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BEHAVIOR AND DESIGN OF PRECAST COLUMN-BASE POCKET CONNECTIONS WITH ROUGH SURFACE INTERFACE

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ملخص البحث

يعرض هذا البحث دراسة عملية ونظرية لسلوك وتصميم وصلات الجيب ذات الأسطح البينية الخشنة بين الأعمدة سابقة الصب والقواعد. تهدف الدراسة إلى تقييم ثلاثة أنواع من وصلات الجيب ذات الأسطح البينية الخشنة بين الأعمدة سابقة الصب والقواعد يتم انتقال الحمل من خلالها عن طريق الارتكاز وقوى الاحتكاك بدون الحاجة لعمل وصلات لحديد التسليح. اشتملت الدراسة العملية على اختبار سبعة عينات بواقع عينتين لكل نوع من الثلاث انواع: الوصلة الخارجية، والوصة الدفونة والوصلة المدفونة جزئيا مع استخدام قيمتين للطول المدفون داخل الوصلة وهما بنسب 1.6 و 1.06 من بعد العامود، وهذا بالإضافة الي عينة تحكم مصبوبة ميليثيا من أجل المقارنة. أظهرت نتائج الاختبارات تحقيق الوصلة لمقاومة وصلت الى 95% من المقاومة الميليثة كحد أدنى. كما تم تطبيق نموذج الضاغط والشداد لكل عينة من العينات المختبرة وتم التأكد من موافقة النماذج للسلوك المعملي للعينات المختبرة.

ABSTRACT

This paper presents theoretical and experimental study to evaluate the behavior of the precast column-base pocket connections with rough surface interface. Three types of rough surface pocket connections were investigated: external pockets, internally embedded pockets and partially embedded pockets. To compare the three types of pocket connections with the monolithic behavior, an experimental investigation program including seven quarter scaled specimens subjected to vertical and horizontal loads at column top with medium eccentricities was carried out. The tested specimens included: two specimens with external pockets, two specimens with internally embedded pockets and two specimens with partially embedded pockets in addition to pilot monolithic specimen. The embedded length to column width ratios were 1.6 and 1.06 for each type of the connections. The experimental observations and results will be presented in the paper including load-displacement curves, load-strains curves, cracks propagation and failure modes for each specimen. A minimum of 95% of monolithic capacity was obtained for the six tested specimens. To provide a representing design model for the tested specimens, a 3D strut and tie model was proposed. The proposed strut and tie model for rough surface interface provides a good agreement to the experimental behavior for each type of the tested pocket connections.

INTRODUCTION

Pocket connection is obtained by inserting the precast column in a prepared pocket that is larger in dimensions than column. The gap between precast column embedded length and the pocket is to be filled with non-shrinkage grout. As there are no reinforcement bars splicing in this connection, this type offers an easy and rapid construction method providing higher limits for construction tolerance.

This study was motivated by the fact that there are few experimental results regarding this connection (Canha[1]) and analytical models that provide the real behaviour of this connection (FIB[2]). An experimental study was carried out by Canha[1] on the effect of changing embedded length and eccentricity on pocket connection behaviour for rough surface interface pocket connections under vertical loading with large eccentricities. The obtained results showed a monolithic behaviour for the tested specimens with embedded length of 1.6 the column width. Figure 1 shows the load transfer concept in rough surface pockets.

