecompositemegacolumn,separatesteelsections,down-scaledexperimentaltests,PlasticStrain Distribution Method

1.INTRODUCTION

1.1 Research background and overview

Building systems for high-rise structures are always in need of optimization and reduction in the size of structural components. At all times, the challenge is to keep vertical structural components as small as possible while still maintaining the economic sustainability of projects and limiting their sizeable part of high-rise floor designs. Concrete and steel may be combined with higher-quality materials to create composite structural parts that can be used in a variety of ways.There are a number of common structural alternatives at this period, including concrete-filled tubes and continuous caissons formed by welding massive plates. For large plates, preheating and maintenance are required in addition to the high expense of the equipment.

"Composite mega columns are defined in this research as vertical structural systems made up of multiple hot-rolled steel sections embedded in concrete and subject to significant vertical loads and bending moments generated by seismic occurrences.In spite of the fact that codes and standards deal with composite structural components, they do not give explicit design guidance for composite sections having two or more enclosed steel sections (AISC 2016 Specifications for instance).Due to a lack of knowledge of axial, bending, and shear behavior of composite mega columns due to ambiguity in codes, it is essential to undertake experimental testing."These tests simplify the design process and aid in the development of numerical techniques for describing and validating the designs. CABR Laboratories and Tsinghua University's Laboratories, Beijing, hosted the experiment.

This information is utilized to determine the specimens' maximum capacity, displacement and stress distribution as well as their ductility and stiffness.To conclude, we provide simpler design approaches based on European, Chinese, and US regulations, and we then compare the resulting outcomes to numerical and experimental findings. For this purpose, we have included three examples of how the simplified approaches might be used to chosen mega column portions to demonstrate their usefulness.

2.EXPERIMENTALCAMPAIGN

Sections of sample full-scale composite columns from Seattle's Magnusson Klemencic Associates, utilized in high-rise structures, were used to help design the specimens' general arrangement and geometry (MKA). To put it another way, the tower's lobby (the base) is 9 meters high, while the usual floor is 4.5 meters. The columns themselves are 1800 x 1800 millimeters in size. "During the experiment, there are six static tests and four quasi-static tests.

Phase1-Statictests

There are six examples in Phase 1, all of which have the identical geometric arrangement, as seen in Figure 1. Specimens are put through its paces on a 200-ton servo system at Tsinghua University until they break. Experiment setup contains

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two hinges as seen in Figure 2. A hinge is buried in the ground and bricked to prevent it from moving horizontally. The hinge assembly, horizontal actuator, and vertical actuator are all connected via a transition beam on top of the specimen.”

Sand layers and polytetrafluorethylene plates underneath the steel sections' end plates are placed between the test specimens and the hinge to mimic real boundary conditions and guarantee that the steel-concrete contact slips away from the test specimen ends.At any position along the composite column, relative slip may occur. To avoid this, sand layers and PTFE plates must be supplied. Without these, the hinge's stiff surface would keep the test specimen in the same plane. It is thus possible to overestimate the strength of the composite column by limiting the relative movement of the concrete and steel sections towards the specimen ends.

Table:1 Obtainedmaterialstrengths (Units:MPa)

Specimen ID	Actualeccentriciтiese/h[%]	Concretecubicstrength	Yield strength ofsteel sectionflange	Yield strength ofsteelsectionweb	Yield strength oflongitudinalbar	Yield strength oftransversebar
E00 –1	0.0	61.17	408	523		
E00 -2	0.0	56.62	398	411		
E10 –1	12.4	59.75	423	435		f3.25 = 597
E10 -2	12.9	68.40	383	415	438	
E15 –1	19.9	67.50	377	404		f4.80=438
E15 -2	17.9	75.17	389	405”		

There are no dynamic effects as a result of the poor loading speed. Only after all the samples have been exhausted can they be said to have failed Each two specimens were loaded with the same eccentricity ratio e/h: 0%, 10%, and 15%. The real eccentricity ratios become bigger as a result of second order effects. Figures for these outliers may be found in Table 1. This test uses horizontal actuators to guarantee that the transition beam's lateral movement is kept to a minimum at all times.

