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Experimental Study on the Shear Behavior of Joints in Precast Concrete Wind Tower with Various Joint Types and Lateral Force Levels

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Abstract

- In response to the need to develop large wind towers, precast concrete towers are being promoted to overcome the high-cost and limitations of the traditional steel towers.
- The precast segmental construction method requires the presence of segmental joints to transfer the loads between neighboring segments, which stresses the importance of securing structural safety and serviceability.
- Therefore, need is for dedicated research on the behavior of the segmental joint.
- This experimental study examines the shear behavior of joints in precast segmental specimens with shear keys considering different joint types and lateral force levels to develop precast wind towers using 80 MPa high strength concrete.
- Analysis is done on the load-displacement relation according to the types of the shear keys and on the failure modes of the shear keys according to the cracking pattern at failure.

Introduction

- The erection of a concrete wind tower by precast assembly requires unavoidably the presence of joints between the segments. The behavioral characteristics of these joints have critical influence on the structural performance and constructability of the concrete wind tower.
- In general, shear keys are disposed in the segmental joint to transmit effectively the shear stresses and vertical compressive stresses. In such case, the mechanical behavior and the load bearing capacity of the shear keys are critical factors for the shear behavior of the joint.
- This paper presents the experimental study on the behavior of shear keys according to the various joint types and lateral force levels in the segmental joint necessary for the construction of precast concrete tower.

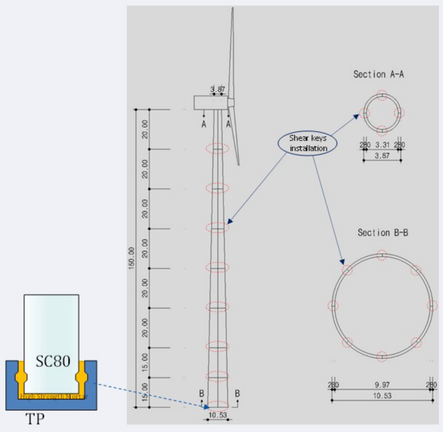

Figure 1. 150m Precast Concrete Wind Tower(10MW)

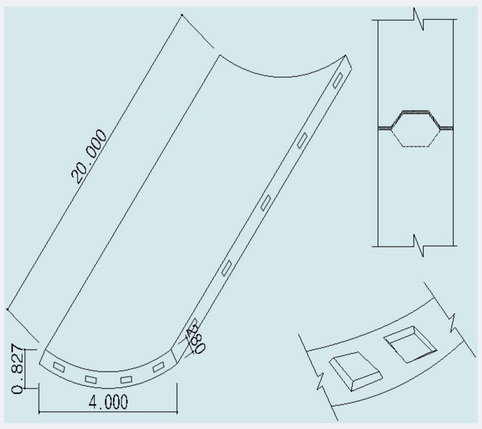

Figure 2. Shear Keys of Precast Segment of Concrete Wind Tower

Structural Performance Test of Shear Keys

✓ *Parameters*

- As a main parameter, the lateral force acting in the specimen was set with the constant values of 2 MPa, 4 MPa and 8 MPa for the cast-in-place joint and epoxy joint. There are 0, 1 and 2 shear keys in the epoxy joint and cast-in-place joint with the height of 7.5 mm, 15 mm and 30 mm.
- Total Specimens : Epoxy Joint(16EA), Cast-in-Place Joint(9EA)