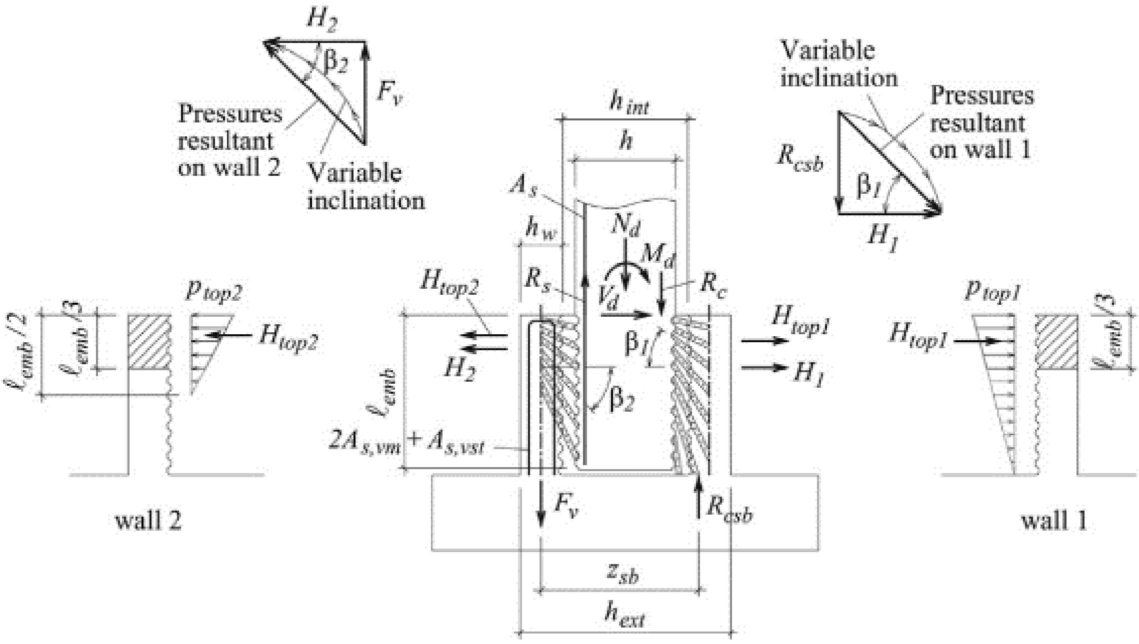


Figure 1 Load Transfer Concept in Rough Surface Pockets (Canha[1])

Strut and Tie model was proposed by Schlaich[3] describing the behaviour of rough surface pocket connections. This model was adopted in this study to design the test specimens of the three types of pocket connections including external, partially embedded and internally embedded pocket connections.

PRELIMINARY ANALYTICAL STUDY

Based on Schlaich[3] Strut and Tie behaviour model for rough surface pocket connections, Strut and Tie models were prepared for the six specimens representing each type of the investigated pocket connections. Figure 2 shows the adopted strut and tie models used to design of test specimens.4

