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CERVICAL SPINE STIFFNESS AND GEOMETRY OF THE YOUNG HUMAN MALE

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FOR THE COMMANDER

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Injuries to the cervical spine incurred during emergency escape from high-performance aircraft are of concern to the Air Force. To provide for safety design, especially in view of newly considered additional head encumbrances such as helmet-mounted sights and displays, and chemical protection equipment, a detailed dynamic structural model of the human head-spine system has been developed. The presently described effort addresses the collection of cervical spine geometric, material property and failure data for use with this model. [continued on reverse]

The specific objectives of this program were 1) to obtain stiffness and failure data for human cervical spine motion segments, and 2) to determine the necessary anthropometric measurements of the cervical vertebrae to establish the cervical spine geometry. Six spines were obtained, radiographs of them were made and, after determining their acceptability, they were frozen until the testing protocol was established. Several testing methods were evaluated and a suitable protocol established.

The six spines were cut into motion segments and, for two specimens, a casting was made of the outer surface. Part of each vertebra was cemented in a polyester resin material. The resulting motion segment had two square, flat bases with four holes in each to attach it to one of four testing fixtures (axial, shear, bending, torsion). Each motion segment was attached individually to a particular test fixture which was itself attached to a feedback control high-strain-rate MTS testing machine. The motion segment was subjected to six different modes (one axial, two shear, two bending, one torsion) at two different strain rates (a total of 24 tests) before being failed following a prescribed protocol. The data from these tests were evaluated for strain energy loss, strain rate, and a linear spring constant, K, for each test. The specimens were refrozen after the tests.

Various methods of geometrical measurements were evaluated and a protocol was established to determine the vertebral measurements. For two of the specimens, the coordinates of points on the vertebral body were determined in a stereotaxic device and the data were manipulated in a computer so that all points were referenced to a coordinate system fixed in the vertebral body, thus allowing certain anthropometric measurements to be calculated for comparison with other published data. The second method of geometrical determination utilized a three-dimensional digitizer to obtain the same data previously obtained stereotaxically.

PREFACE

This report represents the completed research as a result of Contract F33615-76-C-0526 awarded to Tulane University School of Medicine, New Orleans, LA, by the Air Force Aerospace Medical Research Laboratory (AFAMRL), Aerospace Medical Division, AFSC. The contract technical monitor (CTM) is Dr. Ints Kaleps, Chief, Mathematics and Analysis Branch, Biodynamics and Bioengineering Div., AFARML, Wright-Patterson AFB, OH.

The delay in the completion of the above-mentioned contract was due to two principal reasons:

(1) The extreme difficulty encountered in obtaining young human male cervical spines between the ages of 20 to 44 as required by the contract.

(2) The relocation of the principal investigator and his staff from Tulane University School of Medicine, New Orleans, LA to the University of Iowa, College of Engineering, Iowa City, IA in August, 1978.

An interim report was submitted to the CTM in 1978 based on the data for 2 spines. The assistance of Dr. Leon Walker of the Dept. of Anatomy, Tulane University School of Medicine and Drs. Felix Walz and Dirnhofer of Zurich and St. Gailen, Switzerland respectively in obtaining young male cervical spines is gratefully acknowledged. Much appreciation is due Dr. Ints Kaleps, the CTM, for his understanding and patience while this work was being done. The careful reading of the manuscript by Dr. Eberhardt Privitzer, AFAMRL is also acknowledged.

The support provided by the National Institute of General Medical Sciences, NIH after the expiration of the above-mentioned contract, through Grant No. GM-07045-01 and -02 was indispensable for the completion of this research. The generous sharing of equipment by Professor Ralph Stephens (the MTS) and Drs. Richard Brand and Roy Crowninshield (the 3-D Graf-Pen) did much to alleviate the voluminous data acquisition and analysis.

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INTRODUCTION

For many years, experimental and theoretical research has been done by the various services of DOD and NASA to study why pilots are injured during ejection from a disabled aircraft. While many systems have been successful, others have encountered various problems. Heretofore, most of the fracture sites have concentrated in the region of T7-T8 and T12 and L1. More recently, however, the pilot's head and neck have been burdened by unusual loads imposed on them by certain operational requirements. The previously almost symmetric helmet is being proposed as the anchor for high-powered binoculars or monoculars and communication equipment. During ejection in the $+G_z$ direction, these overhangs create a tremendous eccentric load on the head and neck, resulting in a potential increase in the incidence and prevalence of acute and chronic neckaches.

A particular achievement in the above area under AMRL sponsorship is a detailed 3-D dynamic model of the human head-spine system. The model has been formulated with sufficient generality to allow for constraints and encumbrances, changes in loading direction and profiles, etc. The uncertainties associated with the model include geometry, material properties, failure modes and structural peculiarities of the cervical vertebral column.

PROGRAM SUMMARY

The objectives of this research were: 1) to obtain stiffness data for human cervical spine motion segments and 2) to determine certain anthropometric measurements of the vertebra to establish the cervical spine geometry, both of which are necessary as input data for the spine model described in AMRL-TR-76-10. Six spines were obtained, radiographs of them were made and, after determining their acceptability, they were frozen until the testing protocol was established. Several testing methods were evaluated and a suitable protocol was established from the results. The six spines were cut into motion segments and, for 2 specimens, a casting was made of the outer surface. Part of each vertebra was cemented in a polyester resin material. The resulting motion segment had six square flat bases with four holes in each to attach it to one of four testing fixtures (axial, shear, bending, torsion). Each motion segment was attached individually to a particular test fixture which was itself attached to a feedback control high-strain rate MTS testing machine. The motion segment was subjected to six different modes (one axial, two shear, two bending, one torsion) at two different strain rates, (a total of 24 tests) before being failed following a prescribed protocol. The data from the stiffness tests were evaluated for strain energy loss, strain rate, and a linear spring constant, K, for each test. The specimens were refrozen after the tests.

Various methods of geometrical measurements were evaluated and a protocol was established to determine the vertebral measurements. For two of the specimens, the coordinates of points on the vertebral body were determined in a stereotaxic device and the data were manipulated in a computer so that all points were referenced to a coordinate system fixed in the vertebral body; thus allowing certain anthropometric measurements to be calculated for comparison with other published data. The second method of geometrical determination utilized a 3-dimensional digitizer to obtain the same data previously obtained stereotaxically.

REVIEW OF THE LITERATURE

No review of the cervical spine biomechanics can, or should, be made without surveying the other regions of the spinal column. Schultz (1974) has recently reviewed the extensive literature on the mechanics of the spine. Sances et al. (1981) reviewed the bioengineering literature on head and neck. Their exposition on neck injury is quite comprehensive. In the interest of brevity, only the more recent investigations relevant to the present investigation will be reviewed.

Geometry:

There exists little data on the geometry of the cervical spine. Todd and Pyle (1928) gave vertebral body and disc heights along the thoracolumbar spine. Other geometric dimensions, at every spinal level, were given by Lanier (1939). Veleanu (1971) was concerned mainly with the structural peculiarities of the articular facets. He noted the following differences between the cervical and thoracic spine:

a) The facet pedicles of the cervical vertebrae subtend an angle of 145°-156° with respect to the tangent drawn through the rachidian face of the vertebral body circumference, whereas, it is in the neighborhood of 90° in the thoracic vertebrae;

b) The distance between the line drawn to the facet pedicles and the tangent drawn through the rachidian face of the vertebral body circumference is about four times greater in the thoracic vertebrae as compared with the cervical, thus, conferring greater mobility to the cervical spine;

c) The articular facet joint subtends, in sagittal section, an angle of about 50° with the frontal plane from C3-C5. This angle changes to 37° at C6 and becomes 23° at C7, thus, approaching the thoracic facet angle of zero degrees, i.e., the well-known vertical apposition of facets in the thoracic and lumbar area;

d) The cervical articular facet areas are relatively larger compared to those of the other regions of the spine. Between C3 and C6, the sum of the two surface areas ranges from 181 mm^2 (C6) to 184 mm^2 (C3), whereas, at T6 and T12 this sum is 128 mm^2 and 140 mm^2, respectively. To further elucidate the significance of these findings, Veleanu calculated the vertebral disc to articular facet area ratio. This somato-articular ratio ranged from 1.1 to 1.4 between C3 to C6; at C7, it was 1.8. By comparison, it was 3.6 for T6 and 5.6 for T12;

e) The posterolateral slope of the transverse groove, termed the blocking factor, blocks the backward slip movement which occurs during extension of the neck by coming in contact with the apex of the subjacent apophysial joint. This contact simultaneously takes over part of the load. Thus, there are three possible load paths during extension, one, through the discs; the second, through the pedicles; and the third, through the blocking factor.

The structural peculiarities found above were, unfortunately, based on a single "young adult" (sic), hence, no statistical significance can be attached to the data. Nevertheless, its great importance with respect to static and dynamic force transmission cannot be overlooked.

Stiffness and Material Properties:

Lysell (1969) was probably the first to provide quantitative data on the motion segment behavior of the cervical spine. He also exhaustively reviewed the clinical literature up to 1969. Lysell's experiment is so fundamentally interesting that it deserves more than a casual mention. He inserted steel balls at certain critical locations and examined the motion patterns of the cervical spine in sagittal, frontal and horizontal motion as revealed by a 3-D radiographic device. Had he also measured the forces and moments which induced the motion, then he would have obtained the stiffness matrix, or at least part of it. He did not, so it remains to be done.

Essentially similar techniques were used by Rolander (1966) and White (1969) to study the motion segments of the lumbar and thoracic spines, respectively.

When forces and moments are recorded in addition to linear and angular displacements, stiffness data results. Brown et al. (1957) found some stiffness data of motion segments under axial tension and compression as well as bending with axial load. Evans and Lissner (1959) gave load-deflection curves for the lumbar spine in anterior and lateral bending. Farfan (1973) studied the lumbar spine segments in torsion. Markolf (1969) studied the lumbar segments in flexion-extension, lateral bending and rotation, with and without posterior elements. From Markolf's data, six stiffness coefficients, without preload, can be obtained. Panjabi et al. (1976) experimentally determined the so-called "coupling effect" for the thoracic spine. Coupling is defined as motion induced in one axis as a result of motion in another axis, e.g., during flexion, a vertebra rotates about the horizontal axis and translates forward. In matrix notation, the coupling coefficients are the off-diagonal terms of the following matrix equation:

$$\begin{bmatrix} K_{11} & 0 & 0 & 0 & K_{15} & K_{16} \\ & K_{22} & K_{23} & K_{24} & 0 & 0 \\ & & K_{33} & K_{34} & 0 & 0 \\ & & & K_{44} & 0 & 0 \\ \text{Symmetry} & & & & K_{55} & K_{56} \\ & & & & & K_{55} \end{bmatrix} \begin{Bmatrix} u \\ v \\ w \\ \phi_x \\ \phi_y \\ \phi_z \end{Bmatrix} = \begin{Bmatrix} F_x \\ F_y \\ F_z \\ M_x \\ M_y \\ M_z \end{Bmatrix} \tag{1}$$

where u, v, w and ϕ_x, ϕ_y ϕ_z are the linear and angular displacements; F_x, F_y, F_z and M_x, M_y, M_z are the corresponding linear force and rotational moments, along the x, y and z axis, respectively. The zeros in the stiffness matrix result from the principle of energy conservation and the assumption of complete geometric symmetry about the sagittal plane. This comprehensive experimental procedure was done in the absence of any physiological preload.

Discrete-parameter models of the spine, e.g., Orne and Liu (1969) and one by Belytschko et al. (1976), reported in AMRL-TR-76-10, require stiffness and geometric data. Finite-element and continuum models, e.g., Liu and Ray (1973) and Cramer et al. (1976), on the other hand, require material properties, e.g., Young's moduli, Poisson's ratio, etc.

Lin et al. (1978) performed complex loading experiments on intervertebral joints. Complex loading is defined as the simultaneous loading of the specimen by more than one force or moment. Under physiological conditions, the vertebral column is simultaneously loaded in compression, shear and bending because of the anterior eccentricity of the center of mass of the abdominal and thoracic cavities with respect to the centroidal axis of the spine. Furthermore, because of the presence of the posterior elements and other soft tissue, the centroidal axis of the vertebral column is not the curve connecting the loci of the centroid of the vertebral body. An experimental procedure was developed to determine this operational centroidal axis. From this location, the effects of eccentric loading can be more closely assessed. The details of a fixture designed for this purpose is given in Lin et al. (1978). The load-deflection data obtained were analyzed in two ways: (a) in terms of the stiffness matrix coefficient as shown in eqn. (1) and (b) as a means for the identification of the material properties of the intervertebral joint. To obtain the latter, a finite element model of the intervertebral joint was formulated assuming orthotropic material properties for the vertebrae and disc. The difference between the experimentally measured deflections, and the initial deflection output of the model, was termed the error. The material properties of the model were varied systematically through a least-squares criterion, until the error was minimized.

The method of dissecting the spine into individual motion segments suffers from one serious fault, i.e., the contribution to the system stiffness as a result of structural integrity is lost. The intervertebral joint stiffness data tend to be lower than it should be for the intact spine. For example, spinal ligaments span segments of the vertebral column and hence, recruit other levels when loaded intact. Brown et al. (1976) developed a radiographic technique which allows spinal analysis without cutting up the vertebral column. A biplane radiographic system was shown to be capable of accurately determining the 3-D locus of any radiographically identifiable point visible in both biplane radiographs. A computer method for the in vivo analysis of the vertebral column was also developed, which can describe the orientation and angular displacement to a high degree of accuracy.

Laborde (1976), in a feasibility study, added a 3-D dynamometer to the above system to obtain the stiffness data associated with an intact lumbar spine. The radiographically identifiable points on the vertebral column are formed by lead shots placed on each vertebral body, two close to the midsagittal plane anteriorly at the superior and inferior margin of the body, and one near the center of each transverse process. It was shown by Brown et al. (1976) that, together with certain fixed radio-opaque points on the cassette, the above system will yield the entire displacement data following some descriptive geometric calculations.

STIFFNESS AND MATERIAL PROPERTIES OF INDIVIDUAL MOTION SEGMENTS

THEORETICAL CONSIDERATIONS

In theory, the stiffness properties for each motion segment can be determined by applying a known load in a specific configuration to one vertebral body while holding the second fixed and recording the displacements (i.e., translation and rotation) of the loaded body. The force can take the form of either a pure load, a pure moment or a combination of the two. In general, the load has both magnitude and direction, and is a function of time.

The same results can be obtained by the reverse procedure, i.e., cause known displacements and measure the various forces and moments.

Stiffness Matrix

One important goal is the determination of the stiffness matrix given below:

$$\underbrace{\begin{bmatrix} K_{11} & K_{12} & K_{13} & K_{14} & K_{15} & K_{16} \\ K_{21} & K_{22} & K_{23} & K_{24} & K_{25} & K_{26} \\ K_{31} & K_{32} & K_{33} & K_{34} & K_{35} & K_{36} \\ K_{41} & K_{42} & K_{43} & K_{44} & K_{45} & K_{46} \\ K_{51} & K_{52} & K_{53} & K_{54} & K_{55} & K_{56} \\ K_{61} & K_{62} & K_{63} & K_{64} & K_{65} & K_{66} \end{bmatrix}}_{\text{STIFFNESS MATRIX}} \underbrace{\begin{Bmatrix} r_x \\ r_y \\ r_z \\ \phi_x \\ \phi_y \\ \phi_z \end{Bmatrix}}_{\text{DISPLACEMENT VECTOR}} = \underbrace{\begin{Bmatrix} F_x \\ F_y \\ F_z \\ M_x \\ M_y \\ M_z \end{Bmatrix}}_{\text{LOAD VECTOR}} \quad (2)$$

where the K's are the coefficients of the stiffness matrix, r and ϕ are the translational and rotational components of the displacement vector and F and M are the force and moment components of the load vector, respectively, along the reference coordinate system axes x, y, and z as shown in Fig. 1. The x-z plane corresponds to the midsagittal plane, while the x-y and y-z planes represent the transverse and coronal planes, respectively.

The ideal situation is one in which an arbitrary load, F, is applied to the upper vertebra with the lower one fixed. If all the applied forces and moments and the resulting displacements and rotations are recorded, the K's in the stiffness matrix can be obtained numerically. If enough measurements are taken, a complete K matrix can be obtained. Experimentally, this is too complex and unrealistic an approach and must of necessity be simplified.

Flexibility Approach:

One simplification is to apply only one of the six load components, and measure the entire set of displacement components. For example, a specified load, F_x, can be applied, and the displacements r_x, r_y, r_z, ϕ_x, ϕ_y, ϕ_z measured, thus, obtaining C_{11} ... C_{61} from $C_{n1} = x_n/F_x$, where n = 1, ..., 6, C_{ij} are the flexibility coefficients of the flexibility matrix in equation (3), and $x_1 = r_x$, ..., $x_6 = \phi_z$, respectively. The other C's can be found by applying the other load vector components in a similar manner.

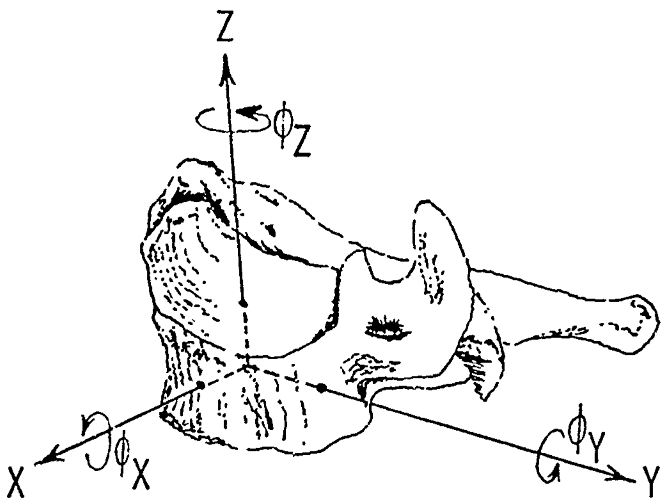


FIG. 1: VERTEBRAL COORDINATE AXES

$$
\underset{\text{FLEXIBILITY MATRIX}}{\begin{bmatrix} C_{11} & C_{12} & C_{13} & C_{14} & C_{15} & C_{16} \\ C_{21} & C_{22} & C_{23} & C_{24} & C_{25} & C_{26} \\ C_{31} & C_{32} & C_{33} & C_{34} & C_{35} & C_{36} \\ C_{41} & C_{42} & C_{43} & C_{44} & C_{45} & C_{46} \\ C_{51} & C_{52} & C_{53} & C_{54} & C_{55} & C_{56} \\ C_{61} & C_{62} & C_{63} & C_{64} & C_{65} & C_{66} \end{bmatrix}}
\underset{\substack{\text{LOAD}\\\text{VECTOR}}}{\begin{Bmatrix} F_x \\ F_y \\ F_z \\ M_x \\ M_y \\ M_z \end{Bmatrix}}
=
\underset{\substack{\text{DISPLACEMENT}\\\text{VECTOR}}}{\begin{Bmatrix} r_x \\ r_y \\ r_z \\ \phi_x \\ \phi_y \\ \phi_z \end{Bmatrix}}
\qquad (3)
$$

If the flexibility matrix is inverted, the stiffness matrix is obtained, i.e., the product of the stiffness and flexibility matrices yields a unity matrix for linear load-deformation behavior.

Stiffness Approach:

An alternate procedure is to cause a specified motion, e.g., r_x, while keeping the remaining displacement components at zero, and then measuring the various forces and moments (F and M).

The K's in equation (2) or equation (4) for the motion, r_x, can be found from $K_{n1} = F_n/x_1$ for $K_{11}, \ldots, K_{61}$, where $n = 1, \ldots, 6$. In a similar manner, the other coefficients can be obtained.

A simplifying assumption was proposed by Panjabi et al. (1976). By assuming anatomical midsagittal plane symmetry and applying the conservation of energy principle, the stiffness matrix becomes symmetrical with certain coupling terms equal to zero, as shown in equation (4).

$$
\underset{\text{STIFFNESS MATRIX}}{\begin{bmatrix} K_{11} & 0 & K_{13} & 0 & K_{14} & 0 \\ 0 & K_{22} & 0 & K_{24} & 0 & K_{26} \\ K_{31} & 0 & K_{33} & 0 & K_{35} & 0 \\ 0 & K_{42} & 0 & K_{44} & 0 & K_{46} \\ K_{51} & 0 & K_{53} & 0 & K_{55} & 0 \\ 0 & K_{62} & 0 & K_{64} & 0 & K_{66} \end{bmatrix}}
\underset{\substack{\text{DISPLACEMENT}\\\text{VECTOR}}}{\begin{Bmatrix} r_x \\ r_y \\ r_z \\ \phi_x \\ \phi_y \\ \phi_z \end{Bmatrix}}
=
\underset{\substack{\text{LOAD}\\\text{VECTOR}}}{\begin{Bmatrix} F_x \\ F_y \\ F_z \\ M_x \\ M_y \\ M_z \end{Bmatrix}}
\qquad (4)
$$

Loading Rate:

Another goal of this study is to discern whether or not there is a difference and, if there is, just how much difference exists between a quasistatic loading rate and a dynamic loading rate.

This can be accomplished by using a loading rate which is nearly constant and comparing the load-deformation curves for the same motion segment at different rates. As will be shown later, the seemingly simple test procedures used by other investigators will be greatly complicated by the use of fast loading rates.

Force and Displacement Measurement:

Since the entire experiment consists of applying loads or displacements and the measurement of both, it seems appropriate to discuss here the criteria that the various measurement techniques should meet.

One criterion is that the load induced by the displacement measuring device on the specimen should be small, so as not to distort the normal physiological motion. In a quasistatic loading configuration, the resultant motion of the vertebral body can easily be measured by Linear Variable Differential Transformers (L.V.D.T.), dial indicators, strain-gaged cantilever beams, optical trackers, etc. At dynamic loading rates, the frequency response of these devices becomes a limiting factor. In addition, the ability to record a continuous time history signal is also important for future data analysis. The viable devices here are the LVDT, the strain-gaged cantilever beam and the optical tracker.

The main requirement in load measurement is that the load measuring device should be stiff in comparison to the specimen. The load cell is an integral part of the mechanism used to give a controlled displacement to the motion segment. If the load cell moves in any direction other than the one intended, the motion is no longer pure, and the conditions for solving equations (2) or (4) are not satisfied. If it moves in the direction of the intended displacement, the stiffness of the load cell will be combined in series with that of the motion segment.

DEVELOPMENT OF PRESENT EXPERIMENTAL METHOD

The first step in the experimental protocol was to evaluate previous experimental techniques of other investigators to determine their applicability in obtaining the stiffness data stated in the objectives. The method which seemed most suitable to begin with was that used by Panjabi et al. (1976). Briefly, this method consists of testing individual spinal motion segments consisting of two adjacent vertebrae, the intervening disc, and their interconnecting soft tissues. The lower vertebra is cemented into a plastic base and attached rigidly to a fixture. The six generalized loads are applied separately, and the ensuing displacements for each individual load are measured. To measure the motion, a set of three spherical balls were rigidly attached to the upper vertebra, and their spatial displacements were measured by three dial gages. The resulting displacement data was reduced to yield the displacement of the vertebra at the point of load application. The load was applied via a 1/4-inch threaded rod placed in either of two perpendicular holes drilled parallel to the plastic cast of the lower vertebra, and in the midsagittal and coronal planes.

Many difficulties were encountered in attempting to adapt this procedure to the cervical spine. The first one was the size of the cervical vertebra. The centrum of the vertebral body was very small in the C_3-C_7 region and essentially non-existent in H-C_2 region. The size of the threaded rod was, thus, reduced from 1/4-inch diameter, to a No. 6 or 8 thread. Attachment of the top plate with three spherical balls to the upper vertebra also presented difficulties. A great deal of time was lost working diligently trying to attach it to the small vertebra, only to have it loosen and move after several tests due to the small area available in the vertebral body for attachment. Application of the load through the threaded rod proved to be of further difficulty. During the sequence of tests, the load was applied in many directions causing severe enlargement of the hole in the vertebra, which left the investigators uncertain as to the exact point of the load application.

The above portion of the protocol was repeated, but this time the upper vertebra was cast in Plastic Padding , giving the necessary area with which to attach the three-ball displacement measuring device as well as the threaded rod. The load was applied via weights on the end of a flexible cable attached to the threaded rod. Moments were applied by two weights through cables in opposing directions.

For loads or moments not in the direction of gravity, the cable was placed over pulleys to direct the load in the proper direction. To determine the effects of the pulley, a small load cell was placed between the vertebra and the pulley to measure the tensile load. In each case, the load measured by the load cell was less than the weight value, which was not unexpected. However, when two separate loads were applied to create a moment, the two load cell outputs were different. The ensuing motion was then the combination of a load and moment, superimposed on each other resulting in coupling coefficients which were in error.

Many other difficulties were encountered while adapting this flexibility technique. The combined weight of the displacement balls, the Plastic Padding®, the threaded rods and cables affected the natural postural relation between the two vertebrae.With the added weight, the upper vertebra has a tendency to rotate to one side. Thus, the position of the upper vertebra had to be held in a natural position, while the first weight was applied, and then, released, allowing it to move to a new position. Then successively larger loads could be added. The load applied by the dial gages on the specimen was significantly large, calling for additional patience during the zero position set-up. The gages exerted forces which tended to decrease the amount of inplane and out-of-plane motion caused by the applied load.

Concerning the dynamic test procedure, another set of problems were encountered. Several options were pursued to apply a dynamic load, including dropping of the weights used in the static case, pulling the cables by hand, and using a high-strain rate testing machine.

Dropping weights did apply a dynamic load but lacked sufficient control. The elasticity in the load application apparati (i.e., cables, pulleys, threaded rods, etc.) caused the load to overshoot and result in vibration of the load. The pulse shape and peak load proved to be unrepeatable. During the torsion tests, two weights need to be dropped simultaneously. The timing of these drops could not be coordinated close enough to result in a pure torque. Pulling on the cables suffered similar problems.

In the next step, a hydraulic, servo-controlled, high-strain rate testing machine with feedback was evaluated as the load application device. The pulse was easily controlled and repeatable. To evaluate the performance, it would be necessary to adapt the test fixture set-up to the machine for each test because the actuator piston only moved along one axis. The first cable attachment technique proved to be unsatisfactory for several reasons. The main reason being that by placing the cables between the specimen and the machine actuator to apply the load, too much elasticity was introduced, causing extremely large actuator displacements and displacement rates, often exceeding the capabilities of the machine. Applying the load directly to the specimen was unsatisfactory because the load was applied by the unidirectional actuator, thus, distorting the natural motion of the vertebra.

At this point, we concluded that the <u>flexibility</u> method was unsuitable for high-strain rate testing of spinal motion segments. It was decided that the controlled displacement of the MTS machine would lend itself much better to individual displacement such as $R_z = f(t)$ with $R_y = 0, \ldots, \phi_z = 0$, while measuring the various forces and moments with an instrumented load cell, as shown in Figure 2.

Four fixtures, which could be adapted to a high-strain rate testing machine, were developed to induce individual motions, δ_x, δ_y, δ_z, θ_x, θ_y and θ_z. These descriptions appear in the next section.

THE EXPERIMENTAL PROCEDURE

Whenever a suitable unembalmed human cadaver was found, the experimental procedure described below was implemented. The suitability criteria were:

1. Age - 20-40 years of age at time of death
2. Sex - Male
3. The skeletal structure and the soft tissue in the vicinity of the spine should be structurally and functionally normal.

The cervical spine was excised from the cadaver within 48 hours of death. It consisted of the base (occipital portion) of the skull, the ligamentous cervical column through T_1 minus most of the muscles. Antero-posterior, lateral and two oblique radiographs were made in order to determine acceptability. The specimen was frozen in a sealed plastic bag. Nothing further was done pending acceptance of the specimen as having met the suitability criteria by the contract technical monitor (CTM).

<u>Preparation of the Specimen</u>:

After approval was obtained from the CTM, the specimen was quickly thawed and excess soft tissue removed, taking extreme care not to damage the ligaments, etc., which might affect the material characteristics of the individual motion segments. The specimen was then sectioned into individual motion segments. All work with the motion segments was carried out in a 100% humidity chamber or directly in the air stream of a cool air vaporizer to minimize dehydration.

A casting was made of each motion segment of the first two spines using Alginate Impression Material Type I and Duroc©. These materials gave excellent surface resolution and cast quickly (1.5 min) with little distortion or surface dehydration of the specimen. To make the casting, a small amount of Alginate Impression Material was mixed and poured into a cup. The vertebra from one side of the motion segment was immediately immersed in the material, which set in 1.5

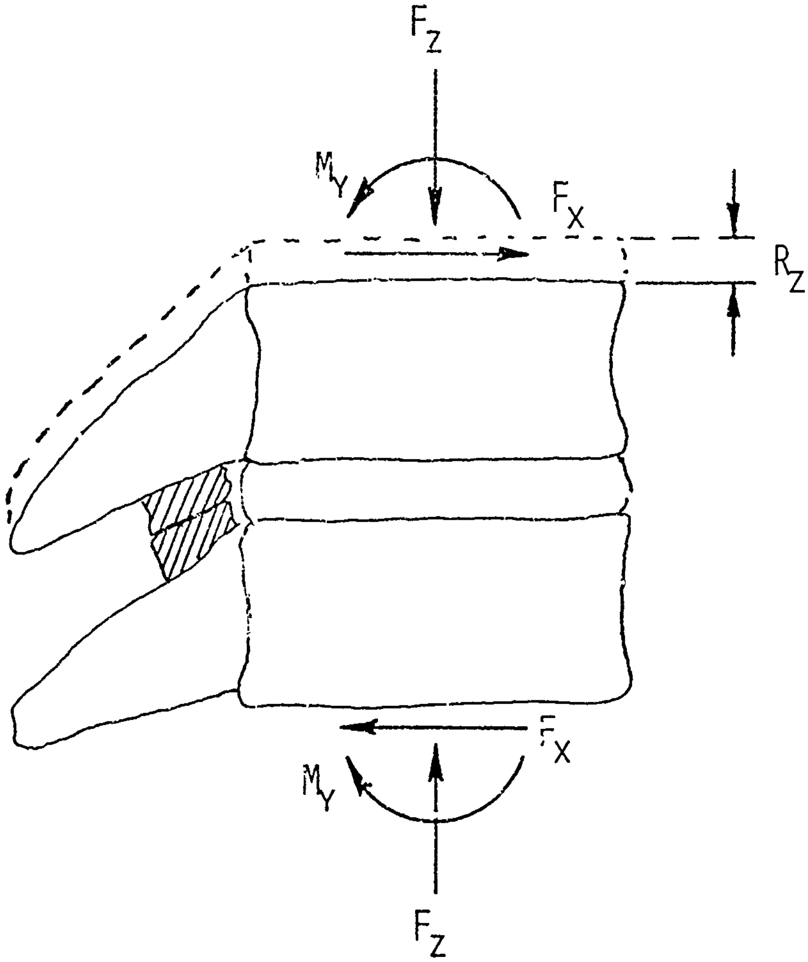


FIGURE 2: A MOTION SEGMENT SUBJECTED ONLY TO A DISPLACEMENT - Z.

minutes. By moving the motion segment, it was easily removed from the flexible material. Next, an amount of Duroc® was mixed and poured into the flexible mold which formed a rock-hard casting of the vertebra in 1.5 minutes. The procedure was repeated for the other vertebra of the motion segment to complete the motion segment casting. It was anticipated that these castings would be used to obtain some of the geometrical measurements in the event that the motion segment failed structurally during the testing procedure.

Small sheet metal screws were then inserted into the vertebrae of all six spines at strategic locations for added purchase. Each individual vertebra was held in a mold with the exposed vertebral body centrum parallel to the base. A quick-setting polyester resin, Plastic Padding®, was poured into the mold to form a 4" x 4" x 5/8" base for attaching the motion segment to the loading fixture. As soon as the base for the lower vertebra was firm, the mold was released and the entire motion segment inverted. The upper surface of the superior vertebra was cast in a similar manner as the lower one with the surface of the inferior base parallel to the mold base. A saturated gauze was wrapped around the exposed part of the motion segment to prevent dehydration during freezing and thawing of the motion segment. It was then marked, placed in a sealed plastic bag and refrozen until just prior to the tests.

<u>Controlled Displacement Tests:</u>

Each motion segment was tested in axial loading, shear, bending and torsion, i.e., the $\pm z$, $\pm x$ and $\pm y$, $\pm\phi_x$, $\pm\phi y$ and $\pm\phi z$ directions, shown respectively in Figure 1. Due to the complexity and the length of the set-up time, the MTS machine was set up for one mode and each specimen was thawed, tested and refrozen if necessary. The first mode chosen was axial loading in compression and tension, or the $\pm z$ direction, because of its simplicity.

Axial Tests

For the axial mode, the motion segment was bolted to two parallel plates, one attached to the load cell and the other to the hydraulic piston, as shown in Figure 3. When the actuator was moved up and down, the motion segment was constrained to move only in the $\pm z$ direction. The displacement between the vertebral bodies was obtained by inserting pins in the vertebra and measuring the displacement of these pins with a strain-gaged cantilever beam. A 1/32 drill was used to make a hole in the vertebra and a #20 gage hypodermic needle stock cut to length acted as the pin. At all times, the motion segment was enclosed in a plastic sheet with a hole to supply 100% humid air, and several small holes for inserting the deflection measurement beams.

Each segment was tested at two constant displacement rates. Two hundred (200) inches per minute (ipm) and 0.02 ipm were chosen as representative examples of pilot ejection dynamic rates and quasistatic rates, respectively. The segments were first tested at quasistatic rates in both tension and compression ($\pm z$). In compression, a 200-lb load was used as a limiting criterion. Messerer (1880) as quoted by White and Panjabi (1978), gave the compressive strength of the cervical spine from C3-C7 at about 1.75kN. A 200-lb (880 N) limit represents less than half of the compressive failure value. The actuator displaced the lower vertebra at a constant rate up to a maximum of 200 lbs and returned to the original position at the same rate. In tension, the criterion for reversing the actuator was a 0.05 inch of displacement since the specimens were much more elastic in tension. The results of the quasistatic tests were examined to provide a limiting criterion for the dynamic rate tests. As a rule, the limits imposed on the dynamic test were set at 75% of the quasistatic values. Load vs time, deformation vs time and load vs deformation were obtained for each specimen.

Shear Tests

The shear mode test fixture consisted of two angle plates with the sides bolted parallel to the displacement direction of the actuator as shown in Figure 4. One side was fixed to the load cell and the other to the actuator piston. The specimen was placed between the two plates and bolted in place. The actuator was moved up and down at a constant displacement rate, as was done for the axial mode. The displacement rates were also the same, i.e., 0.02 ipm and 200 ipm for static and dynamic tests, respectively.

The shear force was measured directly by the load cell. The displacement of the vertebra was measured by the same strain-gaged cantilever beams used in the axial mode. The beams were placed against pins previously fixed to the vertebra and the average was used as the deflection. The maximum load occurred during $+r_x$ loading. A maximum load of 150 pounds was used as the limiting load criterion for the $+r_x$ direction, and the corresponding displacement was then used for the $-r_x$ displacement limit. The limits imposed above were extrapolated from the compressive strength data of Messerer (1880). Previous experience on lumbar and thoracic intervertebral joints under shear loading showed that it is not as stiff as in compression. Furtheremore, antero-posterior shear is stiffer than postero-anterior shear because of the role played by the apophyseal joint. As in the axial tests, the maximum displacement set for the dynamic tests was about 75% of the quasistatic tests. Shear force vs time, deformation vs time and shear force vs deformation were recorded for each test.

Upon completion of the shear test in the x or antero-posterior axis, the specimen was rotated 90° and subjected to the same series of tests along the y or lateral axis.

Bending Tests

Figures 5, 6, and 7 show the bending mode set up. In Figure 5, the specimen is shown bolted to two aluminum fixtures, one of which was instrumented to measure the bending moment. Each aluminum fixture was attached to a square rod which can slide in square brass bearings. The position about the rod axis was fixed by tightening lock nuts against the aluminum fixtures. The load was applied to the square rod through the brass bearings which were pinned to four U-blocks. Two additional detailed views of the U-blocks are shown in Figure 6. The U-blocks were attached to the base through T-slot anchors, which can slide to any position along the base. The U-blocks were adjusted to achieve a four-point bending configuration as shown in Figure 7 so that a pure moment was applied to the specimen about the x or y axis.