Table 1. Parameters of Specimens according to Joint Types

Joint type	No. of shear key	Filler	Curing temp.	Lateral confining force (MPa)	Height of shear key (mm)	Designation
Dry joint (epoxy)	0	Epoxy	Room temp.	8	-	SC80-D-0-E-8-0
		None		8	-	SC80-D-0-N-8-0
	1	Epoxy		2	30	SC80-D-1-E-2-30
					15	SC80-D-1-E-2-15
					7.5	SC80-D-1-E-2-07
				4	30	SC80-D-1-E-4-30
					15	SC80-D-1-E-4-15
					7.5	SC80-D-1-E-4-07
				8	30	SC80-D-1-E-8-30
					15	SC80-D-1-E-8-15
					7.5	SC80-D-1-E-8-07
		None		8	30	SC80-D-1-N-8-30
	2	Epoxy		8	30	SC80-D-2-E-8-30
					15	SC80-D-2-E-8-15
					7.5	SC80-D-2-E-8-07
		None		8	30	SC80-D-2-N-8-30
Wet joint (cast-in-place)	1	High-strength mortar	70℃	8	30	SC80-W-1-BM70-8-30
					15	SC80-W-1-BM70-8-15
					7.5	SC80-W-1-BM70-8-07
	2			8	30	SC80-W-2-BM70-8-30
					15	SC80-W-2-BM70-8-15
					7.5	SC80-W-2-BM70-8-07
	0			2	-	SC80-W-0-BM70-2-0
				4		SC80-W-0-BM70-4-0
				8		SC80-W-0-BM70-8-0

Figure 3. Details of Epoxy Joint and Cast-in-place Joint Specimens

Figure 4. Concept of Specimen and Test guage Set-up

✓ *Mix proportion of 80 MPa concrete(KICT)*

Table 2. Mix proportion(80 MPa)

W/B (%)	W (kg)	S/a (%)	SP/B (%)	Mixture(kg)						
				OPC	BS	FA	Sand	Agg	SP	Water
22.5	150	42	0.7	400.0	200.0	66.7	643.4	895.4	4.7	150.0

✓ *Fabrication of Specimens(Cast-in-place Joint)*

- The specimens have a total height of 500 mm, a width of 500 mm and a thickness of 200 mm. Three segments were precast and assembled by means of two cast-in-place joints.

Figure 5. Fabrication of Cast-in-place Joint

✓ *Test set-up and measurement*

- The lateral force was applied using a 4000kN actuator with the constant stress of 0,2,4,8 MPa. The vertical load was applied by means of a 3500kN actuator at speed of 1 mm/min. The displacement and strain were measured using concrete gauges and LVDTs installed at the top, center and bottom around the shear key.

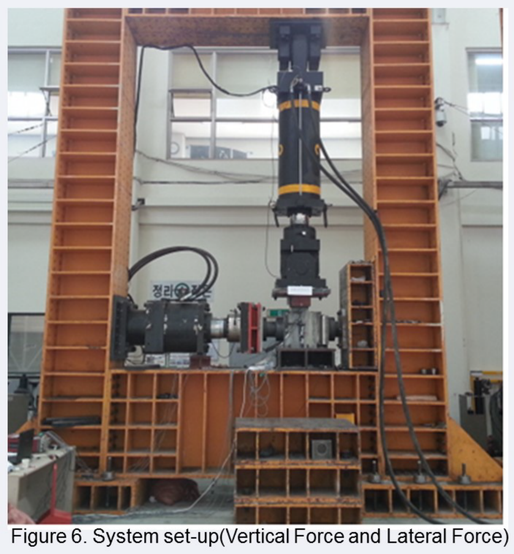

Figure 6. System set-up(Vertical Force and Lateral Force)