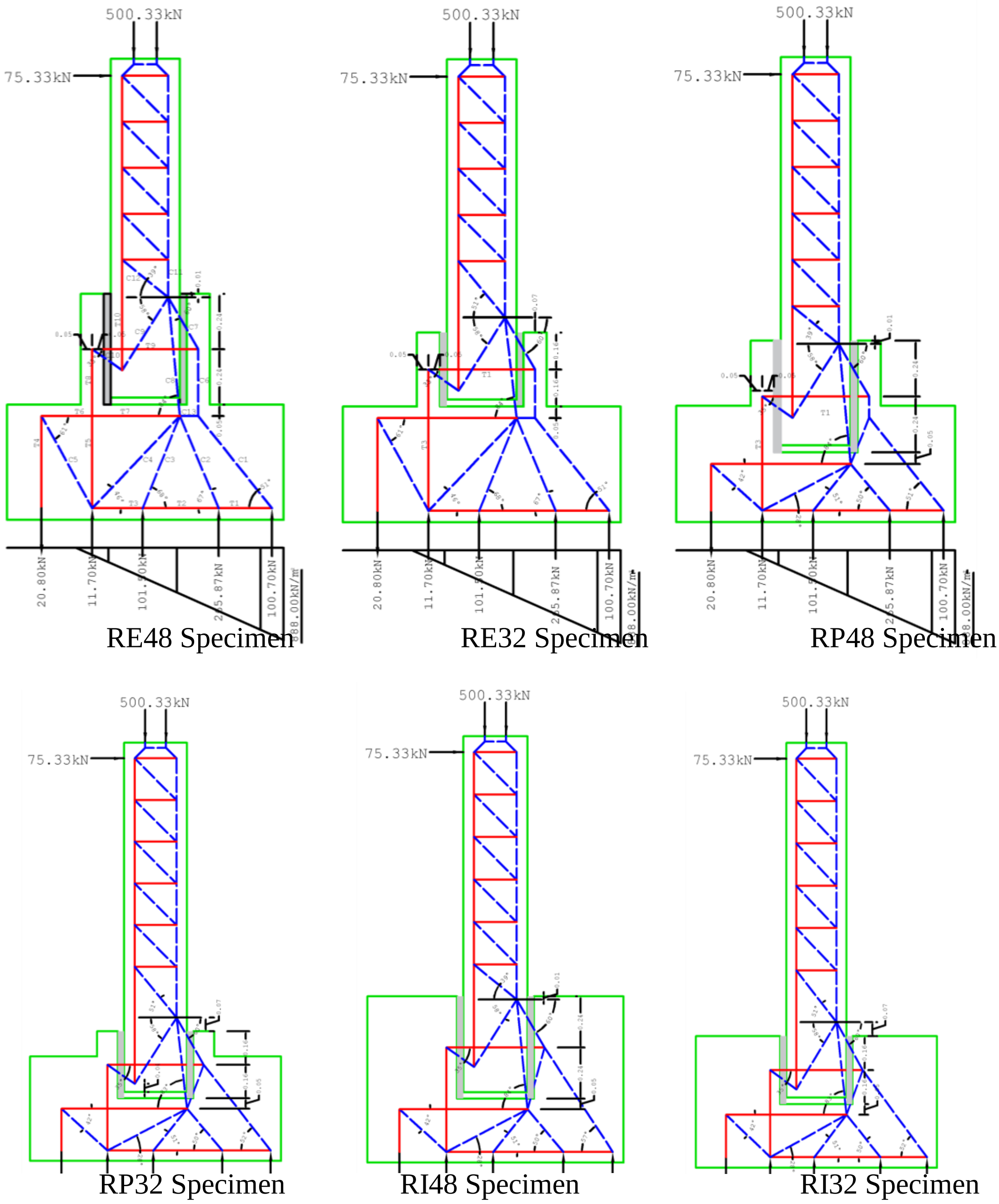


Figure 2 Strut and Tie Design Models Adopted to Test Specimens

Canha[4] proposed inclination angles of: β_f = 60º, β_f = 35º for both front and rear compression struts. In this study, these values were used in addition to angles of 45º to compare the produced forces. Points of application of compression struts were considered at height $L_{emb}/2$. Table 1 shows the resulting forces and main reinforcement values required for each specimen.

		Angles 60&35								Angles 45							
		From Top								From Top							
Specimen		hz Force kN	Area mm^2	RFT		vl Force kN	Area mm^2	RFT		hz Force kN	Area mm^2	RFT		vl Force kN	Area mm^2	RFT	
External	**RE48**	43	179.2	3.56	D8	29	80.6	1.03	D10	41	170.8	3.4	D8	38	105.6	1.34	D10
	RE32	47	195.8	3.89	D8	29	80.6	1.03	D10	49	204.2	4.06	D8	37	102.8	1.31	D10
Partial	**RP48**	62	258.3	5.14	D8	45	125.0	1.59	D10	57	237.5	4.72	D8	55	152.8	1.95	D10
	RP32	48	200.0	3.98	D8	30	83.3	1.06	D10	65	270.8	5.38	D8	45	125.0	1.59	D10
Embedd.	**RI48**	41	170.8	3.4	D8	27	75.0	0.96	D10	48	200.0	3.98	D8	46	127.8	1.63	D10
	RI32	41	170.8	3.4	D8	27	75.0	0.96	D10	48	200.0	3.98	D8	46	127.8	1.63	D10

Table 1 STM Results For Tension Forces and Reinforcement of All Specimens

EXPERIMENTAL PROGRAM

The experimental program included seven specimens subjected to simultaneous vertical and horizontal loads at top of column from zero loads up to failure. The tested specimens were classified as: two specimens with external pockets, two specimens with internally embedded pockets and two specimens with partially embedded pockets in addition to pilot quarter scaled monolithic specimen. The embedded length to column width ratios were 1.6 and 1.06 for each type of the connections. Table 2 shows the tested specimens dimensions and corresponding embedded lengths. All tests were carried out in RC Laboratory, Ain Shams University. Figure 3 shows the concrete dimensions for the test specimens.