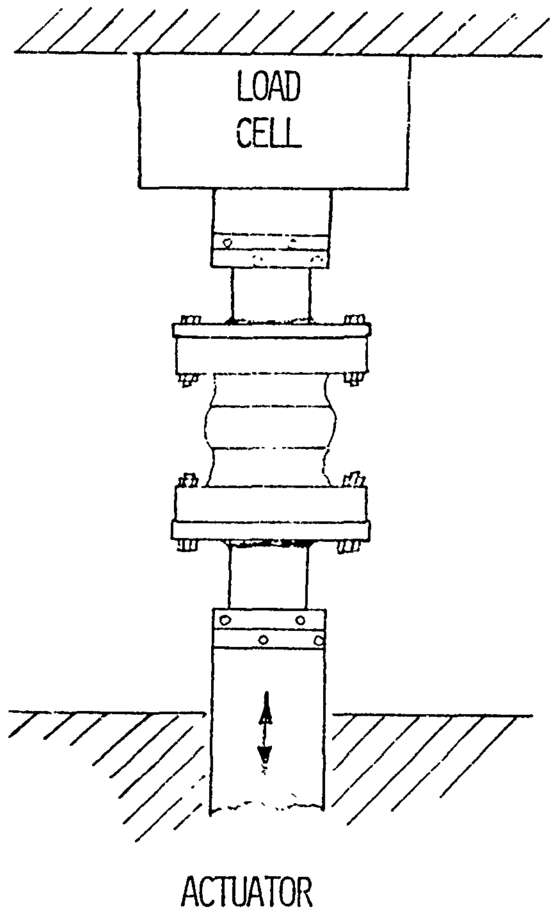


FIG. 3: THE AXIAL MODE TEST FIXTURE

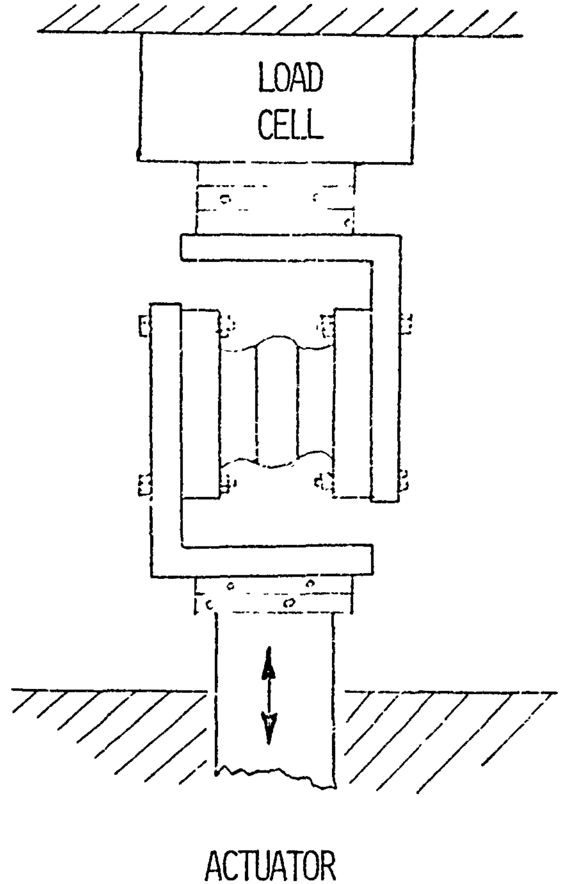


FIG. 4: THE SHEAR MODE TEST FIXTURE

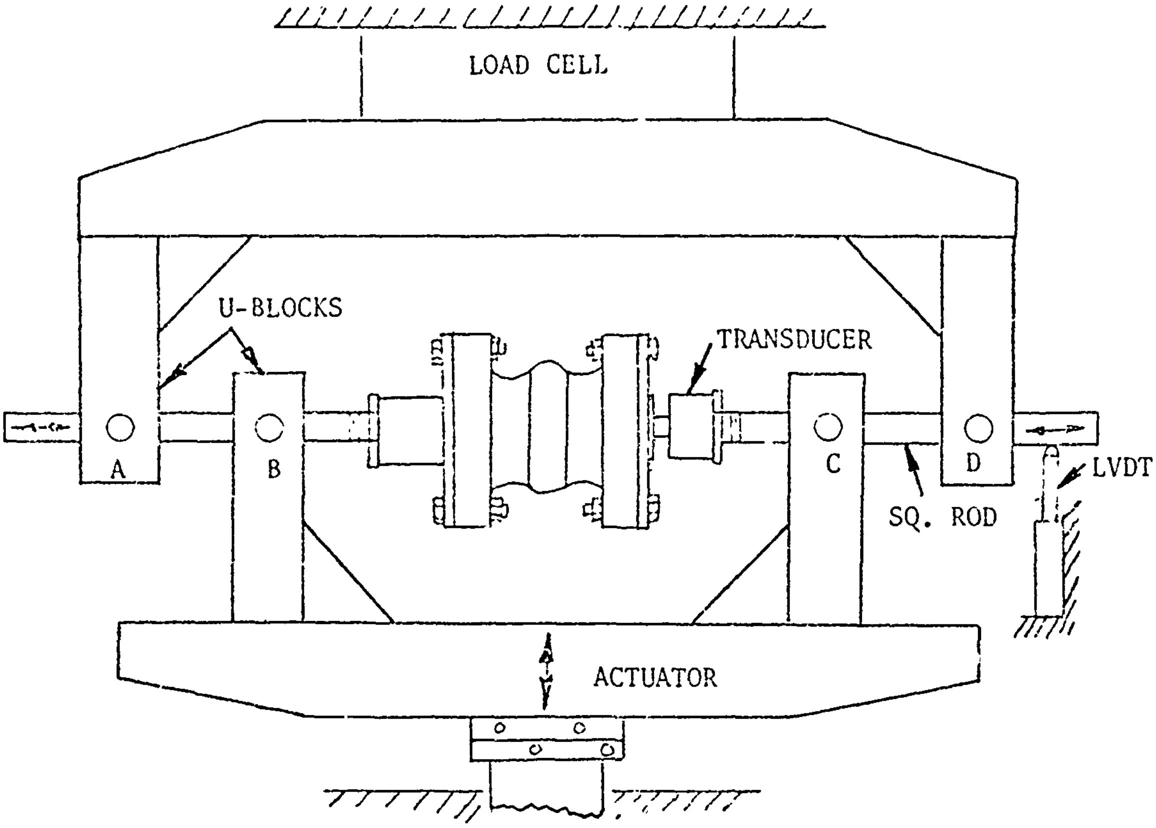


Figure 5: Bending Fixture

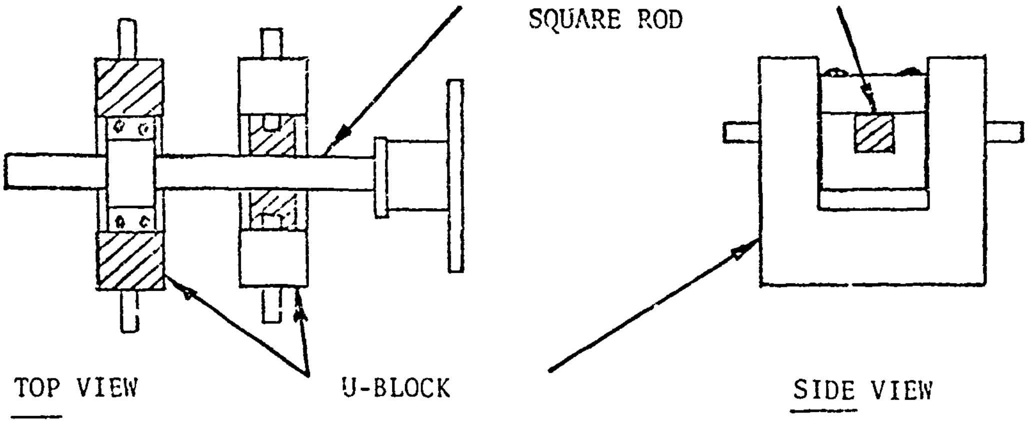


Figure 6: Bending Fixture Detail View

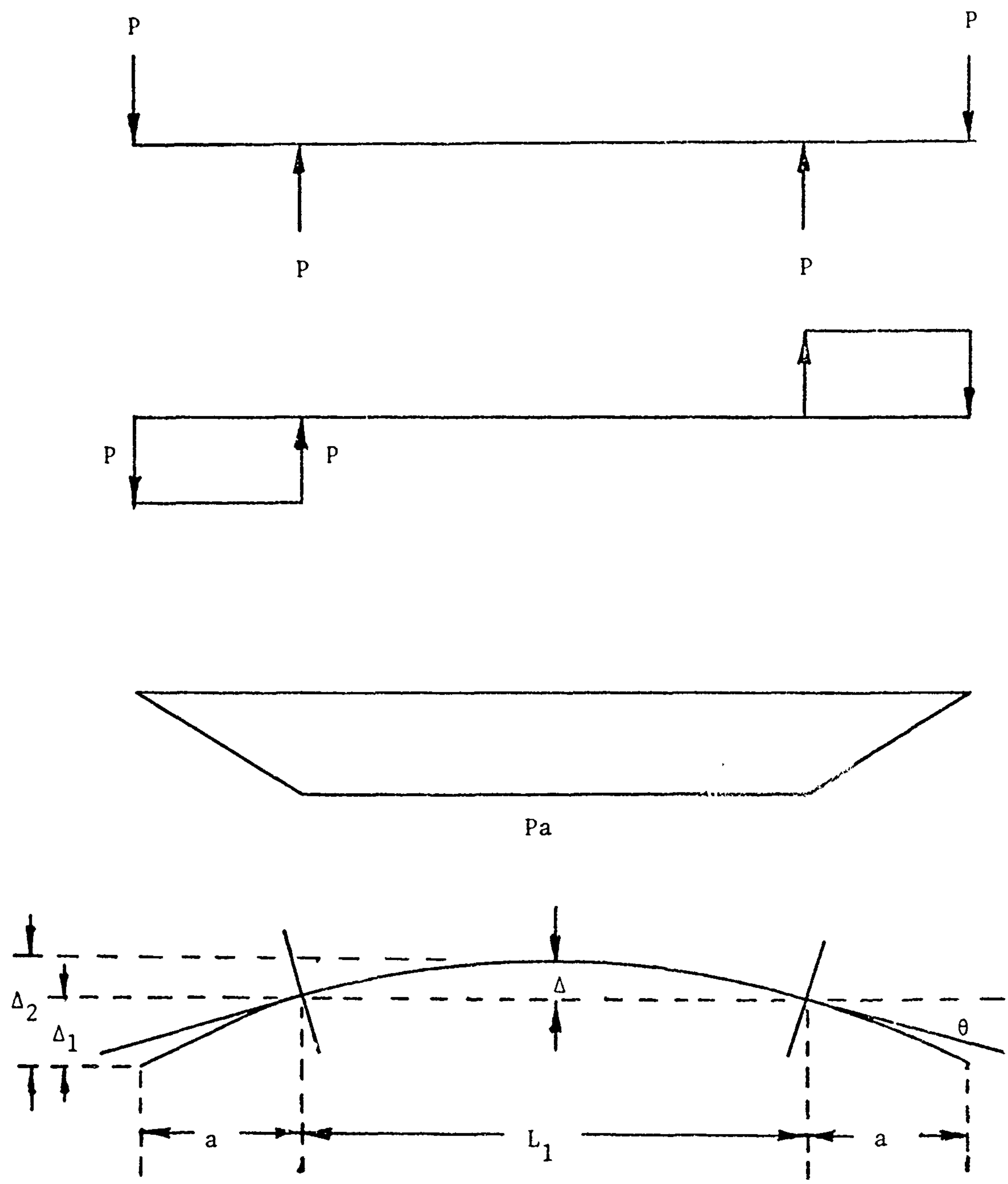


Figure 7: Four-Point bending fixture mechanics

In quasistatic loading, the analysis of a uniform beam subject to pure bending is relatively simple and the slopes and deflections at critical points are found in standard strengths of material books, e.g., Nash (1957). The various slopes and deflections illustrated in Figure 7 are:

$$\Delta = - PaL_1^2/8EI \tag{5}$$

$$\theta = - PaL_1/2EI = - ML_1/2EI \tag{6}$$

$$\Delta_1 = \Delta_2 - \Delta = - (Pa^2 L_1/2EI) - Pa^3/3EL \tag{7}$$

$$\Delta_2 = - (PaL_1^2/8EI) - (Pa^2 L_1/2EI) - Pa^3/3EI \tag{8}$$

where P = the load, a = the distance between loading pin centers, L_1 = the distance between supports and EI is the flexural rigidity.

With dynamic loading, the analysis is complicated by the inclusion of inertial effects.

In the analysis of the motion segment subject to pure bending, there is a functional relationship between the bending moment, M, and the angle, θ, given by $M = f(\theta)$. If this relationship is assumed to be linear, then the relationship between M and θ can be represented by $M = K\theta$ where $K = -2EI/L_1$ from equation (6). Since neither E nor I are known for the motion segment and, in general, one can not assume a linear relationship between M and θ for biological materials, it is necessary to experimentally measure M and θ to determine $f(\theta)$.

In the fixture shown in Figure 5, the motion segment and the square rods make up the beam subjected to four-point bending. Since the square rod and aluminum fixture are much more rigid than the specimen, it is assumed here that the entire motion segment bends as if it were a beam subject to a pure bending moment and that the square rod remains straight.

Therefore, the amount of total angular rotation between the two vertebrae of the motion segment is 2θ. It can be approximately related to the actuator displacement by $\theta \approx \Delta_1/a$ for small angles, where Δ_1 is the displacement of the actuator and a is the distance between loading pin centers on the U-block pairs. The actuator rates were set using the approximation $d\theta/dt \approx (d\Delta_1/dt)/a$.

The bending moment applied to the specimen in a four-point bending configuration is M = Pa. We can, therefore, calculate the bending moment from the load cell output. Practically, however, at high actuator rates the inertia of the upper loading fixture (i.e., the base which is attached to the load cell) distorts the load cell output. The oscillations of the fixture during loading and unloading obscured the desired signal, i.e., the bending moment, and were not at a frequency which could easily be filtered out electronically. Therefore, one of the aluminium fixtures was instrumented with strain gages to measure the bending moment near the specimen. By measuring the bending moment near the specimen, the undesirable inertia was reduced to only the mass of the load cell plate plus the Plastic Padding® base. Preliminary tests showed that actuator rates up to 250 ipm (2.78 rad/sec) could be used with the modified test set-up. The angle through which the specimen was rotated could be found by relating the actuator LVDT displacement to the geometry of the test fixture, i.e., $\theta = \Delta_1/a$. However, the slightest looseness in the square bearing showed up as a phase shift artifact between the bending moment and the rotation angle. An LVDT placed against the square rod measured the angle directly with a similar approximation, $\theta = \delta'/\ell'$, assuming that the rod was very stiff and the potting of the specimen was reasonably good.

For the bending tests, the fixture was set up in the MTS machine, adjusted and calibrated without the specimen in place, after which the aluminum fixtures were slid apart and a motion segment was bolted in place between them. The alignment of the fixture was checked by sliding the specimen from side-to-side by pressing on the square rod. With the extremely close fit, any misalignment created a large amount of friction, therefore, a light, thin coating of LPS® oil was kept on all moving parts. The specimen was then positioned in the middle of the fixture.

As in previous tests, a triangular pulse was applied to the actuator of the MTS machine. Although a constant actuator rate does not imply a constant angular displacement rate, the angle through which the specimen was rotated was small enough so that they agree to within 0.5%. The quasistatic rates were run first, once in each direction of the actuator, at rates of approximately 0.06 in./min (0.00067 rad/sec). The maximum actuator displacement was 0.15" corresponding to 5.72° of rotation. The results were examined to determine the limiting rotation for the dynamic tests. The dynamic tests were then completed. The specimen was removed from the fixture, rotated 90° from the original position and then replaced in the fixture. The entire procedure was repeated for the new axis. At the conclusion of these tests, the specimen was removed, examined, and then placed into a plastic bag and refrozen for the torsional tests.

Torsion Tests

The torsion fixture is shown in Figure 8. The specimen was attached on one side to a load cell which was instrumented to measure torsion. It was, in turn, rigidly mounted to a plate. The other side of the specimen was attached to an adapter which has splines that slid over a central shaft.

Attached to the other side of the central shaft was a resistance potentiometer for measuring the angle of twist. The potentiometer was wired as two arms of a four-arm Wheatstone bridge. The bridge signal was calibrated in degrees, and was used as the feedback signal for the MTS machine actuator to obtain constant angular displacement rates, as well as being recorded as the angular displacement data. The angular motion was applied to the specimen via the actuator moving a lever arm attached to the central shaft.

Each specimen was attached to the adapter which was, in turn, placed on the spline. The load cell was bolted to the other side and fixed to the plate with two nuts. These nuts were tightened so as not to twist the specimen. The torque from the load cell was monitored to ensure no preload. Each motion segment was twisted approximately $\pm 10°$ at a quasistatic rate of 0.006 rad/sec, limiting the maximum torque to about 250 in-lb. The limiting torque was adjusted, and then, each specimen was tested dynamically at rates of 6 rad/sec. The limiting angle for the dynamic tests was approximately $\pm 8°$. The torque vs time, ϕ_z vs time, and torque vs ϕ_z were the data measured.

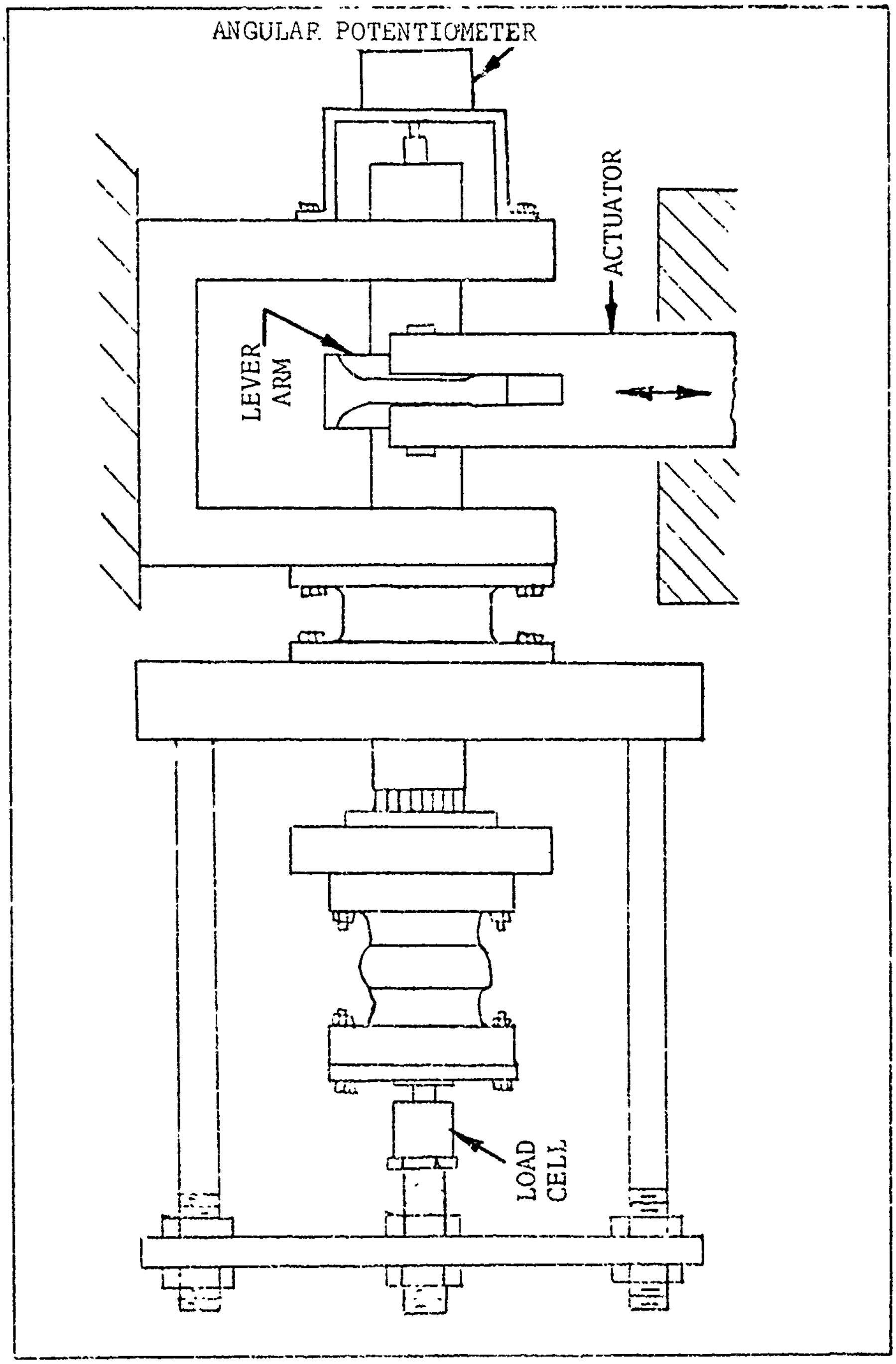


FIGURE 8: TORSION FIXTURE

Failure tests

After completion of the test series on a particular specimen, it was displaced at a constant rate until failure. The two selected modes of failure were torsion and ϕ_y bending (flexion and extension) with one specimen failing inadvertently during axial compression.

CERVICAL SPINE GEOMETRY

The geometry of the cervical spine is an integral part of the development and implementation of any mathematical model of the spine. Information concerning load transmission paths, ligamentous attachment points, vertebral body anthropometry and natural spinal curvature are combined to form an idealized spinal model, i.e., a structure defined mathematically to stimulate the kinematics and kinetics of the human spine.

MEASUREMENT TECHNIQUE

The criteria for determining the method used to obtain the cervical spine geometry were as follows:

1. The resulting data should be easily referenced to a coordinate system fixed at the center of the vertebral body;

2. The data should be in the form that can easily be compared to other anthropometric data on the cervical spine;

3. The method should be as simple as possible;

4. The tools required to perform the measurements should not be unusually complicated or expensive.

Several methods were evaluated in order to satisfy the above criteria. The first method evaluated was classic anthropometric measurements taken directly from the specimen using calipers and a goniometer. This method proved to be cumbersome and somewhat inaccurate when it was used to reconstruct the vertebra from these measurements and reference it to a coordinate system. For example, using the measurement made from the tip of one transverse process to the other as shown in Figure 9, its relationship to the center of the vertebral body cannot be determined if it is not symmetrical. Due to the lip on the centrum, shown in Figure 10, the lateral view gives a totally different perspective of the center of the vertebral body as when viewed anteriorly. Taking measurements directly from the radiographs were impractical because many points were not distinguishable in all views. The third approach was to fix the vertebra and find the coordinates of certain points using a stereotaxic device (Figure 11). The orthogonal coordinates, D_1, D_2 and D_3, were tabulated for points on the vertebra, thus, all points are referred to a fixed reference. However, it was very difficult to measure inferior points when the anterior portion was exposed. If the vertebra was inverted, then the correlation between two sets of readings was lost. This was circumvented by measuring four or five reference points on the vertebra for each change in position. The coordinates of these reference points

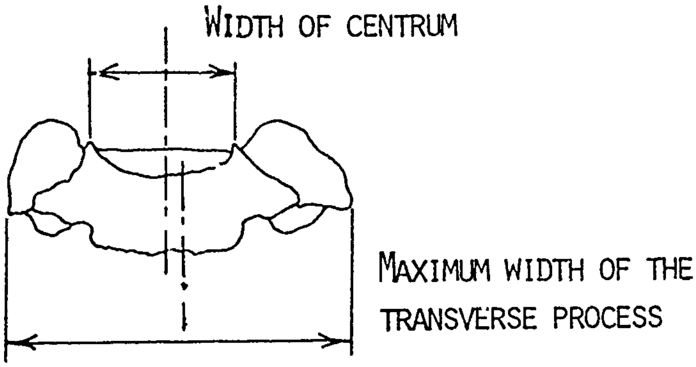


FIG. 9: CENTER OF NON-SYMMETRICAL VERTEBRA USING ANTHROPOMETRIC MEASUREMENTS.

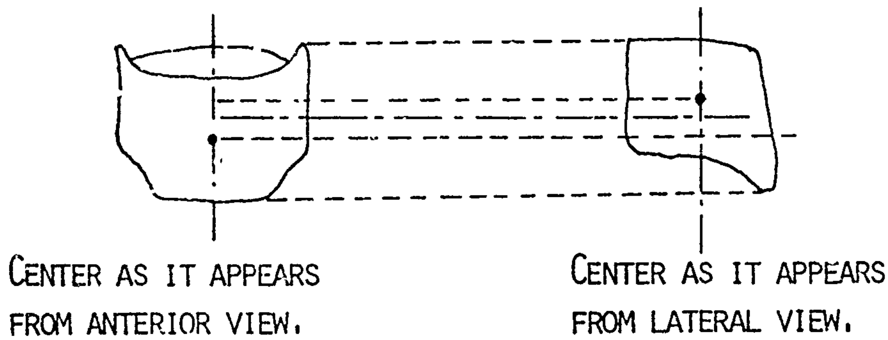


FIG. 10: DETERMINATION OF THE CENTER OF THE VERTEBRA CENTRUM.

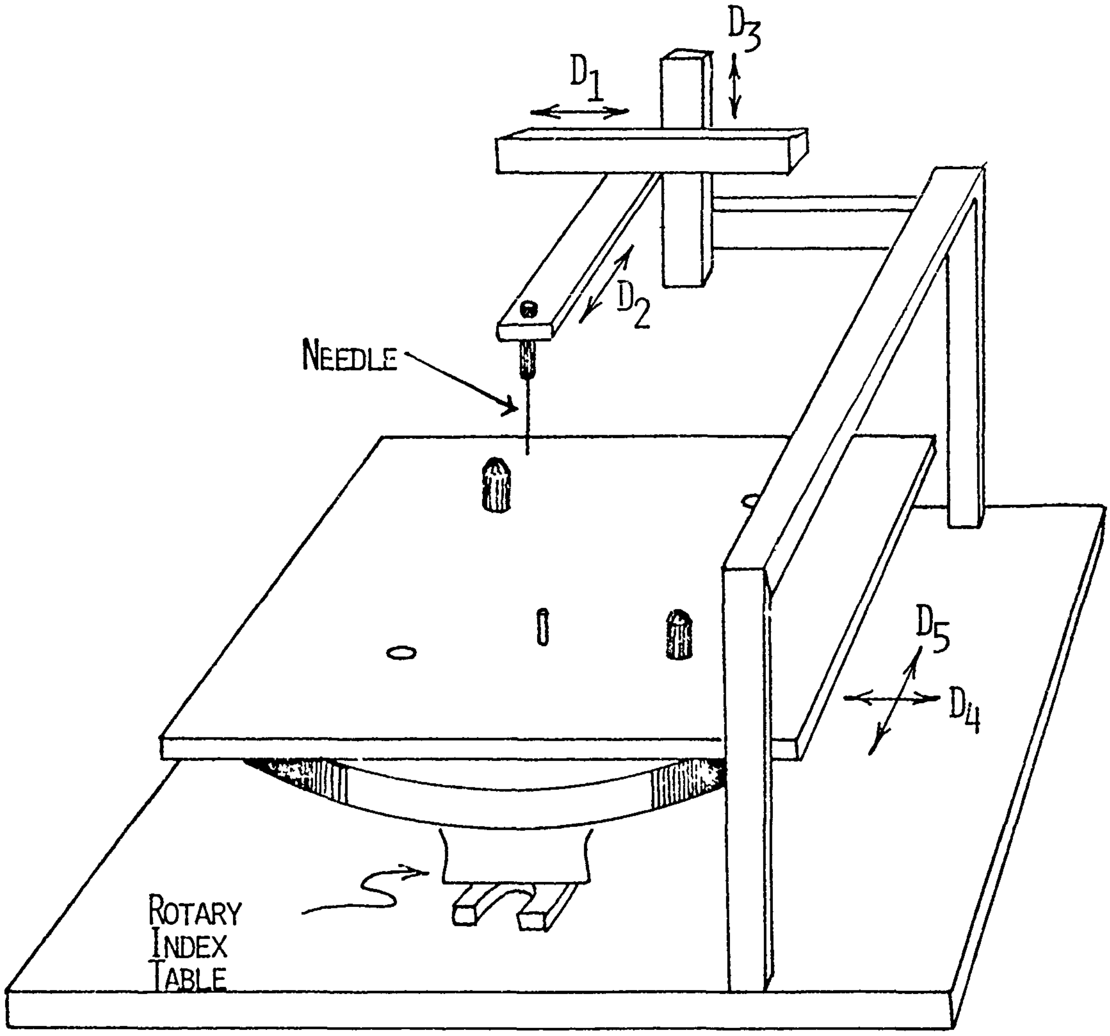


FIG. 11: STEREOTAXIC MEASURING DEVICE

established enough information to find an orthogonal transformation matrix to rotate one set of coordinates into the reference frame of the other. Figure 12 shows points A, B and C which form a plane, and the same points measured in a different position, called A', B' and C' for distinction. By subtracting vectorally coordinate A from coordinate A', points A and A' become coincident. As shown in Figure 13, the vector cross product $V_{AB} \times V_{AC} = V_z$ and $V_z \times V_{AB} = V_y$, when normalized, form an orthogonal set of vectors in position one. Likewise, $V_{A'B'} \times V_{A'C'} = V_{z'}$ and $V_{z'} \times V_{A'B'} = V_{y'}$ form a second set. The simultaneous solution of equations relating V_{AB}, V_y, V_z to $V_{A'B'}$, $V_{y'}$, $V_{z'}$ establishes the transformation matrix by which to rotate the rest of the points to a common reference. By choosing point A as the center of the centrum, criterion 1 is easily satisfied.

Criterion 2 is satisfied by choosing points on the vertebra so that the distance between them represents the desired anthropometric measurement.

Figure 11 shows a representation of the apparatus used for the direct vertebral measurements. A stereotaxic device having three orthogonal motions, referred to as D_1, D_2 and D_3, is mounted on a rigid frame. A standard rotary index table, which had two perpendicular motions, D_4 and D_5, was mounted on the base of the frame. The motions, D_4 and D_5, were parallel to D_1 and D_2, respectively. The motions, D_1, D_2 and D_3, moved an indicator to a point on the vertebra. The motions, D_4 and D_5, moved the base to extend the range if the specimen was larger than the D_1, D_2 scales. The apparatus described above satisfied criteria 3 and 4. Figure 14 describes the methodology used for location of the origin to which the axis was translated from the steriotaxic axis.

MEASUREMENT PROTOCOL

Following the establishment of the measurement technique, an experimental procedure was followed. The criteria used to formulate the measurement procedure were:

1. The location of the vertebra, with respect to the four mounting holes drilled in the Plastic Padding® and the flat bottom surface of the Plastic Padding®, should be established;

2. The points chosen on the vertebra should include those from which general anthropometric data can be determined for comparison with other published data;

3. Certain areas, e.g., centrum and facet areas, need to be measured because they are pertinent to the calculations to obtain the geometric properties. The coordinates of the points on the vertebra should accurately represent the areas to be determined;

4. A reference set of points which can be determined at each position should be established, since it is necessary to move the vertebra during the measurements.

Table 1 is a list of the points which were measured for each vertebra. The points, ref. 1-ref. 4, establish the points needed in criterion 1. In each testing configuration (axial, bending, shear torsion), the four holes in the

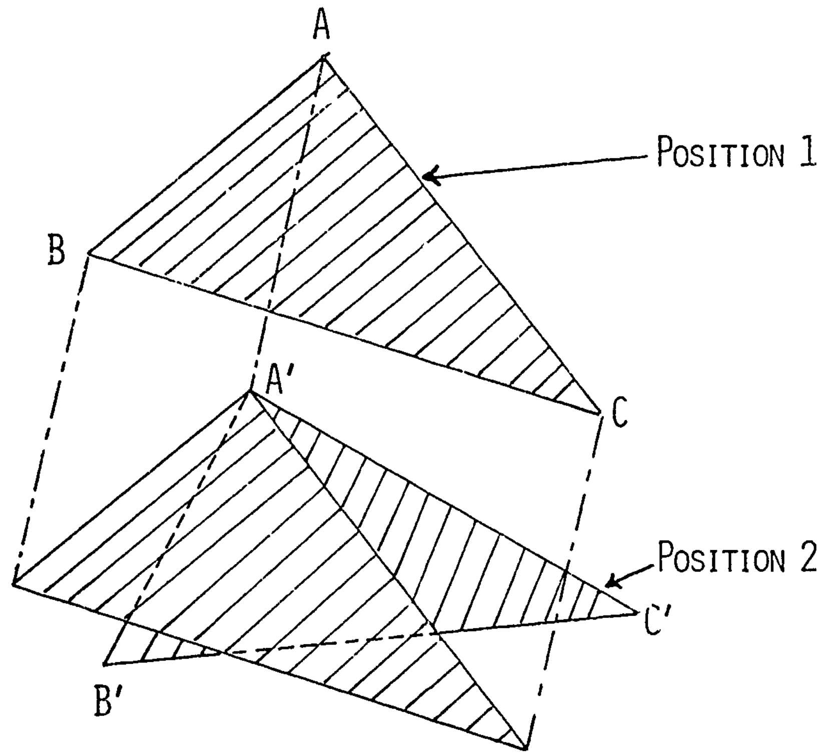


Fig. 12: The use of reference points for relating inferior and superior measurements.

Fig. 13: Establishing an orthogonal set of vectors from the reference points A, B, and C.

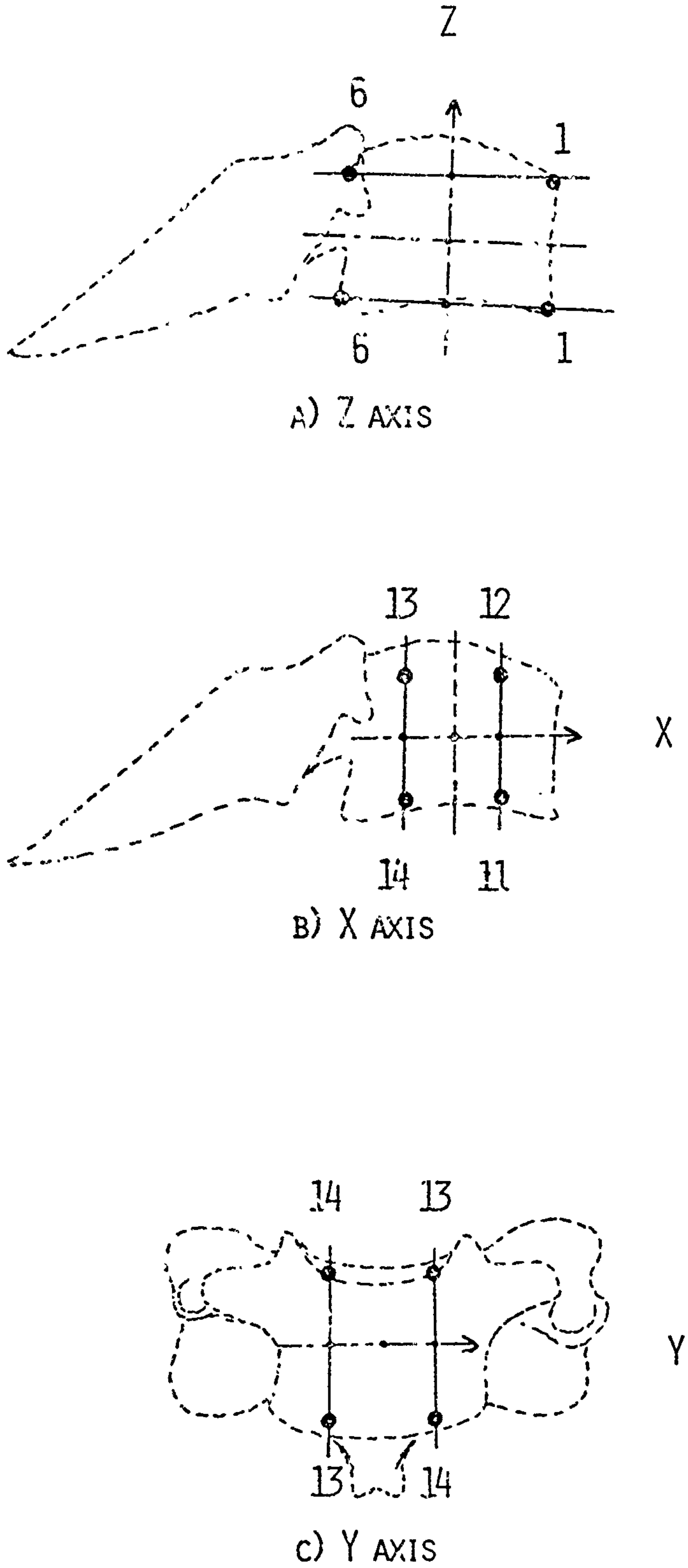


Figure 14: Coordinate Origin Calculation for the First Two Specimens (The center was calculated as the center of the parallelogram formed by the points shown above.)

TABLE 1: CERVICAL VERTEBRA GEOMETRICAL MEASUREMENTS BODY COORDINATES (CONDENSED FROM DATA SHEETS)

SPECIMEN: ____________ VERTEBRA: ____________ SURFACE: INF OR SUP

D_1 D_2 D_3 D_4 D_5

Ref. 1 . . Ref. 4	Reference points on the base of the measurement device Top of locator pin
Ref. 5 . . . Ref. 9	Points used for rotation of coordinates arbitrarily chosen, but must be the same point on the inferior and superior data sheet
Pin 1 . . Pin 4	Location of pin inserted for deformation measurement
SH 1 . SH 3	Centers of screw hole embedded for additional purchase
C.E.P. 1	Visual end plate center
1 . . . 14	End Plate Coordinates (See Fig. 12)
15 . . . 20	Facet Coordinates (Left when facing anterior)
21 . . . 26	Facet Coordinates (Right when facing anterior)
27 . . 30	Ligamentum flavum end attachment points
31, 34	R & L tip of the transverse process - when facing spinuous process
32, 33	Tip of spinous process, 32 and 33 same point if not bifurcated

Plastic Padding© base were used to locate the motion segment in the test fixture. For the tests where a rotation of one vertebra with respect to the other occurred, i.e., lateral bending, flexion-extension bending and torsion, it was necessary to determine the specific axis of rotation since the bending and torsional load-deformation characteristics depend on the location of the axis. Since the axis of rotation of the test fixture is related to the mechanism of loading, the rotational axis can be determined by knowing its position in the test fixture. For example, examining the case of torsion of Figure 11, the fixture for this test rotated the vertebra about an axis, ϕ_z, equidistant from the four holes. Thus, the axis of rotation must pass through point A and is perpendicular to the bottom of the Plastic Padding®. The fixtures for the bending moment test configuration, which was described previously, similarly establishes an axis, ϕ_y or ϕ_x, about which the vertebra is rotated.

Figure 16a and b show the points, 1-36, and their relative relation to the vertebrae, C_3-T1, which were chosen to satisfy criteria 2 and 3. Figure 16c shows the displacement pins used at their respective locations. Figures 16d, e, f and g show the numbering system used for the vertebra, C_1 and the superior portion of C_2. This was necessitated by the unusual geometry found on C_1 and C_2.

Table 2 shows a list of anthropometric measurements which were used as a guideline. For example, to obtain the maximum spread of the transverse process (the distance between the left and right transverse processes), the coordinates at the end of each were needed. Points 31 and 34 were established for that purpose.

Figure 17 shows the contact areas considered to be important for each intervertebral joint. For instance in axial compression the force between the two vertebrae is the same, however, the deformations are different at different locations on the joint, owing to the different areas and angles of contact for the discs and facets. This difference could be normalized by dividing by the x-y plane projected area of the centrum and facet for each motion segment at each level.

The remaining reference points in Table 1 satisfy the fourth criterion, as well as establish the location of the pins inserted for the purpose of deformation measurement and the location of the screws inserted for better purchase with the Plastic Padding© base.

