FEM Analysis of Reinforced Concrete Exterior Beam-Column Joint Structures Subjected to Highly Variable Axial Forces

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INTRODUCTION

In recent years, it has been reported that a type of damage known as axial failur occurs in the exterior column-beam joints in the lower stories of high-rise reinforced concrete buildings during earthquakes. This is due to the action of high fluctuating axial forces on the columns.To avoid building collapse during a severe earthquake, it is crucial to understand the mechanism that leads to axial failure in the exterior beam-column joints. This study aims to elucidate the axial failure mechanism in exterior beam-column joints by conducting a three-dimensional nonlinear finite element method (FEM) analysis. The FEM model is based on a previous experimental study involving exterior beam-column joint specimens subjected to high varying axial forces. The validity of the FEM model will be examined through a comparison of experimental and analytical results.

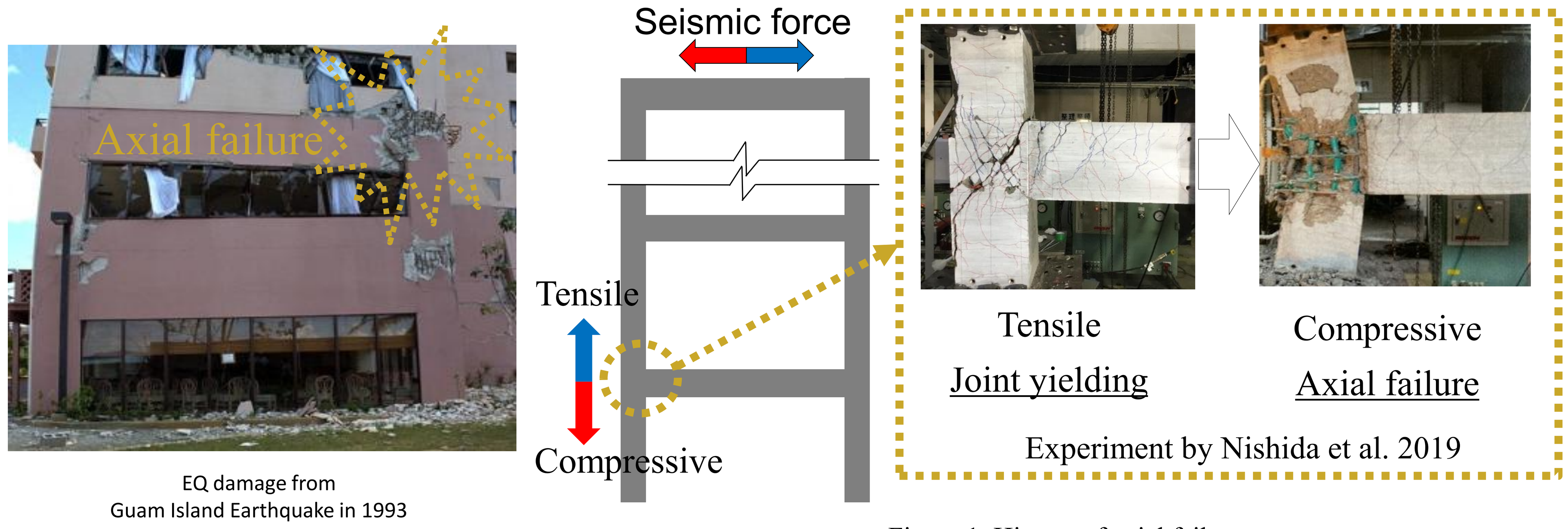

Figure 1. History of axial failure

EXPERIMENT OVERVIEW

Table 1. Details of the analyzed specimens

Analysis specimen		T12-30T4C5-N-13	T12-40 T4C5-N-13	T12-50T4C5-N-13	T12-30T4C3-N-13	T12-30T2C3-N-13
Type of specimen		T12-30T4C5-N-13	T12-40 T4C5-N-13	T12-50T4C5-N-13	T12-30T4C3-N-13	T12-30T2C3-N-13
Failure mode of experiment		Axial failure	Beam yielding		Joint yielding	
H×L		1350×1850(mm)				
Column cross section		250×250(mm)				
Beam cross section		225×275(mm)				
Beam-column bending strength ratio at	(+) Loading	3.03	3.16	3.33	3.5	2.99
	(-) Loading	1.2	1.28	1.29	1.3	1.21
Main parameters						
Joint reinforcement ratio (%)		25	38	46	23	
Axial force ratio at	(+) Loading	0.5	0.5	0.5	0.31	
	(-) Loading	-0.45	-0.38			-0.14
Strength reduction rate β_j	(-) Loading	0.83	0.92	0.98	0.84	0.83

Table 2. Details of reinforcements

Column	Main reinforcement	D13 (SD345)
	Hoop reinforcement	D6 @50 (SD295)
Beam	Main reinforcement	D13 (SD490)
	Stirrup reinforcement	D6 @50 (SD295)
Joint panel	Hoop reinforcement	D6 (SD295)