The cubic compressive strength of concrete was 50 MPa determined according to ECP 203-2007, and the yield strain of reinforcement was obtained from tensile test according to ES 262/2009. For grout material used as filling of the gap between column and pocket, a grout with compressive strength greater than that of the pocket concrete was used.

All precast columns were designed with greater flexural capacity than pocket walls by 50% to ensure pocket rupture. The pocket walls were designed on forces obtained from the adopted strut and tie models.

Type	Specimen	Column Width (h) (mm)	Embedded Length (L_{emb}) (mm)	L_{emb}/h
Monolithic	S1	300	-	-
External Pockets	RE-1-48		480	1.6
	RE-2-32		320	1.06
Partially Embedded	RP-1-48		480	1.6
	RP-2-32		320	1.06
Internally Embedded	RI-1-48		480	1.6
	RI-2-32		320	1.06

Table 2 Specimens Types and Dimensions

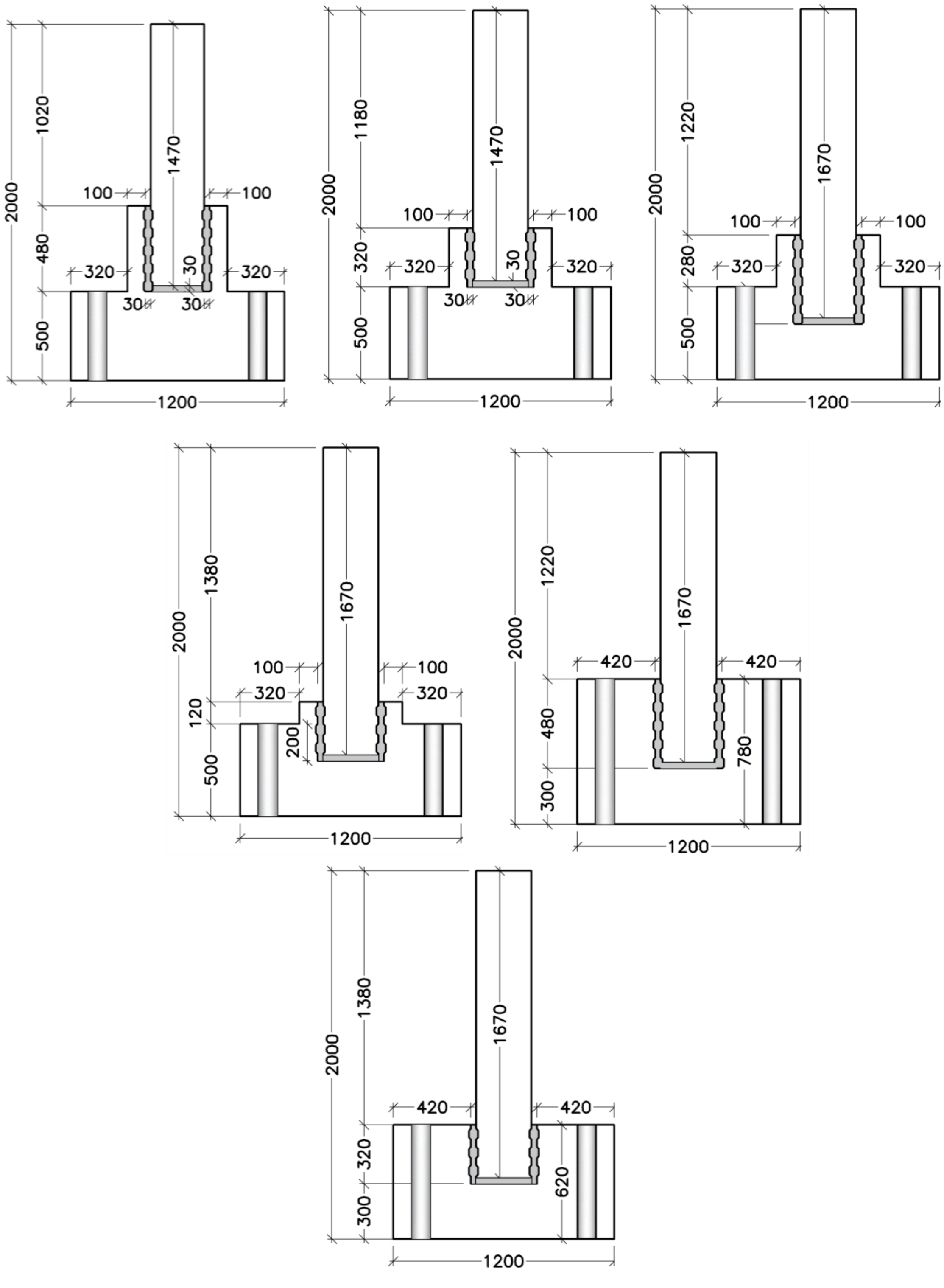


Figure 3 Test Specimens Concrete Dimensions

Figure 4 shows a sample of specimen reinforcement and locations of strain gauges on both reinforcement and concrete. Figure 5 shows test setup used in this study.