METHODOLOGY

The geometrical measurements of the cervical spine were obtained from three sources consisting of:

1. x-rays;

2. a ceramic replica of the motion segment made prior to the potting of the specimen in Plastic Padding®;

3. stereotaxic measurements taken directly from the vertebral body after the stiffness testing;

4. Coordinate measurements of the vertebral body using a 3-D digitizer.

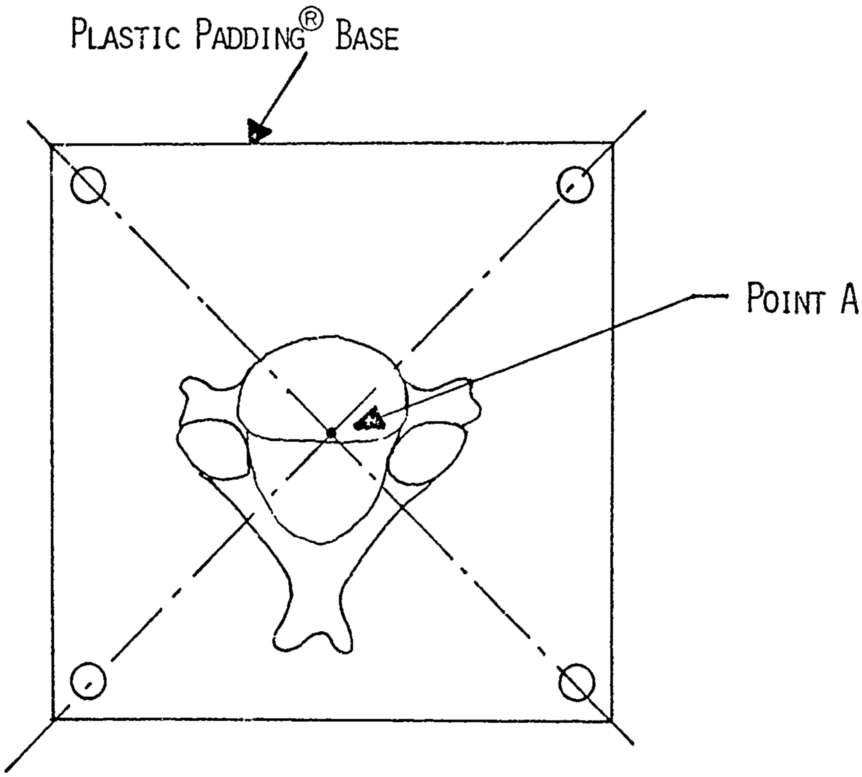
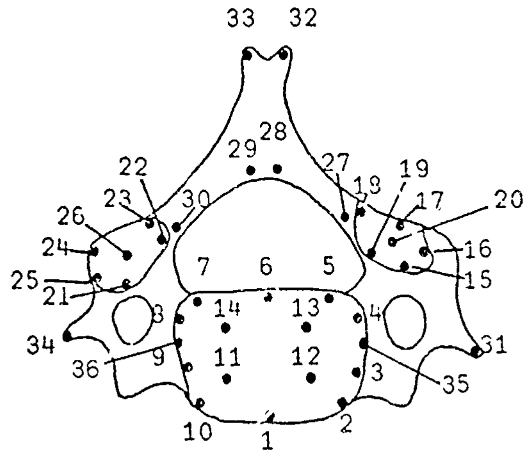
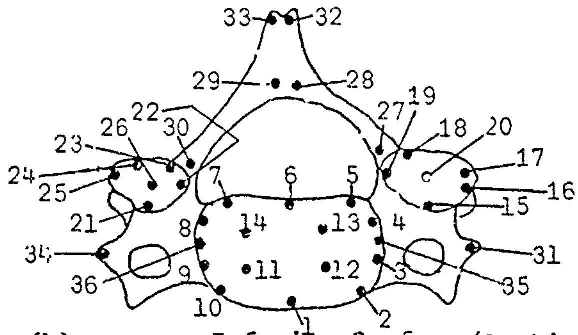


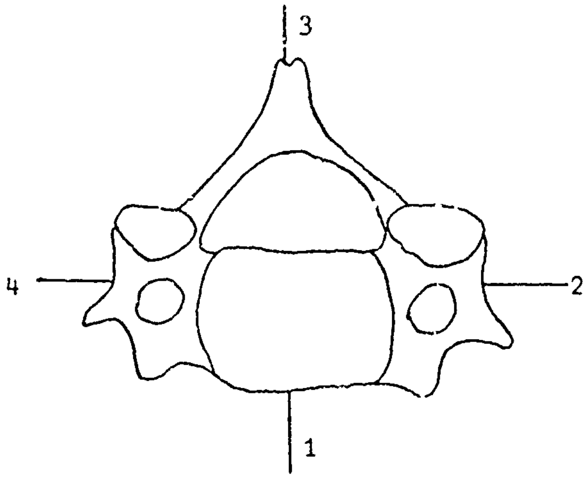
FIGURE 15: AXIS OF ROTATION
DURING TORSION TESTS.



(a) Superior Surface (Looking Down) with Numbering System for vertebra C_3-T_1

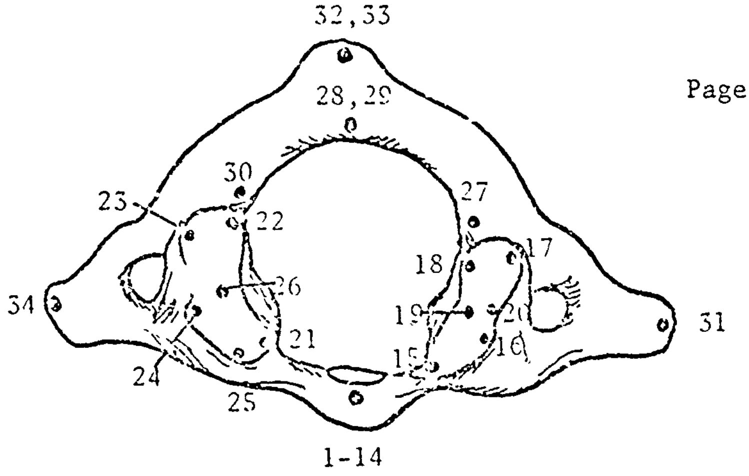


(b) Inferior Surface (Looking Up) with Numbering System for Vertebra C_2-T_1

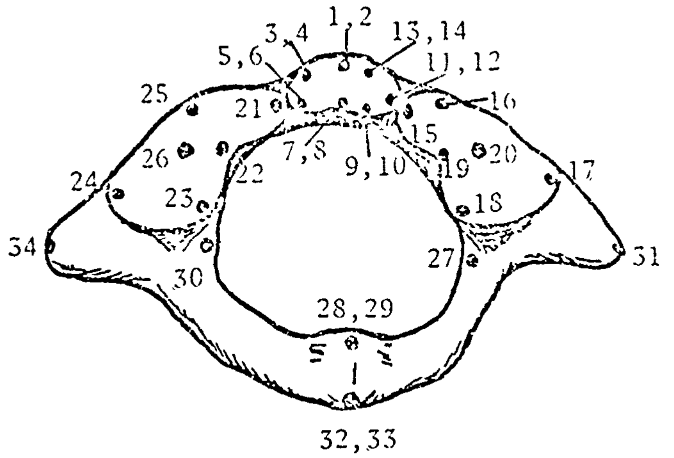


(c) Superior Surface Pin Placement and Location Numbers

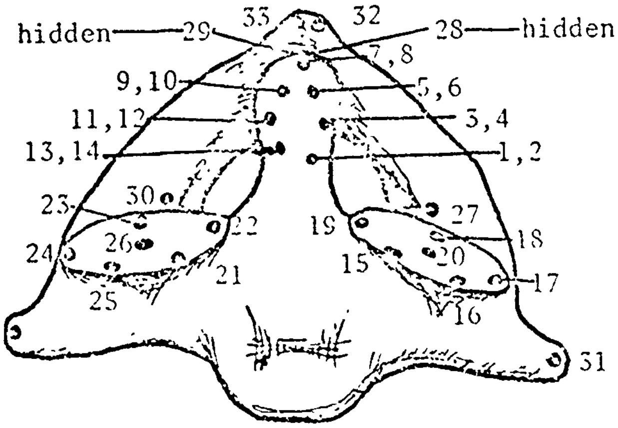
Figure 16: Geometrical Measurements Numbering System (NOTE: Points 35 and 36 are not used on Specimen EJ and PW.)



(d) C_1 - Superior

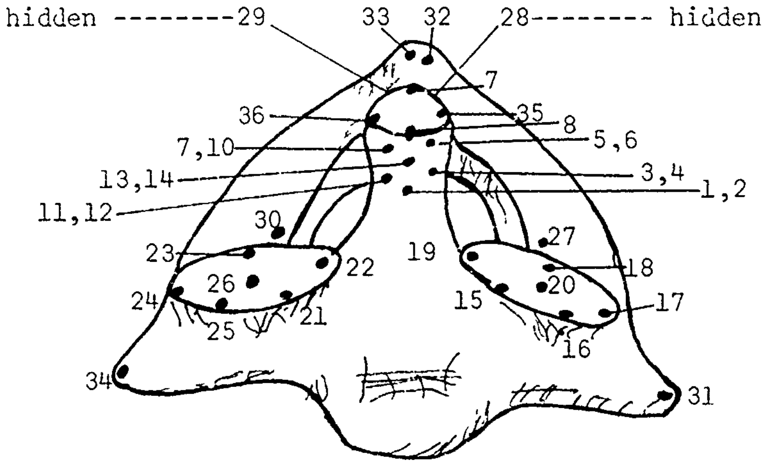


(e) C_1 - Inferior



(f) C_2 - Superior for PW & EJ

Figure 16: Geometrical Measurements Numbering System

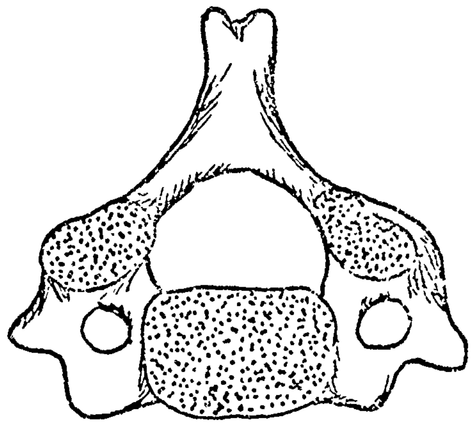


(g) C_2 - Superior for SWE 23, SWE 25, HI and GS

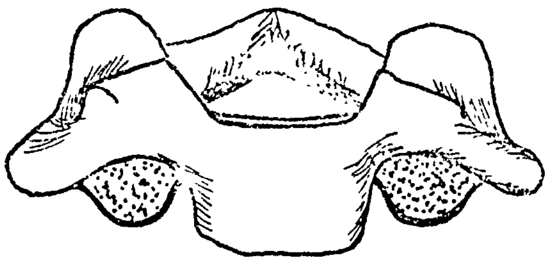
Fig. 16: Geometrical Measurements Numbering System

TABLE 2. COMMON ANTHROPOMETRIC MEASUREMENTS OF CERVICAL VERTEBRA

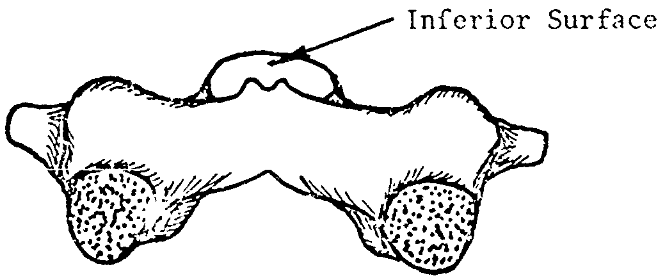
ITEM	
a	Maximum spread of the transverse process
b	Maximum sagittal diameter
c	Transverse diamter of the body (two measurements - superior & inferior
d	Sagittal diameter of the centrum - superior & inferior
e	Vertical height of the centrum (three measurements - anterior, middle and posterior)
f	Vertical height of the disc (three measurements - anterior, middle and posterior)
g	Angle of inclination of the superior surface of the spinous process (with respect to the superior surface of the centrum)
h	Angle of inclination of the inferior surface of the spinous process
i	Height of the posterior margin of the spinous process
j	Angle of inclination of the superior facet for articulation with the inferior facet of the above vertebra (two angular measurements for each side)
k	Normal distance between two articular planes
l	Angle of inclination of the inferior facet for articulation with the superior facet of the next vertebra below (two angular measurements for each lateral side)
m	Normal distance between two articular planes
n	Profile of the cross-sectional area of the disc
o	Profile of the superior and inferior surface of the vertebra



(a) Superior View



(b) Anterior View



(c) Posterior View

Figure 17 : Vertebra area
Measurements

Radiographic Measurements:

Each specimen was x-rayed for evaluation prior to dissection. Appropriate scales were used in order that certain measurements could be made directly from the radiograph. Should it become necessary to make estimates of coordinates from the radiographs for whatever reason, the set of points in Figure 16 will be so indicated on the data sheets.

Ceramic Replica Measurements:

As was mentioned previously, prior to casting of the vertebra in the base of Plastic Padding®, a cast of each motion segment was made in order to preserve the outline of the outer surface of each motion segment. The surface which was eventually cast in Plastic Padding® was thus preserved for measurements in case of segment failure. Measurements were not made from the castings unless other difficulties were encountered which made it impossible to complete the measurements directly from the specimen. They are denoted in the data and may possibly be less accurate than direct measurements.

Direct Stereotaxic Measurements from the Vertebra: (Used on specimen PW and EJ)

After the stiffness data testing protocol was completed on all specimens, the test specimens (motion segments) were photographed and then separated by cutting through the intervening soft tissues. The exposed surfaces were stripped of any remaining soft tissue. A black ink indelible marker with a fine point was used to mark the various points, listed in Table 1, on the exposed surface.

In marking the points, it was necessary to:

a. Make sure that the reference points, A, B, C and A', B', C', in Figure 12 which would be used for calculating the transformation matrix, could be measured at both positions, i.e., when the superior surface was up and when the inferior surface was up, as shown in Figure 18 and 19,

b. Make sure the reference points formed a maximal triangular plane,

c. Select the points which would be used for the calculation of areas, i.e., those on the perimeters, in a manner which would enclose as much of the area as possible when straight lines were drawn connecting the points.

A hole was drilled in the visible center of the centrum of the vertebra perpendicular to the base and a pin inserted to hold the vertebra in position on the measuring device when the inverted side was measured. The measuring device was calibrated so that all four points, shown in Figure 20, on the base were known with respect to the dials. Each vertebra, with the Plastic Padding® base still intact, was placed on the measuring device shown in Figure 18 with the exposed vertebra up. The coordinates of each point in Table 1 were obtained and tabulated. The set of measurements, in the initial position, were made in order to locate the specimen with respect to the Plastic Padding® surface, as well as one side of the vertebra. This made it possible to explain some peculiar data by noting the alignment of a vertebra when cast into the Plastic Padding®. Upon completion of the first set of measurements, the vertebra was

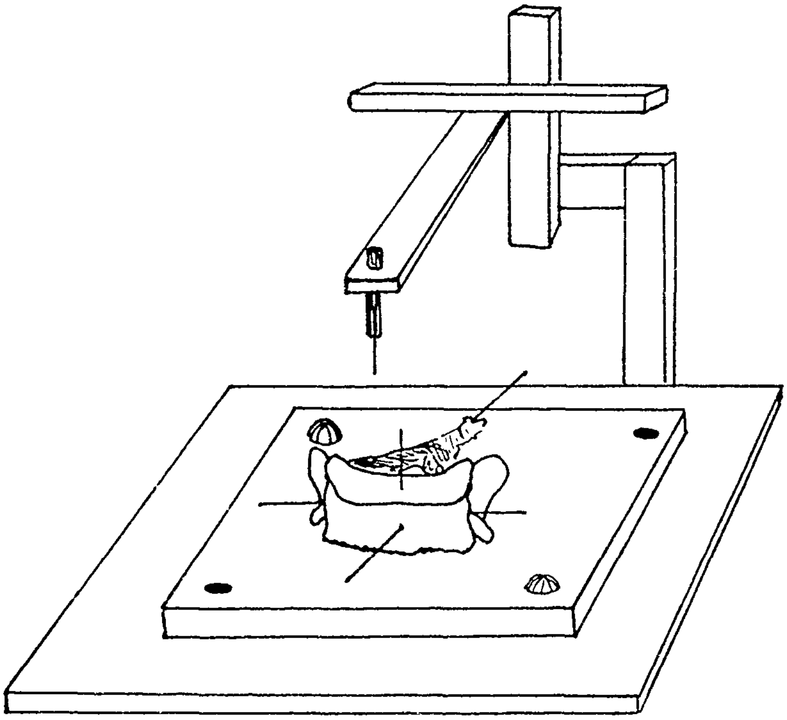


FIG. 18: MEASUREMENT SET-UP WITH PLASTIC PADDING® INTACT.

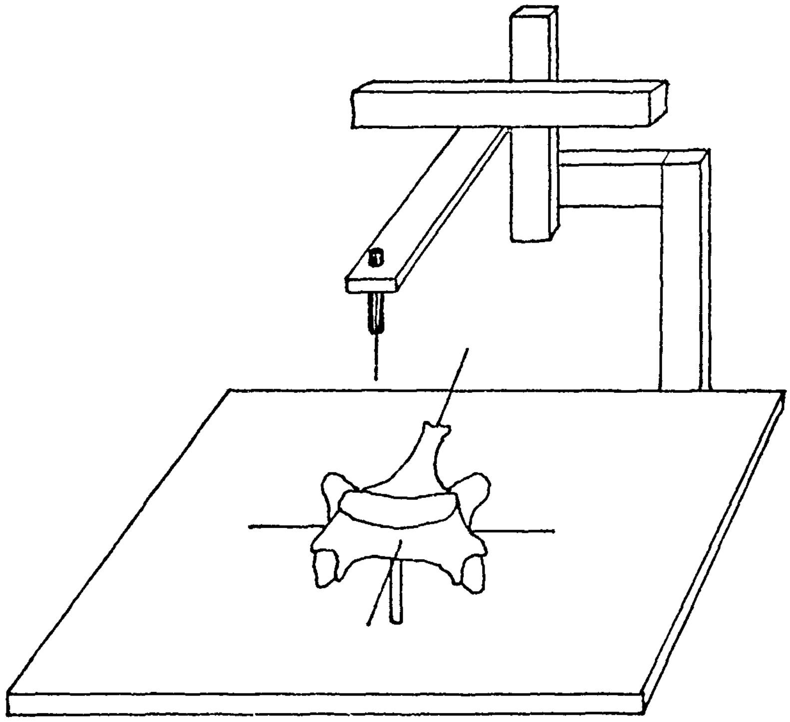
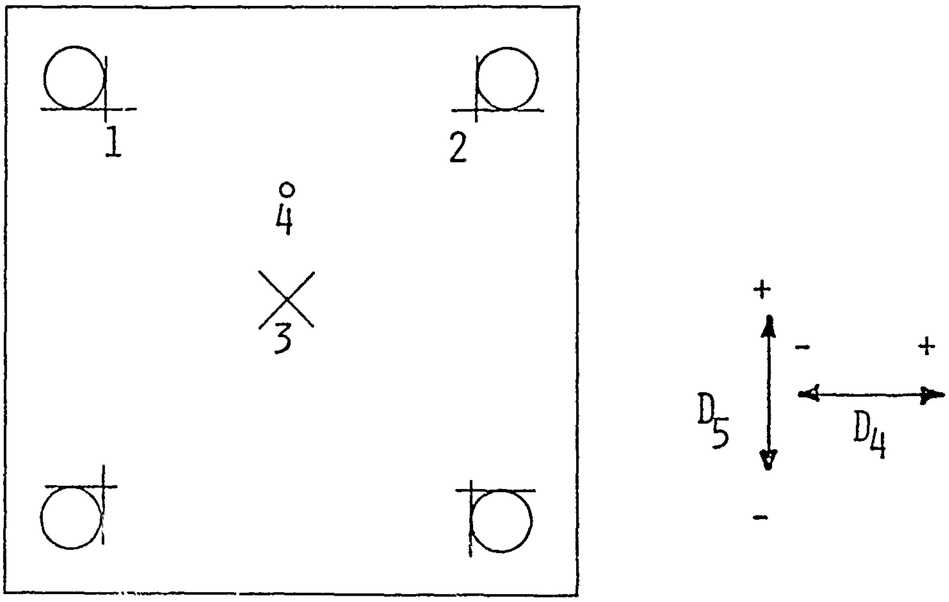


FIG. 19: GEOMETRICAL MEASUREMENTS WITH THE PLASTIC PADDING® BASE REMOVED.



PLEXIGLASS BASE SCHEMATIC SHOWING THE HOLE LOCATIONS, SCRIBE MARKS AND SUPPORTING NEEDLE LOCATIONS CORRESPONDING TO THE CENTER OF THE VERTEBRA END PLATE OR CENTRUM.

1,2: HOLE LOCATERS

3 : CENTER OF PLASTIC PADDING® FIXTURE

4 : 17 G. NEEDLE SUPPORT LOCATER

Figure 20: Geometrical Measurements Stereotaxic Apparatus Base

removed from the measurement device and the Plastic Padding® was removed by making small saw cuts from the edge of the Plastic Padding® to the edge of the vertebra at closely-spaced intervals and breaking off the tabs.

The same set of points in Table 1 were marked on the newly exposed side of the vertebra in the manner mentioned prevously. Then, the vertebra was replaced on the measuring device, as shown in Figure 19, with the unmeasured side up and the pin, previously mentioned, inserted in the center of the centrum placed in position 4, and the coordinates of the newly marked points were noted.

A computer program was developed to reduce the data. The measured coordinates were used as input data. The ouput consisted of a list of coordinates referenced to an orthogonal coordinate system with the origin at the center of the centrum, the projected areas, i.e., x-y, y-z, x-z planes of the facet surfaces and centrum surfaces, and plots of the points in three planes. The documentation is contained in Appendix C and the coordinate system determination methodology is shown in Figure 10.

<u>Three Dimensional Digitizer Technique</u>: (As used on specimen SWE 23, SWE 25, HI 25 and GS 28).

The Graf-Pen 3-D digitizer was used for the measurement of the 3-D geometry of the last 4 spines. The schematic view of the 3-D digitizer is shown in Figure 21. When the digitizing pen is sparked at the point of measurement, its distances from the point to each of the three linear microphones A, B and C are measured by means of the wave travel time of the spark. A computer program, in time sharing mode, was written to convert these distances to coordinates with respect to the fixed coordinate system and then to the body-fixed local coordinate system determined by three reference points of the model. The flow chart of this transformation program is shown in Fig. 22.

Two K-wires were inserted through the anterior and lateral aspects of the body in the fashion shown in Figure 23 in order to determine the local body coordinate system. A total of 72 points were measured for each cervical vertebra. The points are shown in Figs. 12(a-g). The four fixed holes in the Plastic Padding® shown in Figure 15 were also measured.

The coordinates of the vertebra with respect to the three fixed points (the tips of three K-wires) were first obtained. A new coordinate system was then defined with respect to the body geometry itself. This was determined by four points on each endplate surface according to the postero-anterior and the lateral orientation of the body. Figures 24 and 25 show the method of determining the local coordinate system. Points 1 and 6 on the superior and inferior surface determined the x direction. Points 35 and 36 determined the temporary y direction. The z direction was fixed by the cross product of x direction and temporary y direction. Finally, the y direction was determined by the cross-product of z and y direction. All coordinates are now measured with respect to this new body-fixed coordinates system.

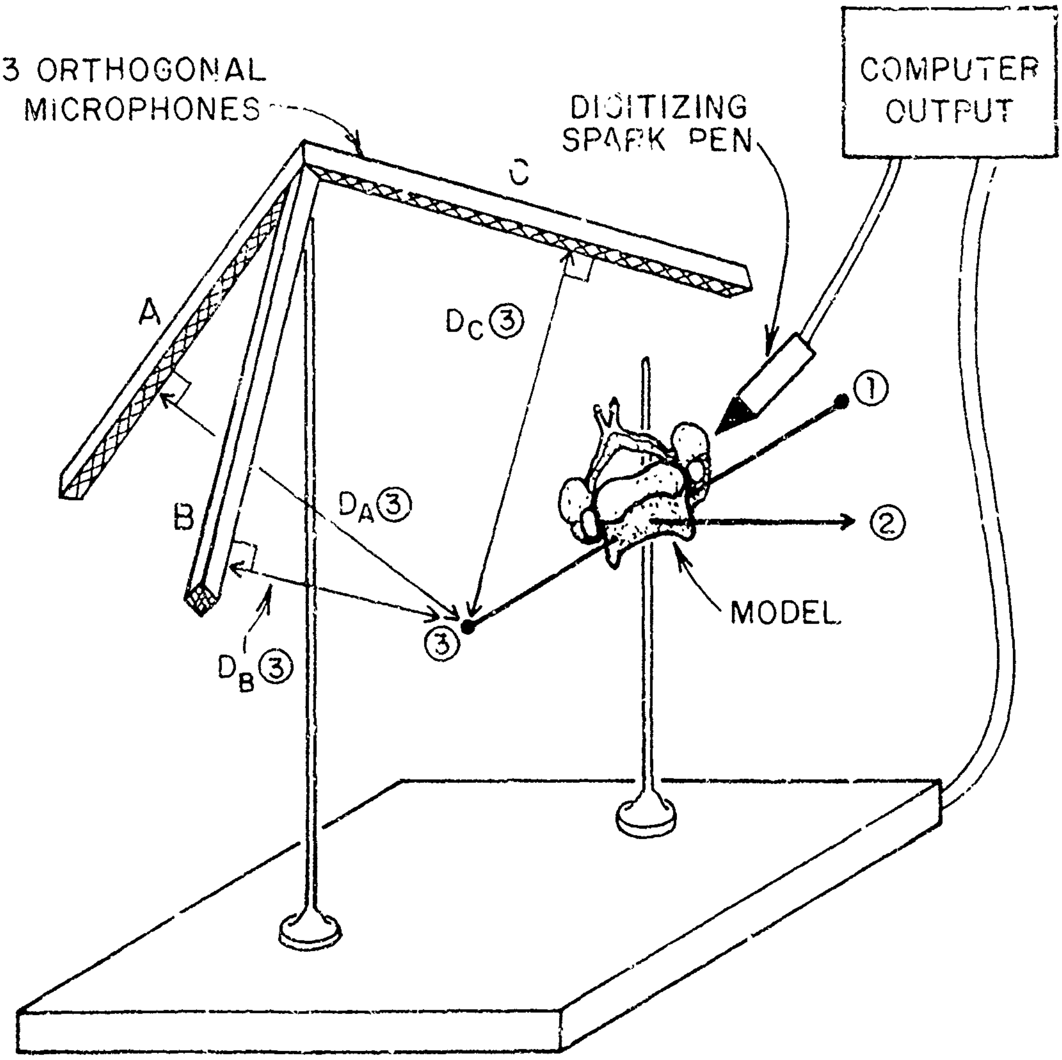


Figure 21: Graf-Pen 3-Dimensional Digitizer System as Used on specimens Hi 23, GS 23, SWE 23 and SWE 25.

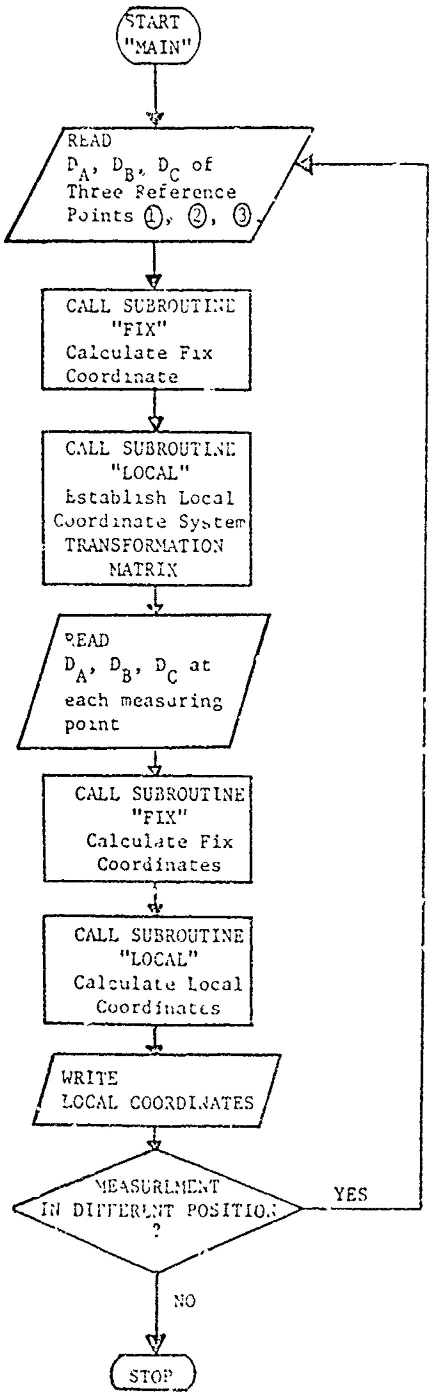


Figure 22: Interactive Local Coordinate Calculation Program Flow Chart Used on Specimens HI 23, GS 28, SWE 23, and SWE 25

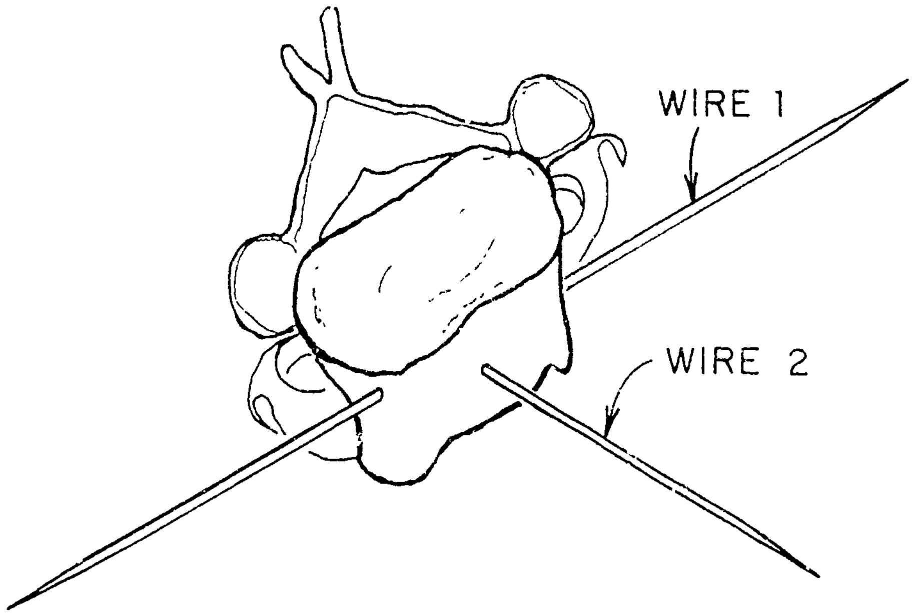


Figure 23: K-Wire Fixture System

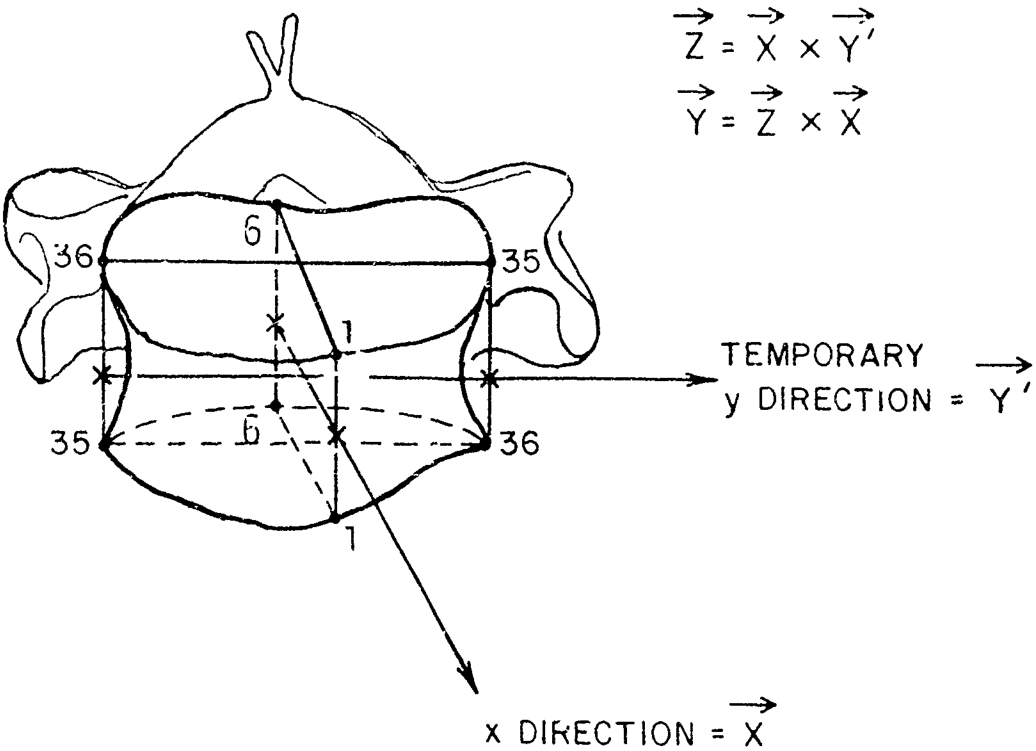


Figure 24: Vertebral Body Coordinate System Used on C-3 through T-1 (Digitizer Method)

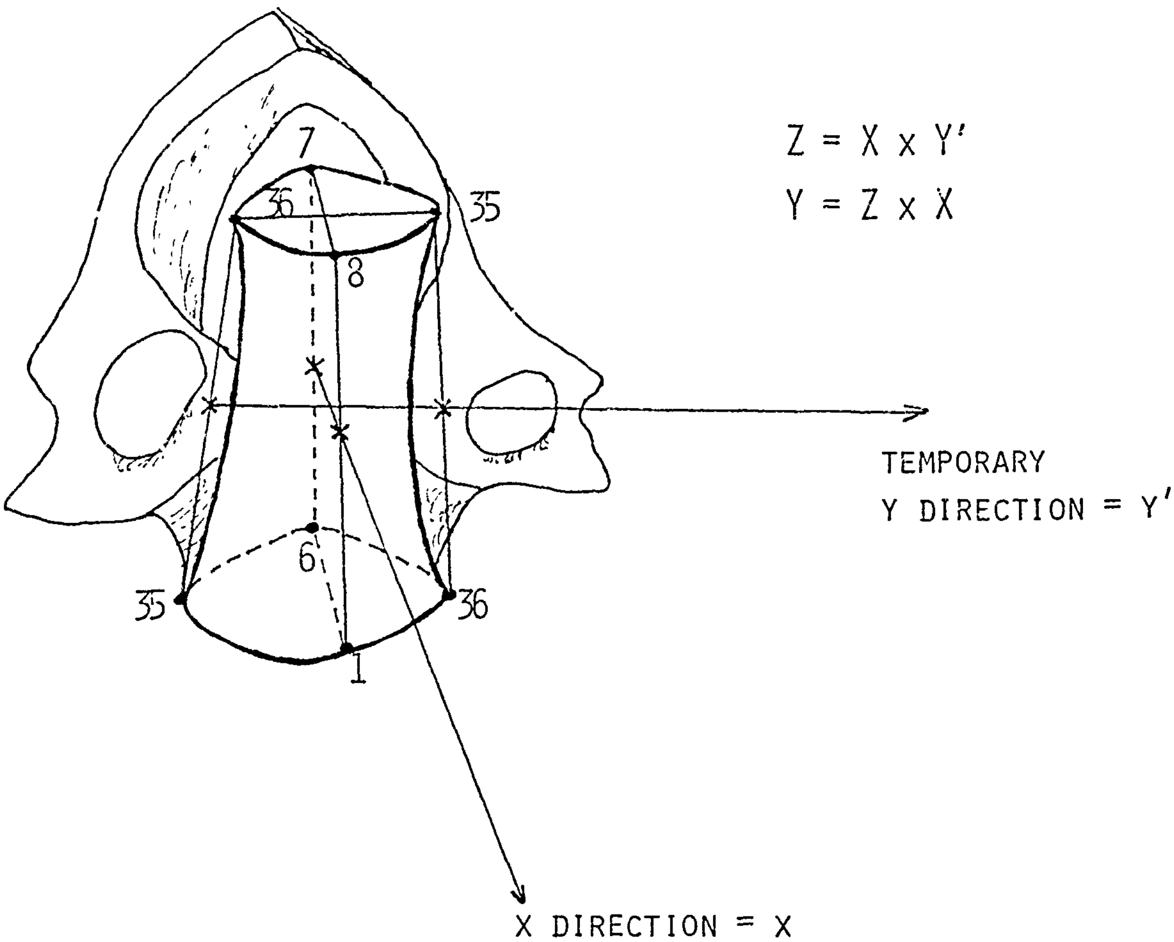


Figure 25: Vertebral Body Coordinate System Used on C-2 (Digitizer Method)

RESULTS

The results from tests on six cervical spines have been separated into two groups: load-deformation tests and geometrical measurements. The bulk of the data acquired has been included in Appendices B and C.

LOAD-DEFORMATION TESTS

A total of six spines were tested following the protocol prescribed for the stiffness tests. Several motion segments failed after the same particular test, precluding the completion of the other tests for that specimen. The complete raw data consisted of time histories of the MTS load cell force, the MTS actuator LVDT displacement, the torque or bending moment from a specially designed load cell and deformation from one or two strain gage beam deflection measurement devices. Graphs compiled from the original tape data as well as the analog tape record have been previously submitted to the Contract Technical Monitor. The pertinent documentation relating the tests, motion segment orientation, specific data recorded, tape location and tape recorder sensitivity will be forwarded to the contract technical monitor together with the raw data under separate cover.

The load-deformation data were derived from the time histories mentioned above. Data from six cervical spines in six test configurations in positive and negative directions at two strain rates were obtained yielding many individual load-deformation curves. Figure 26 shows the general quantitative analysis of each graph. The maximum load (the largest load attained during an individual test) and deformation (the largest angular and/or linear separation between the two vertebrae) were measured from the peak value. A straight line representing the average stiffness was calculated using a least squares fit, the slope of which represents the stiffness. The areas, A_1, A_2 and A_3, representing the strain energy input, output and loss, respectively, were measured with a planimeter from the load-deformation graphs. Tables B1-B12 in Appendix B represent the analysis in tabulated form. Graphs corresponding to the data in Tables B1-B12 were plotted for various levels of the spine in order to clarify and compare the results and have been included in Appendix B as Figures B1-B12. Representative load-deformation curves of each test mode are shown in Figures 27-32. Plots comparing the load-deformation curve for each test at slow and fast loading rates are shown in Figures 32-38.

GEOMETRICAL MEASUREMENTS

The coordinates from the cervical vertebrae taken from the six spines used in the load-deformation tests were obtained. The numerical results are listed in Tables C-1-C-38. The center of the vertebral centrum was calculated and all the points were referenced to the calculated center as the origin of the coordinate system. The specific methodology for determining the center of the vertebra centrum can be found in Figure 14. As mentioned previously, it was hypothesized that the projected areas of the centrum and facets may be influential in the results of the axial and shear tests. These areas were calculated using the perimeter of points of the particular area desired. For example, the x and y coordinates of the points 1-10 in Figure 16a were used to determine the area of the centrum in the x-y plane.

Similarly, the areas of the centrum in the y-z and x-z planes were calculated using the y and z coordinates of points 1-6, 13 and 14 and the x and z coordinates of the points 1-4, and 8-14, respectively. The results are summarized in Tables C-39-C-44 in Appendix C. To study the results, the sum of the facet and centrum areas for each plane were plotted for each level of the spine as shown in Figures C-1-C-4. In addition, the equations of the plane of each facet face and the centrum surface were calculated from the coordinates representing the surface. The normal vector to each plane is given in Tables C-45-C-56. The coordinates of the center of the Plastic Padding base for determining the relation of the vertebra to the test fixture (refer to Figure 14) are given in Tables C-57-C-62. To visualize the vertebra, the points 1-34 were plotted in six different views. Figure C-4 shows the relation of the plots to the cut-away views of the vertebra. The plots are included in Appendix C as Figure C-5.