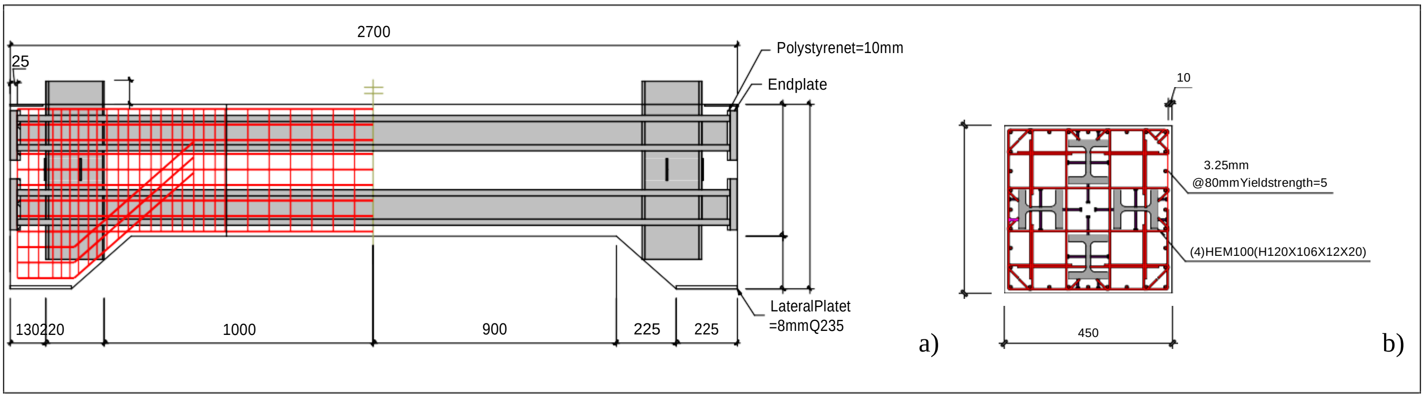

Figure:1.Detailsofthestatictests:a)steellayout–longitudinalview;b)Crosssectiondetails

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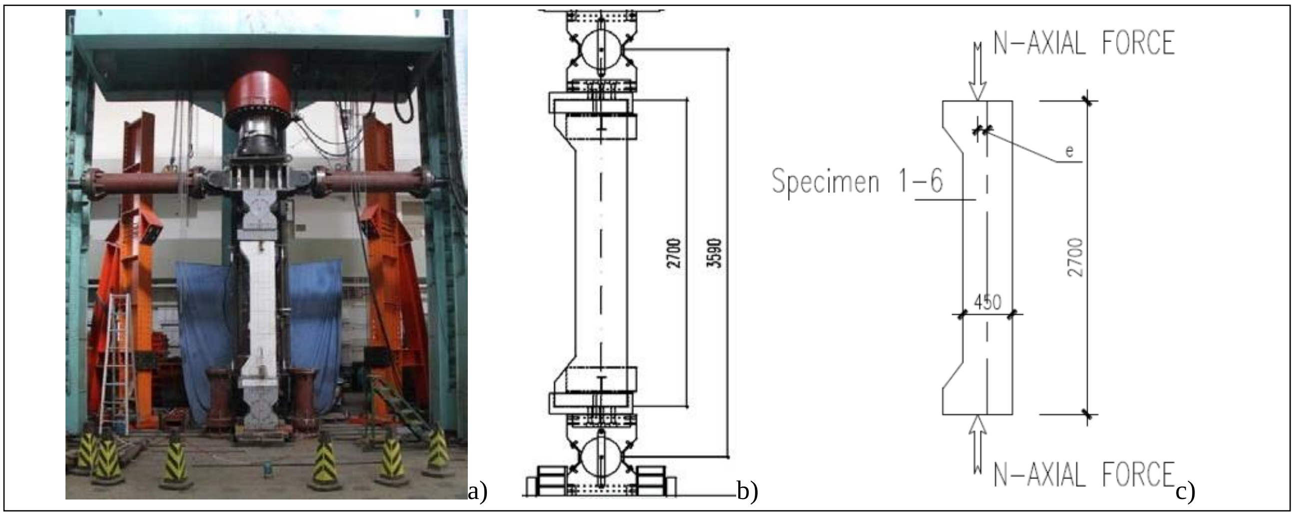

Figure:2.Phase1:Testsetup:a)staticsetupinlaboratoryb)boundaryconditions;c)loadapplication.”

