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Jacketed columns subjected to combined axial load and reversed cyclic bending

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ABSTRACT

Jacketed column behaviour is being investigated. Two of the four test series planned have been completed. The first series consisted of five specimens (two repaired, two strengthened and one monolithic reference) subjected to uniaxial loading. In the second series, five specimens (two repaired, one strenthened and two monolithic reference) were tested under combined constant axial load (the balanced axial load approximately) and either monotonically increased or reversed cyclic bending. In the third series in progress, effects of various bar (longitudinal reinforcement of the jacket) development techniques on the behaviour and strength are being studied. Tests indicated that the strengthening jackets generally performed satisfactorily, but the repair jackets were less successful, especially in the case of uniaxial loading.

INTRODUCTION

In the structural sense, rehabilitation can be defined as an operation to bring a structure (or a structural member) which does not meet the design requirements to the specified performance level. Depending on the state of the structure and the post-intervention performance level desired, rehabilitation is divided into two main categories. Repair is the rehabilitation of a damaged structure or a structural member with the aim of bringing the capacity back to the pre-damage level or higher. Strengthening is increasing the existing capacity of a non-damaged structure (or a structural member) to the specified level.

Load level at the time of intervention has a significant effect on the post-intervention performance. In practice repair/strengthening interventions in many cases are introduced while the structural member is still under load and sometimes after unloading the member by jacking. With these considerations, rehabilitation interventions can be classified in four main groups plus an auxiliary one.

a. Repair under load (post-damage)
b. Unloaded repair (post-damage)
c. Strengthening under load (no damage)
d. Unloaded strengthening (no damage)
e. Soft interventions (non-structural measures and/or load limitations)

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A group of researchers led by the authors have been actively working on various aspects of the problem for the last four years. Current research projects being carried out by this team at Middle East Technical University and Gazi University in Ankara are concerned with post-intervention behaviour and strength of various structural members (columns, beams and slabs) and structural systems. Due to space limitations, only one major project (jacketed column behaviour) is reported in the present paper. A brief summary of the work related to the other projects is presented in another paper (Tankut and Ersoy 1991).

Jacketing is a technique widely used for repair or strengthening of reinforced concrete columns. Column cross section is enlarged by forming a jacket around the existing column, and additional longitudinal and transverse reinforcement is provided. The basic concept of jacketing is simple, but the actual behaviour involves many uncertainties. Questions such as,

- How is the load shared by the jacket and the column ?
- Does the jacket take a share from the present load ?
- When does it take a share from the new load ?
- How is the interaction with the neighbouring members ?
- Where and how should the reinforcement be developed ?
- How and to what extend can the bending capacity be improved ?

can not be easily answered, and they require further research. The present investigation was designed to obtain information in this respect.Only the experimental aspect of the work is discussed in the following paragraphs. The analytical work is not included due to space limitations.

SPECIMENS

In practice, jacketing is used mainly for increasing the axial load capacity. This relatively simple and basic case was investigated first (Aksan 1988, Tankut, Ersoy and Aksan 1989) and the first series consisted of four identical specimens representing four different jacket types and a monolithic specimen serving as reference,Table 1. Five specimens of the second series (Suleiman 1991, Tankut and Ersoy 1990) were designed to investigate the behaviour of repair and strengthening jackets under monotonic and reversed cyclic bending moment combined with axial load, Table 2. The dimensions and reinforcement of the specimens are given in Figure 1 and Table 3.

TESTS

Uniaxial loading tests (Series 1) were performed in a horizontal closed frame consisting of two reinforced concrete beams connected with steel tension bars. Axial strains were measured by four dial gauges along the two opposite faces of the specimen as shown in Figure 2. Dial gauge frames were attached to anchor bars embedded in the core. This kind of attachment enabled reliable readings beyond cover crushing and even after buckling. The test set-up for the combined bending and axial load series is shown in Figure 3. The axial load was applied by the universal testing machine while the bending moments were introduced by side loads applied by hydraulic jacks through prestressing cables. Instrumentation was basically the same as that of the uniaxially loaded series. However, measurement of the column midheight deflection was essential in this case, since second order moments could be very significant. A roller-to-roller stretched wire marking the deflection on a scale attached to the specimen was used as shown in Figure 3.

