TESTS ON A POST TENSIONED MOMENT RESISTING CONNECTION FOR PRECAST CONCRETE STRUCTURES

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ABSTRACT

The seismic performance of a post-tensioned beam-column connection was investigated. The test unit consisted of a rigid central block and a half scale precast cantilever beam having the same geometry and reinforcement as the prototype, which had been defined to represent the current practice. The beam was connected to the central block by prestressing cables capable of providing the required positive and negative bending capacities and by some non-prestressed steel. The performances of the precast concrete specimens under reversed cyclic loading were evaluated by comparing them with that of the reference specimen, in which the beam having the same geometrical and material properties as the precast specimens was monolithically connected to the central block.

Three precast concrete beams were tested under reversed cyclic load resembling the seismic action. Deficiencies observed in one case were corrected in the following one until a satisfactory performance was obtained. The connection performance observed in the third precast concrete specimen was quite satisfactory, and led to the conclusion that the proposed post-tensioned connection could well be used in practice in the earthquake prone areas. It is however recommended that the scale effect should also be experimentally investigated.

INTRODUCTION

Great majority of the precast concrete structural systems used in Turkey can be classified as pin connected. Industrial building structures consisting of pin connected beams supported by free standing cantilever columns are very common. Precast concrete rigid framed structures involving connections capable of moment transfer are developing recently. The most critical elements in such structures are no doubt the connections. Presence of seismic action makes the connections even more critical, and this is the case almost everywhere in Turkey. A comprehensive experimental research program has been realised over the past ten years in the Structural Mechanics Laboratory of the Middle East Technical University, concerning the seismic performances of a number of connection details widely used in the country.

Post-tensioned connection may be a very practical and also very reliable type of moment transferring connection to be used in precast concrete structures. A simple detail proposed by the Yapı Merkezi design engineers was elaborated to develop a connection of this type(1). Three specimens were tested, and a connection displaying a rather satisfactory seismic performance was developed(2). The investigation performed is briefly summarised in the present paper.

EXPERIMENTAL WORK

Test Specimens

The test unit consisted of a rigid central block and a medium scale precast cantilever beam having an I-section with rectangular (240 mm x 520 mm) end zones. The beam was connected to the central block by prestressing cables capable of providing the required positive and negative bending capacities and some non-prestressed steel connectors. The connection principle is schematically illustrated in Figure 1, and the beam reinforcement and the reinforcement at the critical connection section of the test specimens are summarised in Table 1.

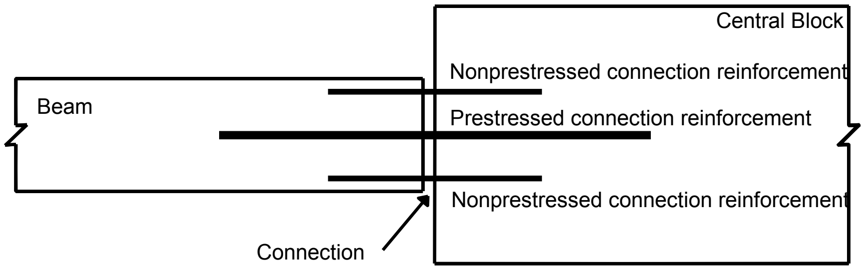


Figure 1: Connection principle

Table 1: Reinforcement in test specimens

Specimen	Beam		Connection			Resulting Behaviour
	Non-prestressed		Prestressed	Non-prestressed		
	Top	Bottom	Middle	Top	Bottom	
MR1	942 mm^2 (2Φ20 + 4Φ10)	314 mm^2 (4Φ10)	---	942 mm^2 (2Φ20 + 4Φ10)	314 mm^2 (4Φ10)	Reference behaviour
PO1	942 mm^2 (2Φ20 + 4Φ10)	314 mm^2 (4Φ10)	2D10 (eqv~1000mm^2)	308 mm^2 (2Φ14)	226 mm^2 (2Φ12)	Insufficient connection capacity
PM1	942 mm^2 (2Φ20 + 4Φ10)	314 mm^2 (4Φ10)	2x2D10 (eqv~2000mm^2)	402 mm^2 (2Φ16)	308 mm^2 (2Φ14)	Premature beam failure
PM2	1080 mm^2 (2Φ16 + 6Φ12)	314 mm^2 (4Φ10)	2x2D10 (eqv~2000mm^2)	402 mm^2 (2Φ16)	308 mm^2 (2Φ14)	Satisfactory behaviour