Further data is provided for vertical and horizontal displacements, curvature and ductility, axial stiffness, relative steel-concrete section displacements, and the ability of the composite mega column to resist deformation.This causes fractures to grow in both the vertical and horizontal directions as the axial stress rises. When the deflections are considerable, the axial load diminishes and the test is stopped. Because of the increasing vertical deflection, the axial load on solely axial specimens begins to decrease after it reaches its maximum value. Column failure causes a severe deflection and damage that lowers the second load level. It is fairly uncommon for eccentric specimens to undergo a progressive decline in applied stress following the highest point. There is also a constant development of horizontal deflection and concrete degradation on the portions of reinforced concrete that are under stress. On exclusively axial specimens, longitudinal rebar buckling and tie breakage may be seen.Figures 3 and 4 show the progression of cracks throughout the loading period. Steel profiles are pliable, but not buckling, in nature. The profiles have not been found to be significantly deformed.

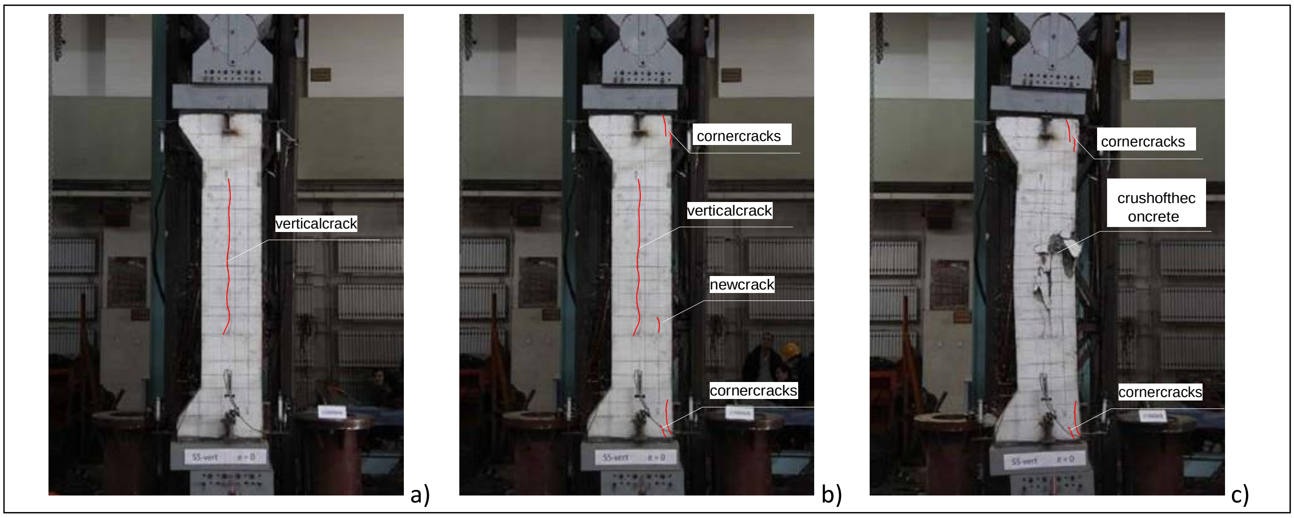

Figure:3Crackdevelopmentofspecimenssubjectedtoaxialload:a)70%ofthe maximumload;b)afterthe maximum load;c)failureload.

Figure:4Crackdevelopmentofspecimenssubjectedtoeccentricloads:a)70%ofthe maximumload;b)failureload."

Bending moment vs. rotation is illustrated in Fig. 5a for the central section of the specimens. The bending moment of the central section remains constant despite the curvature. A decrease in bending stiffness is shown by a decrease in curve slope as rotation increases. Mid-absorbed energy is represented by the'moment vs. rotation' curve's area beneath it, since the moment's magnitude multiplied by the angle equals the amount of energy. The ductility of columns with an eccentricity ratio under 15% is exceptional, to put it another way.