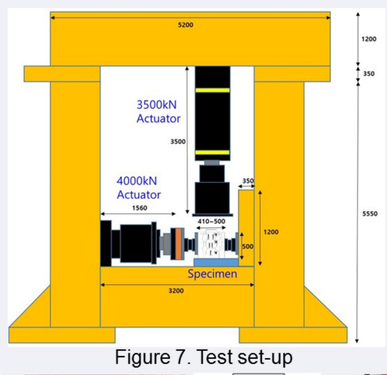

Figure 7. Test set-up

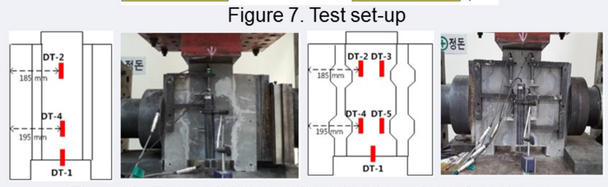

Figure 8. Epoxy Joint and Cast-in-place Joint Specimen

Evaluation of Shear Strength of Precast Concrete Joint

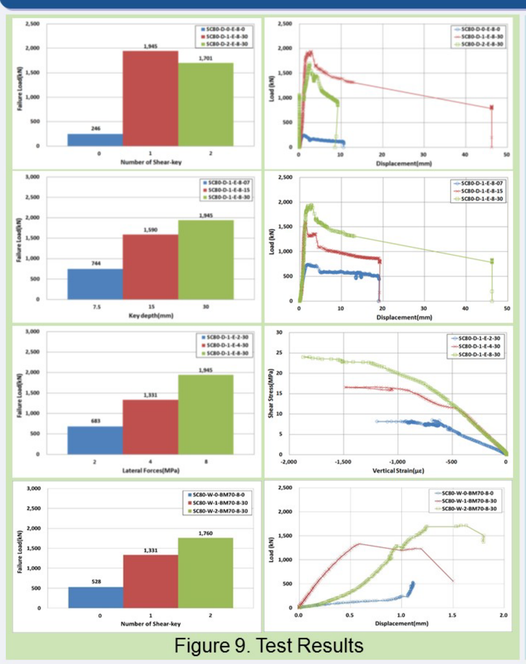

Figure 9. Test Results

Figure 10. Failure mode of Shear Keys and cracking pattern

Table 3. Maximum Failure Load and Displacement

Joint type	Specimen	Lateral Load (kN)	Max.Vertical Load(kN)	Max. Displacement(mm)
Dry Joint (Epoxy)	SC80-D-0-E-8-0	640	2,462	1.12
	SC80-D-0-N-8-0	640	977	1.64
	SC80-D-1-E-2-30	160	684	1.33
	SC80-D-1-E-2-15	160	574	2.60
	SC80-D-1-E-2-07	160	765	2.24
	SC80-D-1-E-4-30	320	1,331	2.04
	SC80-D-1-E-4-15	320	1,206	1.14
	SC80-D-1-E-4-07	320	376	1.83
	SC80-D-1-E-8-30	640	1,945	2.79
	SC80-D-1-E-8-15	640	1,590	1.40
	SC80-D-1-E-8-07	640	744	2.51
	SC80-D-1-N-8-30	640	1,746	1.20
	SC80-D-2-E-8-30	640	1,701	1.33
	SC80-D-2-E-8-15	640	1,421	1.00
	SC80-D-2-E-8-07	640	1,385	0.85
	SC80-D-2-N-8-30	640	1,643	2.77
Wet Joint (Cast -in -place)	SC80-W-1-BM70-8-30	640	1,331	0.59
	SC80-W-1-BM70-8-15	640	1,464	1.00
	SC80-W-1-BM70-8-07	640	1,160	0.63
	SC80-W-2-BM70-8-30	640	1,760	1.29
	SC80-W-2-BM70-8-15	640	1,869	1.54
	SC80-W-2-BM70-8-07	640	1,432	1.56
	SC80-W-0-BM70-2-0	160	377	0.50
	SC80-W-0-BM70-4-0	320	727	2.10
	SC80-W-0-BM70-8-0	640	1,824	1.58

Conclusions

- The shear failure load of the dry joint using epoxy and cast-in-place wet joint in the 80 MPa concrete joint specimens appeared to have similar levels even if in several cases, the dry joint sustained larger ultimate failure load than the wet joint.
- In relation with the number of shear keys, it was verified that the shear resistance capacity increased linearly with the number of shear keys and their heights. It seems advisable to introduce the shear keys as much as possible with the big size in the shear section to guarantee the shear resistance.
- Future works shall propose optimal shear keys by evaluating and analyzing in details the shear performance based on experimental results relative to the precast concrete segmental joint.
- The experimental data acquired in this study will provide valuable information for the shear design of the joint in precast concrete wind tower. Full scale test shall also be conducted prior to the actual application of the precast concrete wind tower.

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