The 3-D Graf-Pen digitizer yielded similar geometrical data as the stereotaxic technique. The speed of measurement was, however, increased by an order of magnitude. The data analysis remained the same as for the stereotaxic data.

DISCUSSION

The results of the above tests are from six cervical spines. For various technical reasons, the number of specimens per motion segment ranged from two to four. This is not considered a large enough population to obtain statistical variations.

By using the motion segment approach, the ligaments which span more than one motion segment have been neglected. The six spines were divided into two groups to cover all possible motion segment combinations.

AXIAL TESTS

Figures 27 and 33 (a) through (l) show the loading curves for the slow and fast axial loading rates, respectively. The following can be qualitatively noted:

1. The stiffness is generally higher in compression (-) than in tension (+);

2. The stiffness increases as one descends cephalocaudally the vertebral column. The exception to this is the segment C_5-C_6 which is less stiff than C_3-C_4 in tension;

3. The stiffness increases at the faster loading rate. The increase is more pronounced in the compression (-) mode;
4. With faster loading the motion segment tends to be very stiff during early deformation, and then decreasing later, showing very definite viscoelastic properties. This trend seems to be more pronounced in the compression tests.

Tables C-39 through C-44 show a smaller inferior area than superior area in the C5-C6 region, which may account for the decreased stiffness. Furthermore, the clinical vulnerability of the C_5-C_6 motion segment is well-known, e.g., spondylosis of the cervical spine begins here and traumatic hyperextension injuries are common at this site. Whether or not its lower mechanical stiffness is the reason for this special vulnerability is still an open issue. Much more stiffness and geometrical data need to be accumulated in order to substantiate this observed trend. In Figure B-1, it appears that the energy loss increases as the stiffness decreases.

SHEAR TESTS

In the +x direction, the observed force deformation behavior is very similar to the axial compression mode. When the upper vertebra is displaced in the +x direction, the interaction of the facets compresses the material between them and then places the disc material between the centrum in shear. In the -x direction, the behavior is very similar to tension since the material is placed in a pseudo state of tension at the facets, which is reflected in a much lower stiffness than in the +x direction. Comments 1 through 4 given above for the axial direction apply for +x shear when +x shear is substituted for compression. Figures 28, 34(a) through (1), B-3 and Tables B-5 and B-6 contain most of the results for the $\pm$ x shear load-deformation tests.

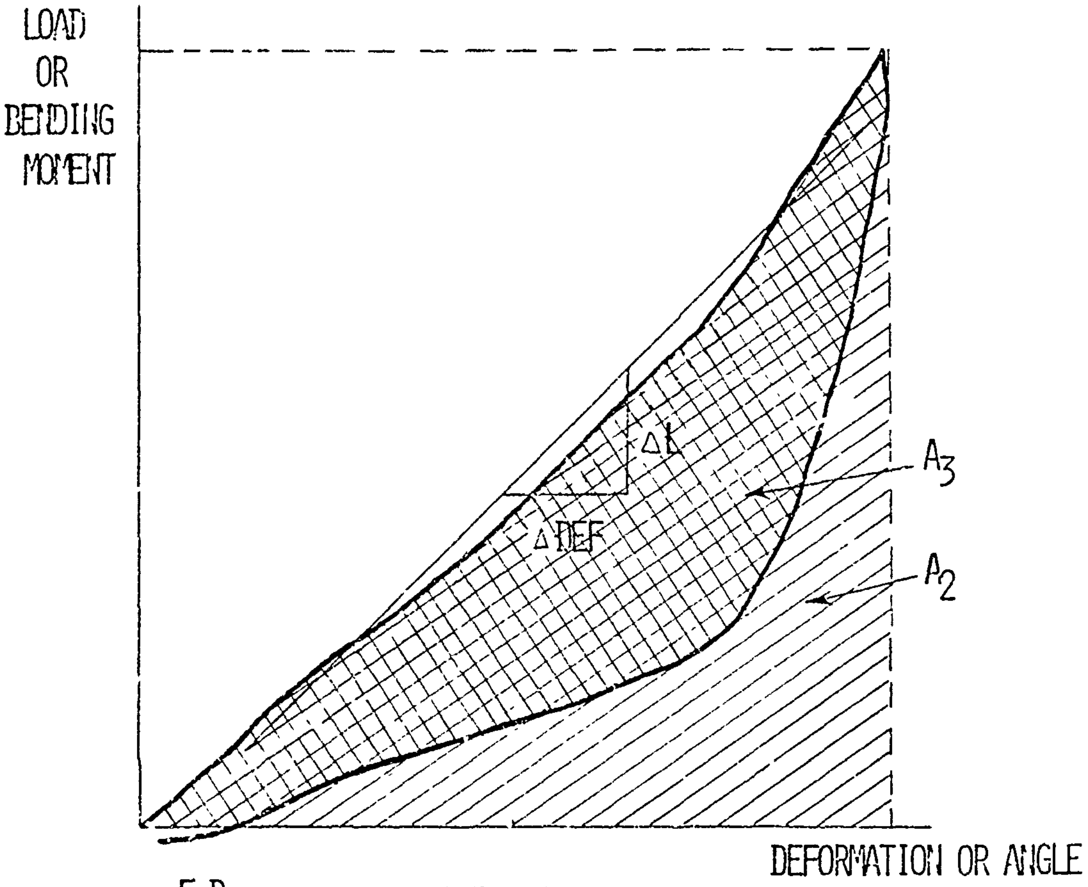
In the y axis (lateral shear), the stiffness is generally symmetrical with a slight increase in stiffness at higher strain rates. The stiffness values generally fall in between the +x and -x values. Figures 29, 35(a) through (1), B-2 and Tables B-3 and B-4 should be consulted for the $\pm$y direction shear loading results.

BENDING

The results of the bending tests are shown in Figures B-5, B-6, 30, 31, 37(a) through (1), 38(a) through (1) and Tables B-9, B-10, B-11, and B-12. The dynamic tests show a general increase in stiffness over the quasistatic tests. The stiffness of the ϕ_x values are, in general, higher than those of the ϕ_y rotation. There is a significant amount of scatter in the data probably due to the small sample size. The expected trend of increasing stiffness as one descends down the vertebral column is not evident in the bending tests as it was in the axial and shear tests. A comparison with results given by Panjabi et al. (1976) for the thoracic spine indicate that the cervical values are, in general, lower in stiffness in both ϕ_x and ϕ_y.

TORSION

The stiffness is higher than either of the bending values as shown in Figures 32, 36(a) through (1), B-4 and Tables B-7 and B-8. As one descends down the cervical column, stiffness seems to increase. The stiffness seems to be symmetrical about the origin.



F-D CURVES EVALUATED FOR:

1. MAX. LOAD OR BENDING MOMENT
2. MAX. DEFORMATION OR ANGLE OF ROTATION
3. STIFFNESS $= \Delta L / \Delta DEF$
4. A_3 = [cross-hatched], A_2 = [hatched], $A_1 = A_2 + A_3$
5. ENERGY LOSS RATIO = A_3/A_1