In Series 1 (uniaxial loading), following a few low level loading and unloading cycles (to check the alignment and minimize accidental eccentricity), each basic column was loaded upto a pre-determined load or deformation level at which jacketing was introduced. When the jacket concrete acquired a reasonable strength, jacketed column was loaded monotonically upto failure.

Mechanical bar development is a much preferred method of column repair/strengthening in practice. This method was used in all specimens Series 2 (combined bending and axial load). Brackets were formed by tightening two angles placed on top and bottom faces of the beam by a pair of high strength steel pull bars, and the longitudinal bars of the jacket were welded to these brackets.

In all tests of the combined bending and axial load series (basic columns and jacketed specimens alike) an axial load of 500 kN was applied first and kept constant throughout the test. This axial load corresponded approximately to 70% of the axial load capacity of the basic column or 35 % of that of the monolithic column. Bending moment was then introduced gradually. In monotonic loading cases, bending moment was increased upto failure. In cases of cyclic loading, moment was reversed with gradually increasing magnitudes. After testing the basic column to a predetermined level, the specimen was unloaded; the loose concrete was taken out and the jacket was cast. When the jacket concrete gained adequate strength, the jacketed specimen was tested in accordance with the predetermined load history. Tests results are given in Figures 4 and 5 in terms of moment-curvature and moment-strain diagrams.

In a third series (Yumak 1991), the effect various bar development techniques on the behaviour and strength are being investigated by performing similar combined bending and axial load tests on similar test specimens in which longitudinal reinforcement of the jacket is developed in different ways.

CONCLUSIONS

The following points seem to be valid within the limitations of the data obtained in the study.

Under uniaxial load,

a. Strengthening jackets proved to be very effective. Their axial load capacity, ductility, energy dissipation capacity and stiffness were quite close to those of the monolithic reference specimen. Both types (made unloaded and made under load) were equally good.
b. Repair jacket made unloaded was a little inferior to strengthening jackets; however, it was still quite successful.
c. Repair jacket made under load performed rather poorly displaying an axial load capacity around half of that of the monolithic reference specimen.

Under combined bending and axial load,

a. All the jacketed specimens performed satisfactorily under both monotonic and reversed cyclic loading.
b. Strengthening jacket made unloaded was very effective in improving the flexural capacity under constant axial load.
c. Repair jackets made unloaded were slightly less effective than the strengthening jacket.
d. All the test specimens displayed considerable ductility and satisfactory energy dissipation capacity.

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Table 1 : Uniaxial loading specimens (Series 1)