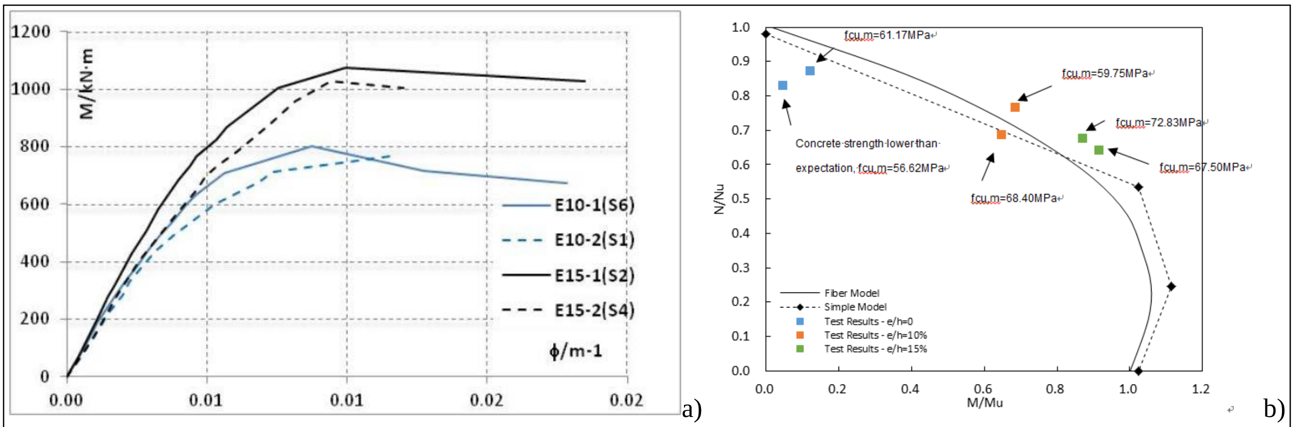

Figure:5.a)Momentvs.rotationatmid-section;b)bendingmoment–axialforceinteractioncurves

According to the Plumier technique et al. [3], [4], the trial connection locations in Fig. 5b correspond to the worked on association bend. Interest bends and connection bends' recorded data tend to differ since the test instances' typical material assets are employed to build cooperation bends. Because the considerable hammering stresses outside the stirrups are less than 3.5-E-3, the plan an incentive for this pressure, the hub load design value cannot be met. The findings of the testing suggest that individuals subjected to unusual loads have a temper tantrum. Stresses on the hub are expected to lead to worse experimental results in both models. There are lesser real characteristics in both cases than in the standard six-part example. In addition, the results of these two cases have not yet included the effects of clasping and P-impacts.Steel profiles, concrete, and longitudinal rebar may all be subjected to the same amount of stress since shear powers are not present. As long as the hub example achieves its maximum deformation, longitudinal rebars and steel sections are still malleable. Longitudinal steel sections and rebars on eccentric specimens fail before the specimen reaches its full capacity. The 'Plane Section Assumption' is validated by the midsection strain distribution during this test phase.

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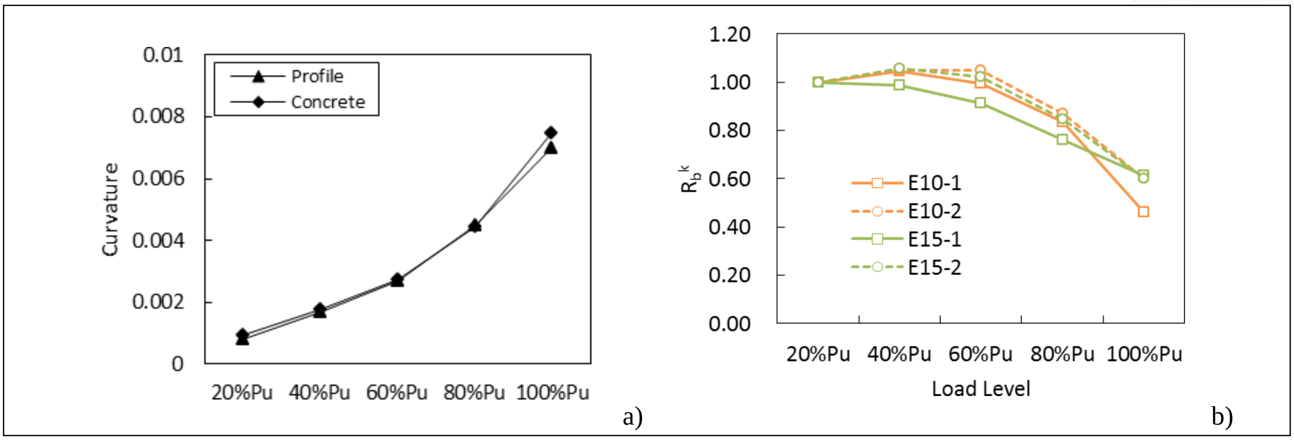