FIG. 26: ANALYSIS METHOD FOR LOAD-DEFORMATION CURVES

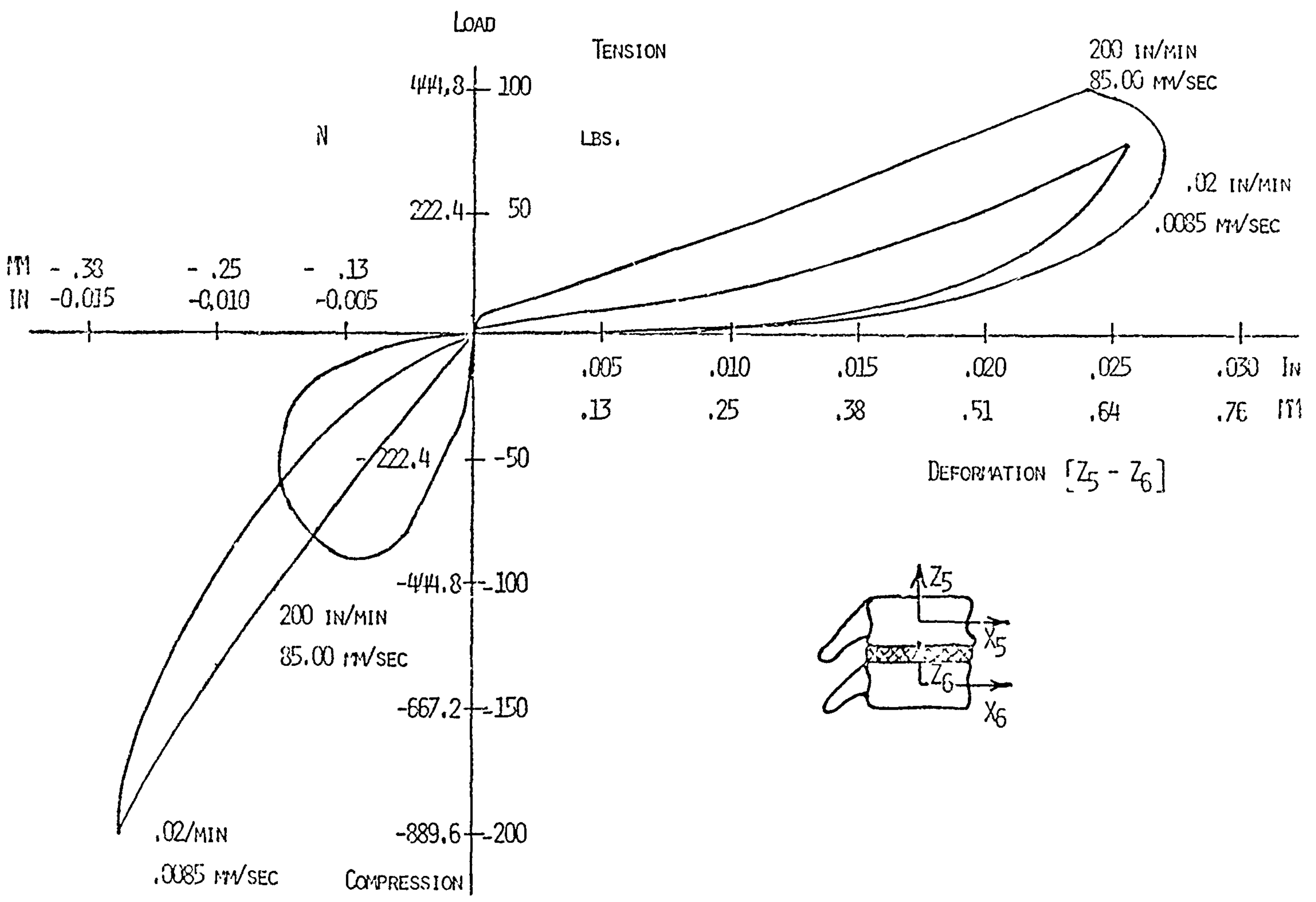


Figure 27: Axial Loading Specimen EJ42 C_5C_6

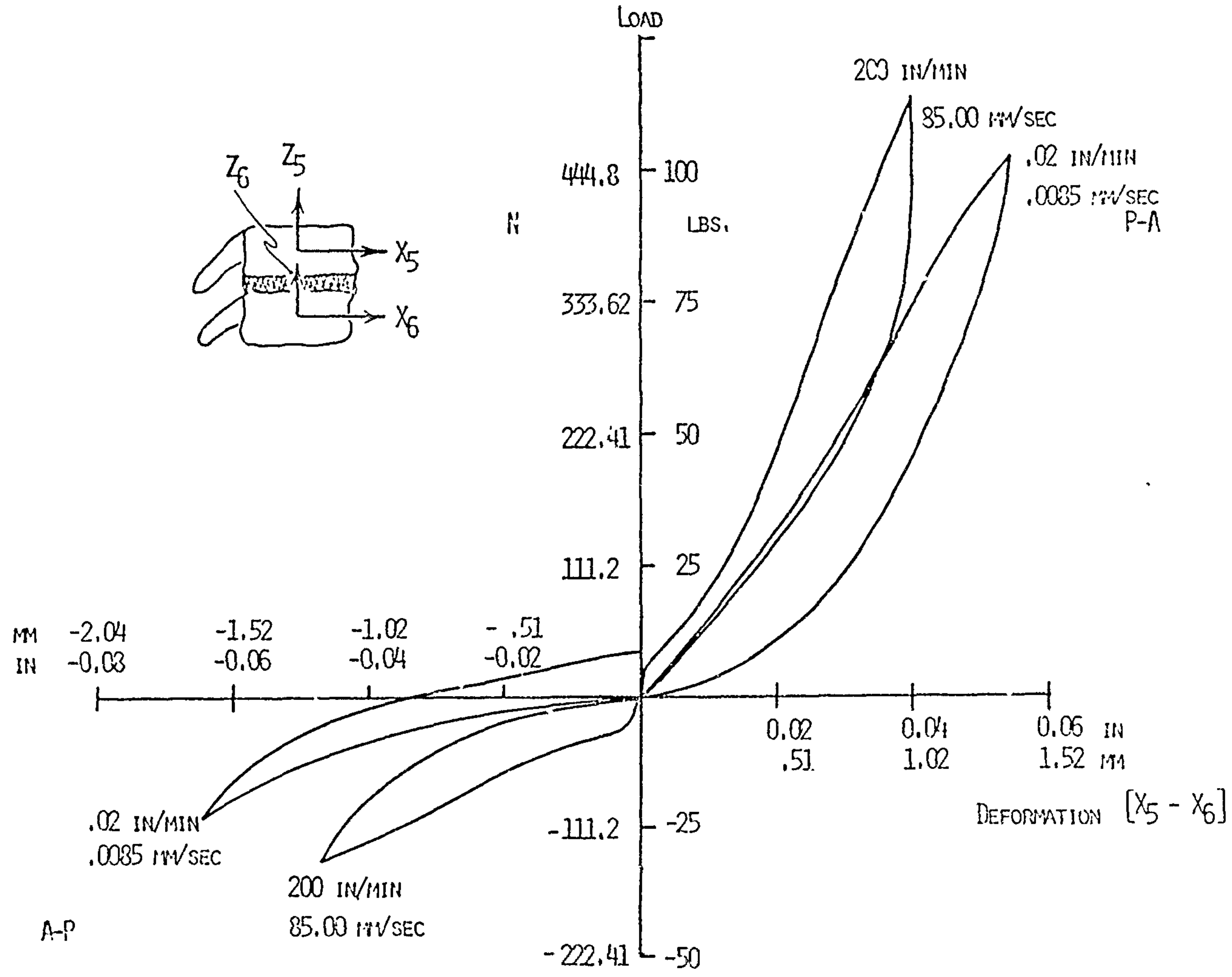


Figure 28: Shear (P-A and A-P Specimen EJ41 C_5C_6

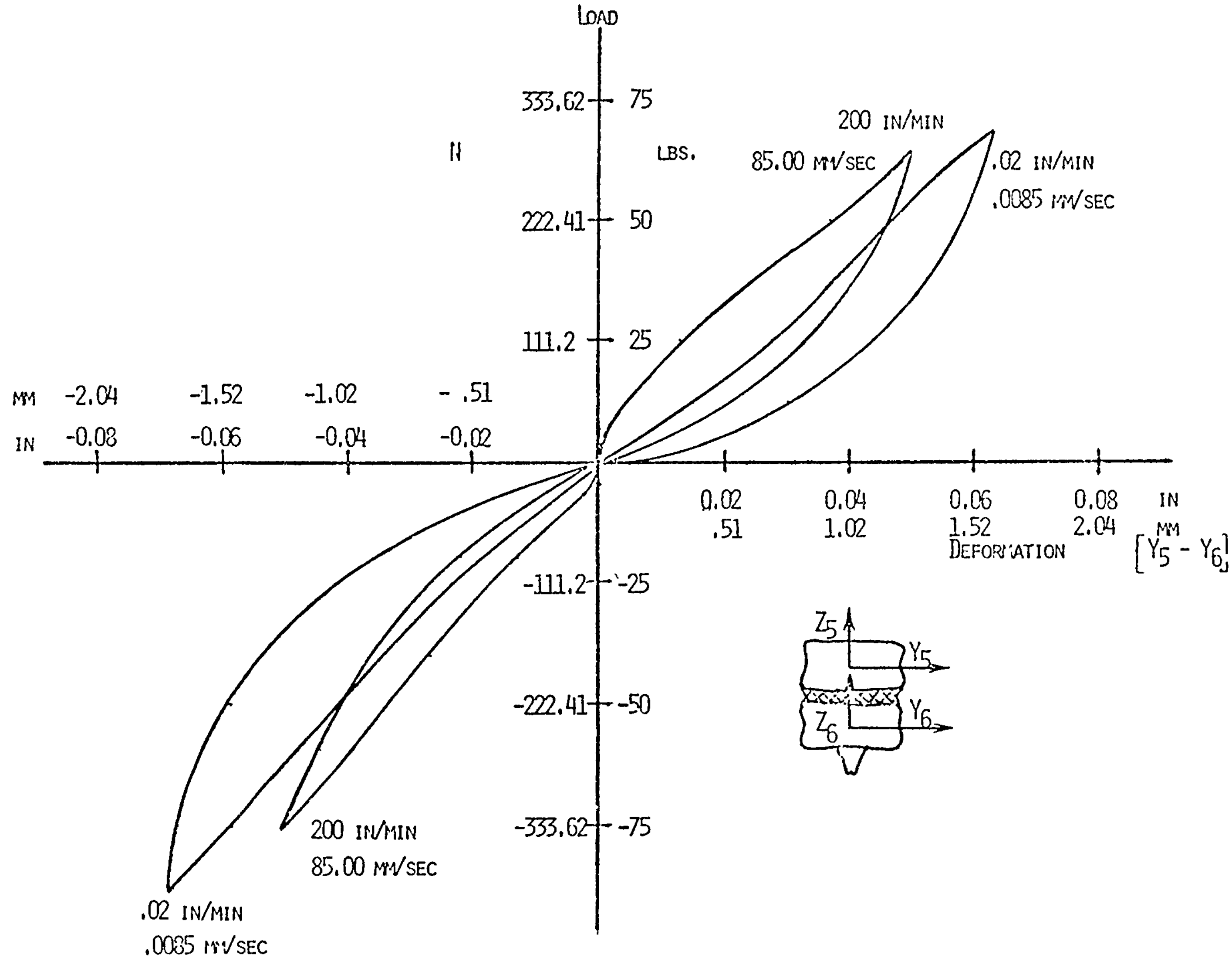


Figure 29: Shear (Lateral) Specimen EJ42 C_5C_6

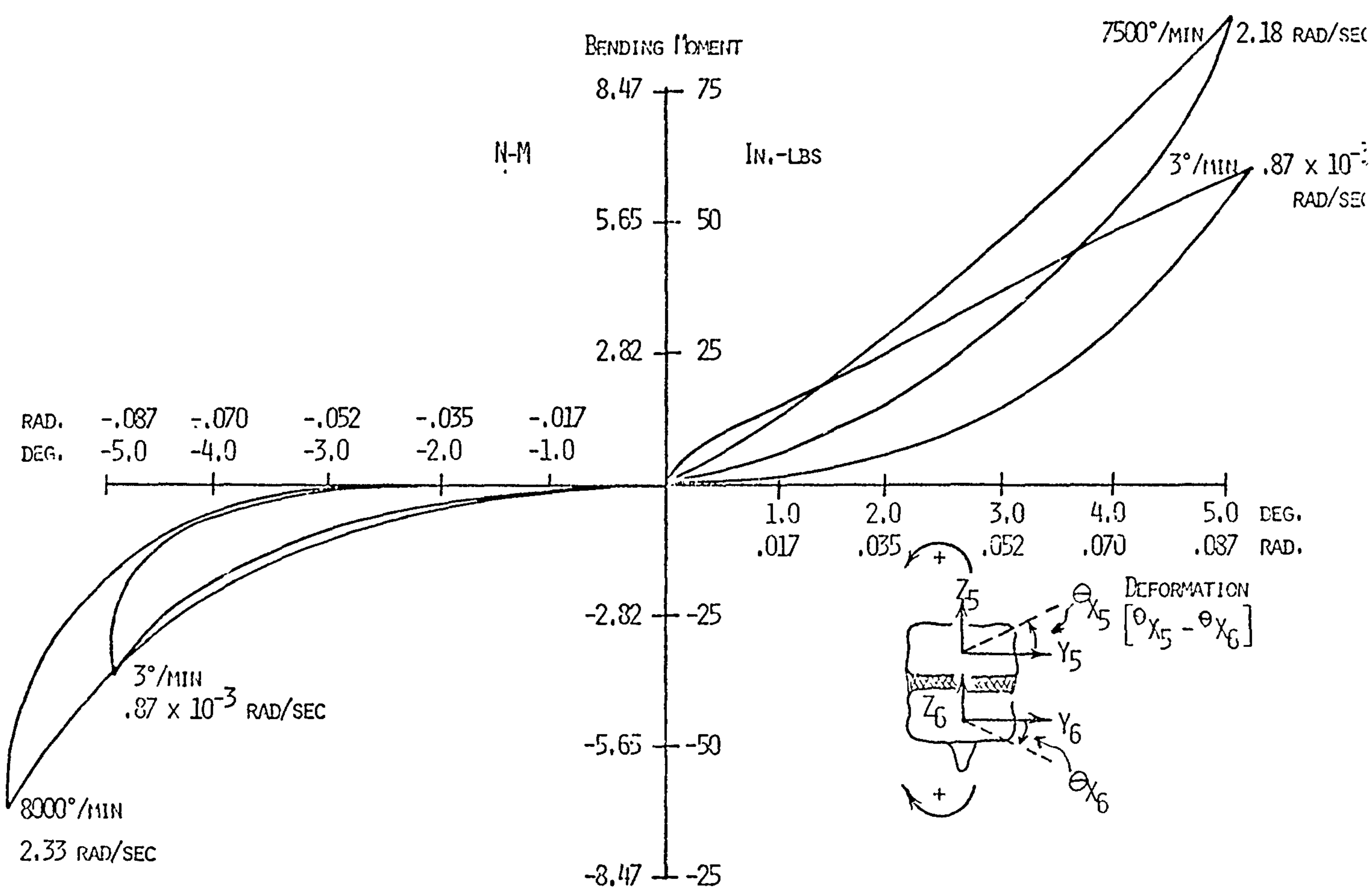


Figure 30: Bending (Lateral) Specimen CJ41 C_5C_6

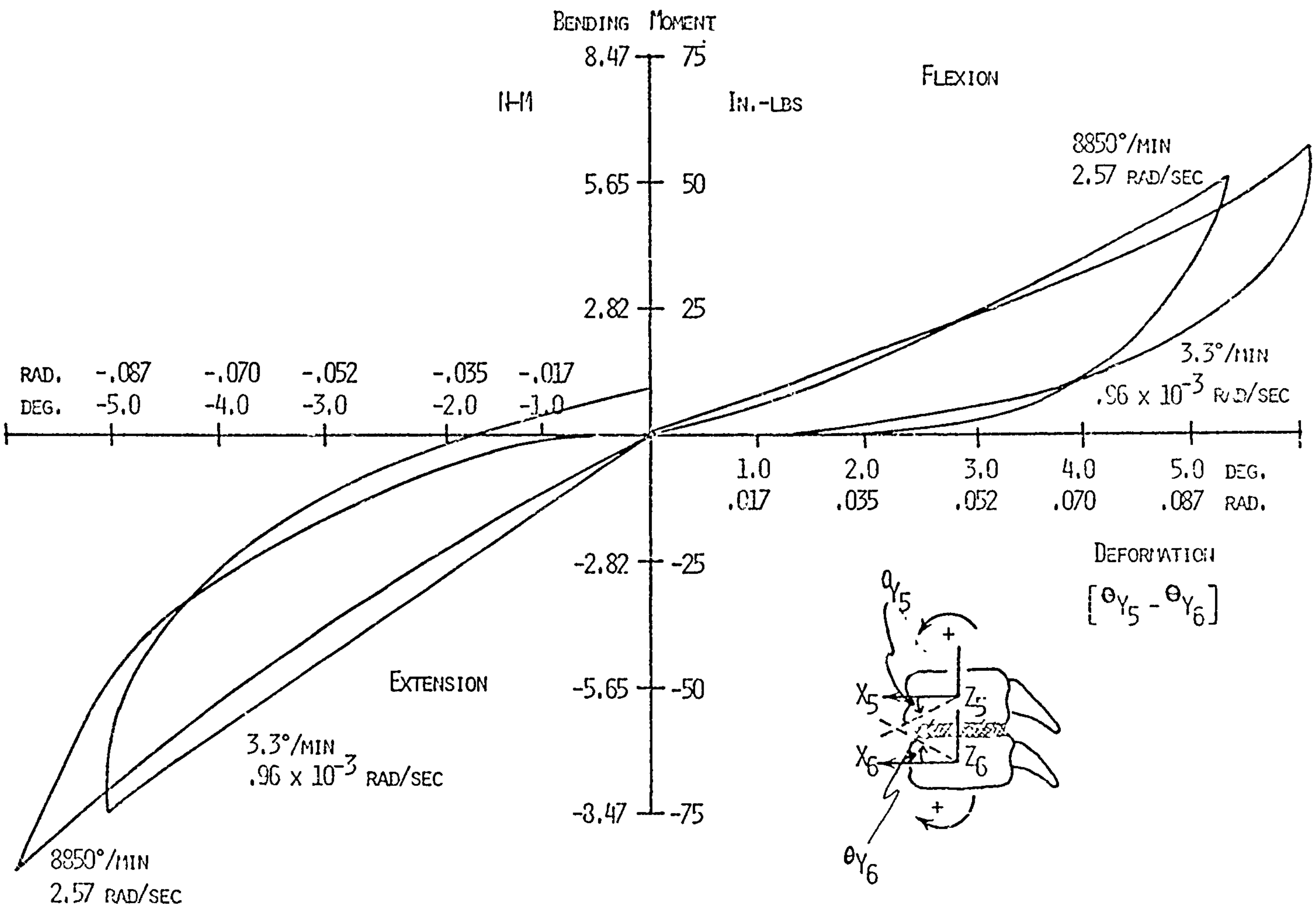


Figure 31: Bending (P-A and A-P) Specimen EJ41 C_5C_6

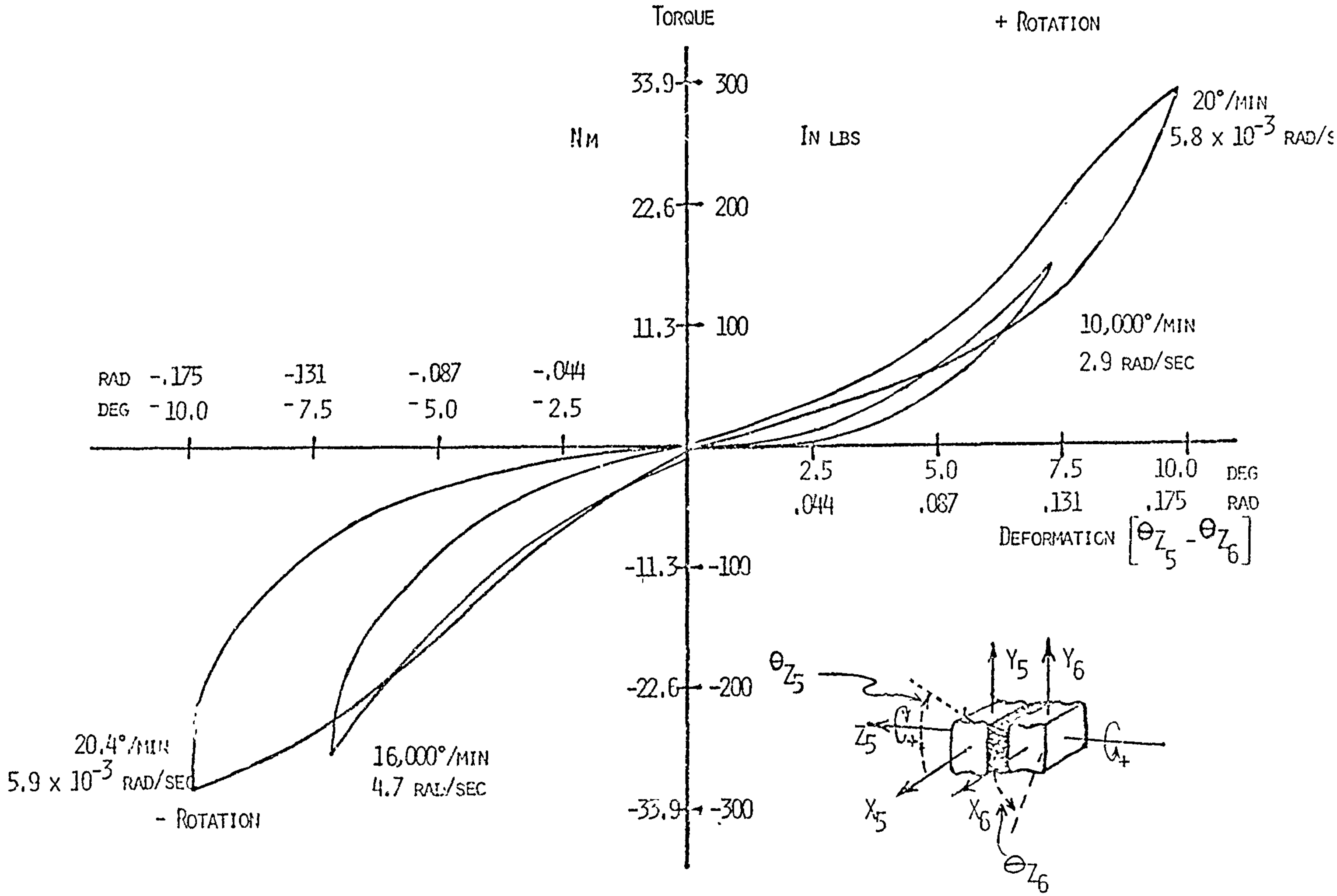


Figure 32: Torsion Specimen EJ41 C_5C_6

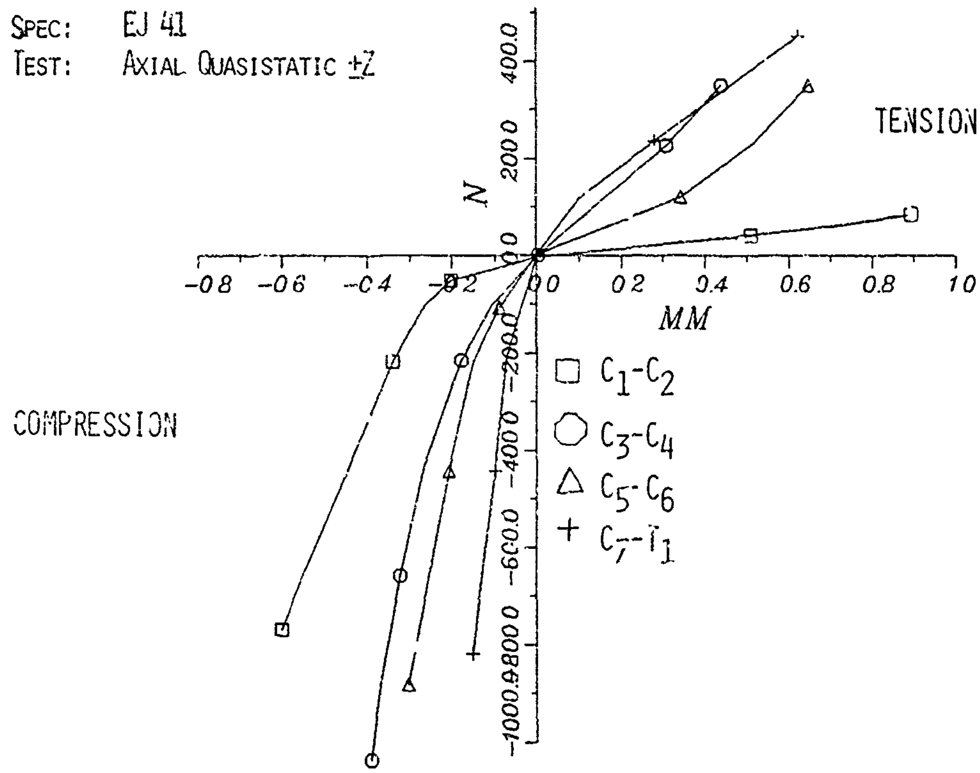


Figure 33(a): Axial Load-Deformation Curves

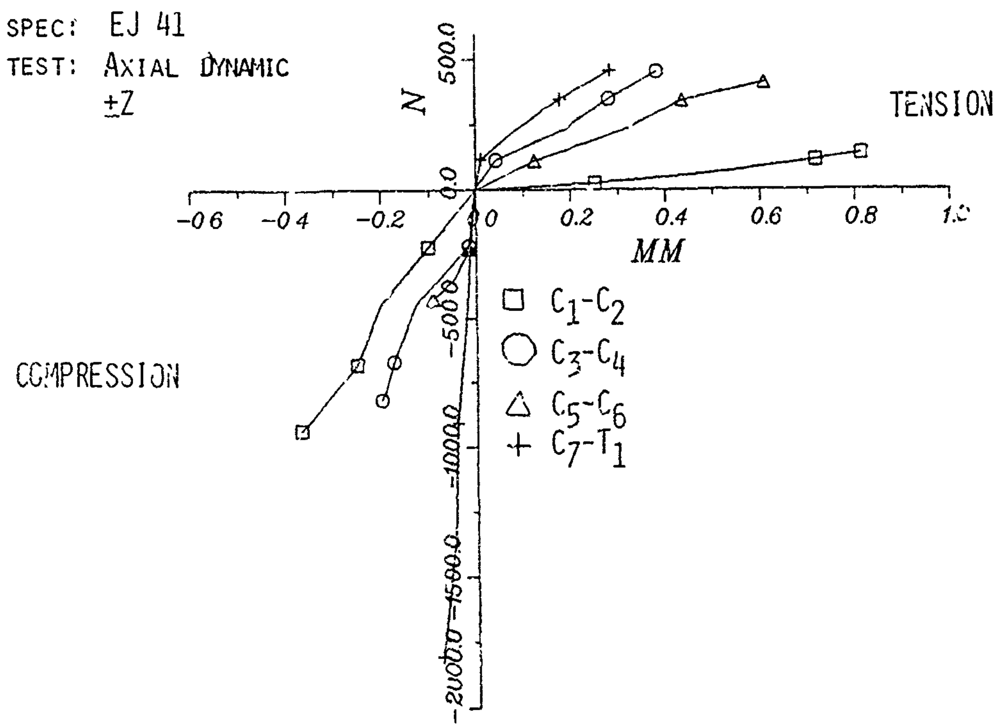


Figure 33(b): Axial Load-Deformation Curves

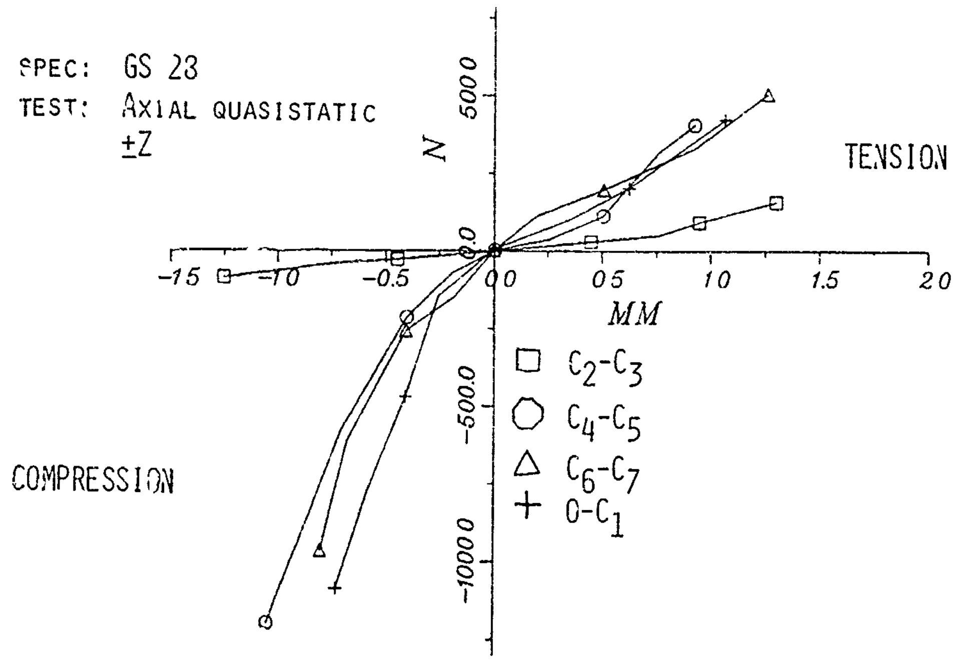


Figure 33(c): Axial Load-Deformation Curves

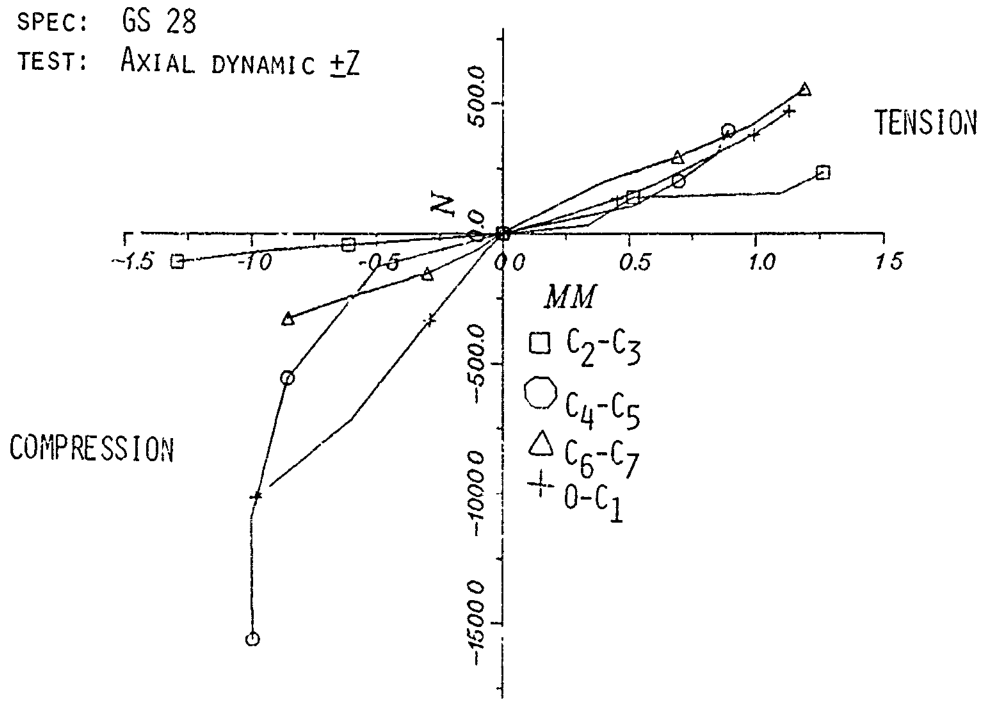


Figure 33(d): Axial Load-Deformation Curves

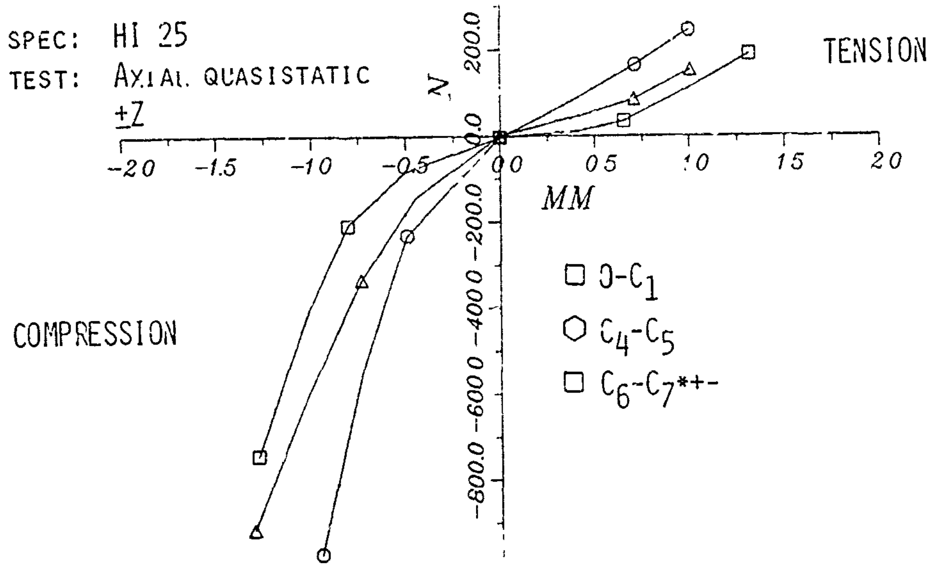


Figure 33(e): Axial Load-Deformation Curves

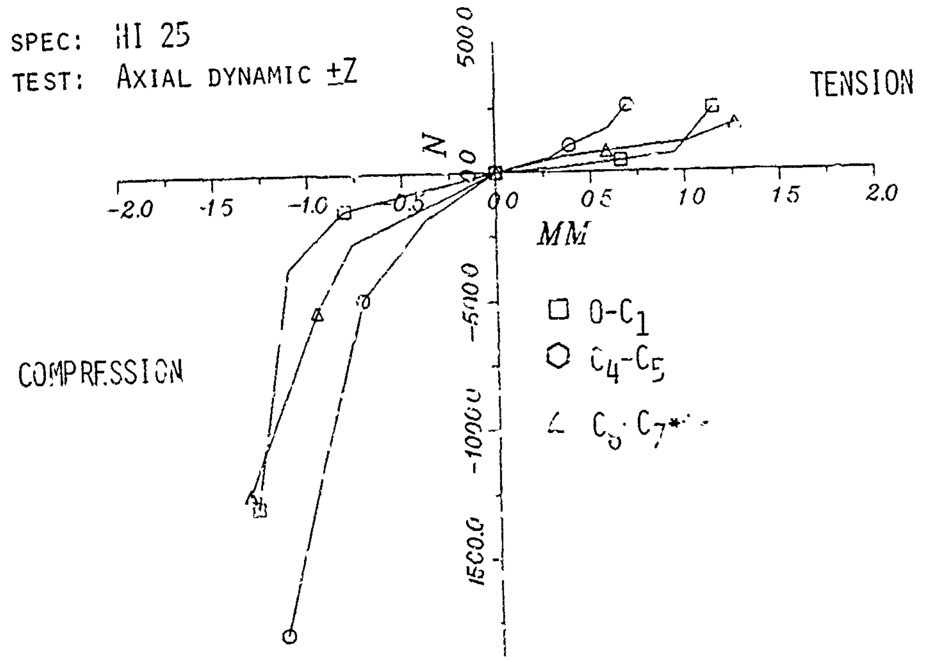


Figure 33(f): Axial Load-Deformation Curves

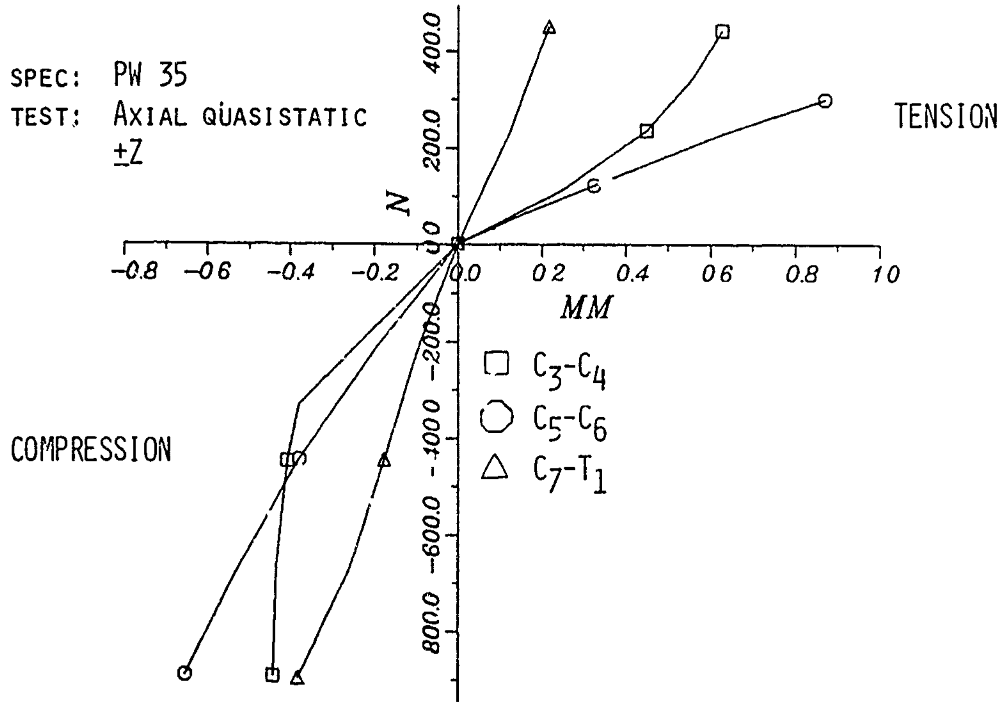


Figure 33 (g): Axial Load-Deformation Curves

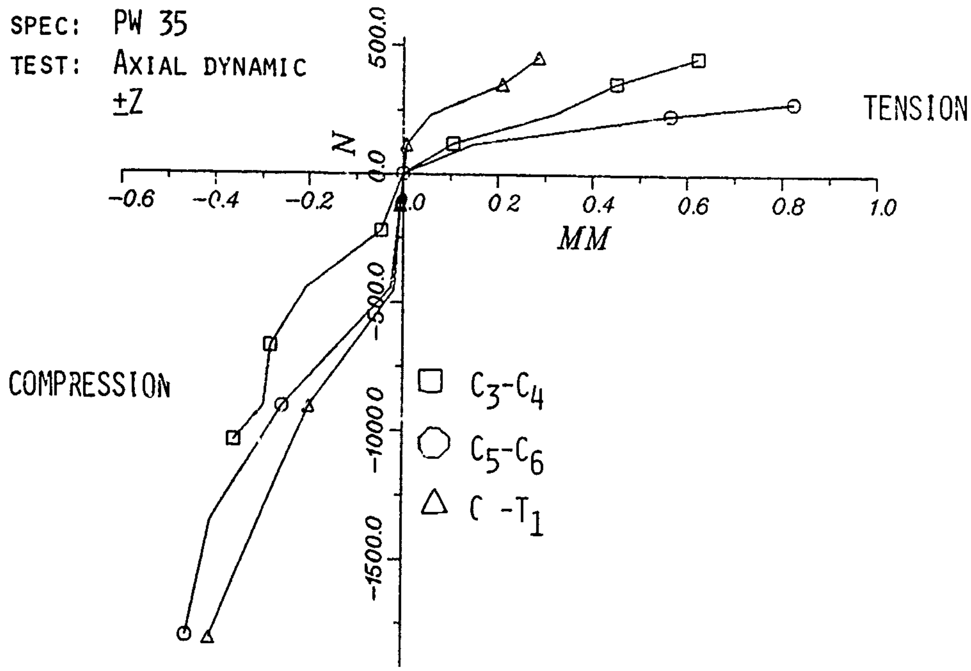


Figure 33(h): Axial Load-Deformation Curves

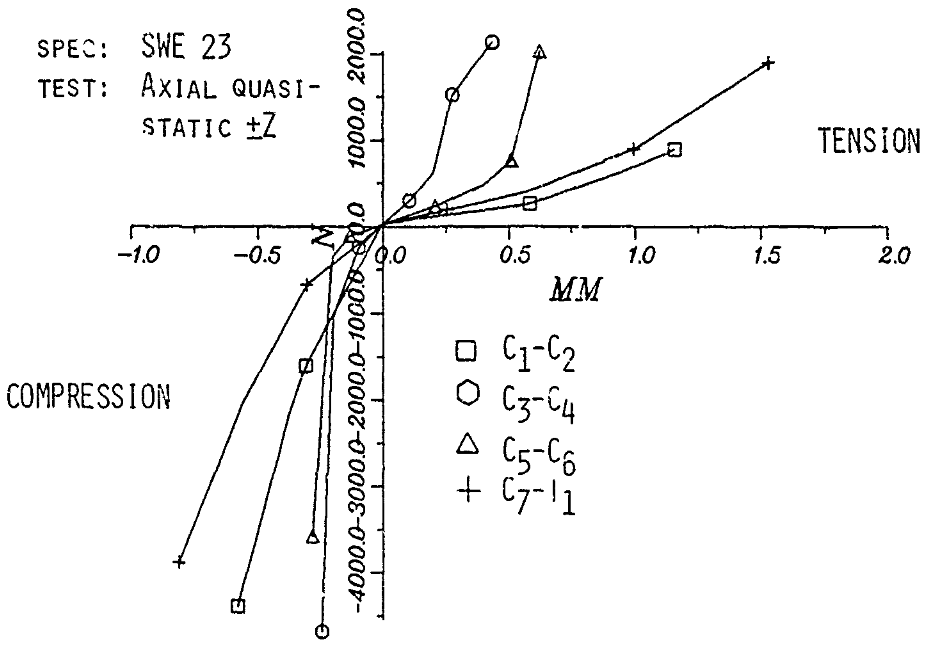


Figure 33(i): Axial Load-Deformation Curves

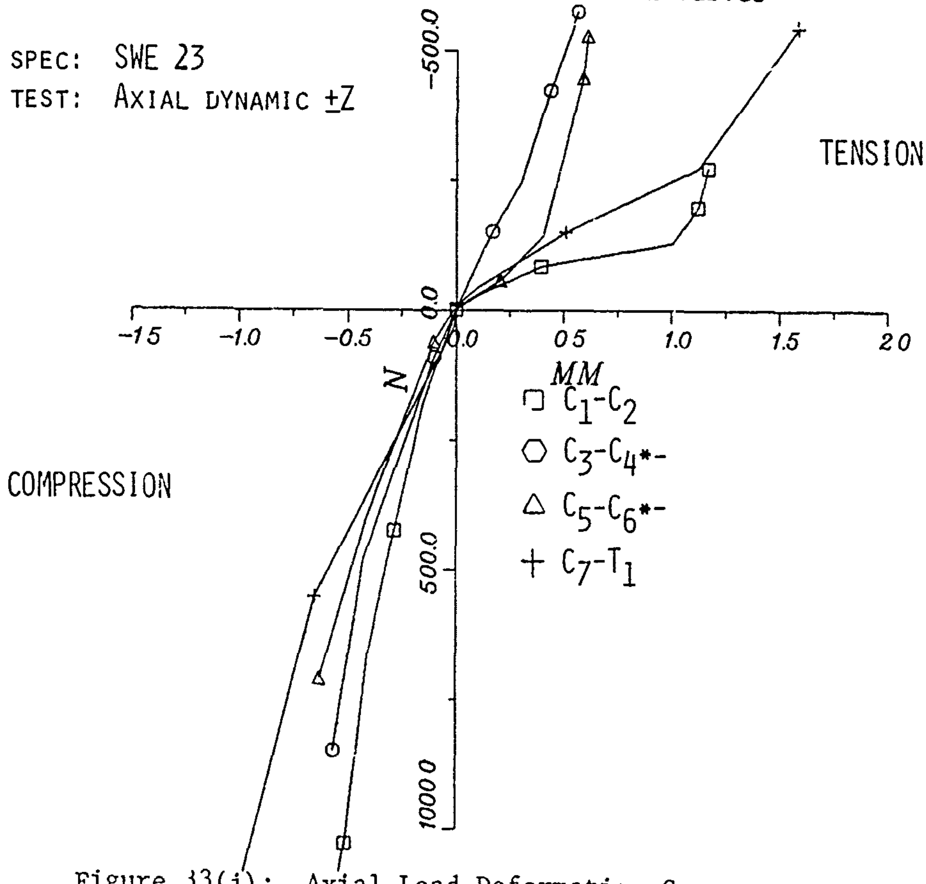


Figure 33(j): Axial Load-Deformation Curves

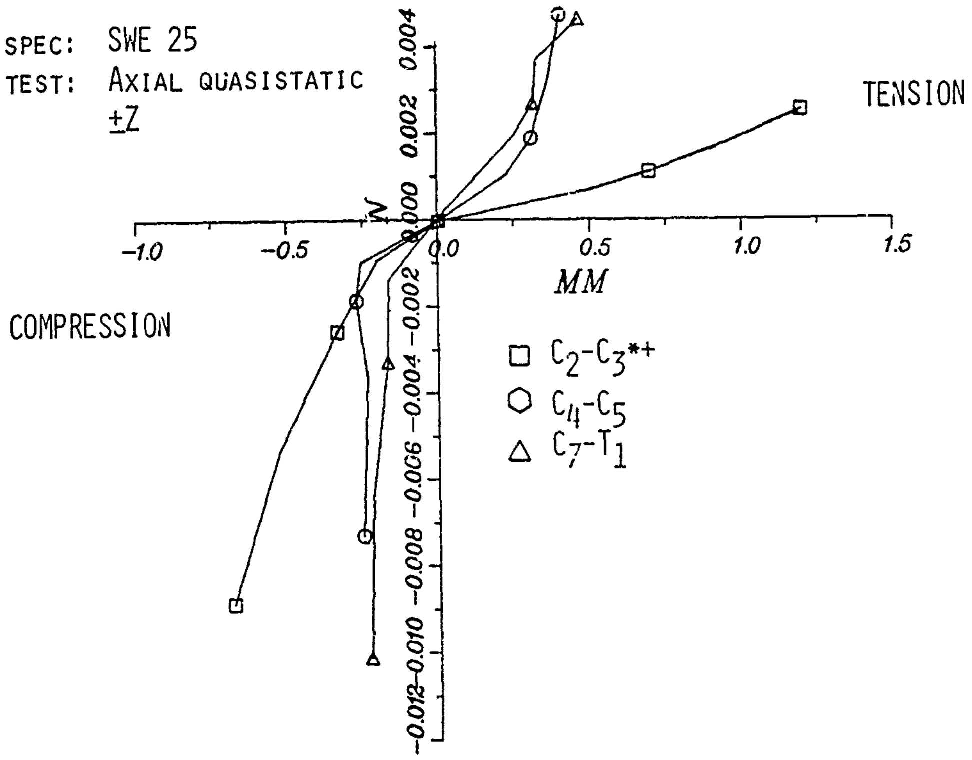


Figure 33(k): Axial Load-Deformation Curves

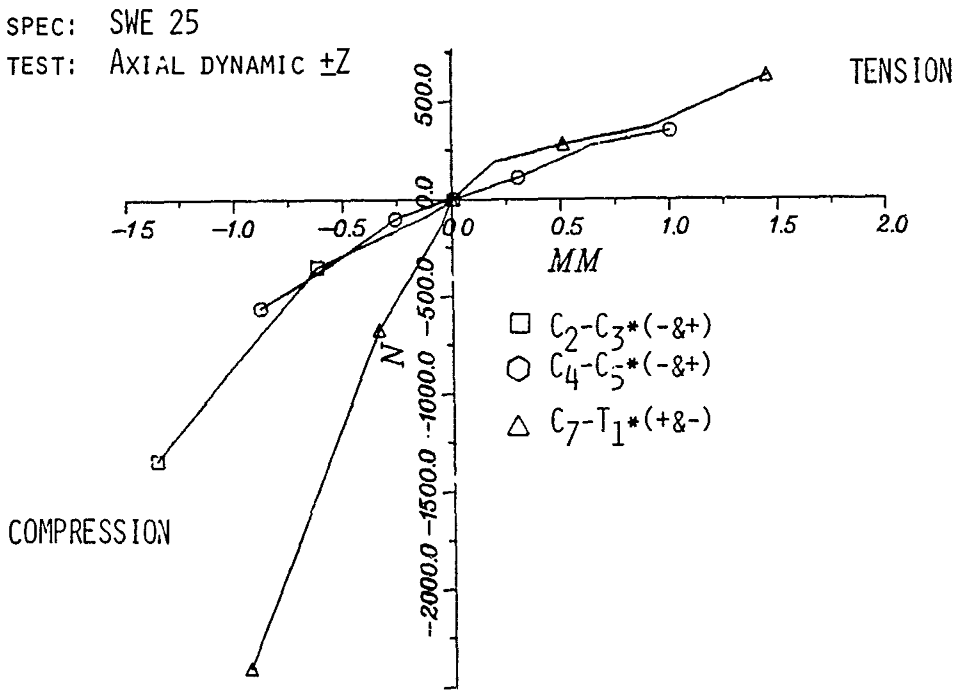


Figure 33(l): Axial Load-Deformation Curves

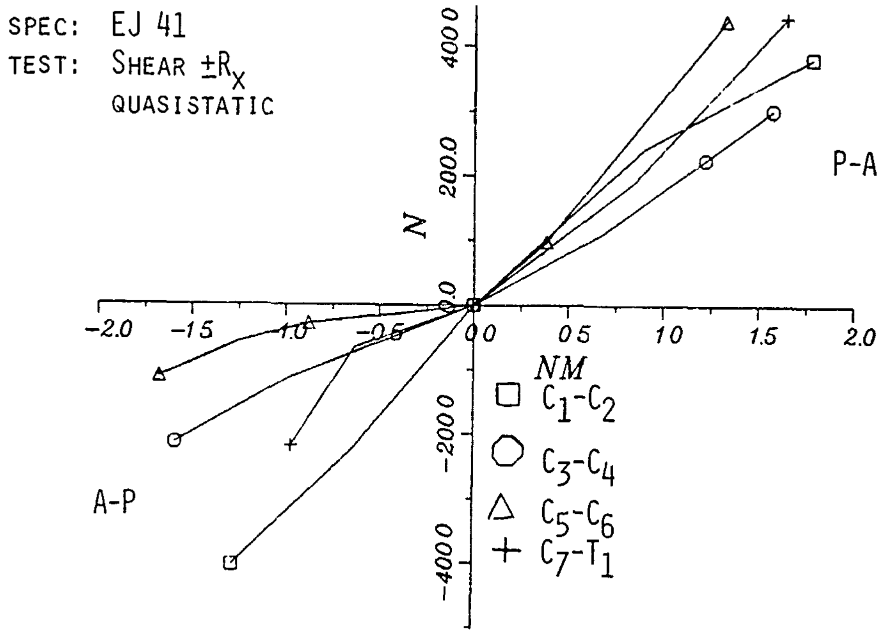


Figure 34(a): ±X Shear Load-Deformation Curves

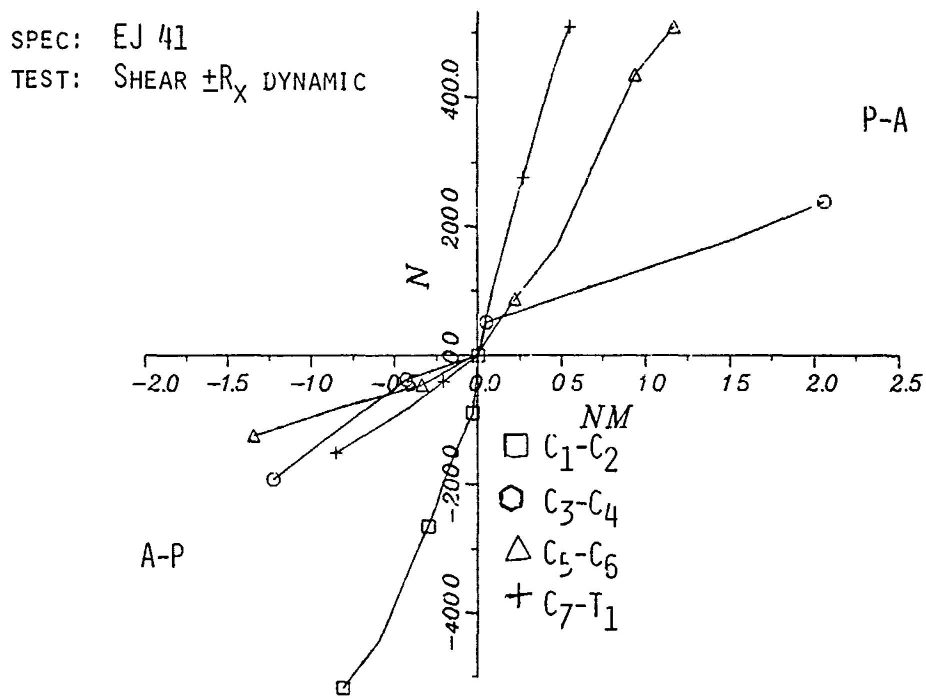


Figure 34 (b): ±X Shear Load-Deformation Curves

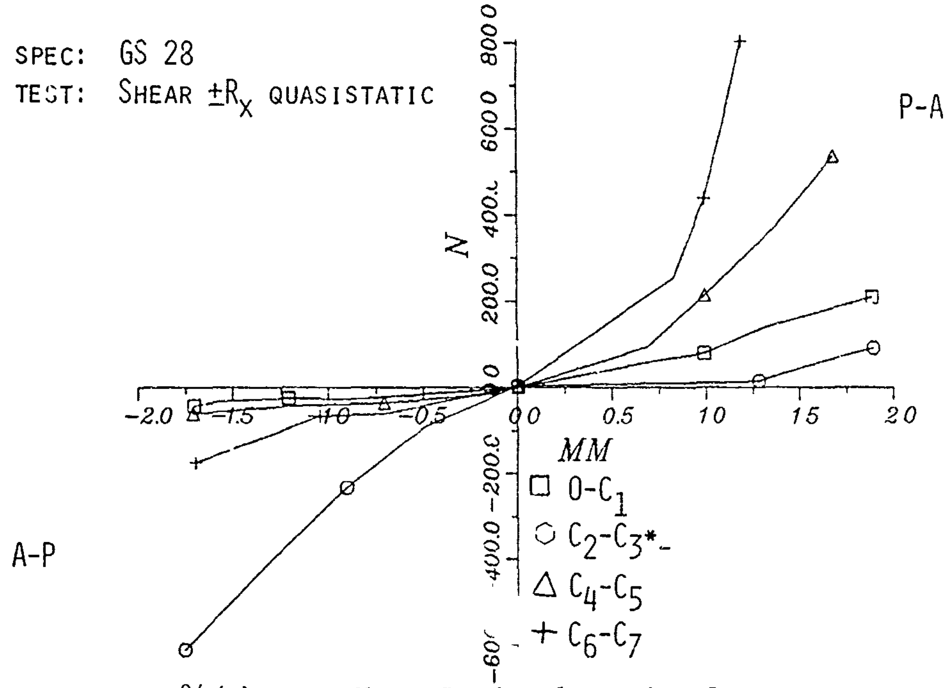


Figure 34(c): ±X Shear Load-Deformation Curves

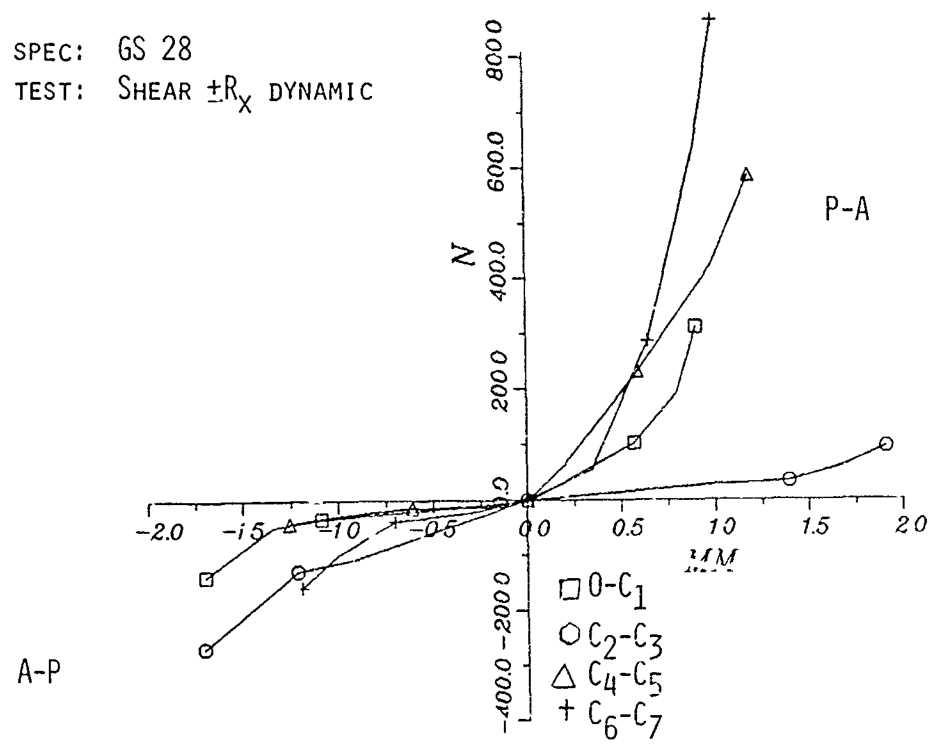


Figure 34(d): ±X Shear Load-Deformation Curves

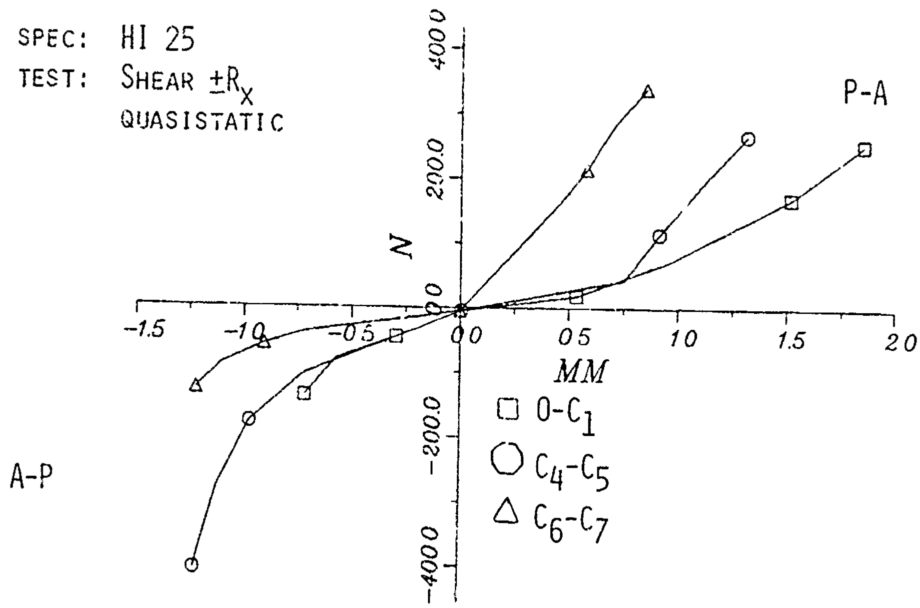


Figure 34(e): ±X Shear Load-Deformation Curves

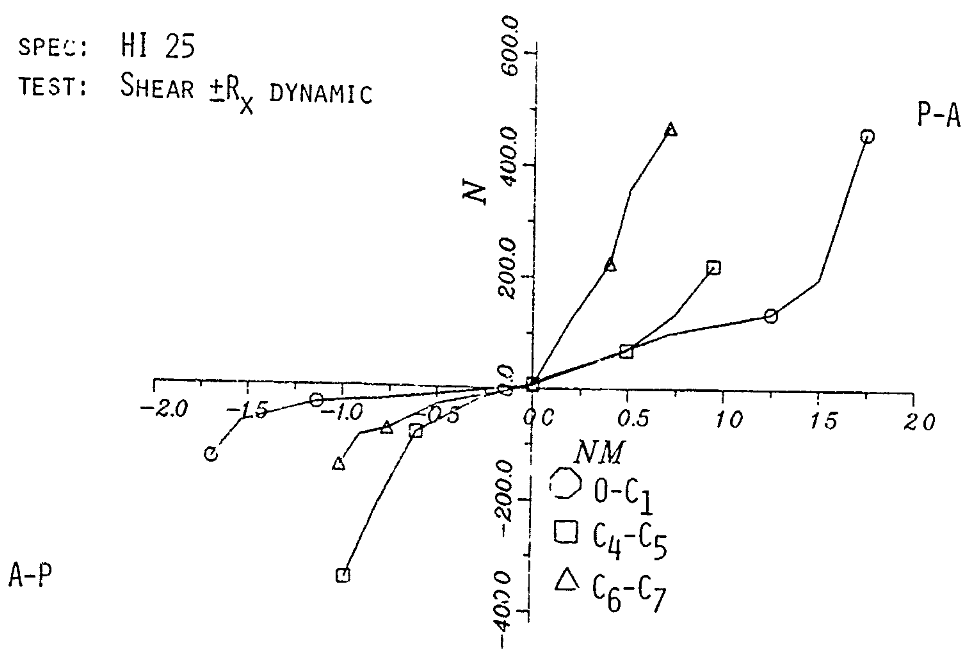


Figure 34(f): ±X Shear Load-Deformation Curves

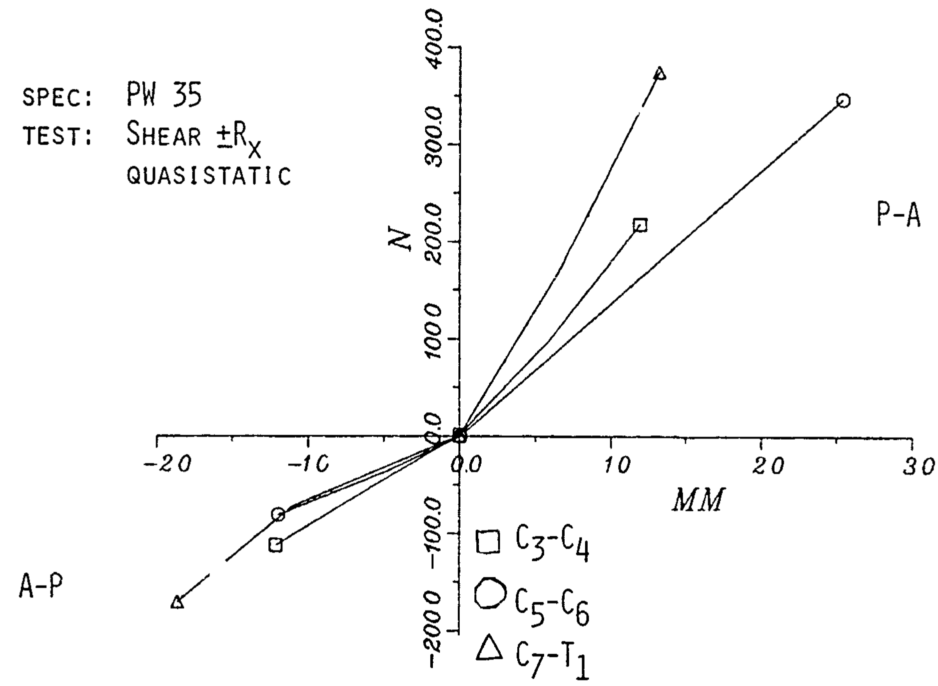


Figure 34(g) ±X Shear Load-Deformation Curves

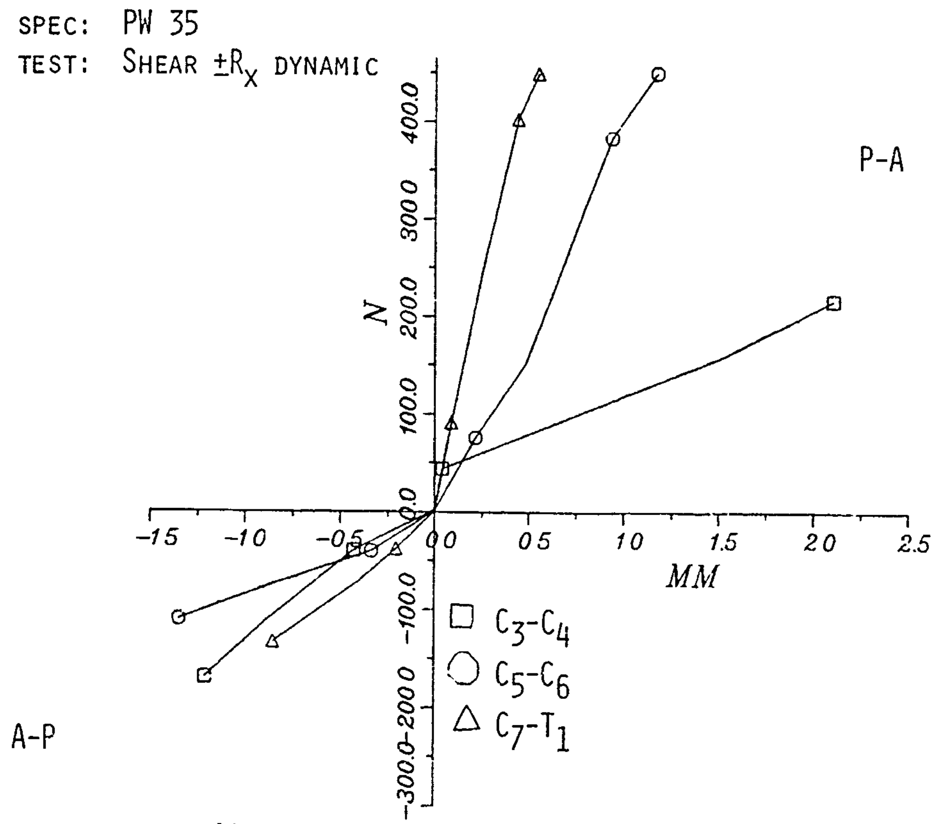


Figure 34(h): ±X Shear Load-Deformation Curves

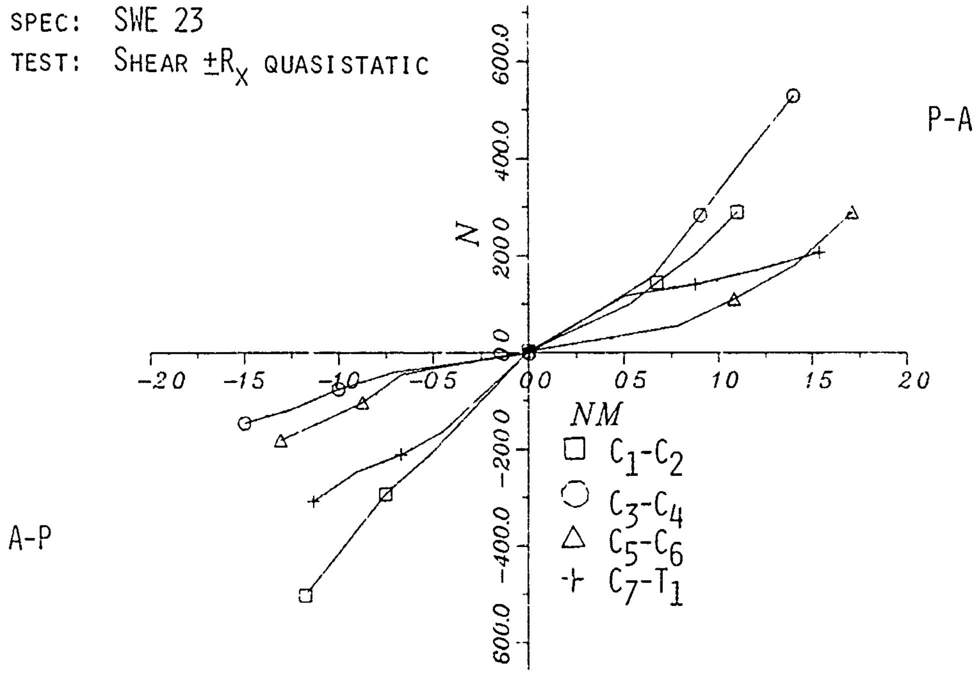


Figure 34(i): ±X Shear Load-Deformation Curves

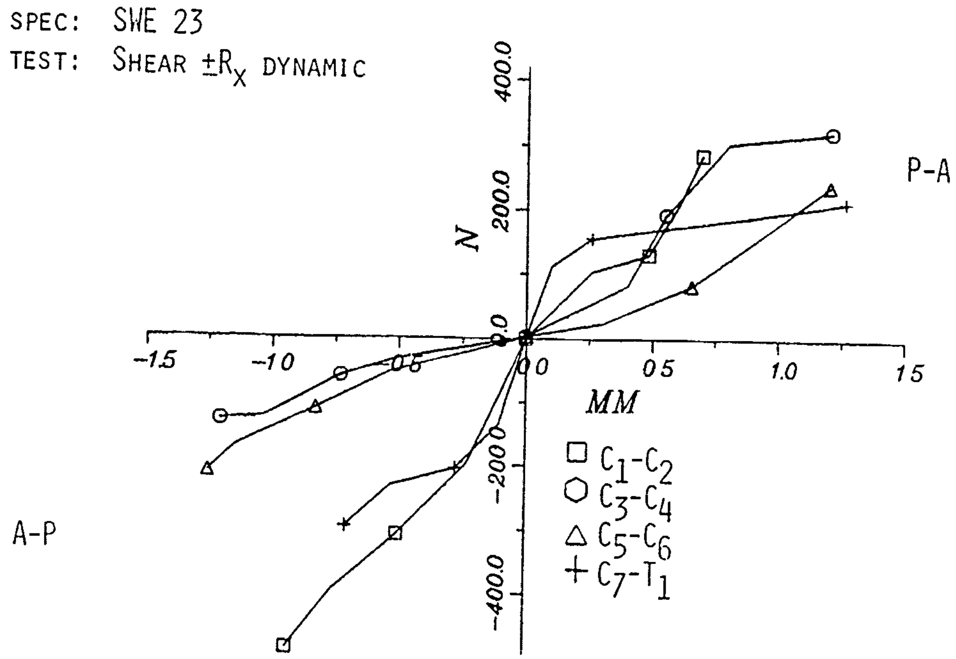


Figure 34(j): ±X Shear-Load Deformation Curves

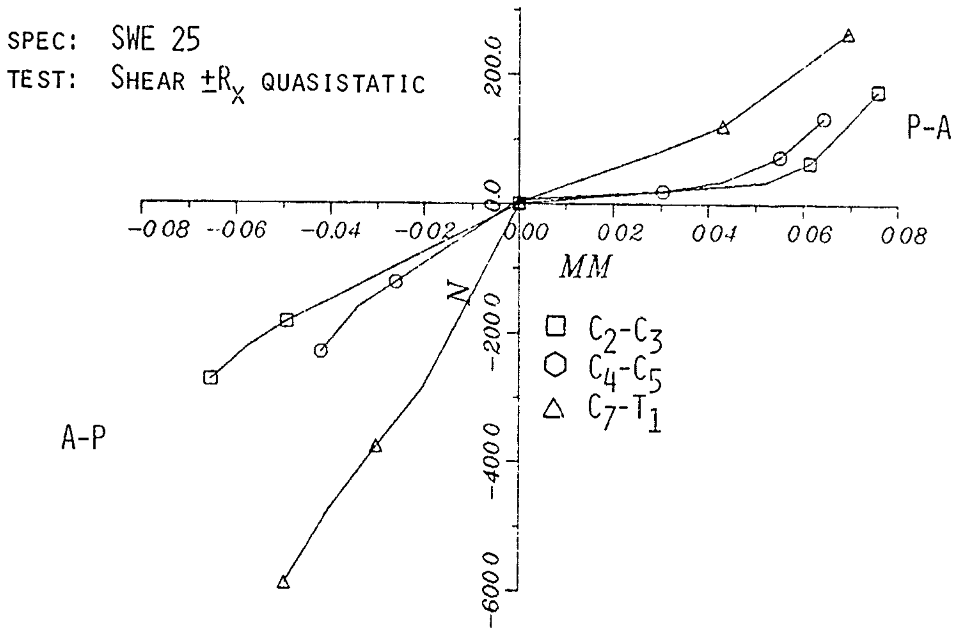


Figure 34(k): ±X Shear Load-Deformation Curves

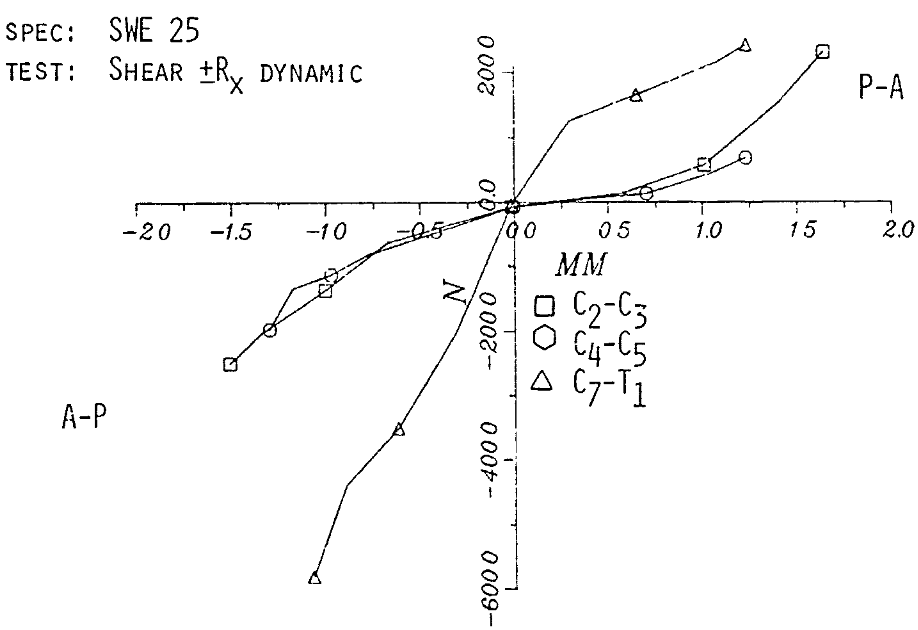


Figure 34(l): ±X Shear Load-Deformation Curves

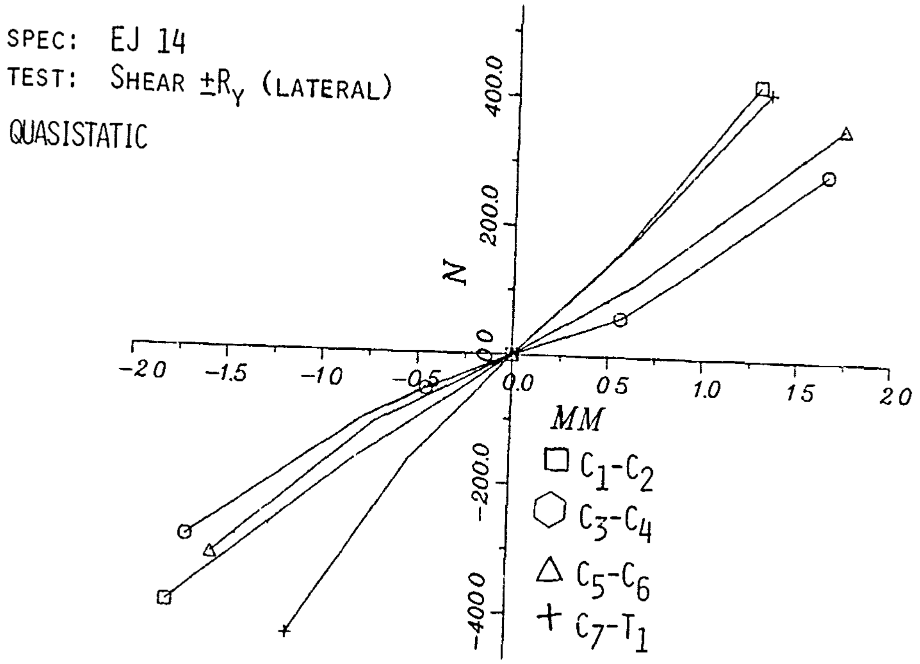


Figure 35(a): ±Y Shear Load-Deformation Curves

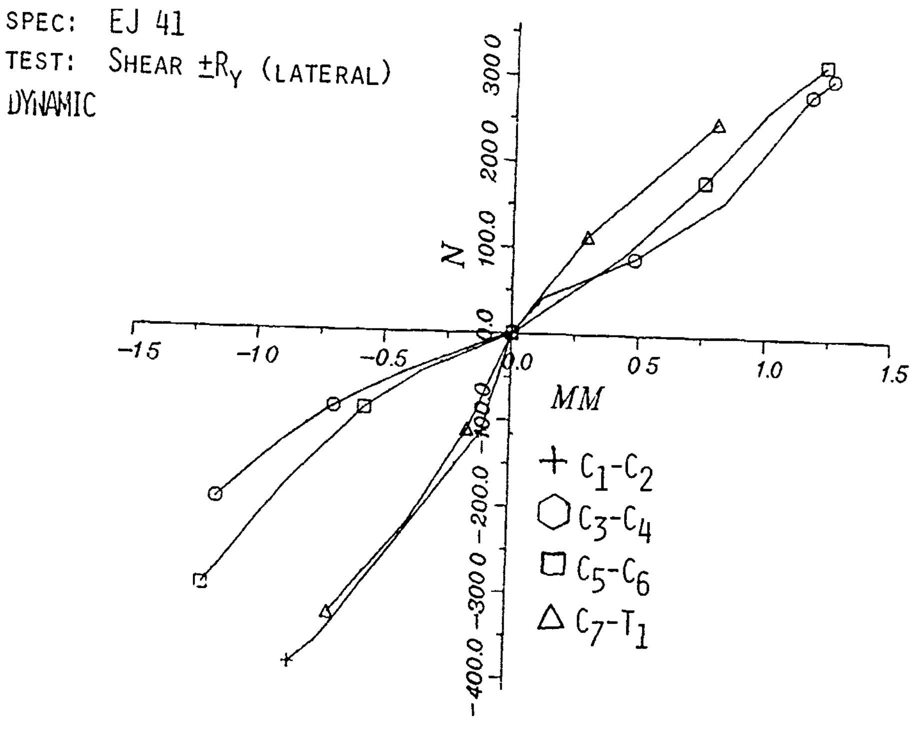


Figure 35(b): ±Y Shear Load-Deformation Curves

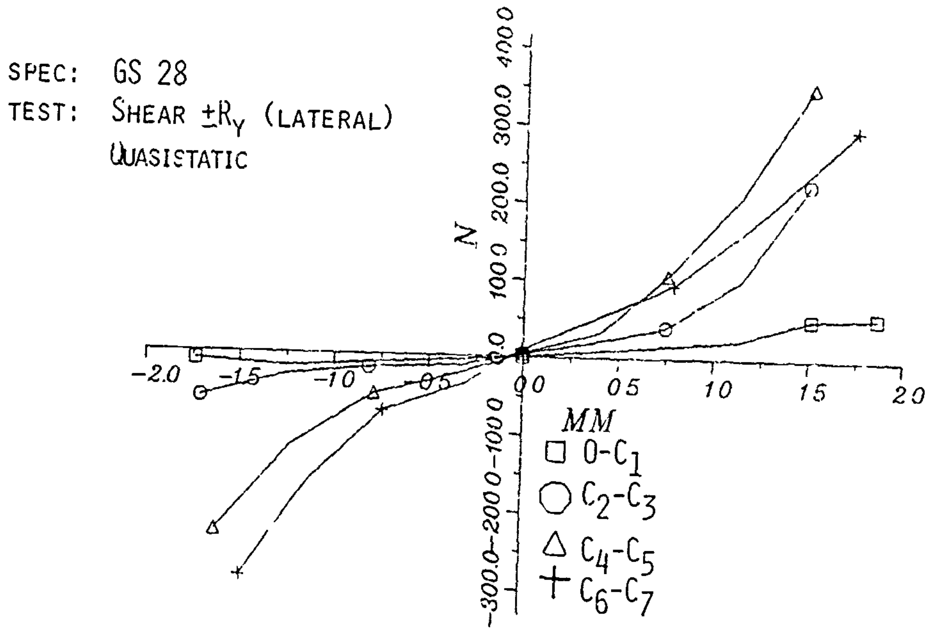


Figure 35(c): ±Y Shear Load-Deformation Curves

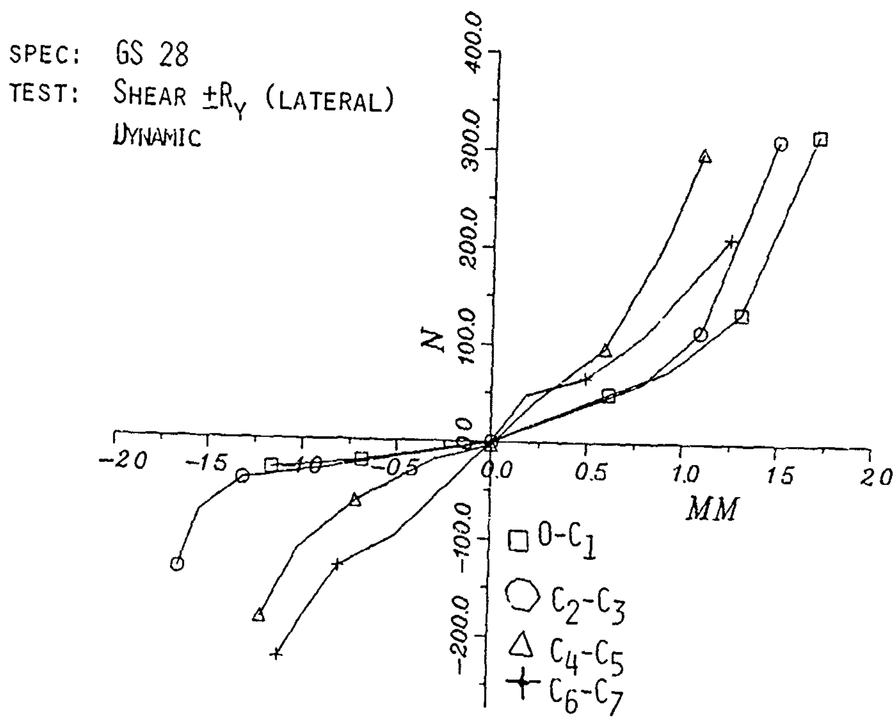


Figure 35(d): ±Y Shear Load-Deformation Curves

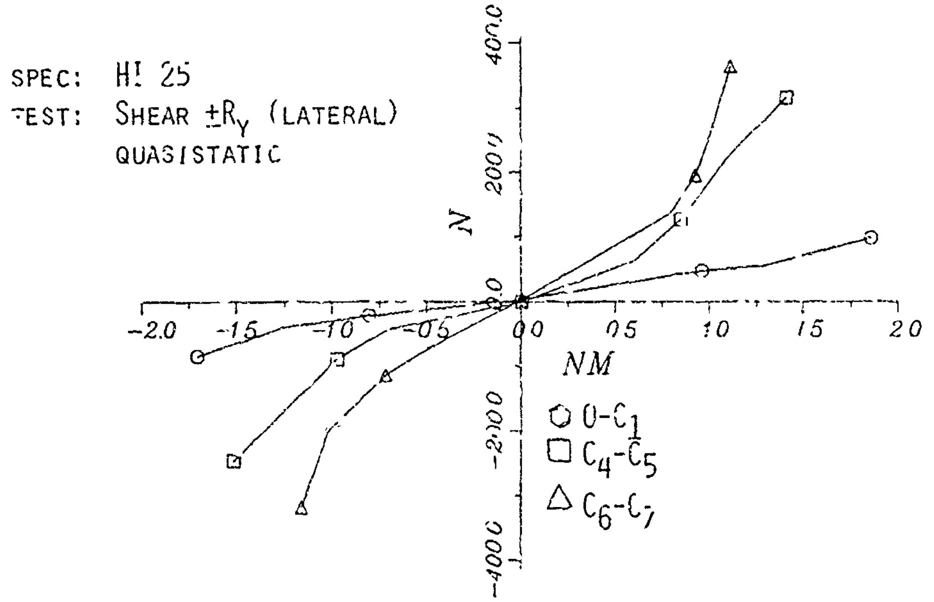


Figure 35(e): ±Y Shear Load-Deformation Curves

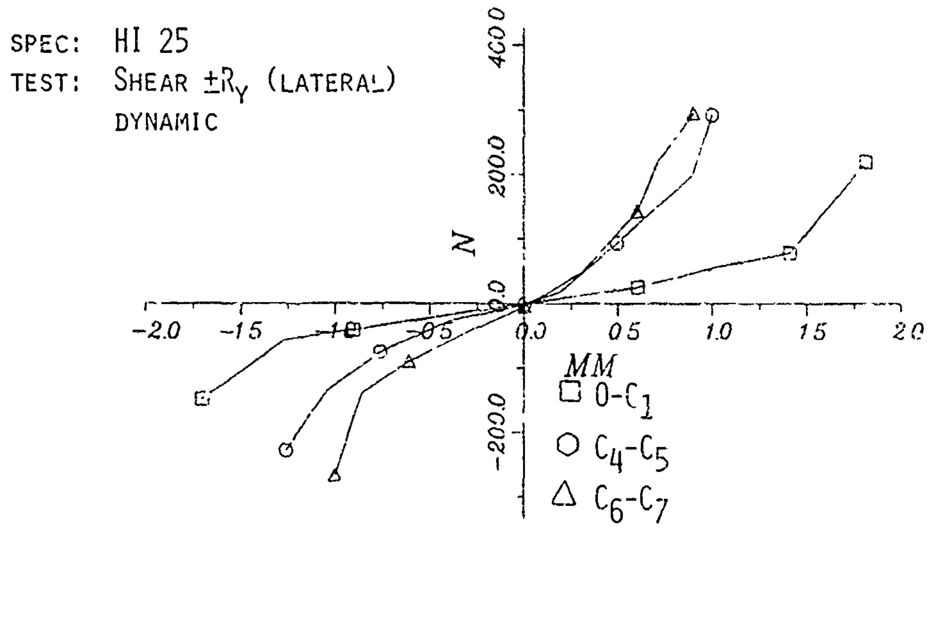


Figure 35(f): ±Y Shear Load-Deformation Curves

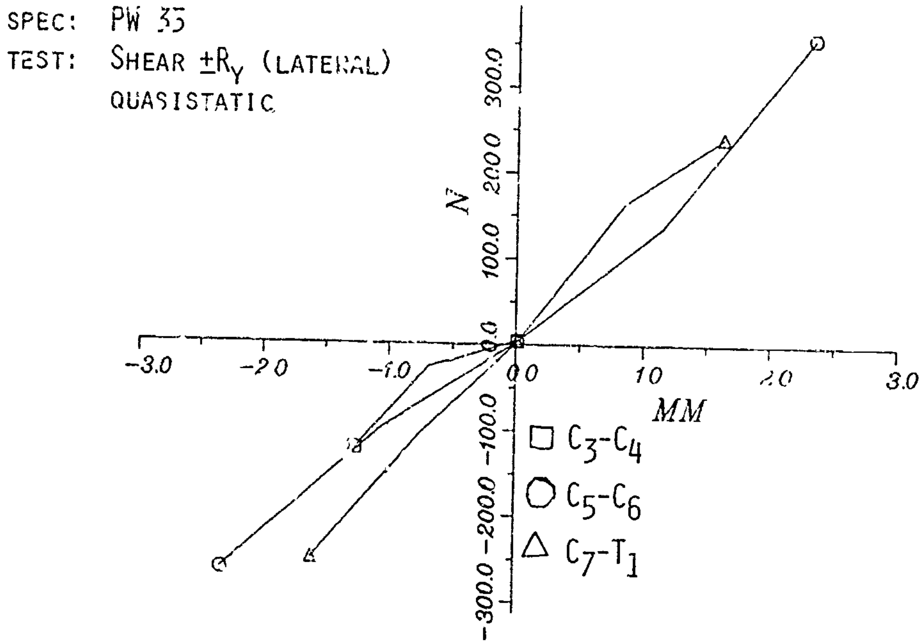


Figure 35(g): ±Shear Load-Deformation Curves

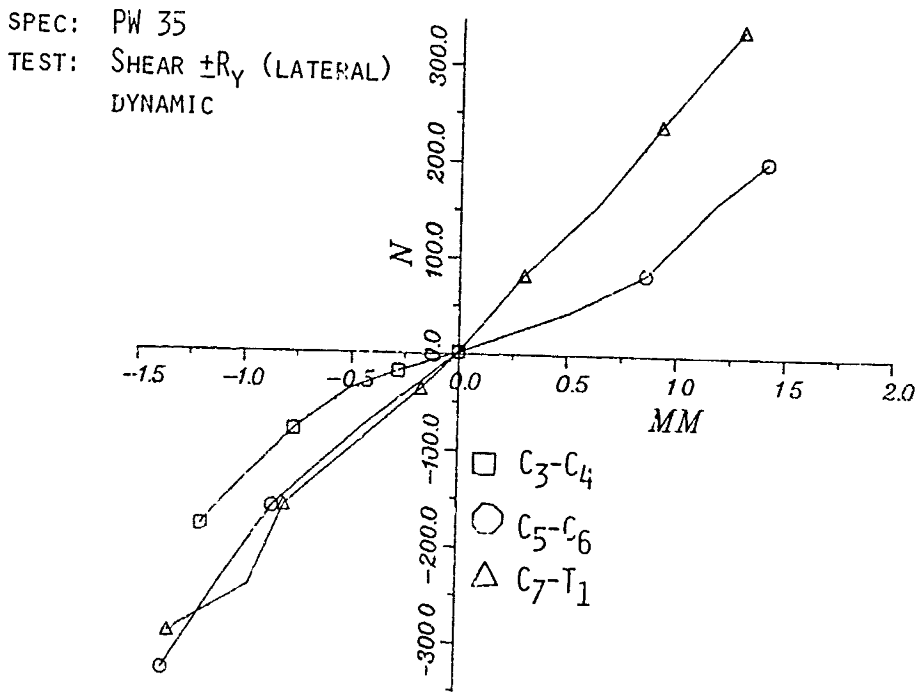


Figure 35(h): ±Shear Load-Deformation Curves

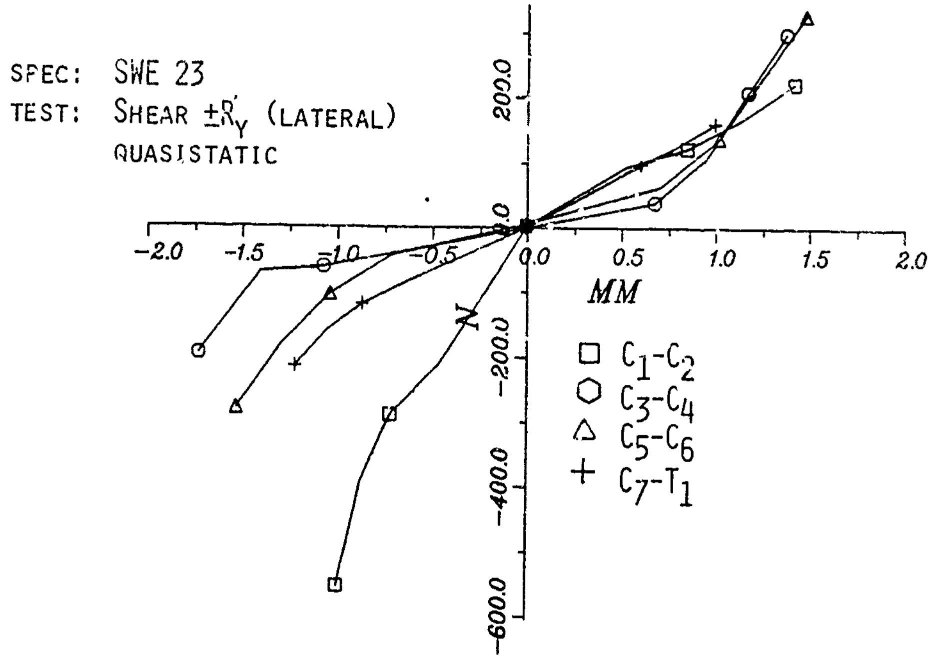


Figure 35(i): ±Y Shear Load-Deformation Curves

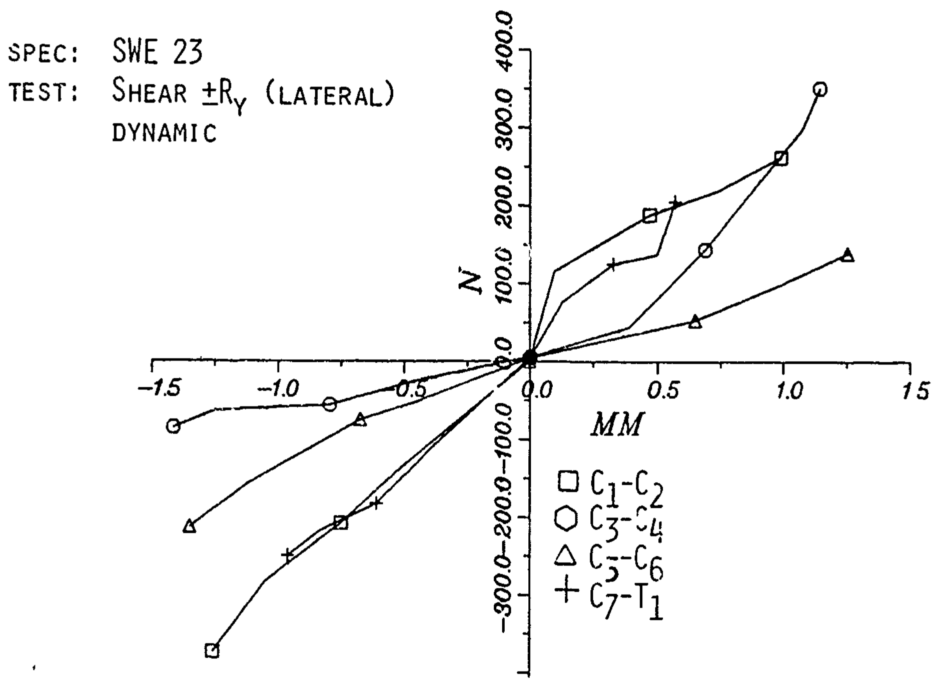


Figure 35(j): ±Y Shear Load-Deformation Curves

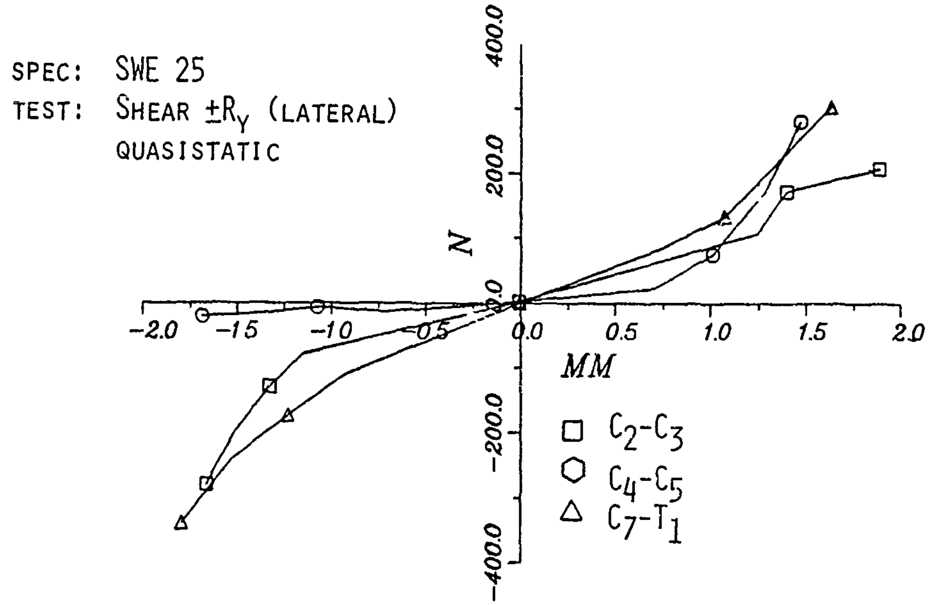


Figure 35(k): ±Y Shear Load-Deformation Curves

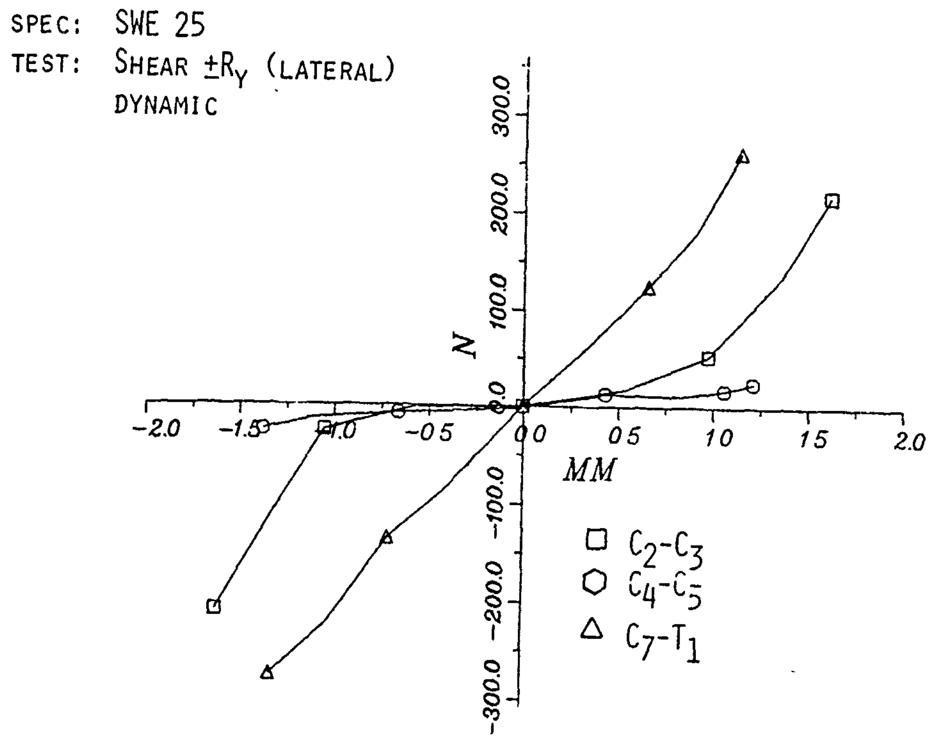


Figure 35 (l): ±Y Shear Load-Deformation Curves

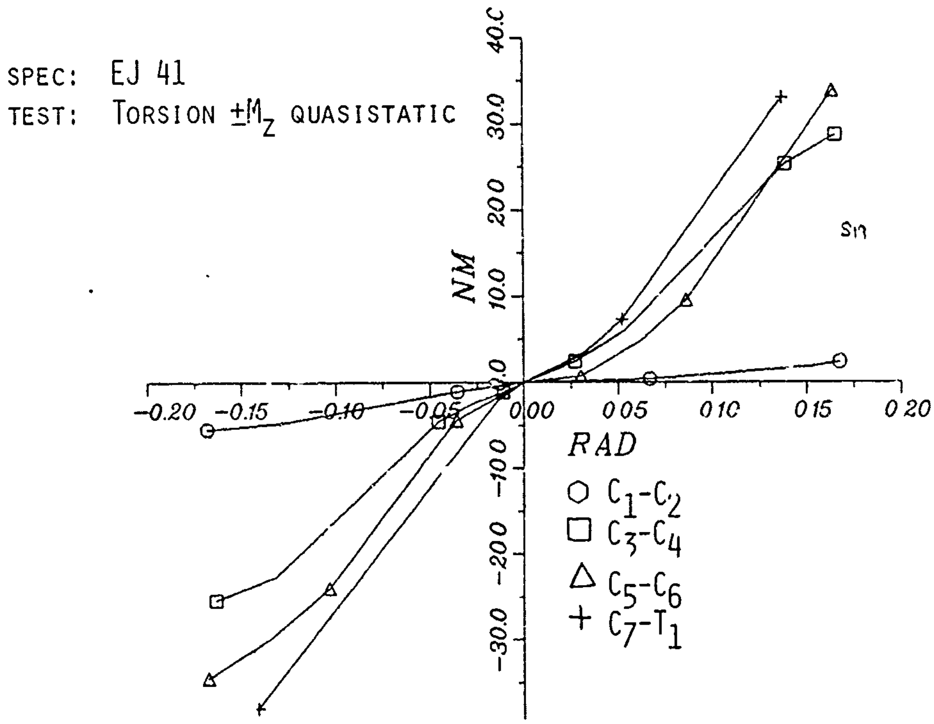


Figure 36(a): Torsional Load-Deformation Curves

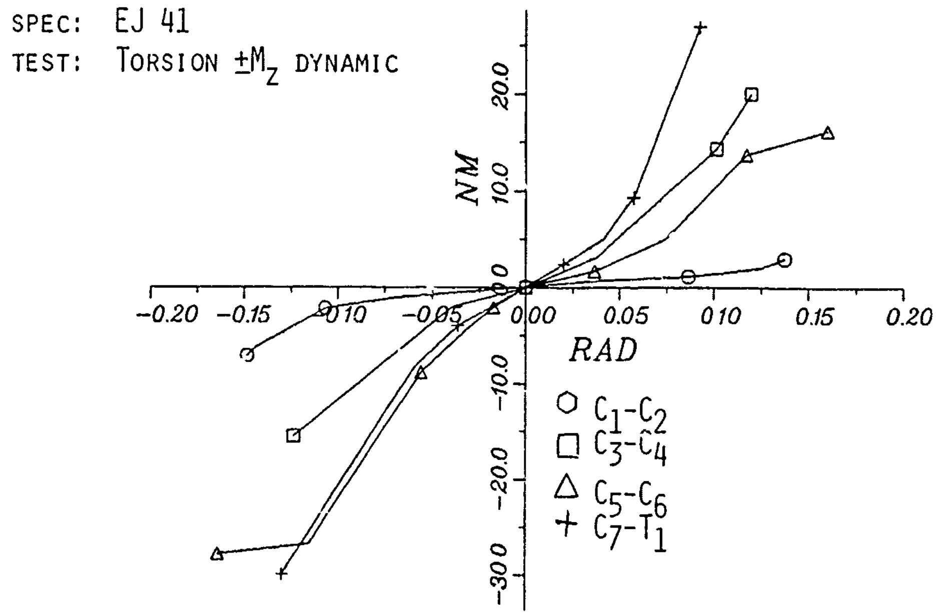


Figure 36(b): Torsional Load Deformation Curves

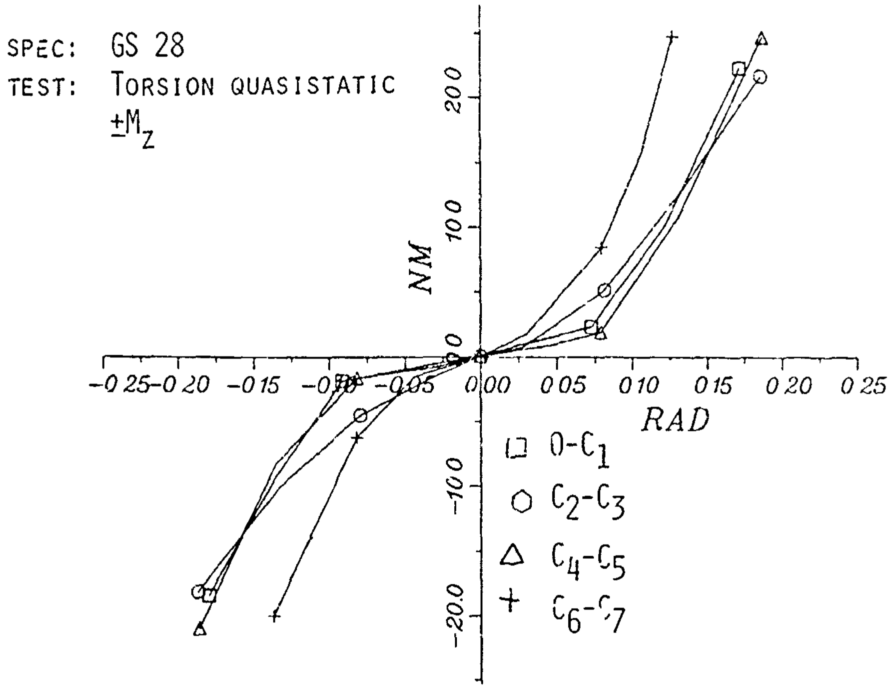


Figure 36(c): Torsional Load-Deformation Curves

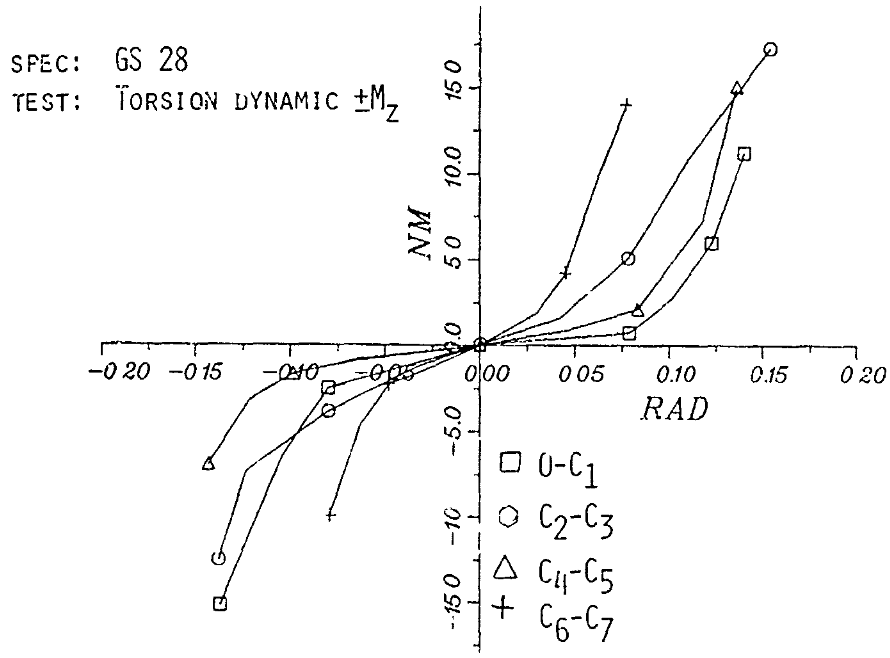


Figure 36 (d): Torsional Load-Deformation Curves

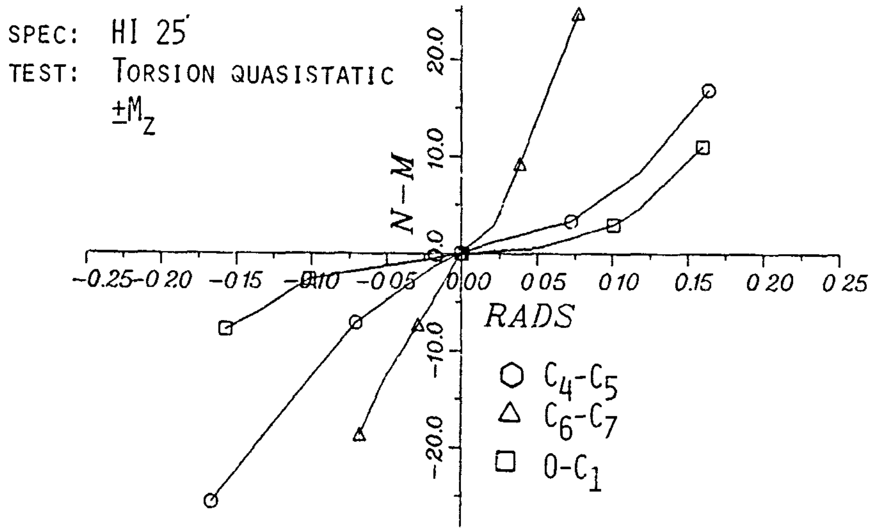


Figure 36(e): Torsional Load-Deformation Curves