Loading and Measurement Systems

The rigid central block was connected to the strong testing floor by means of post-tensioned bolts, as shown in Figure 2. The reversed cyclic load was applied at the free end of the cantilever beam using a double acting hydraulic jack, coupled with a tension-compression load cell, bearing against a reaction frame, as illustrated in the same figure.

The basic principle of the measurement system is schematically shown in Figure 3. Besides the deflections of the test beam and the rigid body movements of the entire test unit, local flexural and shear deformations were measured and carefully studied at two critical zones; namely (i) the hinging zone and (ii) the connection zone at the root of the cantilever. The horizontal LVDT readings were used to compute the curvatures, and the diagonal ones to determine the shear strains.

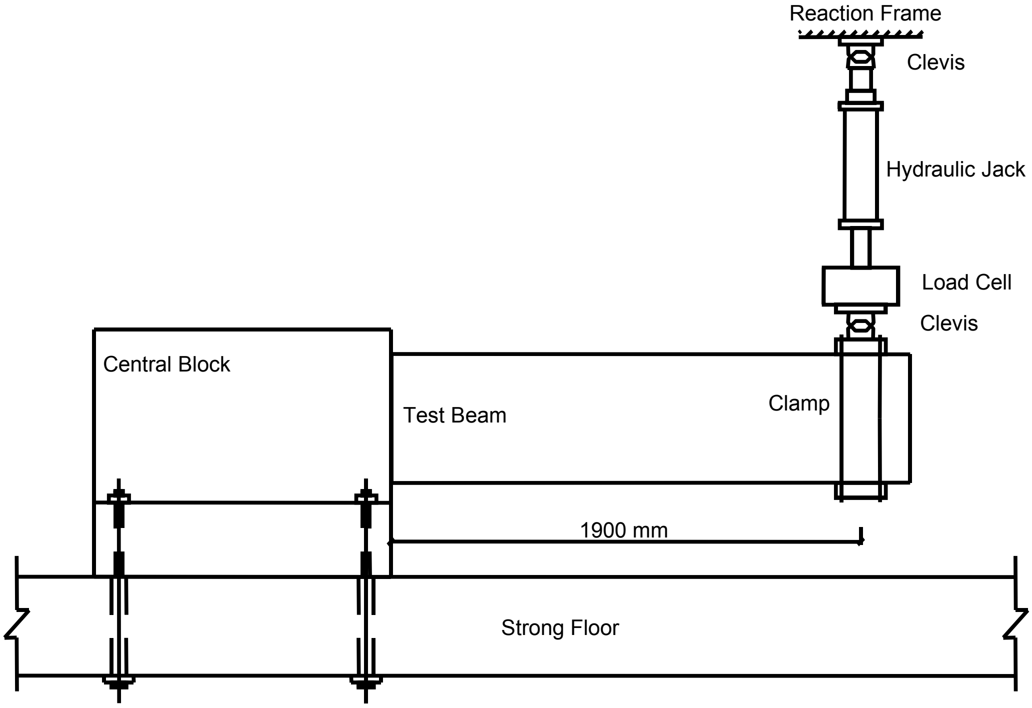


Figure 2: Loading and supporting system

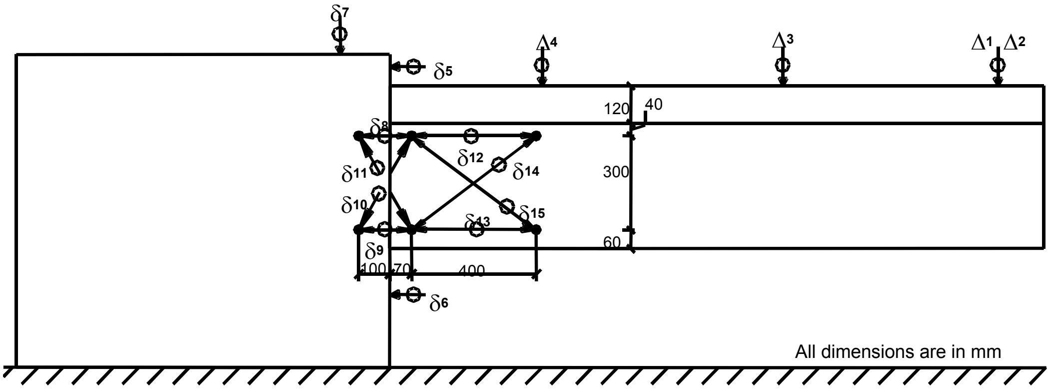


Figure 3: Measurement system

Test 1 – Monolithic Reference Specimen MR1

The expected reinforced concrete beam behaviour was obtained, indicating that the specimen was appropriate as a reference specimen, and the loading and measurement systems were functioning well. The load-deflection diagram given in Figure 4a indicates a sound and stable behaviour in both directions with an adequate ductility and energy dissipation. A comparison of the moment-curvature diagrams given in Figures 5a (hinging zone) and 6a (connection zone) shows very clearly that proper hinging has developed at the expected location whereas the connection zone remained almost intact.