Figure:6.a)SpecimensE10-1andE10-2–curvaturedevelopment;b)flexuralrigiditydegradationusingEC4design method.

Table:2.Stiffnessreductionfactors–comparisons.

	EC4-kevalue	Rbk_EC4-Experimentalvalue	Ratio
E10_1	0.6	0.462	130%
E10_2	0.6	0.599	100%
E15_1	0.6	0.612	98%
E15_2	0.6	0.599	100%

Phase2-Quasi-statictests"

Experiment 2 includes four 1:6 scale specimens, whose geometrical arrangements are shown in Figure 7 and Table 3 (see below for more information). In order to better understand the behavior of the specimens under simulated seismic stresses, researchers vary the eccentricity at which the specimens are tested.

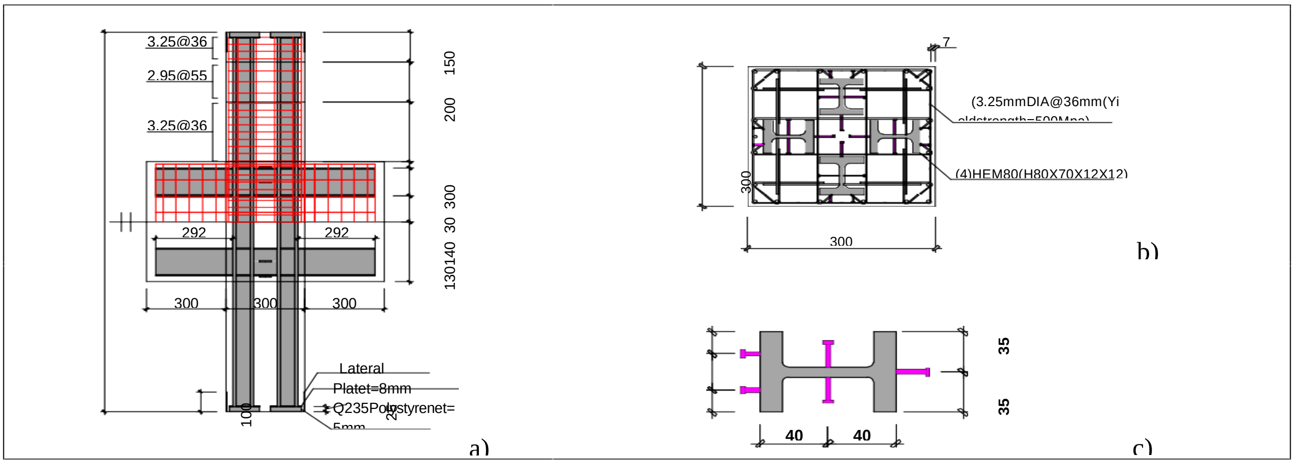


Figure:7.Phase2:Quasi-statictests:a)steellayout–longitudinal;b)steellayout–crosssection;c)shearstudslayout.