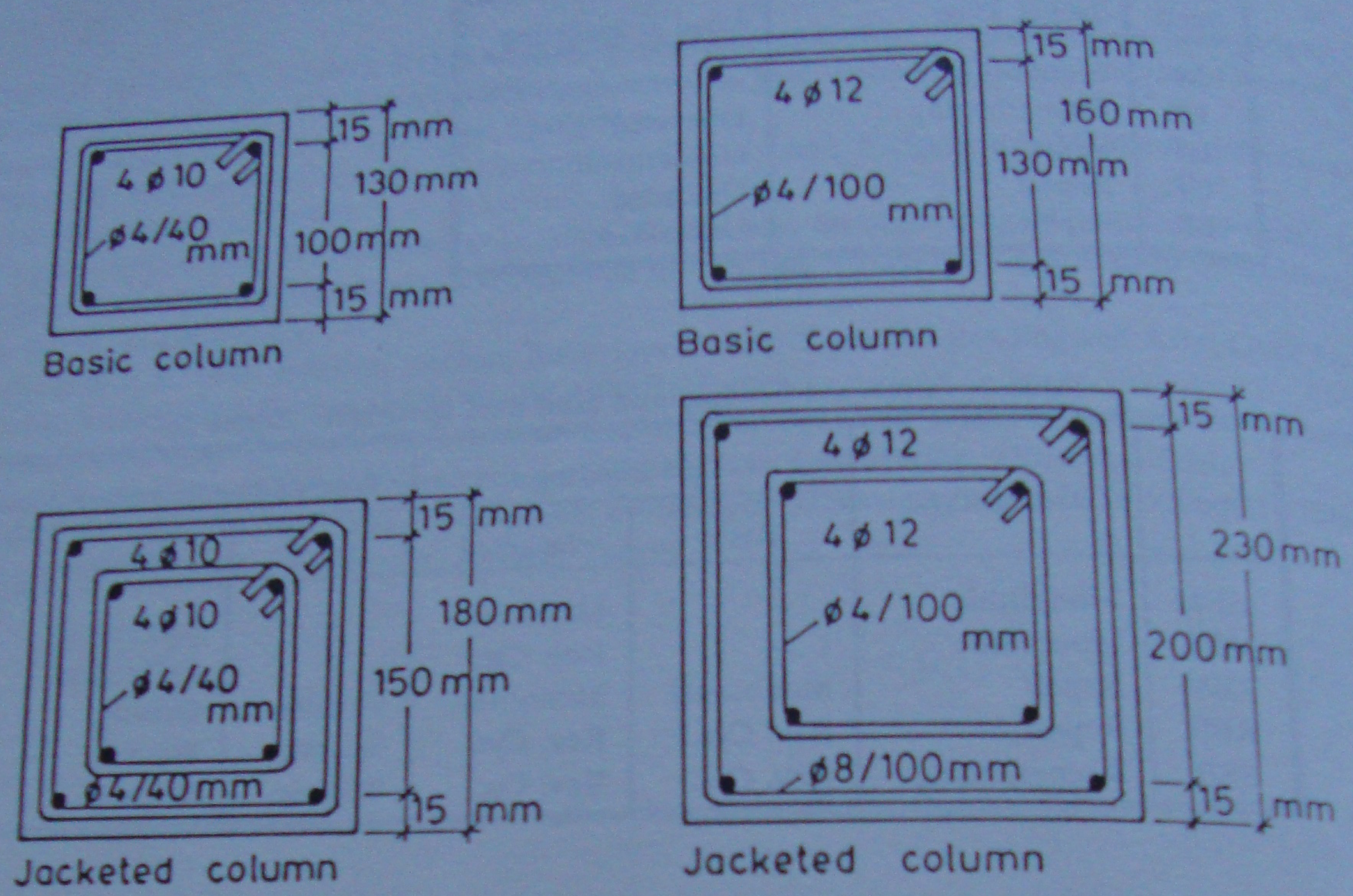
Spec.	Jacket Type	Load at Jacketing
M	Monolithic	–
US	Strengthening	Unloaded
LS	Strengthening	Under Load
UR	Repair	Unloaded
LR	Repair	Underload

Table 2: Combined bending and axial load specimens (Series 2)

Spec.	Jacket Type	Test Loading		Type of Loading Simulated	
		Basic	Jacketed	Basic	Jacketed
MBM	Monolithic	–	Monotonic	–	Reference
MBR	Monolithic	–	Rev. Cyc.	–	Reference
RBM	Repair	Monotonic	Monotonic	Gravity	Gravity
RBR	Repair	Rev. Cyc.	Rev. Cyc.	Seismic	Seismic
SBR	Strengthening	Rev. Cyc.	Rev. Cyc.	Seismic	Seismic