Test 2 – First Design Precast Concrete Specimen PO1

The beam having the same dimensions and reinforcement as the monolithic reference specimen was connected to the central block by means of two post-tensioned prestressing cables located at approximately two-fifth depth from the top and mild steel screw-in type connectors located at the top and bottom flanges. The flexural capacity, provided by these connectors in each direction was estimated to be approximately equal to those of the monolithic reference specimen.

Although the flexural capacity reached was considerably smaller than expected in both directions, the overall behaviour was rather reasonable with a stable character and a considerable ductility, as observed in Figure 4b. A comparison of the moment-curvature diagrams given in Figures 5b (hinging zone) and 6b (connection zone) shows that, unlike the monolithic reference beam, the major part of the deformation took place at the connection, and the hinging zone deformations were very small indicating almost no damage in the beam. It was evident from this observation that the connection needed to be strengthened.

Test 3 – Modified Precast Concrete Specimen PM1

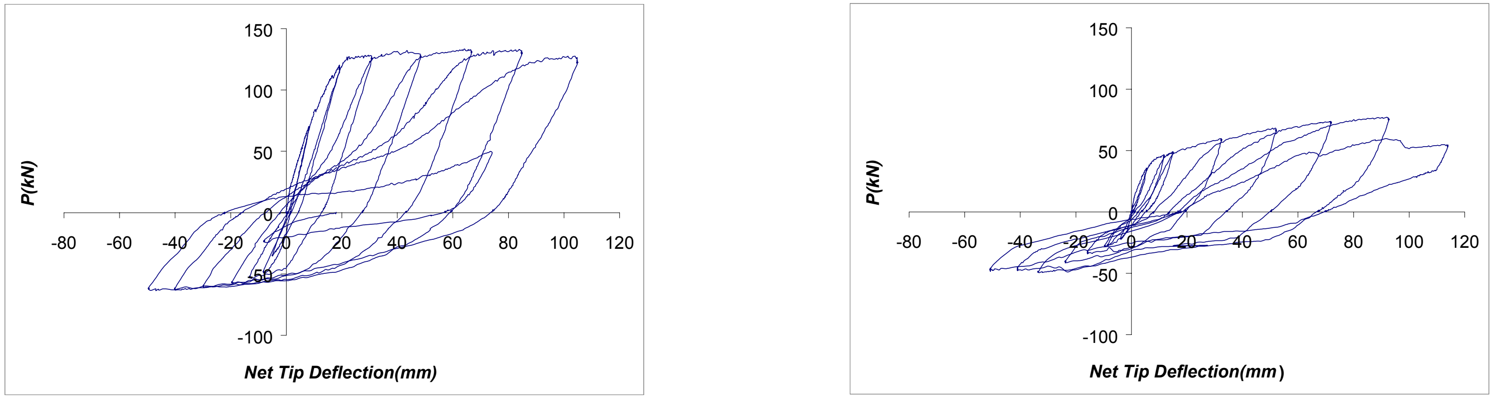
In line with the above observation, the connection was improved in this specimen by doubling the post-tensioning steel and using larger mild steel connectors at the top and bottom, see Table 1.