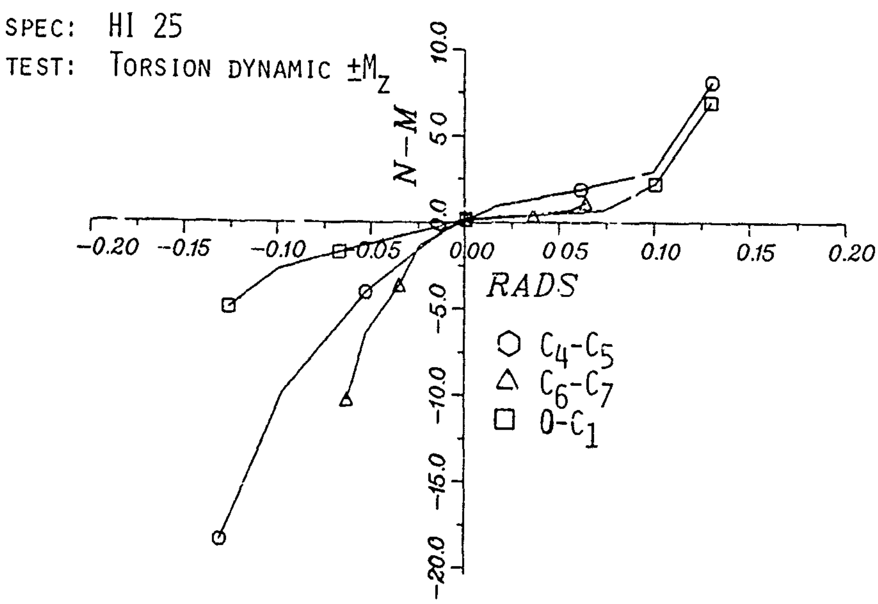


Figure 36(f): Torsional Load-Deformation Curves

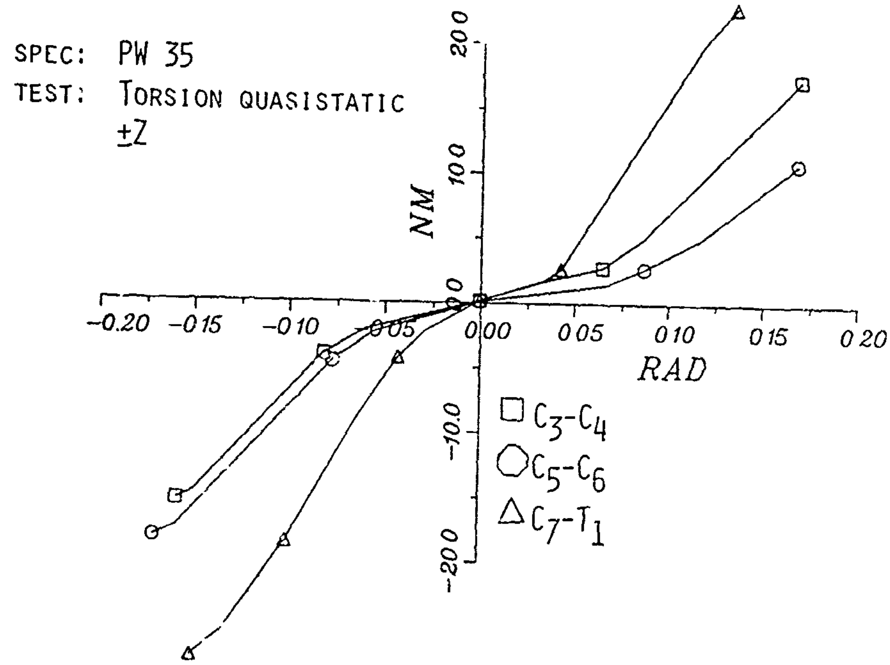


Figure 36(g): Torsional Load-Deformation Curves

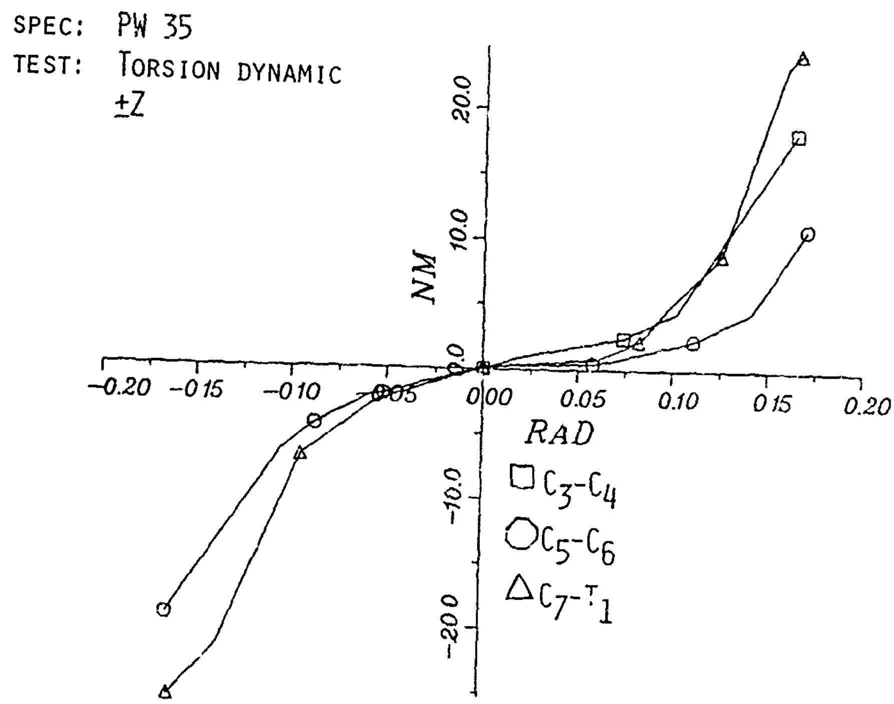


Figure 36(h): Torsional Load-Deformation Curves

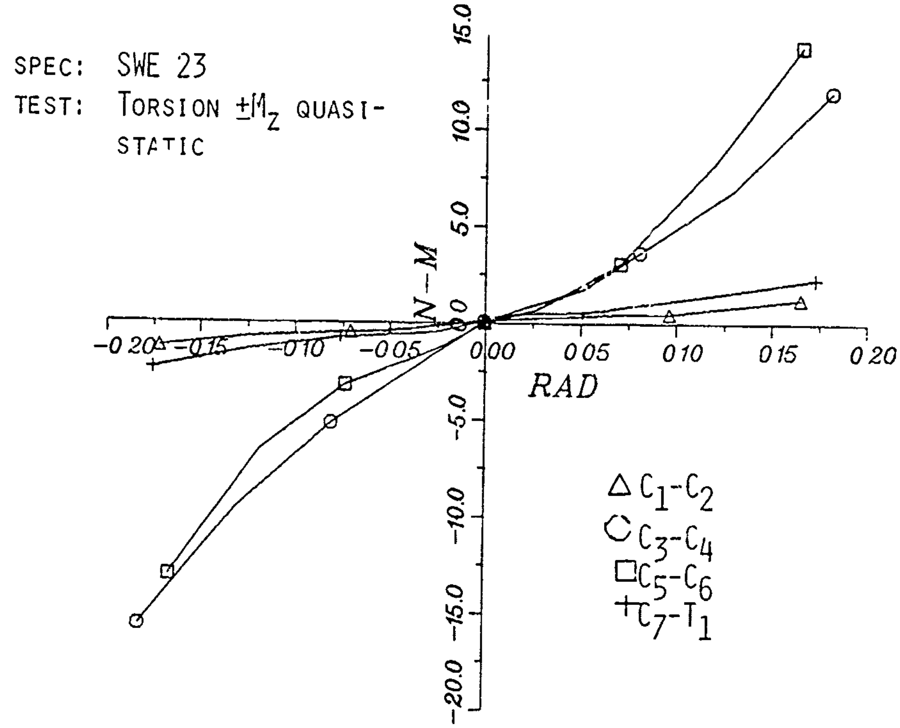


Figure 36(i): Torsional Load-Deformation Curves

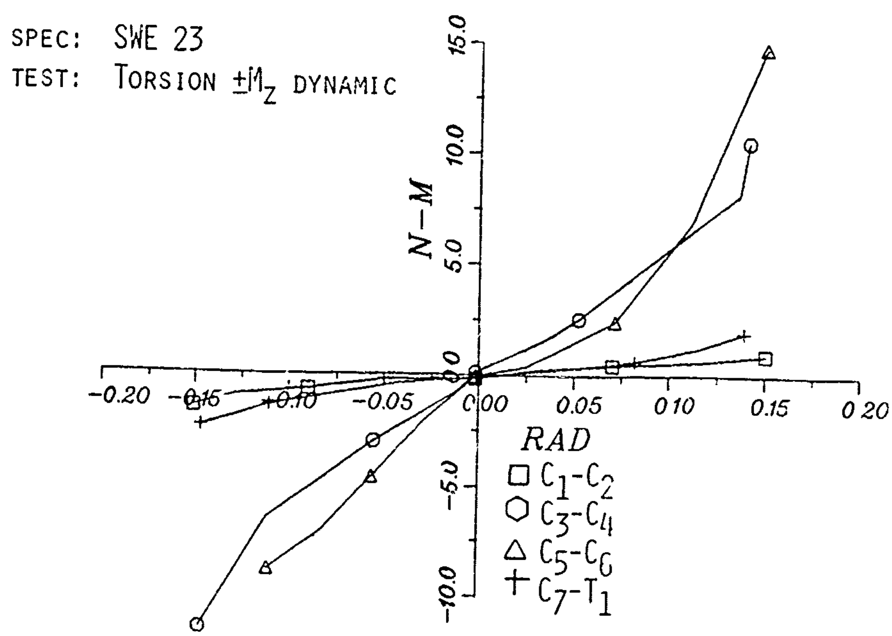


Figure 36(j): Torsional Load-Deformation Curves

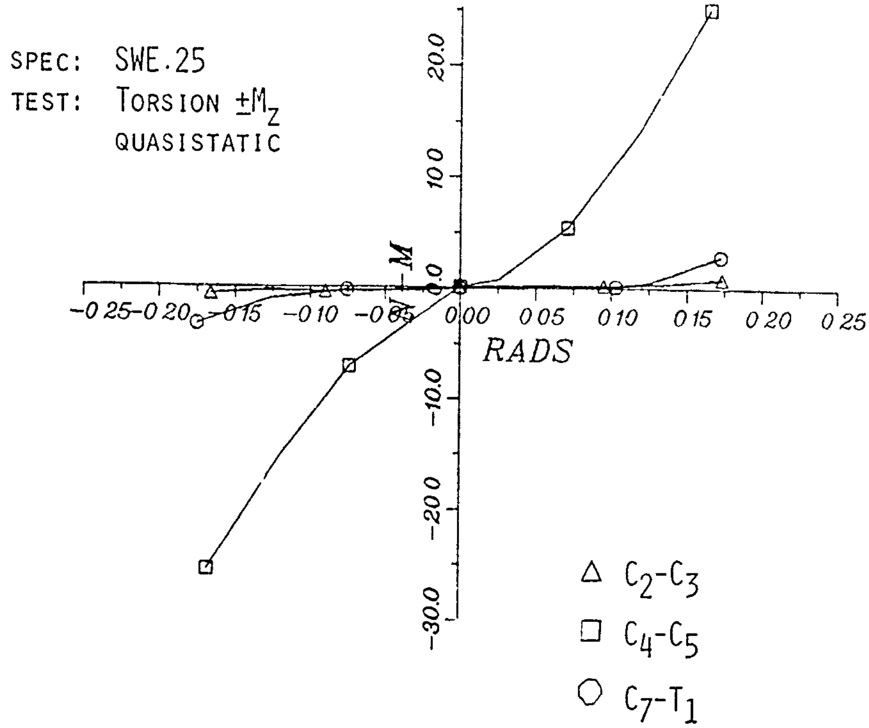


Figure 36(k): Torsional Load-Deformation Curves

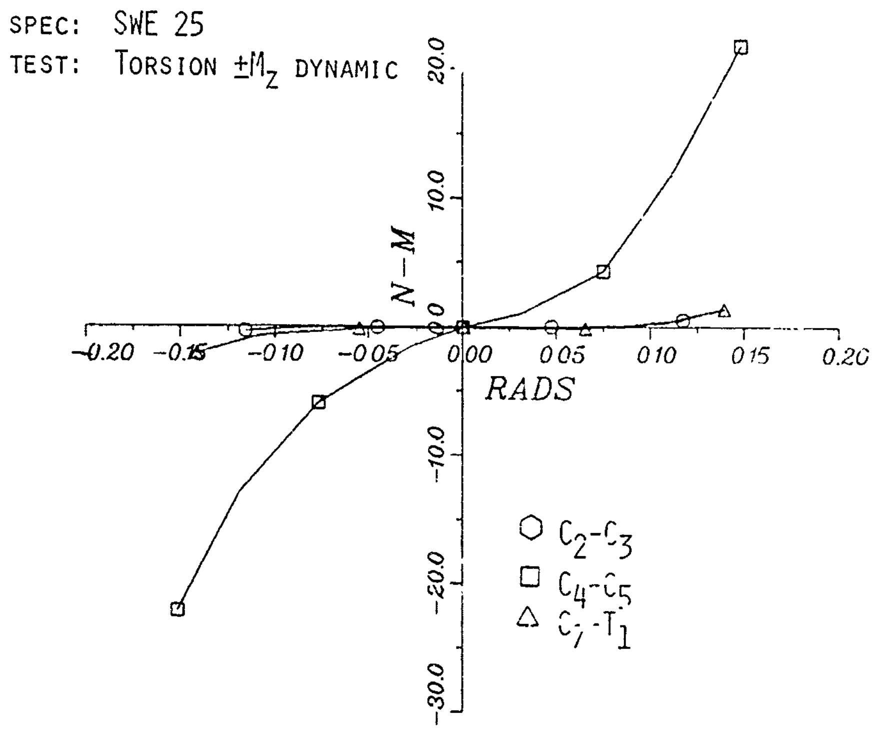


Figure 36(l): Torsional Load-Deformation Curves

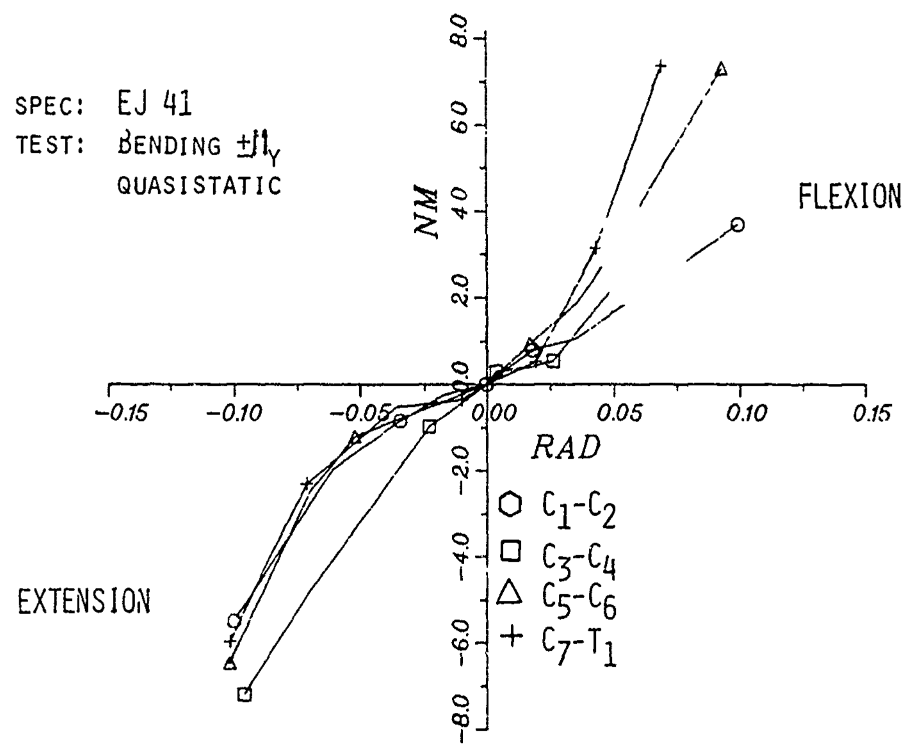


Figure 37(a): Antero-Posterior Bending Load-Deformation Curves

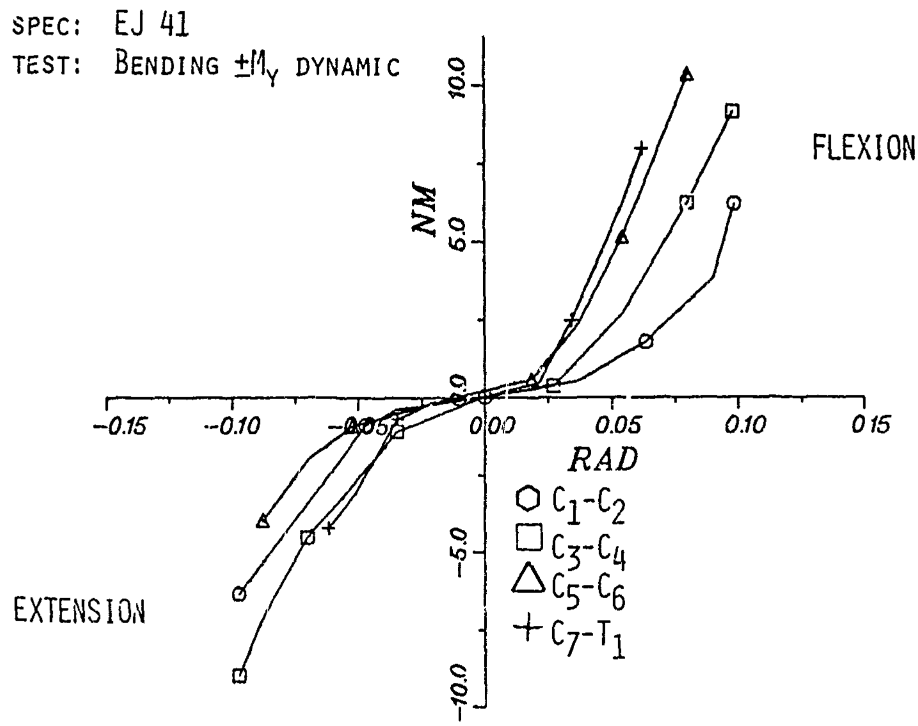


Figure 37(b): Antero-Posterior Bending Load-Deformation Curves

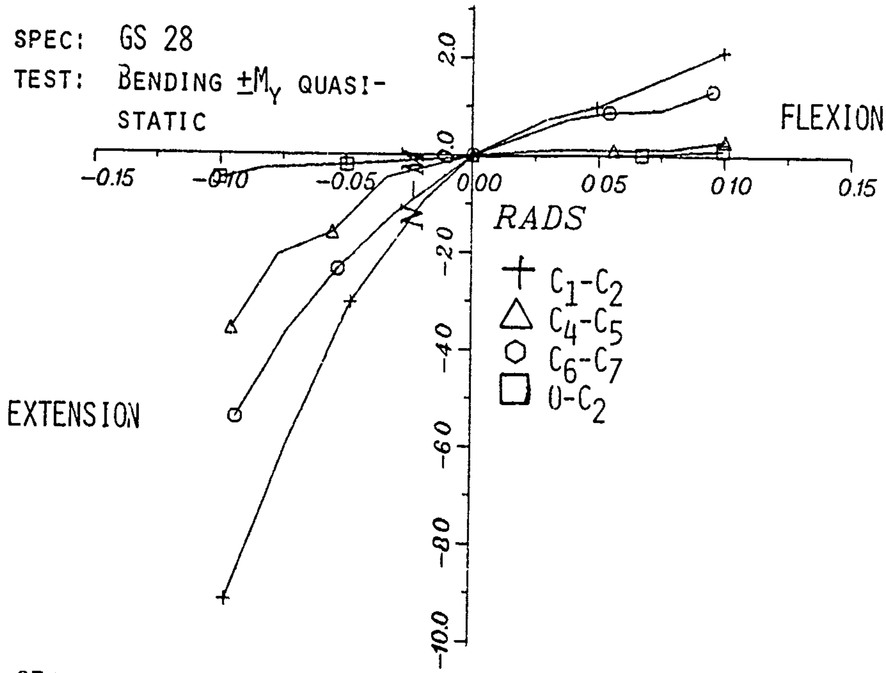


Figure 37(c): Antero-Posterior Bending Load-Deformation Curves

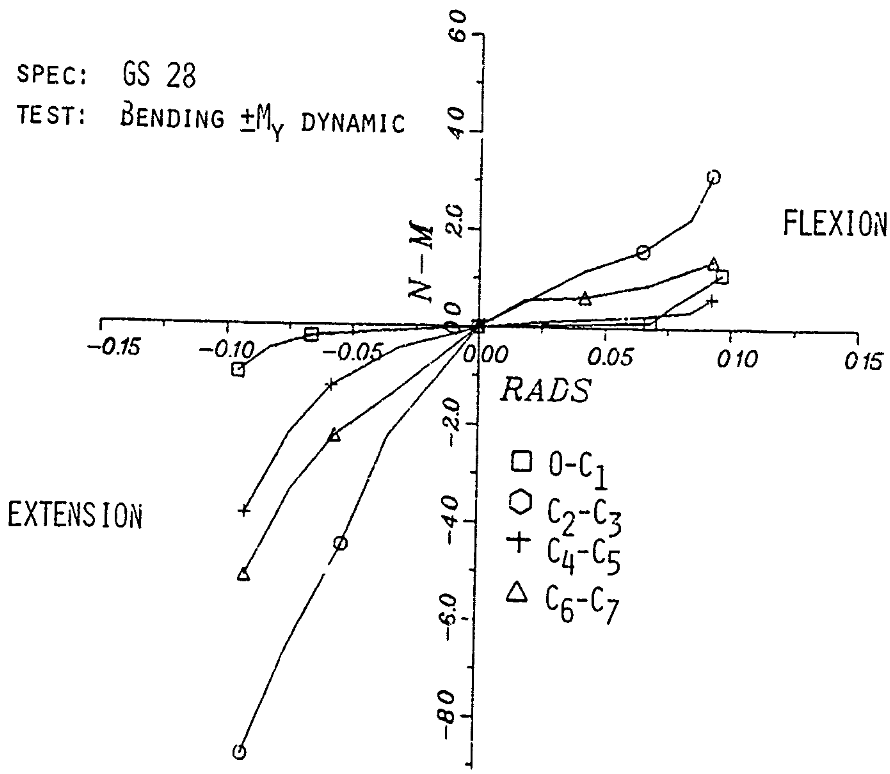


Figure 37(d): Antero-Posterior Bending Load-Deformation Curves

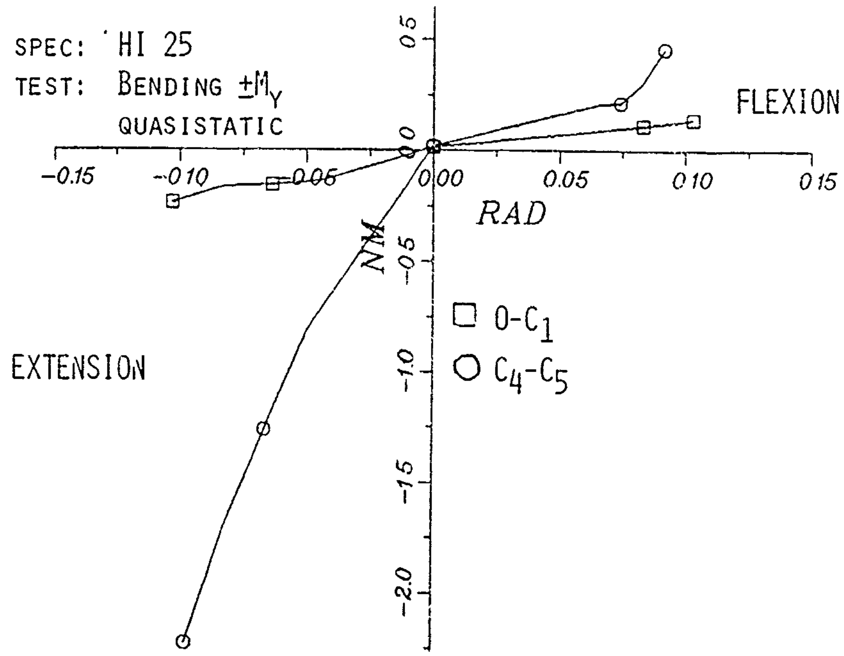


Figure 37(e): Antero-Posterior Bending Load-Deformation Curves

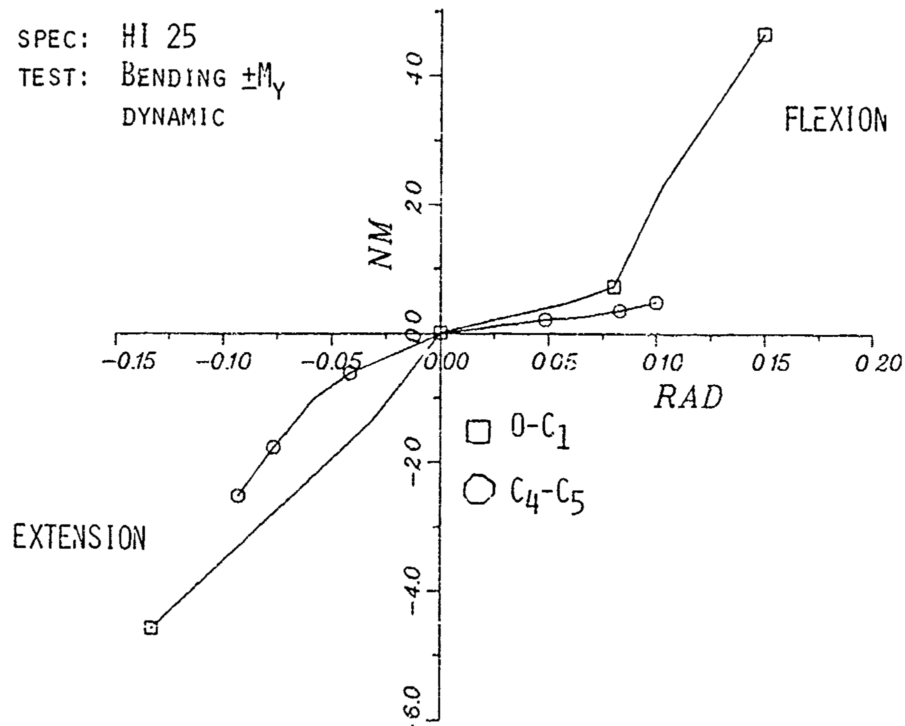


Figure 37(f): Antero-Posterior Bending Load-Deformation Curves

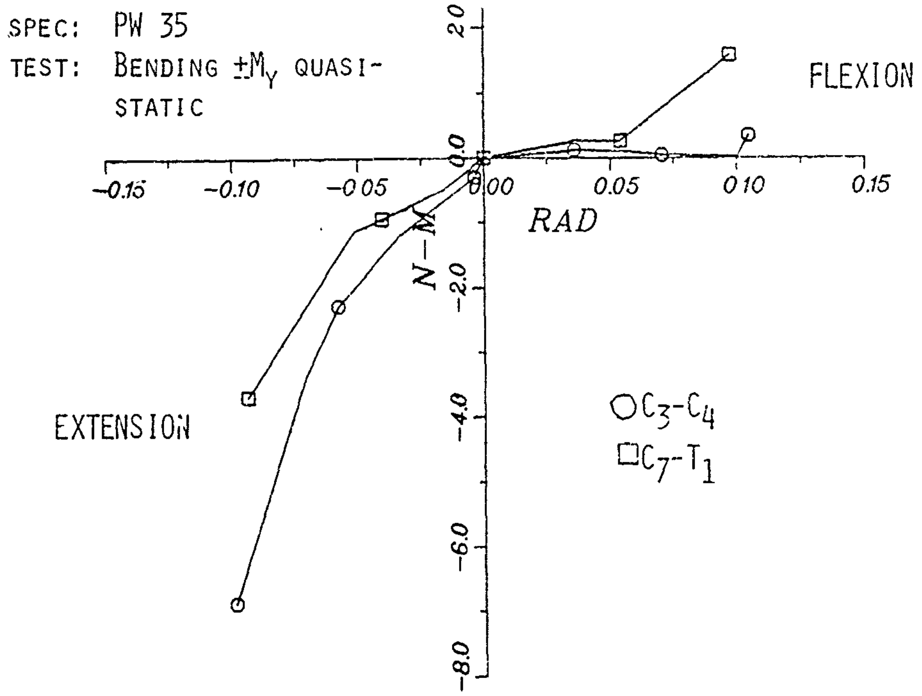


Figure 37(g): Antero-Posterior Bending Load-Deformation Curves

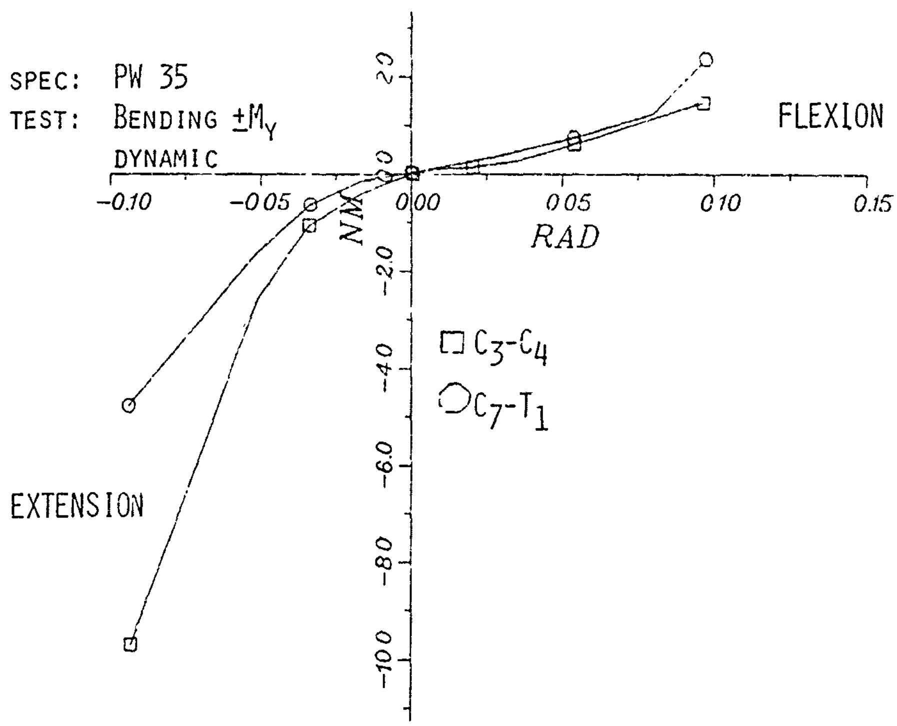


Figure 37(h): Antero-Posterior Bending Load-Deformation Curves

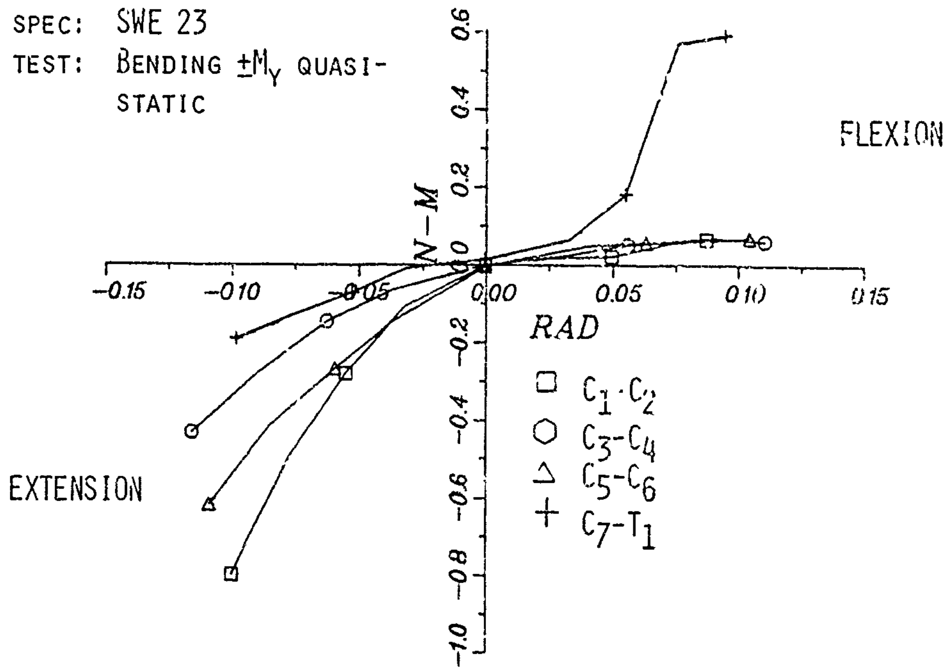


Figure 37(i): Antero-Posterior Bending Load-Deformation Curves

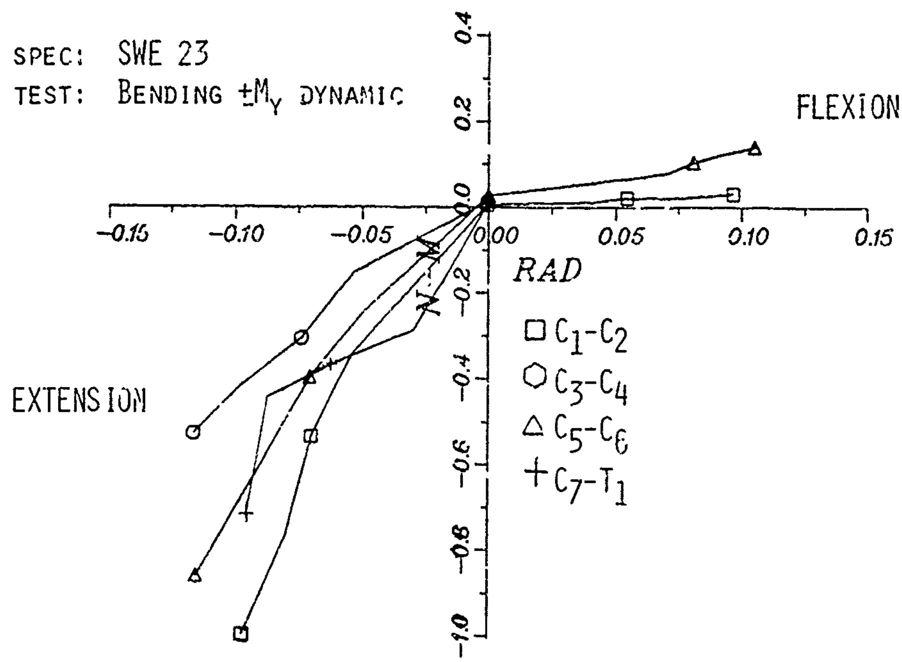


Figure 37(j): Antero-Posterior Bending Load-Deformation Curves

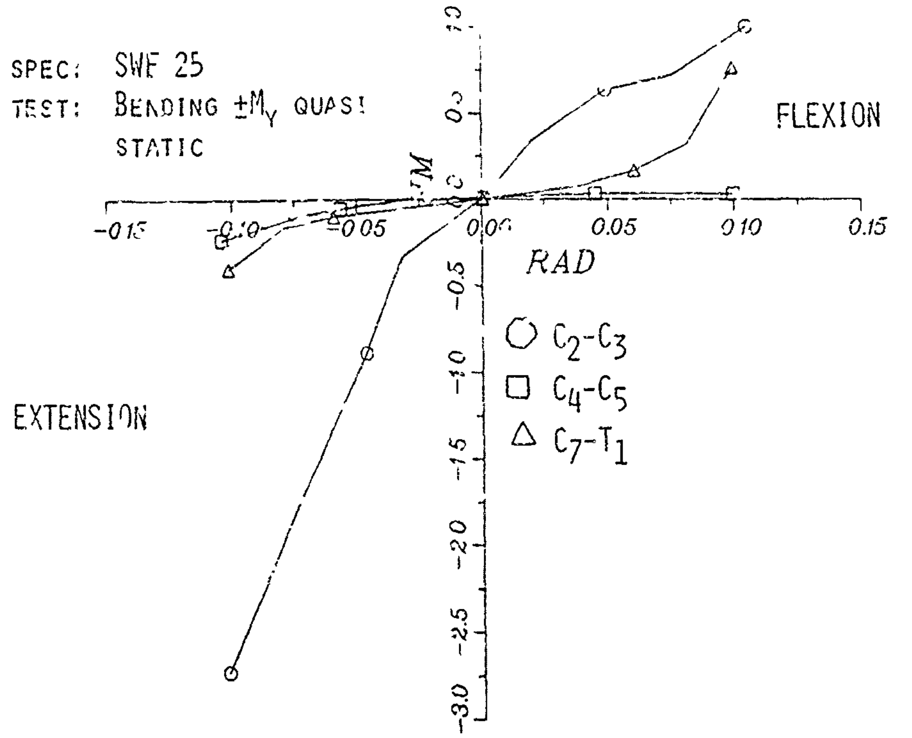


Figure 37(k): Antero-Posterior Bending Load-Deformation Curves

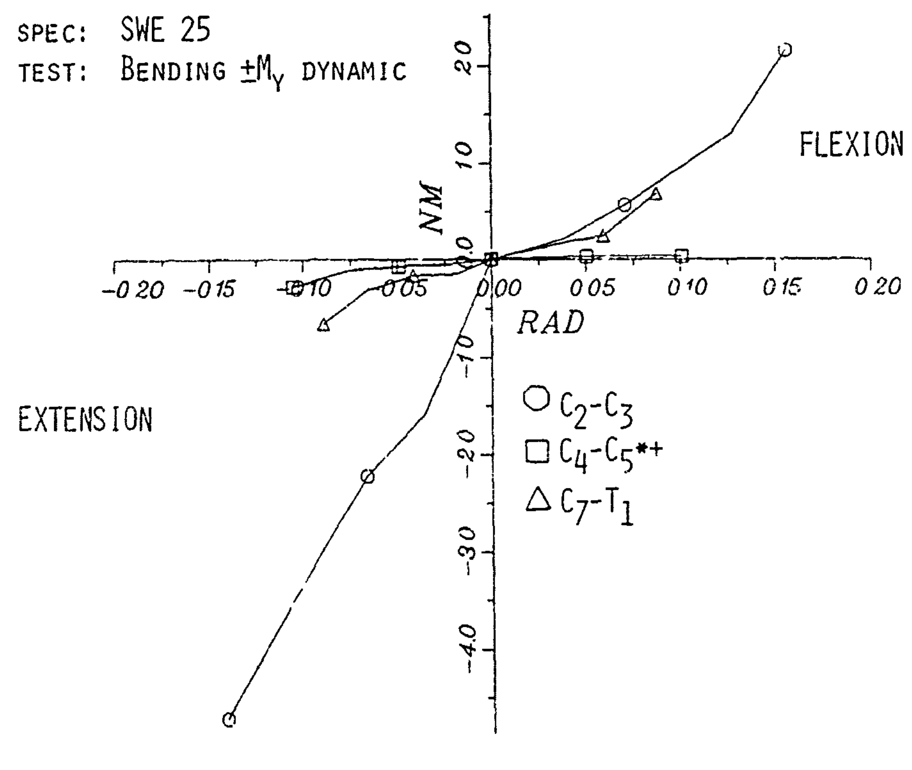


Figure 37(1): Antero-Posterior Bending Load-Deformation Curves

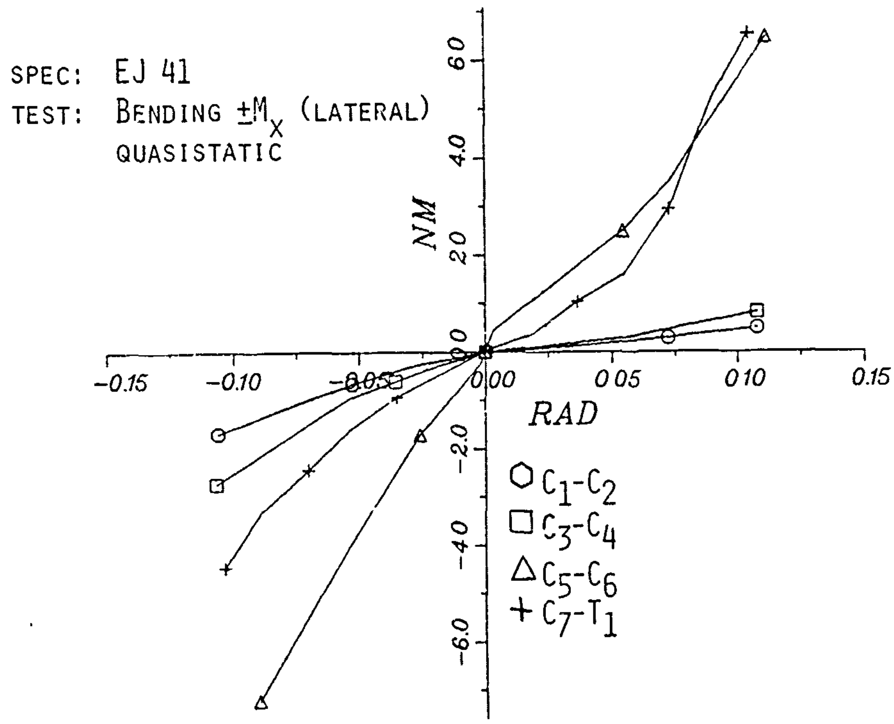


Figure 38(a): Lateral Bending Load-Deformation Curves

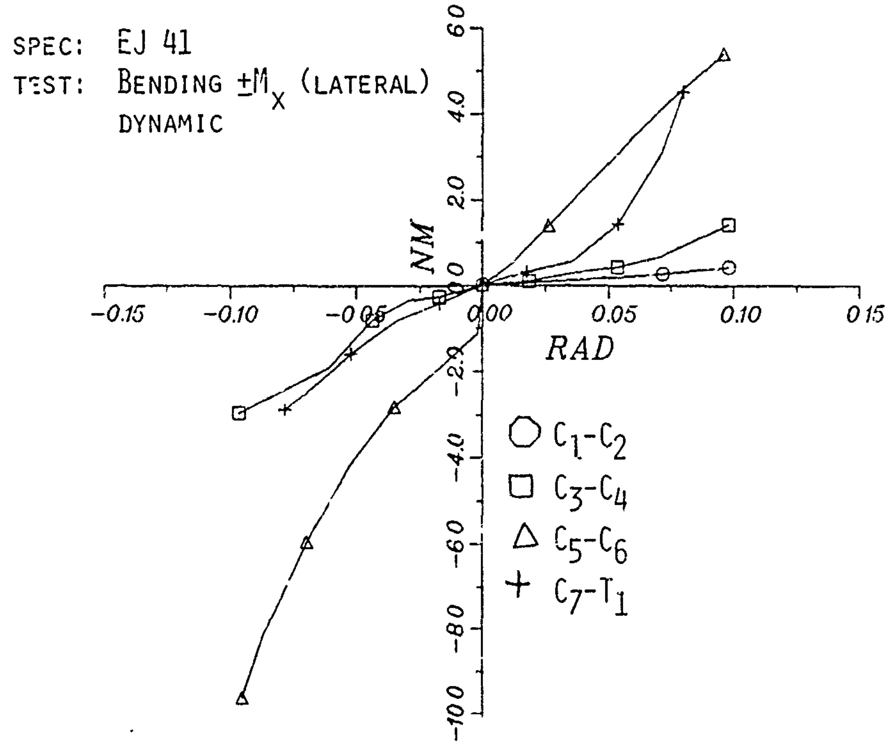


Figure 38(b): Lateral Bending Load-Deformation Curves

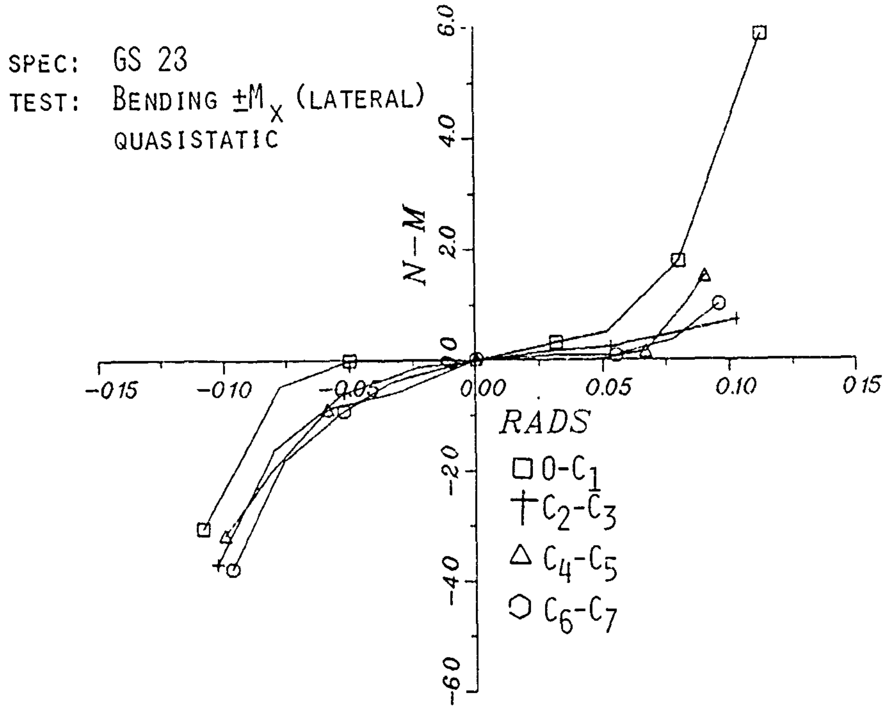


Figure 38(c): Lateral Bending Load-Deformation Curves

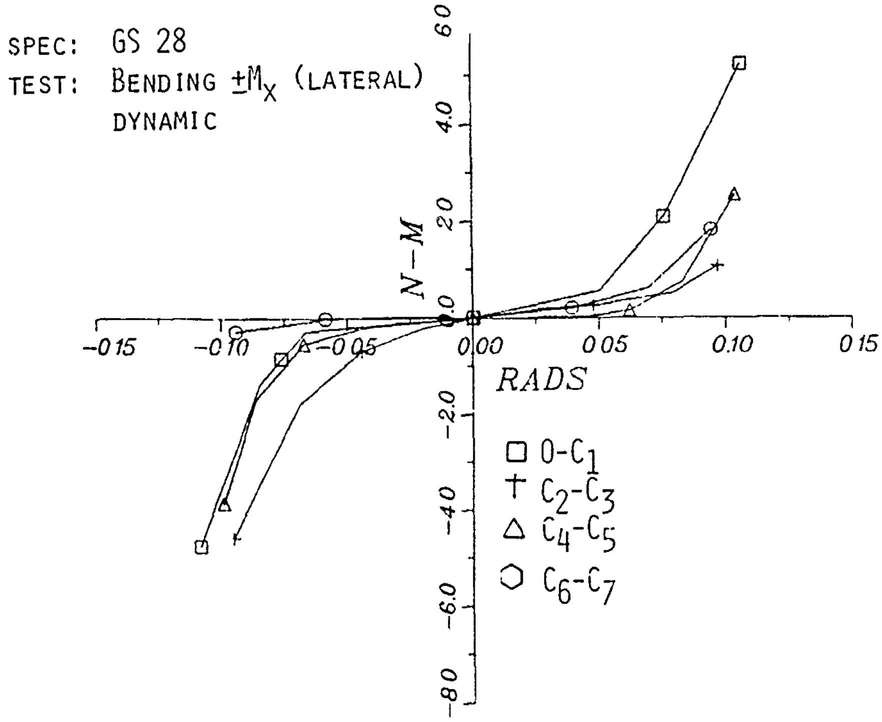


Figure 38(d): Lateral Bending Load Deformation Curves

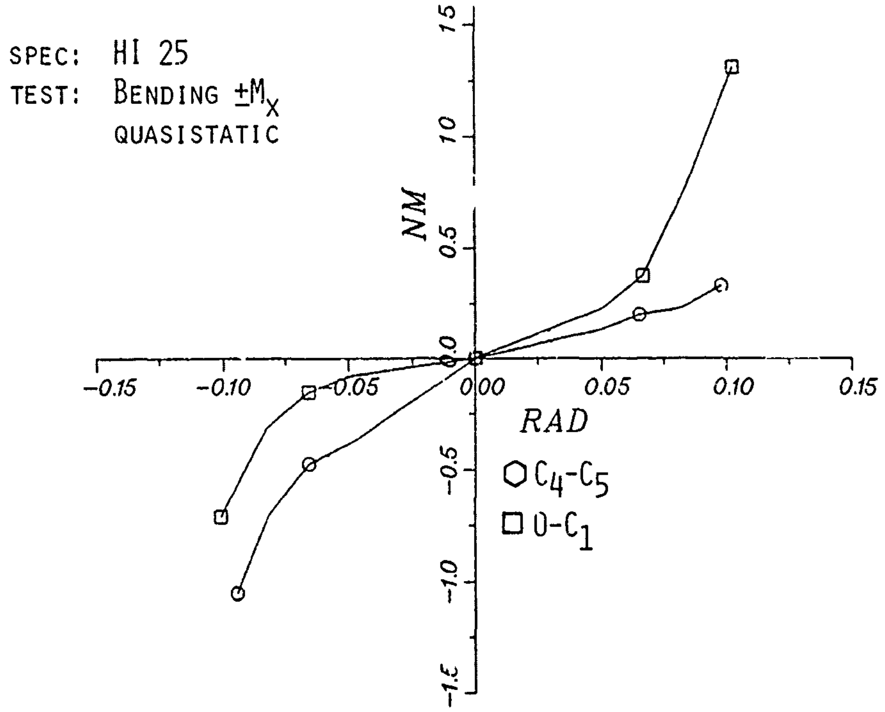


Figure 38(e): Lateral Bending Load-Deformation Curves

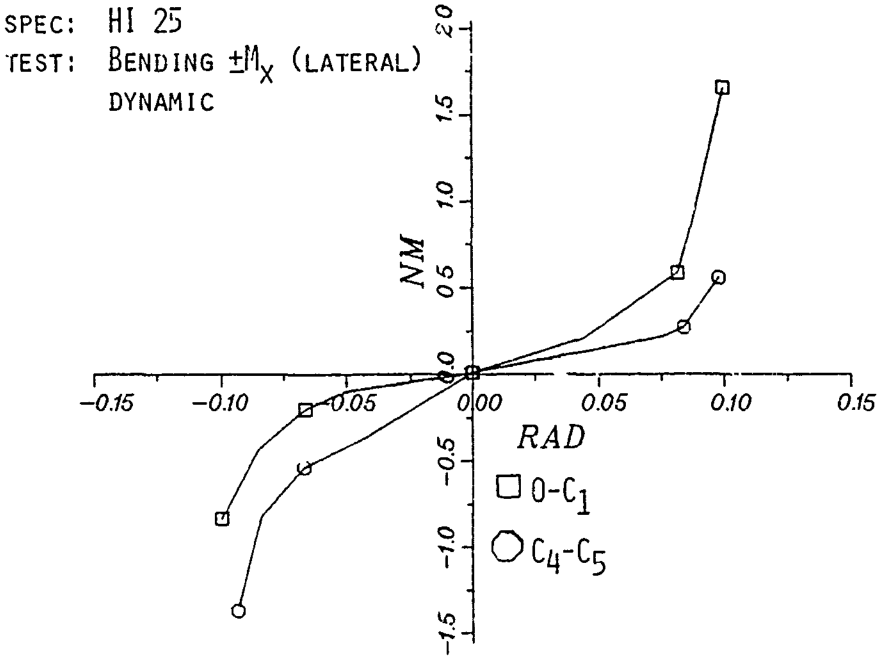


Figure 38 (f): Lateral Bending Load-Deformation Curves

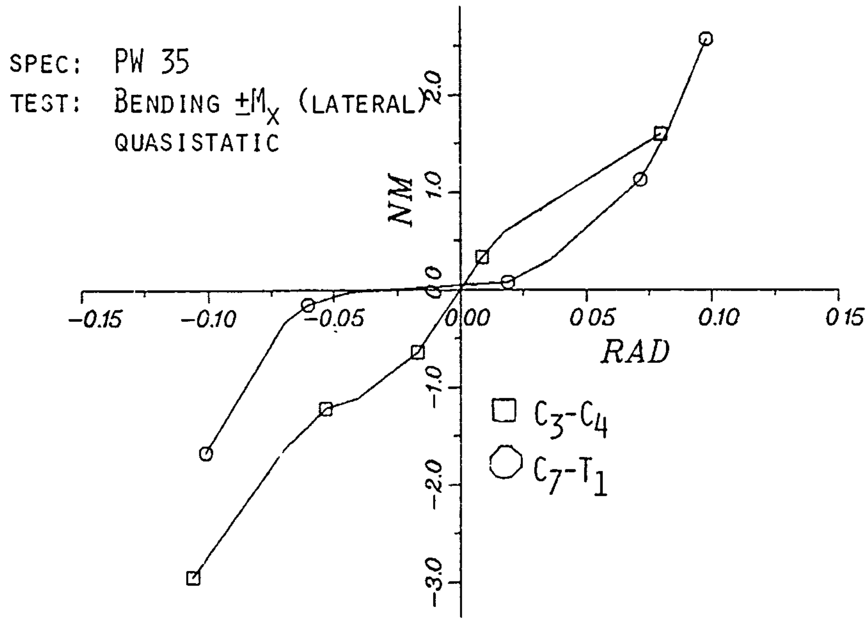


Figure 38(g): Lateral Bending Load-Deformation Curves

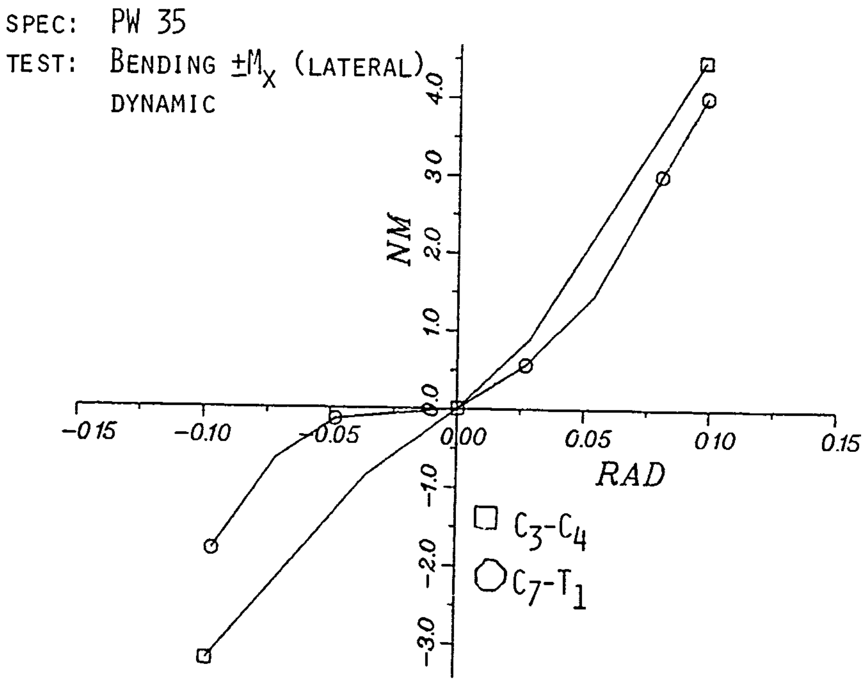


Figure 38(h): Lateral Bending Load-Deformation Curves

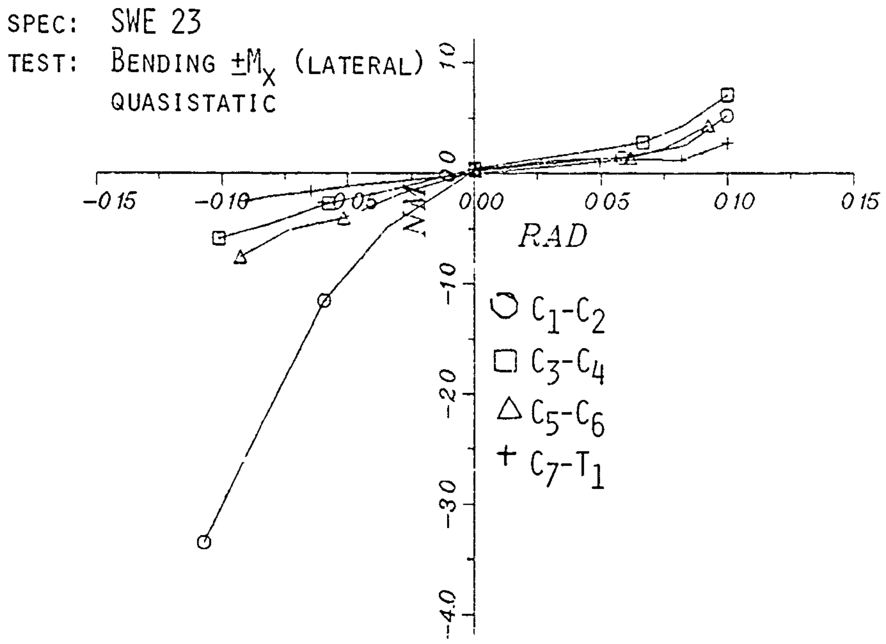


Figure 38(i): Lateral Bending Load-Deformation Curves

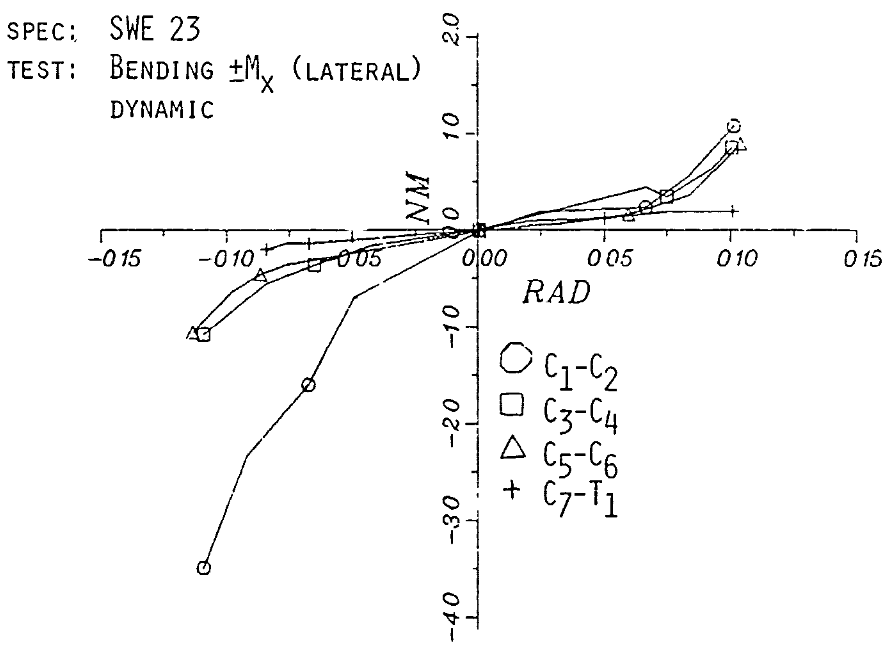


Figure 38(j): Lateral Bending Load-Deformation Curves

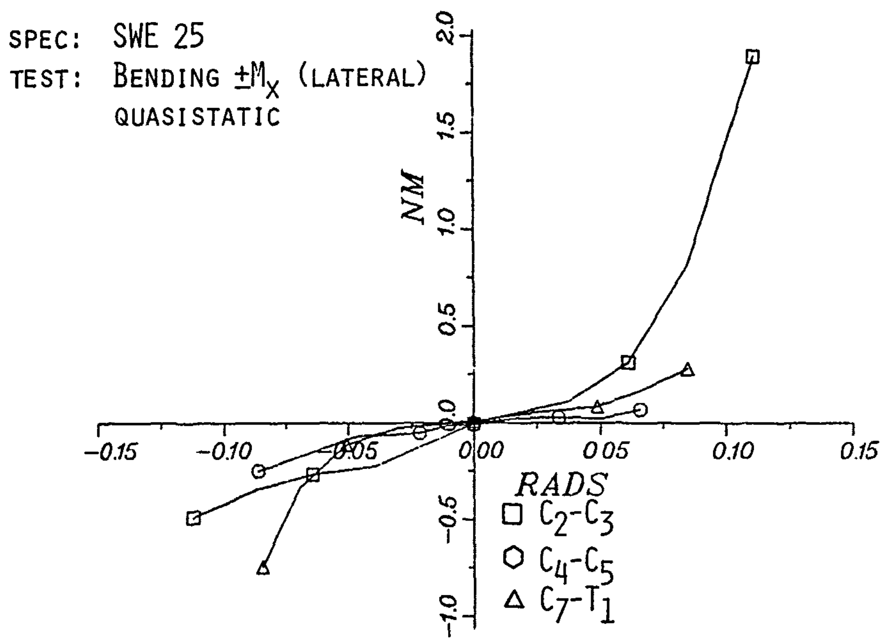


Figure 38(k): Lateral Bending Load-Deformation Curves

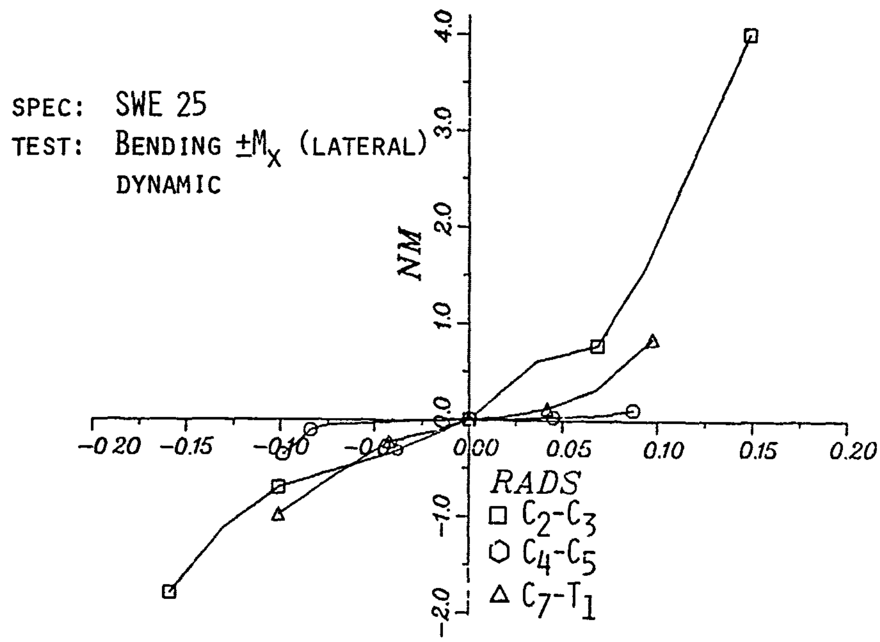


Figure 38(l): Lateral Bending Load-Deformation Curves

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APPENDIX A

The following is a matrix of all tests performed in this study, with notes explaining all deficiencies in the data.

TABLE A1: CERVICAL SPINE TESTS PERFORMED

Specimen		Axial Z (Q + −, D + −)	Shear Lateral R_y (Q + −, D + −)	Shear Ant-Pos R_x (Q + −, D + −)	Torsion M_z (Q + −, D + −)	Bending Lateral M_x (Q + −, D + −)	Bending Ant-Pos M_y (Q + −, D + −)	Failure C Z −	Failure B M_y +	Failure T M_z −
EJ 41	C1-C2	3 3 3 3	3 2 3 6	3 3 2 3	1 1 1 1	3 3 3 3	3 3 3 3		5	
	C3-C4	3 3 3 3	3 3 3 3	3 3 3 3	1 1 1 1	3 3 3 3	3 3 3 3			5
	C5-C6	3 3 3 3	3 3 3 3	3 3 3 3	1 1 1 1	3 3 3 3	3 3 3 3			5
	C7-T1	3 3 3 3	3 3 3 3	3 3 3 3	1 1 1 1	3 3 3 3	3 3 3 3		5	
GS 28	0-C1	1 1 1 1	1 1 1 1	1 1 2 1	1 1 6 6	1 1 6 1	1 1 1 6			1
	C2-C3	1 1 1 3	1 1 1 1	1 4 1 1	1 1 1 1	1 3 1 1	1 1 1 1			1
	C4-C5	1 1 1 1	1 1 1 1	1 1 1 1	1 1 1 1	2 3 1 3	6 1 1 1			1
	C6-C7	1 1 1 1	1 1 1 1	1 1 1 1	1 1 1 6	1 1 1 1	1 1 1 1			1
HI 25	0-C1	1 1 1 3	1 1 1 1	2 1 1 1	1 1 1 1	1 1 6 1	1 1 1 1			1
	C4-C5	1 1 1 1	1 1 1 1	1 1 1 1	1 1 1 1	1 1 1 1	1 1 1 1			1
	C6-C7	1 1 3 1	1 1 1 1	1 1 1 1	1 1 6 1	8 8 8 8	8 8 8 8	3		
PW 35	C3-C4	3 3 3 3	3 3 2 3	3 3 3 3	1 1 1 1	3 3 3 3	3 3 3 3		5	