Table3.Quasi-static selectedmaterials

Concrete	C60(fck=38.5MPa),with5mmaggregatemaximumsize
Hotrolledjumbosections	Horizontal: 140x73x4.7x6.9 mmVertical:HEM80(80x60x12x12m

	m)S235(fyk=235MPa=34 ksi)
Longitudinalreinforcement	6 /8 mmdia-HRB400 (ASTMA615),(fyk=400 MPa)
Stirrups	3.25mmdia@36mm HRB500(fyk=500MPa)
Shearstuds	5mmDIAx25mmNelsonheaded Studs; ASTMA108@150mmO.C.5mm DIA x 15 mm Nelson headed Studs; ASTM A108 @ 150 mm O.CGrade 4.8”

Samples D10-1 and D10-2 were 10 percent eccentric, whereas specimens D15-1 and D15-2 were 15 percent eccentric to account for the wide range of materials used and production methods used. The specimens are subjected to a horizontal force at their mid-height. The specimens' top and bottom horizontal end reactions are multiplied by two to arrive at the transverse load (V). On top of the specimen, a top hinge is attached to the vertical actuator via a bottom hinge that is positioned on the ground. A frame holds both hinges in place, preventing them from moving horizontally or out of plane (Fig. 8c).

Because the eccentricity ratios are so similar, the general behavior of the quasi-static tests is quite similar. FIG. 10 shows a combined compression-and-flexure-pattern failure in the specimens based on crack distributions and failure mechanisms. During the initial stage of loading, the test specimens do not exhibit substantial deformations or cracking. Fractures and concrete crush appear during the second stage of loading, and the specimen eventually collapses due to the accumulation of damage at the column corners.It is confirmed within a 15% eccentricity ratio by static experiments that the theory, known as the "Plane Section Assumption," is right on. Steel pieces operate as a confining force that keeps the core concrete from crumbling, despite the damage to the concrete's outside surface. Steel parts can not buckle due to the concrete core confinement. Transverse ties and longitudinal rebar have been found to be bowing locally. Stable and circular hysteretic curves exhibit the capacity to dissipate energy without a substantial influence on the eccentricity ratio (Fig. 11).Ten percent eccentricity till failure results in a linear strain distribution in concrete and steel sections, hence the 'Plane Section Assumption' can be shown to be correct. The assumption holds true for specimens evaluated at a yield load level of 15% eccentricity. Because of buckling, longitudinal rebar goes against the assumption. Within a 15% eccentricity ratio, the plane section assumption is more likely to be proven.

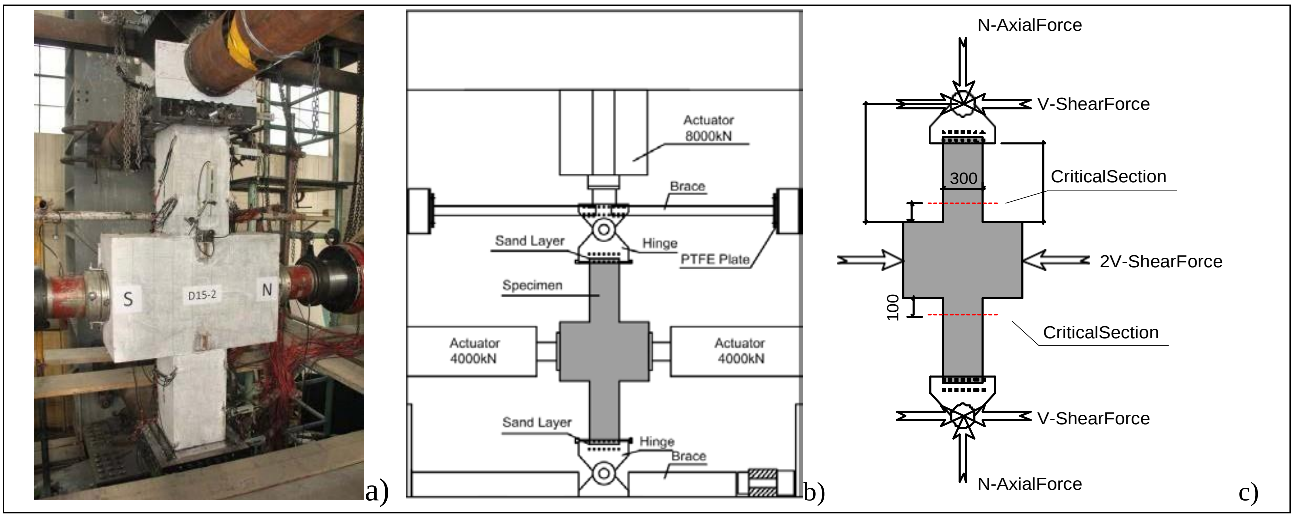


Figure:8.Phase2:Quasi-statictests:a)laboratorysetup;b)boundaryconditions;c)testsetup.