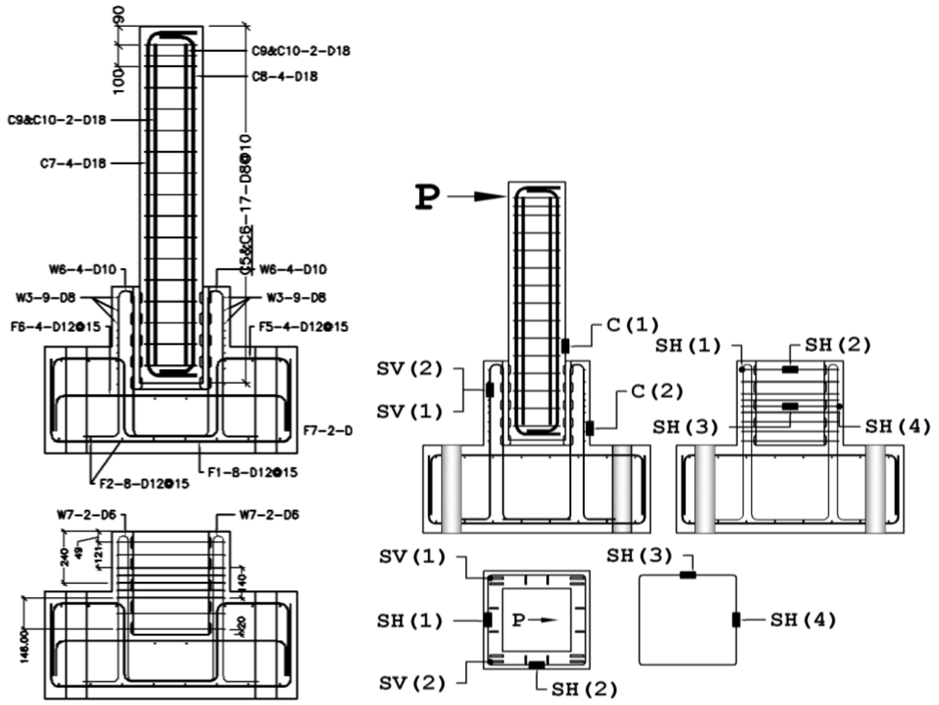


Figure 4 Specimens Reinforcement and Locations of Instrumentations

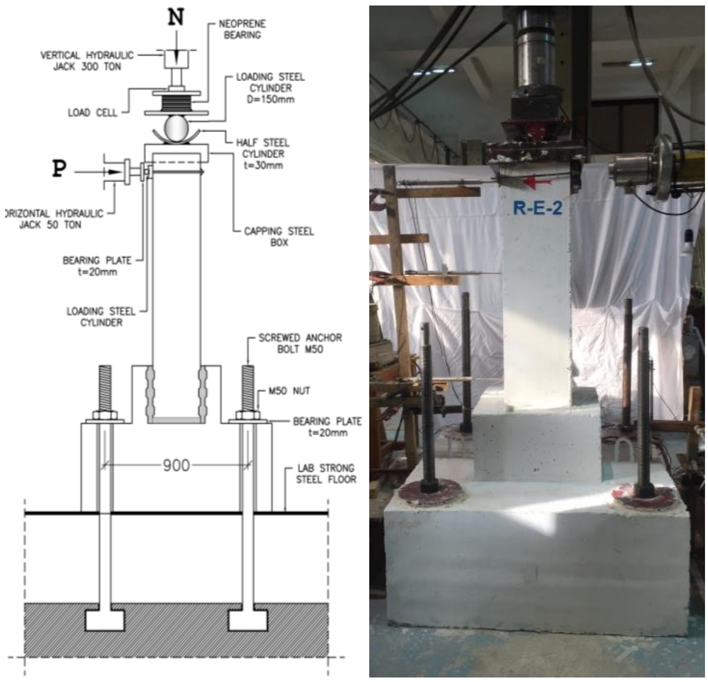


Figure 5 Test Setup

EXPERIMENTAL RESULTS

Table 3 presents failure load results obtained from the experimental program with comparison to the pilot specimen. As shown in table 3, all tested specimens of external, partially embedded and internally embedded pockets with embedded lengths equal to 1.6h and 1.06h exceeds monolithic connection failure load except partially embedded specimen with embedded length 1.06h that reached 95% of monolithic failure load for medium eccentricity loading. Figures 6 shows cracking pattern for pocket walls. It's worth noting that the cracking patterns of the two internally embedded specimens occurred at columns tension sides only indicating column failure due to total fixation resulting from this type of pocket connection.

Specimen		Concrete F_{cu} (Mpa)	RFT F_y (Mpa)		Vl Load (kN)	Horizontal Load Comparison	
Type	Specimen		D8	D10		Failure Load (kN)	% of Pilot Specimen Load
Pilot	S1	50	300	520	650	115	100%
External	RE-1-49					165	143%
	RE-2-32					125	109%
Partially Embedded	RP-1-48					182	158%
	RP-2-32					109	95%
Internally Embedded	RI-1-48					159	138%
	RI-2-32					161	140%

Table 3 Failure Loads Comparison For All Specimens

As shown in figure 6, vertical cracks appeared at top mid width of front walls for RE48, RE32 and RP48 specimens indicating tensile strains in top horizontal stirrups at front wall due to transverse bending. For rear wall of RE48, RE32 and RP48 specimens, vertical cracks appeared at mid width of rear indicating transverse bending effect on rear walls. For RE48 specimen, horizontal cracks appeared at bottom of rear wall indicating vertical tensile strain in vertical reinforcement due to pocket rotation. For side walls of the mentioned three specimens, diagonal cracks appeared indicating diagonal tensile strains due to pocket rotation. For RP32 specimen with small cantilever height of 12cm only, four diagonal cracks appeared at four pocket corners indicating diagonal tension effect accompanied with four compression struts applied at four pocket corners. For RI48 and RI32 specimens, all cracks appeared at column tension side representing column failure with a neglected response of pocket.