Table 3: Dimensions and reinforcement of column jacketing specimens

Properties	Uniaxial Loading		Bending + Axial Load	
	Basic	Jacketed	Basic	Jacketed
Dimensions(mm)	130x130	180x180	140x140	230x230
A_{conf}/A_{gross}	0.52	0.47	0.83	0.55
Long. Steel	4φ13mm	8φ10mm	4φ12mm	8φ12mm
ρ_l	[illegible]	[illegible]	[illegible]	[illegible]
Ties	[illegible]	[illegible]	[illegible]	[illegible]
ρ_s	[illegible]	[illegible]	[illegible]	[illegible]



a. Uniaxial loading

b. Axial load & bending

Figure 1 : Sectional properties of test specimens

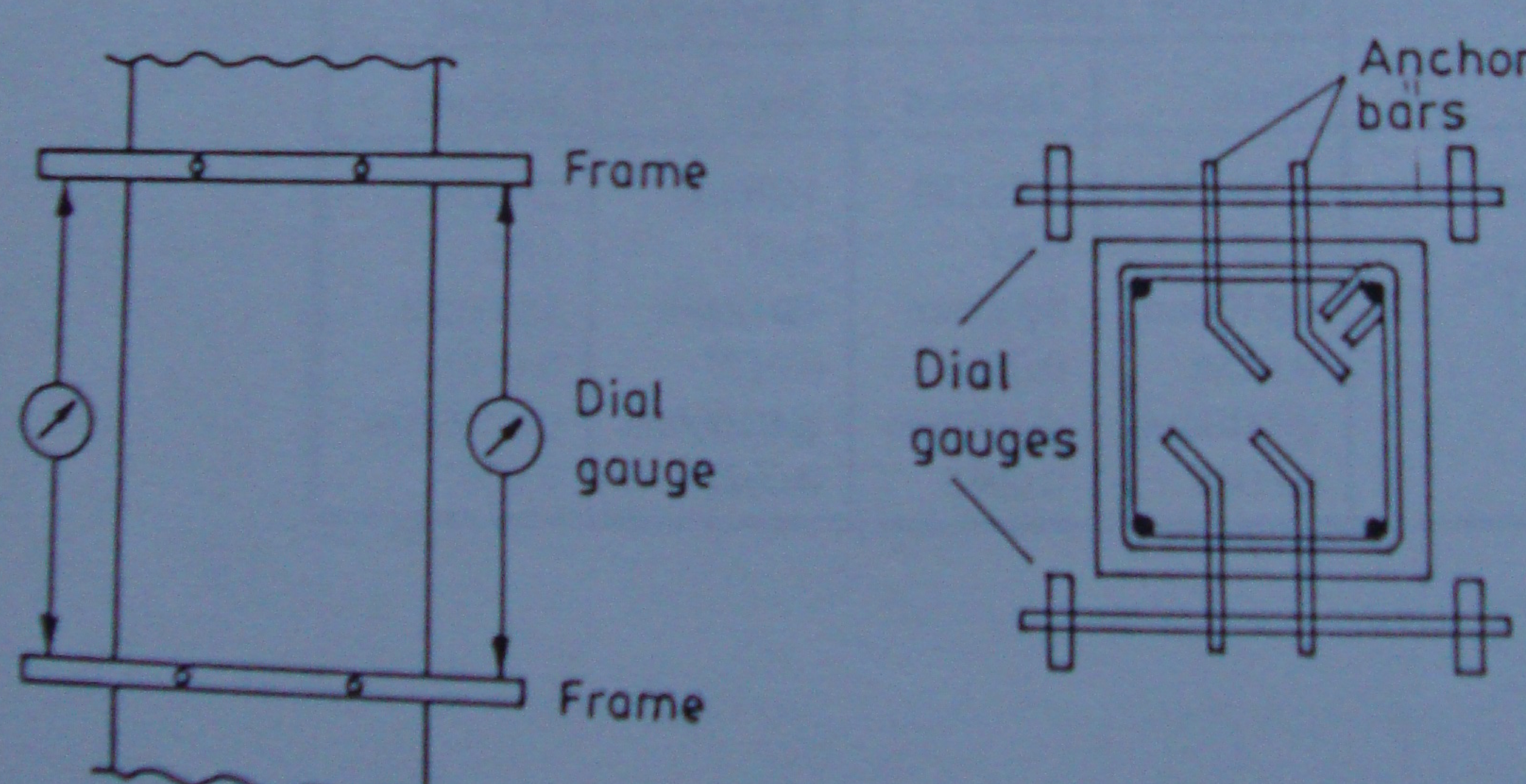


Figure 2 : Strain measurements

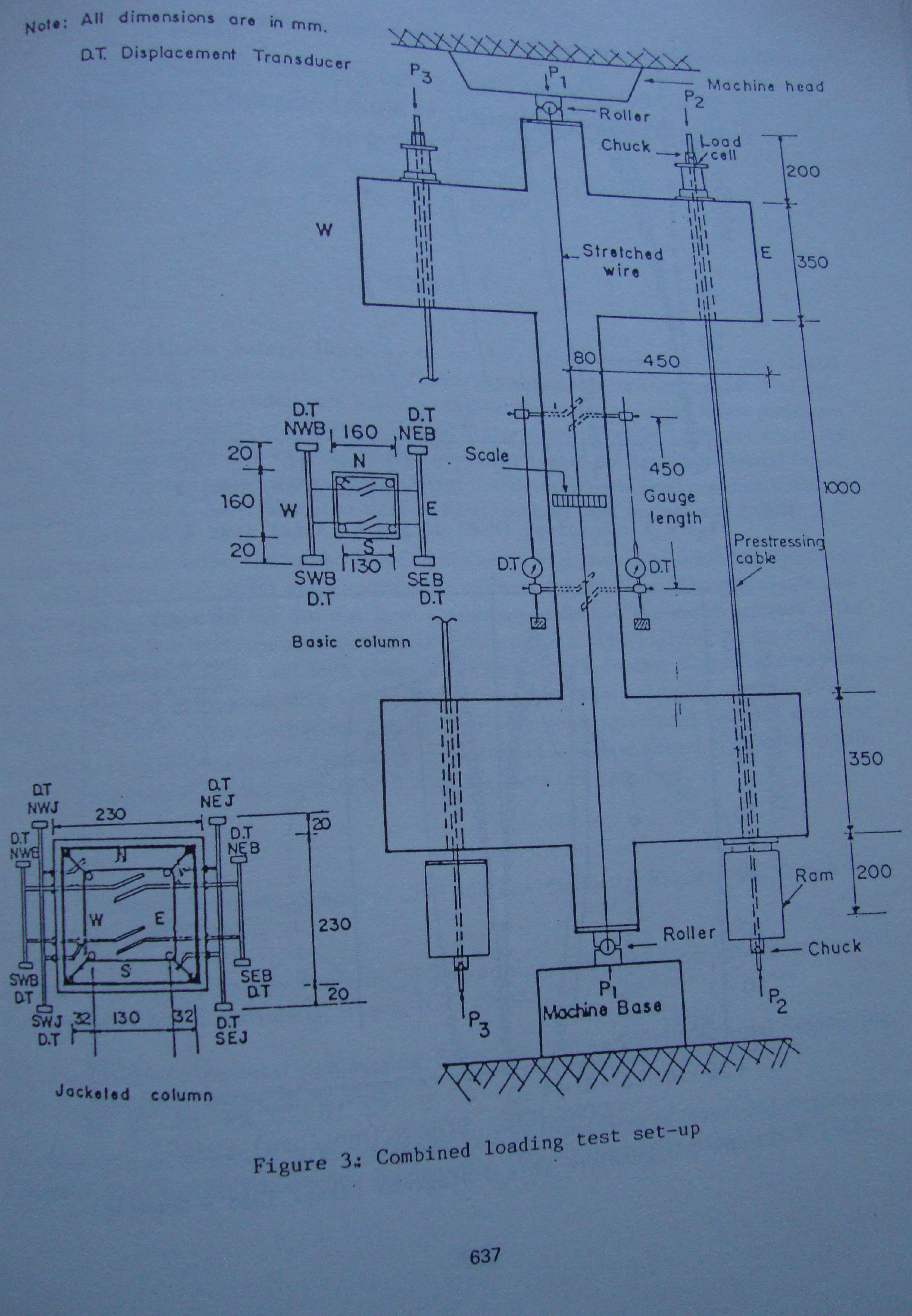


Figure 3: Combined loading test set-up

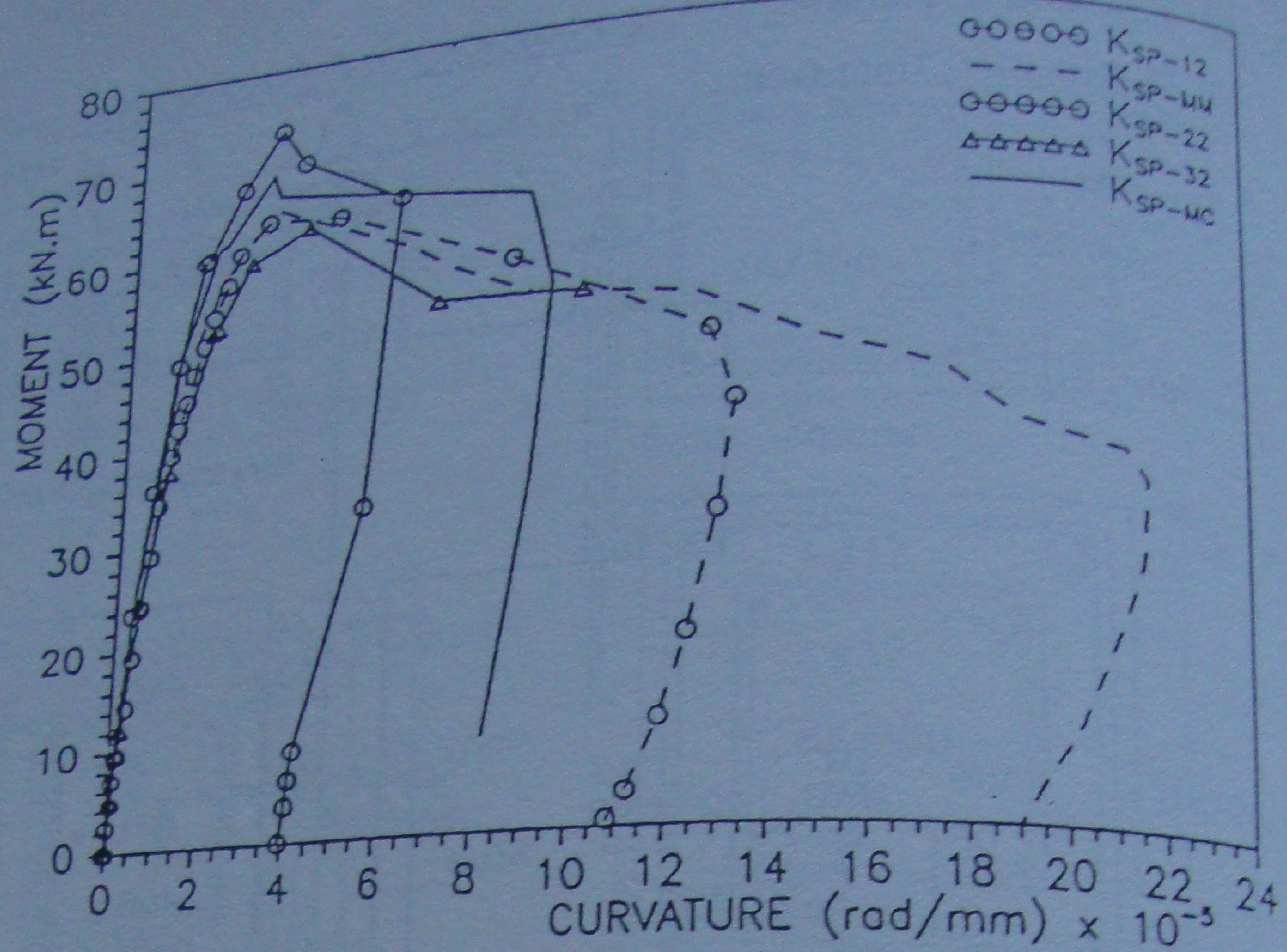


Figure 4 : Envelope (M-K) diagrams (Axial load & bending)