Fig. 9 depicts the gradual rise in the axial load until it approaches the gravity load. Then, the axial and transverse loads are raised in proportion to the increase in the weight. As the applied axial force rises, so does the applied lateral load, which is applied in cycles of 500 kN each.

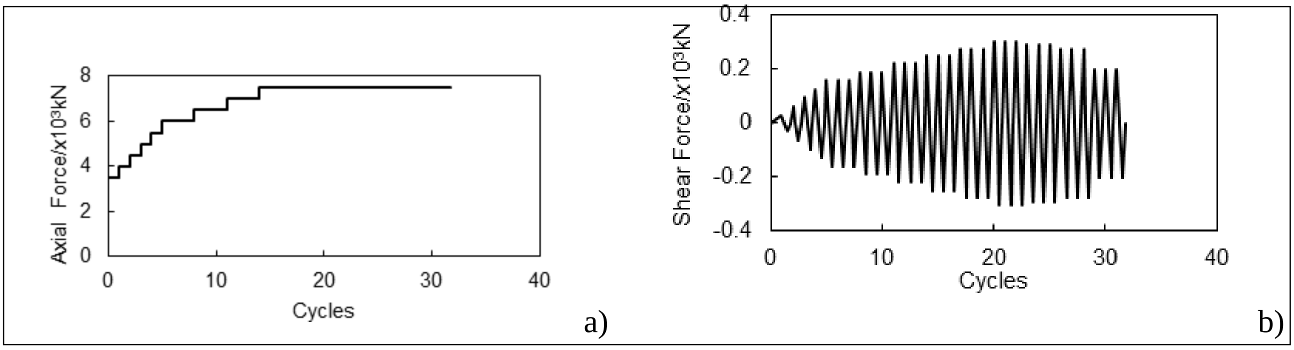
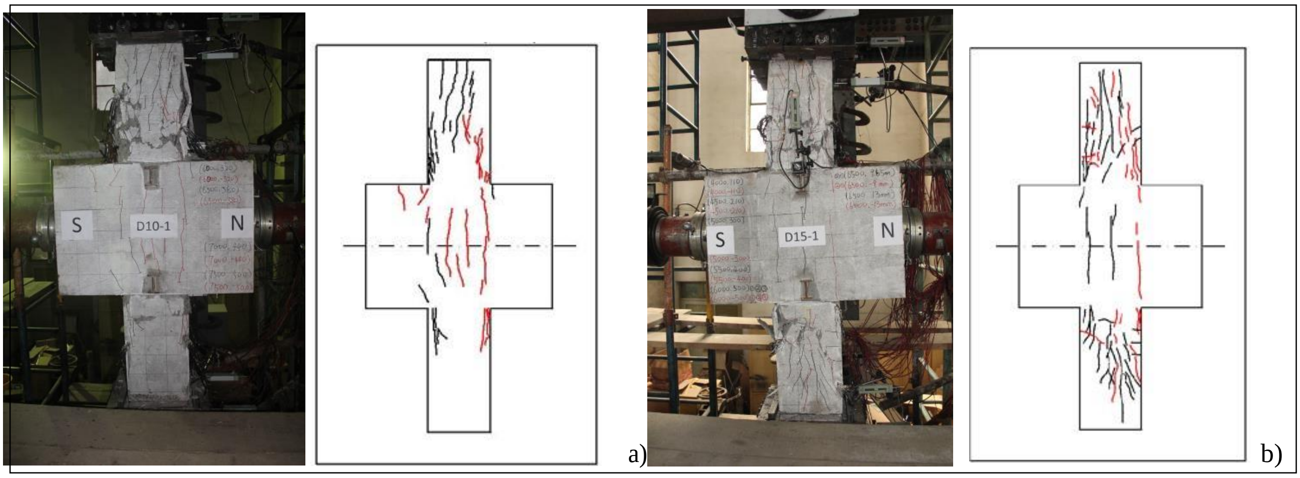


Figure:9.Phase2:Loadintroduction:a)axialloadhistory;b)horizontalloadhistory.”