Due to an unexpected premature failure in the beam, caused by certain changes in the beam geometry to accommodate the larger prestressing anchor plates, the connection could not be loaded to its capacity and its behaviour could not be thoroughly investigated. The load-deflection diagram given in Figure 4c displays an insufficient capacity and inadequate ductility, and the moment-curvature diagrams given in Figures 5c (hinging zone) and 6c (connection zone) support the impression that the connection could not be sufficiently stressed.

Test 4 – Further Modified Precast Concrete Specimen PM2

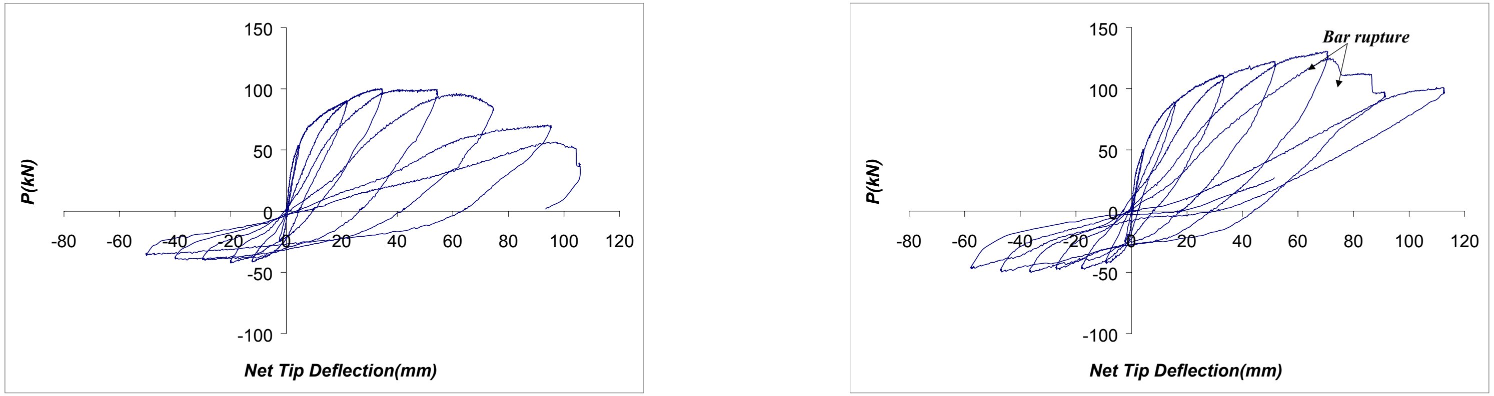
Beam geometry and reinforcement detailing were modified to eliminate the weakness leading to premature failure. Besides, (2Φ20+4Φ10) top steel in the beam was replaced by (2Φ16+6Φ12) bars which provide the same capacity with a better bar arrangement. By using the 2Φ16 bars directly as the screw-in connectors, stress concentration complications could be eliminated.