	C5-C6	3 3 3 3	3 3 3 3	3 3 3 3	1 1 1 1	8 8 8 8	8 8 8 8	------		
	C7-T1	3 3 3 3	3 3 3 3	3 3 3 3	1 1 1 1	3 3 3 3	3 3 3 3		5	
SWE 23	C1-C2	3 1 1 1	1 1 1 3	1 7 1 1	1 1 1 1	1 1 1 1	1 1 1 1		3	
	C3-C4	1 3 1 3	1 1 1 2	1 1 1 1	1 1 1 1	1 1 1 1	1 1 3 1			1
	C5-C6	1 3 1 3	1 1 3 1	1 1 1 3	1 1 1 1	1 1 1 1	1 1 5 1			1
	C7-T1	3 3 3 3	1 1 1 1	1 1 1 3	1 1 1 1	1 1 3 1	1 1 5 1		3	
SWE 25	C2-C3	3 1 2 3	1 1 1 1	1 1 1 1	1 1 1 1	1 1 1 1	1 1 1 1		3	
	C4-C5	4 1 3 3	1 1 1 1	1 1 1 1	1 1 1 1	1 1 1 3	5 1 5 1		3	
	C7-T1	3 3 3 3	1 1 1 1	1 1 1 1	1 1 1 1	1 1 1 1	1 1 1 1			1

Q = Quasistatic
D = Dynamic
C = Compression
B = Bending
T = Torsion

Notes:
1) Test performed, all data available
2) Test performed, Data invalid due to operator error
3) Test performed, beam gauge data invalid or unavailable
4) Test performed, RAM displacement data unavailable
5) No data available due to technical difficulties
6) Energy loss ratio data unavailable due to operator error or technical difficulties
7) Energy loss and Stiffness data calculated graphically due to large noise spike
3) Specimen failed during previous test: Test <u>not</u> performed

APPENDIX B

The contents of Appendix B consists of the reduced data from the load-deformation tests. Tables B1 - B12 are the values derived from the raw data as analyzed by the method shown in Figure 20. To examine trends from these values, the data from the displacement rate, stiffness, and energy loss ratio were plotted in Figures B1 - B6. Extreme care should be used while examining these figures because of the large amount of data per page.

Where explanatory notes are needed, the following symbols are used:

<u>NOTES</u>:

1 = Specimen failed during a previous test; the indicated test was, therefore, not accomplished.

2 = The indicated test was performed; however, the data is invalid due to operator error.

3 = The indicated test was performed; however, the beam gauge data is invalid or unavailable.

4 = The indicated test was performed; however, the ram displacement data is unavailable.

5 = The indicated test data is unavailable due to technical difficulties.

6 = Energy loss ratio data is unavailable due to operator error or technical errors.

7 = Energy loss ratio and stiffness data calculated graphically due to a large noise spike.

Also: a) Bending test data computed using the angle θ where 2θ = actual bending angle.

b) For the max. deformation, where the beam gauge data is available, it is included on the data sheets in the following manner:

Ram Displacement/Beam Gauge Displacement

TABLE B1: STIFFNESS DATA SHEET

AXIAL (+Z)(TENSION)

Specimen	Note	Test	Displacement Rate In/Min	Displacement Rate MM/Sec	Maximum Deformation In	Maximum Deformation MM	Maximum Load Lbs	Maximum Load N	Stiffness Lbs/In ($x10^3$)	Stiffness N/MM	Energy Loss Ratio A3/A1
HI 25 $0-C_1$		1	.019	.00804	.053/.048	1.35/1.22	53.5	238.	.966	169.	.14
HI 25 $0-C_1$		3	191.	80.9	.054/.051	1.37/1.30	61.5	274.	1.046	183.	.22
GS 28 $0-C_1$		1	.021	.00889	.052/.052	1.32/1.32	41.	183.	.712	124.	.15
GS 28 $0-C_1$		3	210.	88.9	.055/.053	1.40/1.37	53.5	238.	.962	168.	.30
SWE 23 C_1-C_2		1	.019	.008	.05 /.047	1.27/1.19	47.	209.	.968	169.	.10
SWE 23 C_1-C_2		3	177.	74.7	.050/.048	1.27/1.22	64.	285.	1.02	175.	.59
EJ 41 C_1-C_2	3	2	.040	.0169	.0355	.902	22.5	100.	0.5	88.	.64
EJ 41 C_1-C_2	3	3	234.	99.1	.0370	.94	32.5	145.	1.25	219.	.93
SWE 25 C_2-C_3	3	2	.019	.008	.048/x	1.22/x	59.6	265.	1.17	204.	.31
SWE 25 C_2-C_3	2	3									
GS 28 C_2-C_3		2	.014	.006	.05 /.036	1.27/.914	90.	400.	2.39	418.	.052
GS 28 C_2-C_3		4	146.	61.8	.053/.039	1.35/.991	89.	1610.	2.12	371.	.26

TABLE B1: STIFFNESS DATA SHEET

AXIAL (+Z)(TENSION)

Specimen	Note	Test	Displacement Rate In/Min	Displacement Rate MM/Sec	Maximum Deformation In	Maximum Deformation MM	Maximum Load Lbs	Maximum Load N	Stiffness Lbs/In ($x10^3$)	Stiffness N/MM	Energy Loss Ratio A3/A1
SWE 23 C_3-C_4		10	.020	.0084	.050/.018	1.27/.457	109.	485.	2.03	355.	.26
SWE 23 C_3-C_4	3	12	189.	80.1	.052/x	1.32/x	127.4	567.	2.49	436.	.035
PW 35 C_3-C_4	3	2	.018	.0076	.0255	.648	93.0	414.	2.50	438	.31
PW 35 C_3-C_4	3	3	240.	102.	.0290	.737	103.	456.0	5.00	876.	.72
EJ 41 C_3-C_4	3	3	.0221	.0094	.0210	.533	80.0	356.	4.29	751.	.36
EJ 41 C_3-C_4	3	4	136.	57.6	.0225	.572	134.	595.	6.62	1160.	.62
SWE 25 C_4-C_5	4	2	.0076	.0032	x/.018	x/.457	108	478.	2.36	399.	.26