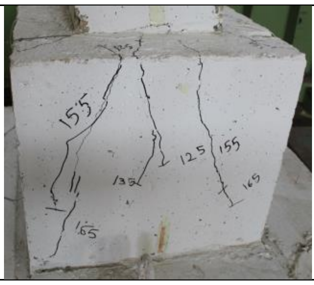
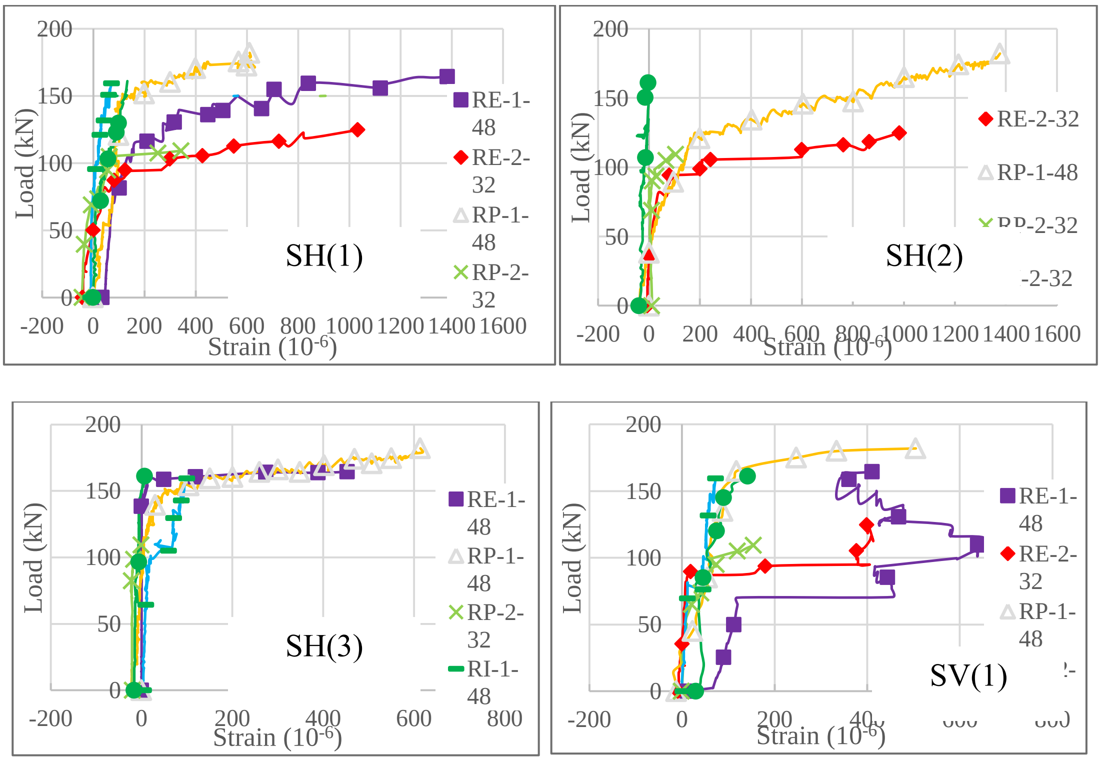
	Front Wall	Rear Wall	Side Wall
RE48			

Figure 6 Cracking Pattern of Partially Embedded Pockets Test Specimens

Figure 7 shows load-strain curves for the tested specimens. As shown in figure 7, SH(1) and SH(2) strain gauges that are located at top horizontal stirrup showed larges response in RE48, RE32 and RP48 specimens with the largest cantilever heights. For SH(3) that is located at the middle horizontal stirrup, RE48 and RP48 showed the largest response with much smaller values than top horizontal stirrup. For SV(1) strain gauge at vertical reinforcement, the largest strain values were obtained at RE48 specimen then RP48 then RE32 and other specimens had much smaller values.