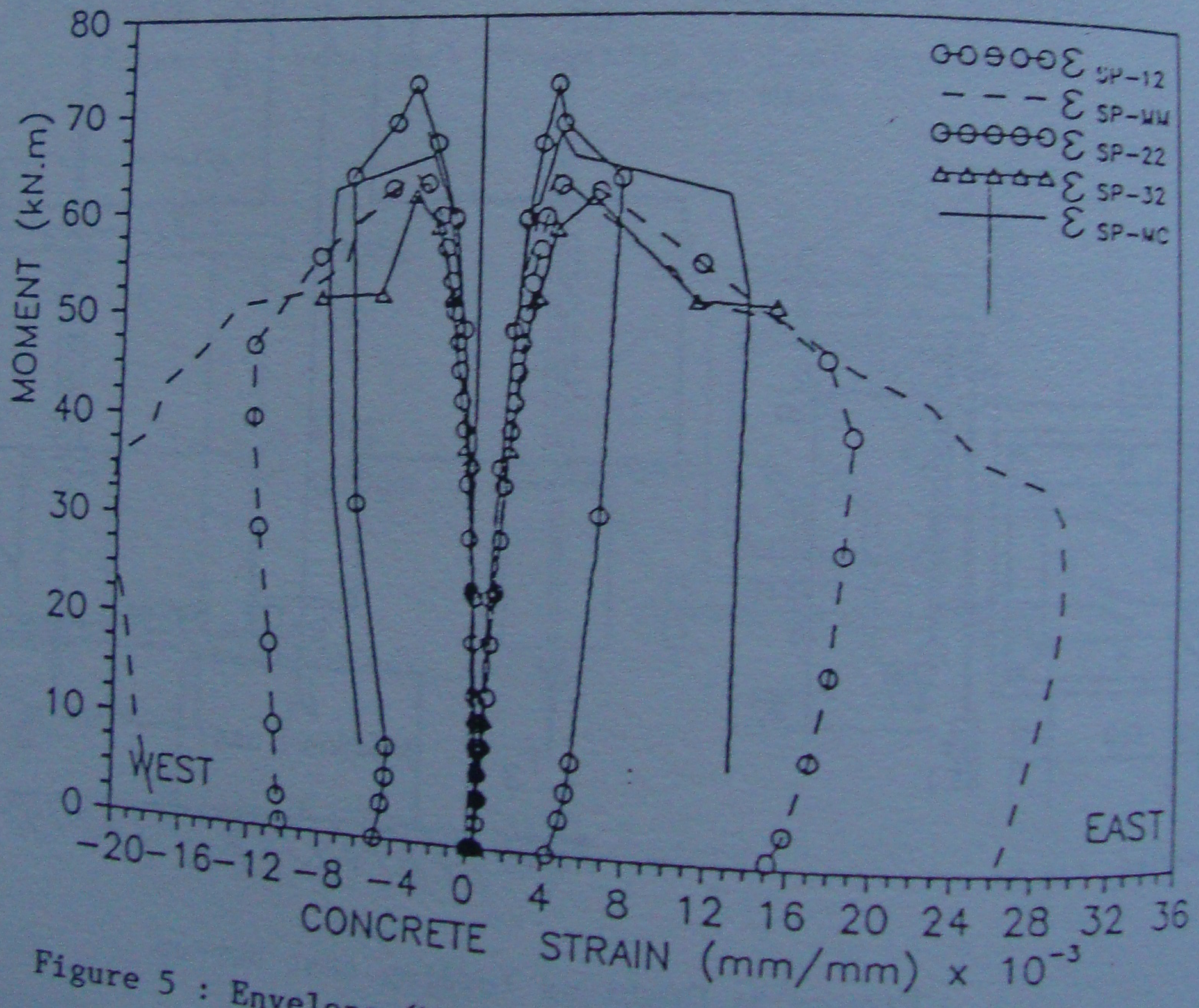


Figure 5 : Envelope ($M-\varepsilon_c$) diagrams (Axial load & bending)