“*Fig.10.*Phase2:Crackdistributionandfailure modesofspecimens:a)SpecimenD10-1;b)SpecimenD15-1.

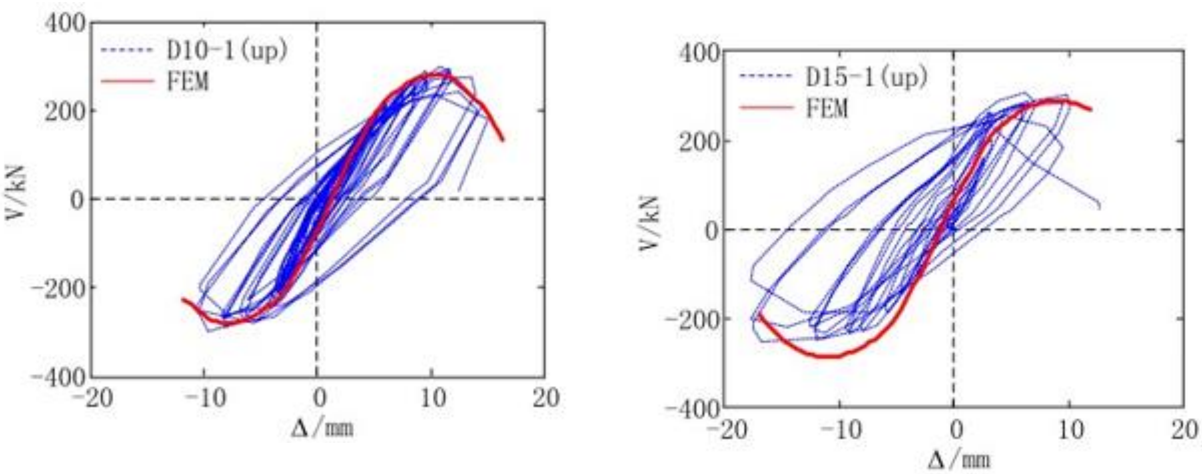


Figure:.11.Phase2:hystereticcurvesa)SpecimenD10-1;b)SpecimenD15-1.”

CONCLUSIONS

Mega columns with embedded steel profiles were subjected to two sets of experiments to verify their performance and behavior. The two processes provide the predicted outcomes. Compression and flexure failures are seen in the specimens.It is possible to identify the composite action even when the steel portions are not attached to one other throughout the test. According to the test findings, the 'Plane Section Assumption' holds true for specimens with an e/h of 10% and 15%, although the interface slip increased with eccentricity, indicating that the shear requirement for mega columns may be higher. The static specimens"moment vs. curvature' ductility is exceptional. Minimum requirements stated by regulations are met by quasi-static specimens' deformation capacity. The specimens' energy usage is consistent, showing that they are doing well in earthquakes.

It is possible to compute the structure's first-order elastic response using a concrete part or composite member with lower stiffness. During moderate or severe earthquakes, the second order effect and concrete fracture might be simplified in this fashion. “It is clear from this program's findings that the EC4 method's stiffness reduction factor may be reduced to 0.6. (the factor is applied to the concrete part only).

The ductility of the composite column is increased since the concrete core is substantially contained by the steel profiles.The static and quasi-static specimens have adequate deformation ability.There are two types of static tests: those that simulate real-world conditions, and those that simulate laboratory conditions. Experimental results show that in quasi-static testing, the ultimate drift ratios of specimens match the Chinese code's (JGJ 3-2010) technical criteria for concrete tall building structures [6].

For reinforced column sections with more than one embedded steel profile, there are currently no design guidelines available. Using a simplified technique based on the plastic stress distribution, an in-depth report was developed and may be seen at [4].” There is no doubt that the approach given in this study is accurate.Actual project needs for China's high-rise structures have led MKA to develop this mega column section layout.

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