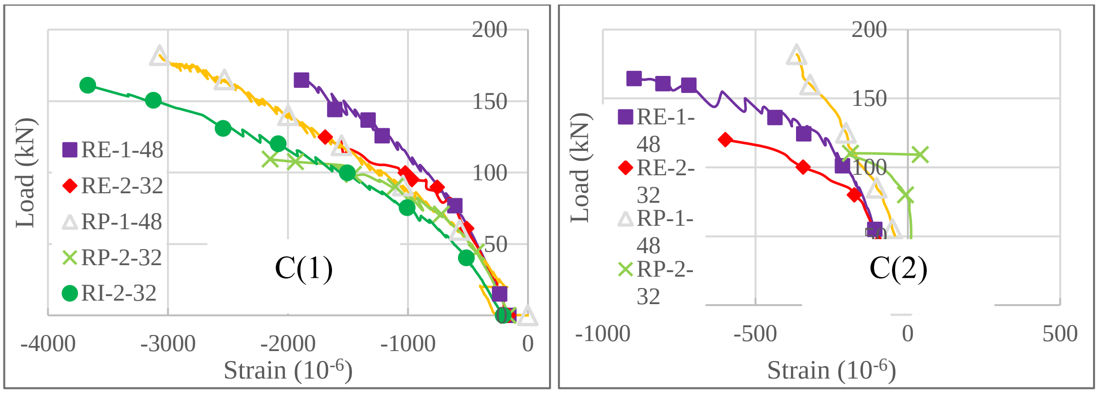


Figure 7 Load-Strain Curves For Tested Specimens

For C(1) strain gauge at compression side of column concrete, the largest values reached are at RI32, RI48 and RP48 specimens represent flexural failure of columns in this specimens. For C(2) strain gage at compression side of pocket concrete, maximum compressive strain reached was at specimen RE48 then RE32 and RP48 specimens with the largest cantilever heights indicating pocket failure for these specimens due to longitudinal bending.

From the presented observations, failure of specimens RE48, RE32 and RP48 is governed by a combined transvers and longitudinal bending behavior as shown in figure 8. The transverse bending behavior is prior to longitudinal bending that causes the failure of pocket front wall.

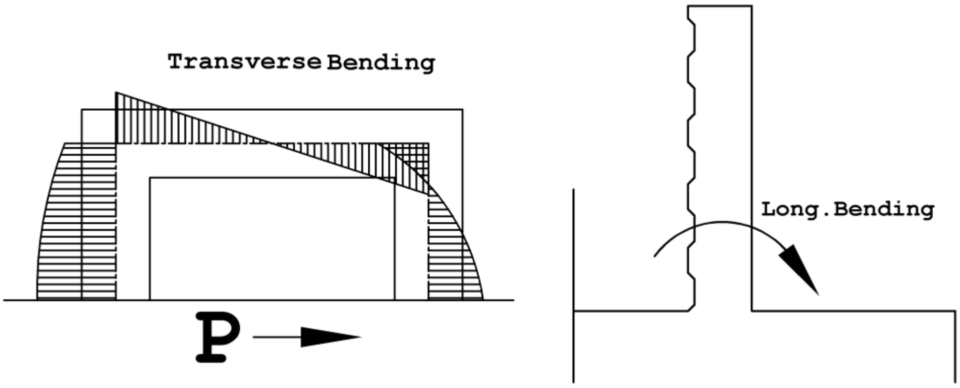


Figure 8 Combined Bending Behavior

CONCLUSIONS

Based on the experimental study results and observations and comparing the observed with the preliminary analytical study performed, following conclusions can be drawn:

1- For rough surface pocket connections, all tested specimens of external, partially embedded and internally embedded pockets with embedded lengths equal to 1.6h and 1.06h exceeds monolithic connection failure load except partially embedded specimen with embedded length 1.06h that reached 95% of monolithic failure load for medium eccentricity loading.

2- For external and partially embedded pocket connections, transverse bending at mid width top of front wall accompanied with longitudinal bending at front wall bottom govern the failure of pocket.

3- For external and partially embedded pocket connections with smaller cantilever heights, longitudinal bending is the major behavior causing failure at lower values of load.
4- For external and partially embedded pocket connections with larger cantilever heights, transverse bending is the major behavior in early stages of loading causing strain increase in top horizontal stirrups before longitudinal bending failure occurs reaching higher values of load.
5- For partially embedded specimens with very small cantilever lengths, the failure may occur at pocket walls corners by diagonal tension produced by diagonal compression struts.
6- For internally embedded pockets with embedded lengths of 1.6h and 1.06h, failure was governed by column flexural capacity indicating total fixation of the connection.
7- The adopted Strut and Tie design models are representing the behavior of pocket connections closely.

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