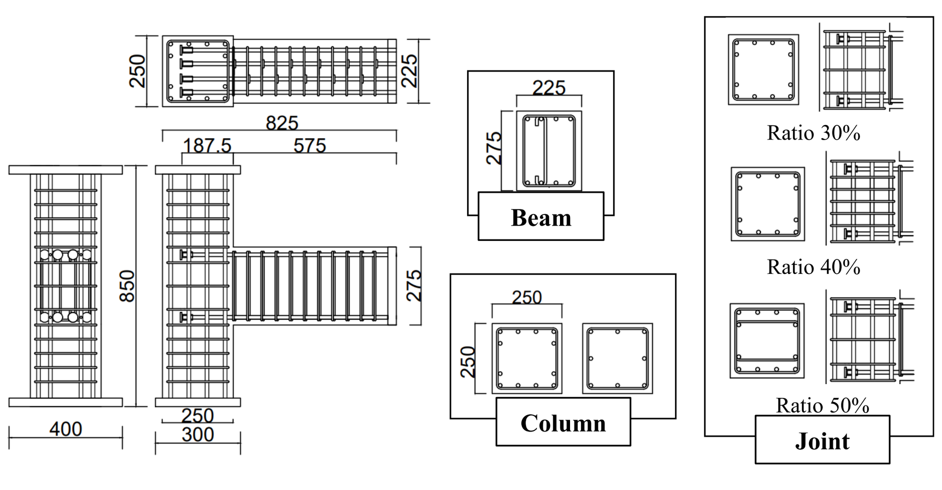

Figure 2. Details of bar arrangement

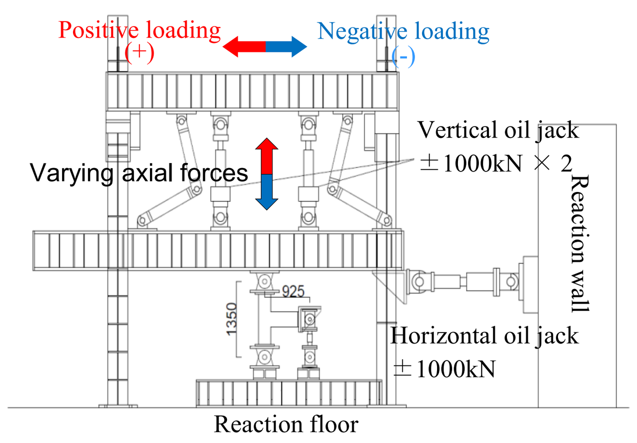

Figure 3. View of the loading setup

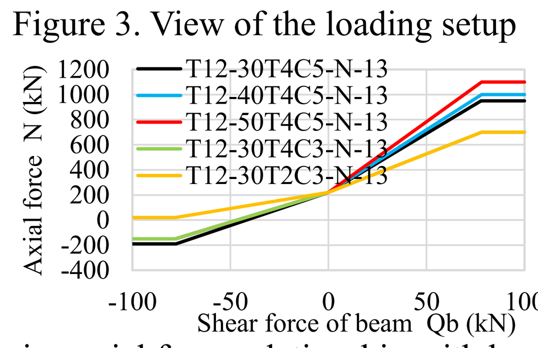

Figure 4. Varying axial force relationship with beam shear force

ANALYSIS OVERVIEW

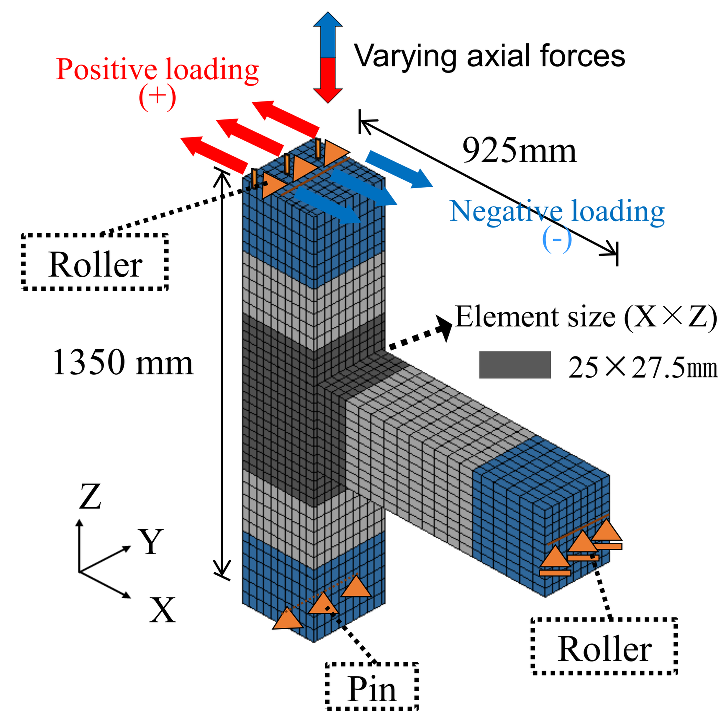

Figure 5. FEM model

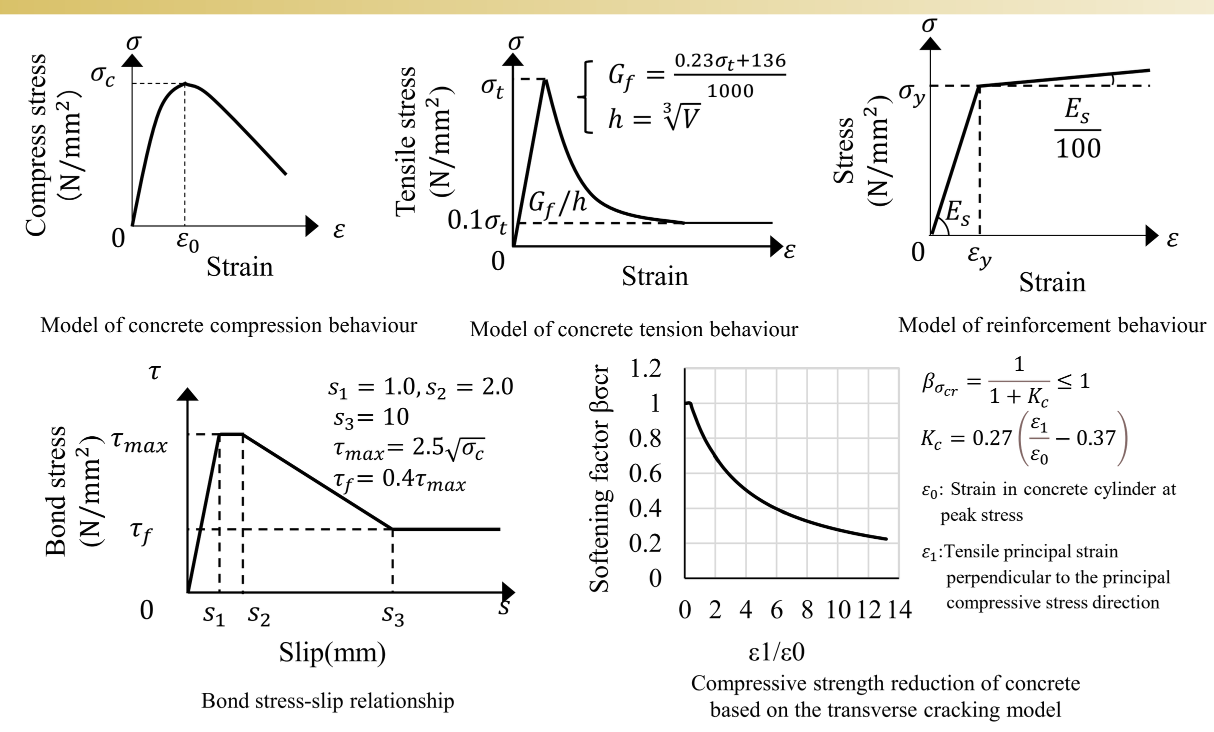

Figure 6. Material constitutive law

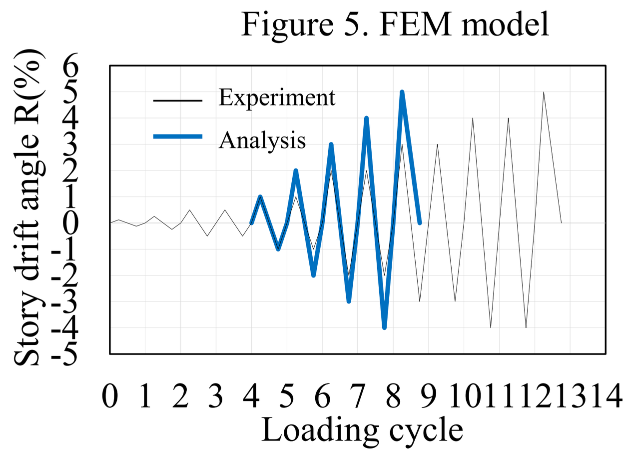