Almost the same flexural capacity as the monolithic reference specimen and a rather stable behaviour with a reasonable ductility could be obtained, Figure 4d. The relatively narrow loops indicating smaller energy dissipation compared to the fat loops of the monolithic reference specimen is obviously the result of the elastic behaviour of the prestressing cable. The moment-curvature diagrams given in Figures 5d (hinging zone) and 6d (connection zone) indicate an appreciable amount of deformation at the hinging zone, although major rotations take place at the connection zone. The performance of this specimen can therefore be accepted as satisfactory.



a. MR1

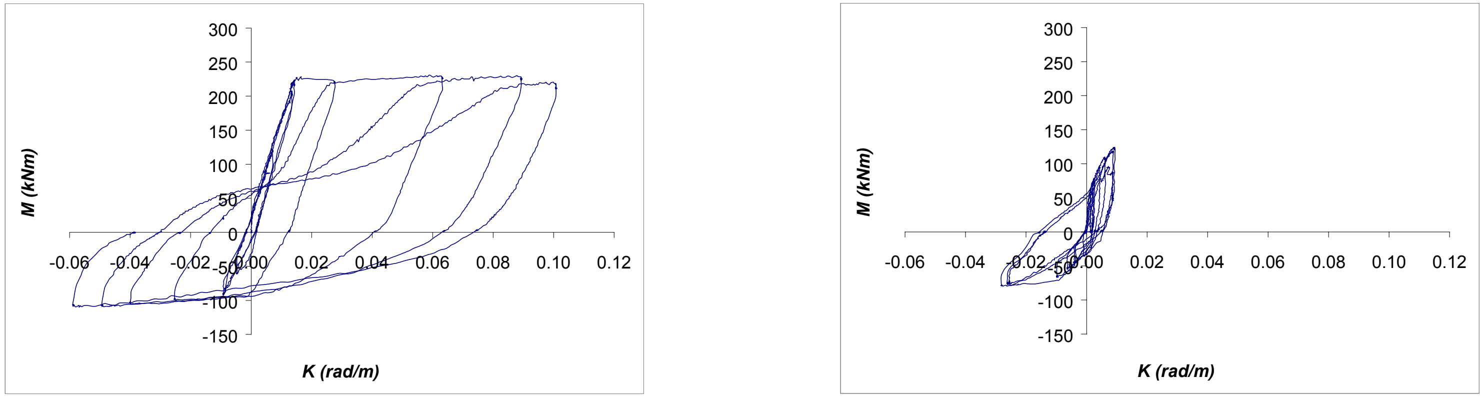
b. PO1



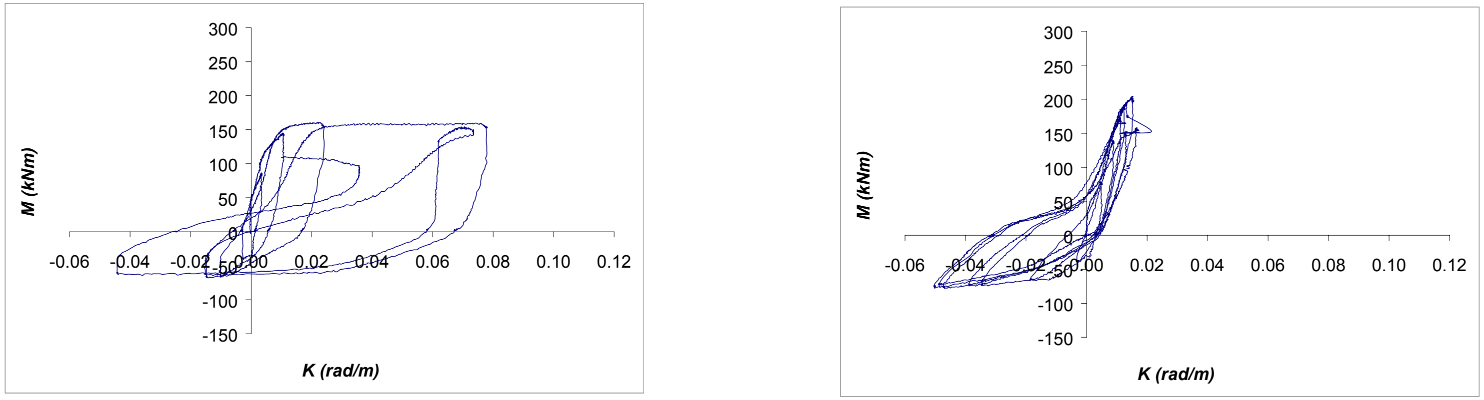
c. PM1

d. PM2

Figure 4: Load-tip deflection diagrams

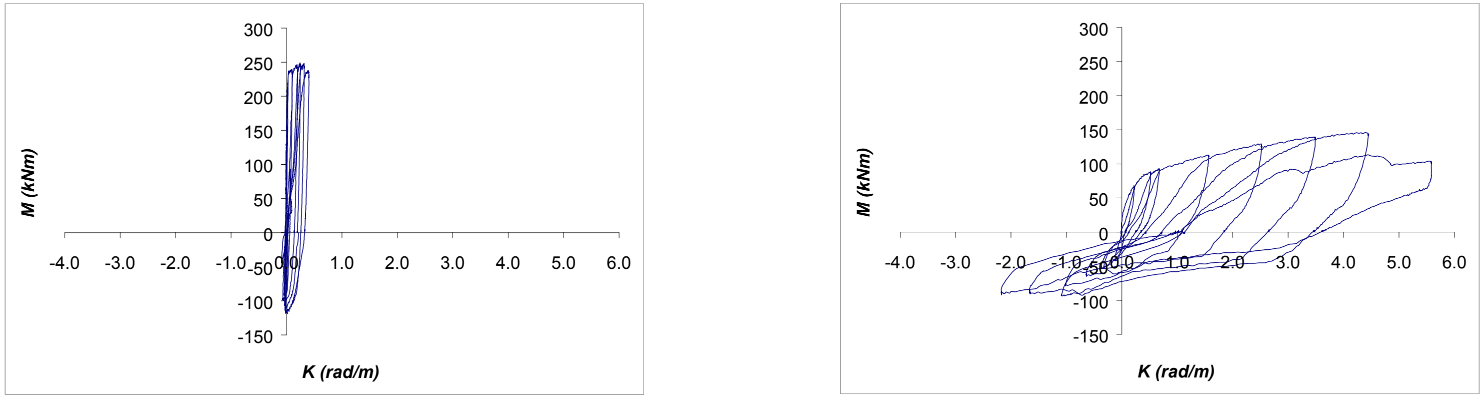


a. MR1 b. PO1

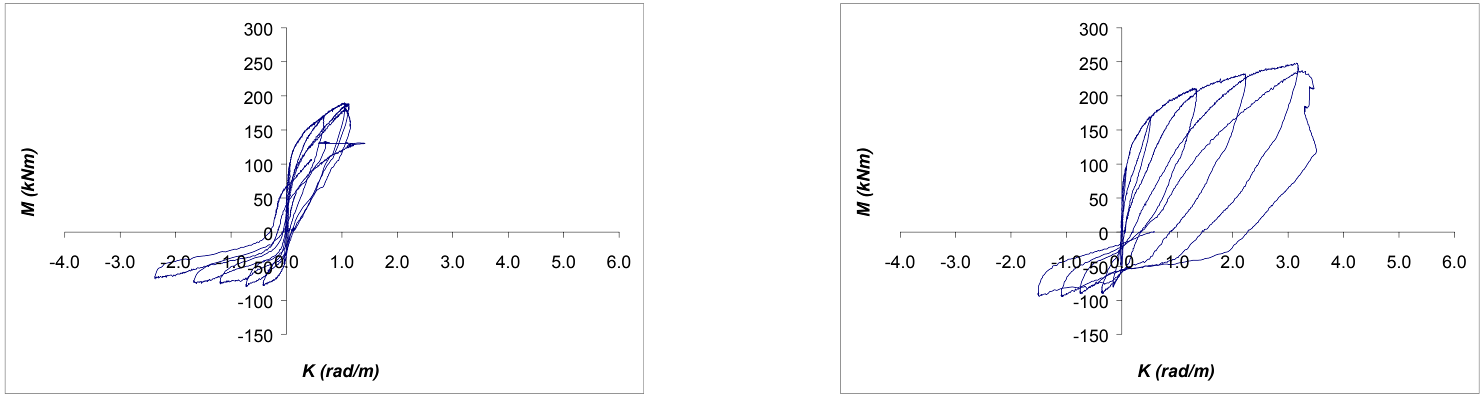


c. PM1 d. PM2

Figure 5: Moment-curvature diagrams - Hinging zone



a. MR1 b. PO1



c. PM1 d. PM2

Figure 6: Moment-curvature diagrams - Connection zone

DISCUSSION OF TEST RESULTS

Test data were evaluated and elaborated to study the performance of each specimen in terms of ductility, energy dissipation, stiffness degradation, shear deformations, deformation components etc. Further details of the investigation can be obtained from the MSc thesis(2) listed among the references. However, the envelope load-tip deflection diagrams presented in Figure 7 give a fairly good overall idea about the performances of the test specimens.

Although the performance of the precast specimen PM2 appears to be somewhat inferior to that of the monolithic reference specimen MR1, it should still be classified as "satisfactory". It is not realistic to expect a behaviour from a precast specimen identical to that of the monolithic one, since higher elastic deformations are unavoidable, especially in cases where prestressing cables are used.

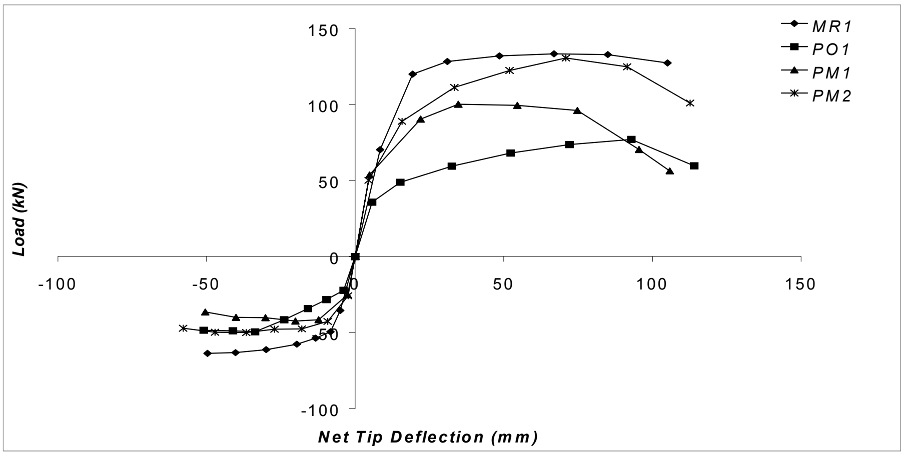


Figure 7: Envelope load-tip deflection curves

CONCLUSIONS AND RECOMMENDATIONS

Within the limited test data, the following conclusions and recommendations can be made:

a. The proposed post-tensioned connection proved to be successful, providing sufficient strength and ductility, and therefore it is recommended for application on medium size structural members.

b. Relatively low energy dissipation and stiffness are the consequences of elastic behaviour of the unbonded prestressing cable. They can be improved by increasing the non-prestressed connectors.

c. Similar tests are needed on larger scale specimens to generalise the results confidently. Effects of grouting should be experimentally investigated too; it may significantly improve the performance.

REFERENCES

1. Ersoy, U. & Tankut, T., "Seismic Behaviour of Precast Concrete Connections – Yapı Merkezi Post-Tensioned Beam-Column Connection", Research report, January 2000, Ankara (in Turkish).

2. Pınarbaşı, S., "Development and Seismic Performance of a Precast Concrete Beam-Column Connection by Post-tensioning", MSc thesis, Department of Civil Engineering, Middle East Technical University, September 2000, Ankara.