Figure 7. Loading history

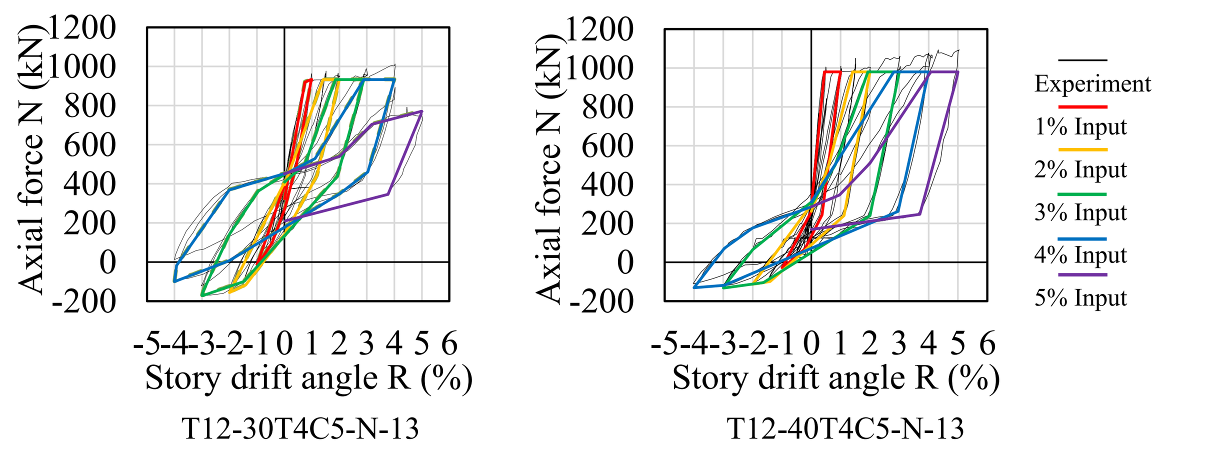

Figure 8. Introduced axial force model

RESULTS AND DISCUSSION OF THE ANALYSIS

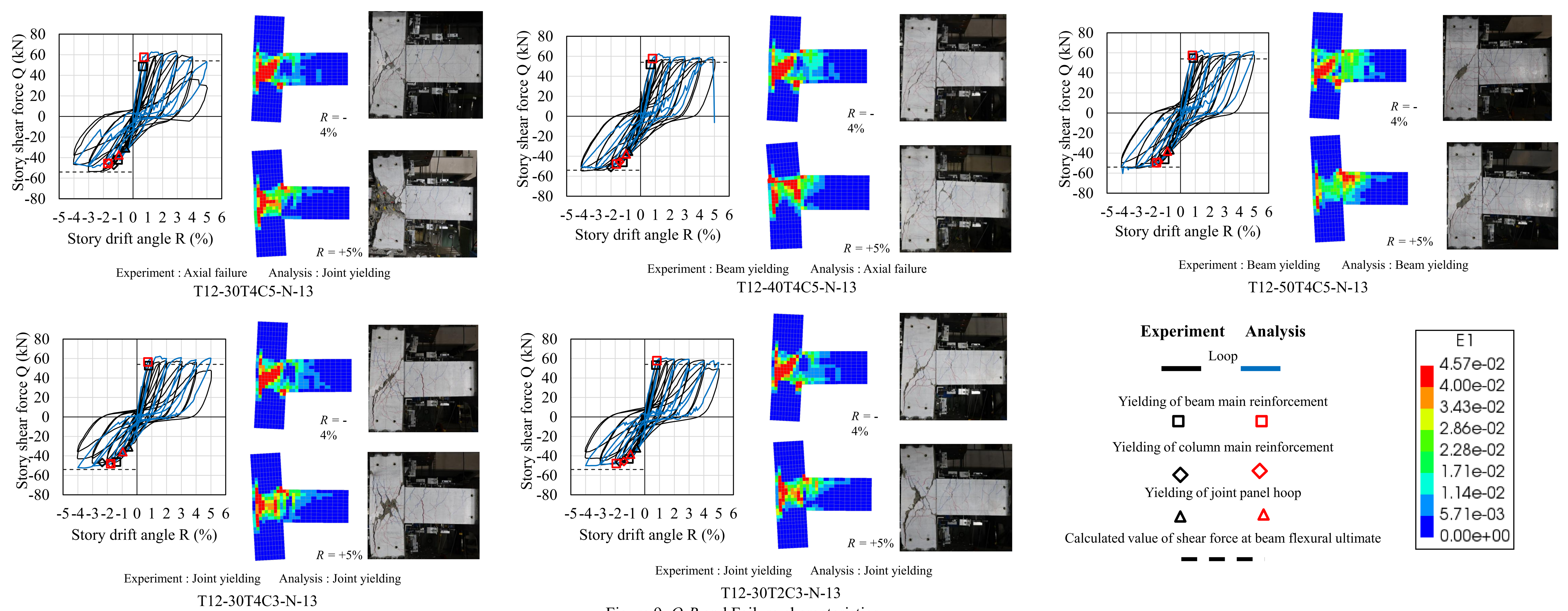

Figure 9. *Q-R* and Failure characteristics

- The maximum force in both positive and negative loadings in the analysis were simulated to be approximately equal to those observed in the experiment.
- The story drift angles at the time of rebar yielding were generally similar, with no significant differences observed.
- At R = -4.0 %, the analysis is the same as the experiment ,with the damage pattern in the joint area was apparently concentrated in the diagonal central part.
- At R = +5.0%, the influence of the compressive axial forces resulted in the damage being concentrated at the beam ends. With the exception of T12-40T4C5-N-13, the damage to the joint panels is generally consistent between the experiment and analysis.

CONCLUSION

In this study, analysis results from FEM models of exterior beam-column joint specimens subjected to large varying axial forces, are presented. The results are consistent in terms of maximum yield strength, the timing of yield in each reinforcing bar, stiffness, and failure properties. This comparison demonstrates that the experiment results can be effectively reproduced using the FEM modelling methodology used in this study.