SWE 25 C_4-C_5	3	4	197.	82.6	.040/x	1.012/x	83.4	371.	2.23	391.	.32
GS 28 C_4-C_5		6	.020	.0084	.051/.051	1.29/1.27	114.	507.	2.04	357.	.25
GS 28 C_4-C_5		8	176.	74.3	.052/.050	1.32/1.27	122.	541.	2.32	406.	.29
HI 25 C_4-C_5		9	.015	.0063	.072/.050	1.83/1.27	66.5	295.	1.43	250.	.25
HI 25 C_4-C_5		11	90.	38.	.05 /.03	1.27/.762	58.5	260.	1.75	307.	.23

TABLE B1: STIFFNESS DATA SHEET

AXIAL (+Z)(TENSION)

Specimen	Note	Test	Displacement Rate In/Min	Displacement Rate MM/Sec	Maximum Deformation In	Maximum Deformation MM	Maximum Load Lbs	Maximum Load N	Stiffness Lbs/In ($x10^3$)	Stiffness N/MM	Energy Loss Ratio A3/A1
SWE 23 C_5-C_6		2	.011	.0046	.048/.025	1.22/.635	102.	454.	3.82	669.	.22
SWE 23 C_5-C_6		4	99.1	41.8	.049/.025	1.25/.635	126.	561.	4.86	852.	.47
PW 35 C_5-C_6	3	2	.0514	.0218	.0390	.991	64.	285.	2.11	370.	.56
PW 35 C_5-C_6	3	3	321.	136.	.0368	.935	60.	267.	1.58	277.	.81
EJ 41 C_5-C_6	3	2	.0250	.0106	.0275	.699	77.5	345.	3.57	625.	.40
EJ 41 C_5-C_6	3	3	185.	77.5	.0270	.686	101.	451.	3.82	669.	.75
GS 28 C_6-C_7		1	.017	.0072	.049/.042	1.24/1.07	94.6	421.	1.97	344.	.21
GS 28 C_6-C_7		3	173.	72.8	.052/.046	1.32/1.17	103.	458.	2.11	370.	.18
HI 25 C_6-C_7		13	.0124	.00525	.051/.032	1.29/.813	61.5	274.	1.17	204.	.14
HI 25 C_6-C_7	3	15	194.	82.2	.055/x	1.39/x	45.4	202.	.761	133.	.11
SWE 23 C_7-T_1	3	2	.027	.0114	.049/x	1.25/x	107.5	478.	1.96	343.	.30
SWE 23 C_7-T_1	3	3	198.	83.8	.062/x	1.58/x	124.	552.	2.014	353.	.499
SWE 25 C_7-T_1	3	2	.019	.008	.048/x	1.22/x	96.5	429.	1.95	342.	.38
SWE 25 C_7-T_1	3	3	205.	86.8	.063/x	1.600/x	137.	609.	2.01	352.	.43
PW 35 C_7-T_1	3	3	.0655	.0277	.0390	.991	82.0	364.8	3.666	642.	.61
PW 35 C_7-T_1	3	5	369.	156.	.0363	.922	107.5	478.2	3.049	534.	.77
EJ 41 C_7-T_1	3	2	.028	.012	.0260	.660	103.0	458.2	3.800	669.	.36
EJ 41 C_7-T_1	3	3	144.	67.	.0195	.495	121.25	539.6	6.666	1167.	.67

TABLE B2: STIFFNESS DATA SHEET

AXIAL (-Z)(COMPRESSION)

Specimen	Note	Test	Displacement Rate In/Min	Displacement Rate MM/Sec	Maximum Deformation In	Maximum Deformation MM	Maximum Load Lbs	Maximum Load N	Stiffness Lbs/In ($x10^3$)	Stiffness N/MM	Energy Loss Ratio A3/A1
HI 25 $0-C_1$		2	.016	.00677	.050/.040	1.27/1.02	170.	757.	3.663	641.	.40
HI 25 $0-C_1$	3	4	199.	84.2	.053/.027	1.35/.686	287.	1280.	7.6	1330.	.6
GS 28 $0-C_1$		2	.019	.00804	.051/.047	1.29/1.19	20.6	91.6	.399	70.	.11
GS 28 $0-C_1$		4	173.	73.1	.054/.046	1.37/1.17	23.2	103.	.437	77.	.26
SWE 23 C_1-C_2	3	2	.018	.0076	.021/x	.521/x	220.	979.	10.4	1820.	.45
SWE 23 C_1-C_2	3	4	73.9	31.3	.021/x	.533/x	290.	1290.	14.8	2590.	.29
EJ 41 C_1-C_2	3	1	.035	.0148	.0215	.546	178.	790.	12.1	2130.	.56
EJ 41 C_1-C_2	3	4	245.	104.	.0184	.467	205.	912.	15.	2630.	.89
SWE 25 C_2-C_3		2	.012	.0051	.049/.030	1.25/.762	197.	875.	6.32	1110.	.37
SWE 25 C_2-C_3	3	3	140.	59.3	.058/x	1.47/x	303.	1350.	22.1	3880.	.74
GS 28 C_2-C_3	3	5	.007	.0030	.042/.014	1.07/.356	267.	1190.	6.56	1150.	.43
GS 28 C_2-C_3	3	7	184.	78.8	.043/x	1.09/x	363.	1610.	10.0	1780.	.60
SWE 23 C_3-C_4	3	10	.022	.0093	.037/x	.940/x	231.	1030.	6.71	1170.	.38
SWE 23 C_3-C_4	3	12	135.	57.1	.027/x	.686/x	191.	850.	8.02	1400.	.18
PW 35 C_3-C_4	3	1	.0302	.0128	.0195	.495	200.	890.	17.1	2990.	.75
PW 35 C_3-C_4	3	4	84.	35.6	.0143	.363	235.	1050.	30.4	5320.	.97
EJ 41 C_3-C_4	3	2	.0231	.0098	.0150	.381	235	1050.	25.	4380.	.40
EJ 41 C_3-C_4	3	5	141.	59.7	.0095	.241	190.	845.	21.8	3820.	.85

TABLE B2: STIFFNESS DATA SHEET

AXIAL (-Z)(COMPRESSION)

Specimen	Note	Test	Displacement Rate In/Min	Displacement Rate MM/Sec	Maximum Deformation In	Maximum Deformation MM	Maximum Load Lbs	Maximum Load N	Stiffness Lbs/In ($x10^3$)	Stiffness N/MM	Energy Loss Ratio A3/A1
SWE 25 C_4-C_5	3	2	.020	.0085	.046/x	1.17/x	169.	750.	3.35	587.	.4
SWE 25 C_4-C_5	3	4	154.	65.4	.036/x	.914/x	129.	572.	3.82	670.	.39
GS 28 C_4-C_5		6	.017	.0072	.036/.031	.914/.787	218.	970.	6.47	1130.	.39
GS 28 C_4-C_5		8	192.	81.3	.036/.034	.914/.864	73.4	326	1.99	349	.34
HI 25 C_4-C_5		10	.015	.0064	.042/.036	1.07/.914	221.	983.	5.45	954.	.52
HI 25 C_4-C_5		12	171.	72.4	.049/.040	1.25/1.02	398.	1770.	8.82	1540.	.27
SWE 23 C_5-C_6	3	2	.011	.0047	.033/.011	.838/.279	180.	801.	5.48	960.	.31
SWE 23 C_5-C_6	3	4	141.	59.7	.029/.012	.736/.305	160.	710.	6.33	1110.	.53
PW 35 C_5-C_6	3	1	.0489	.0207	.0256	.650	200.	890.	8.41	1470.	.67
PW 35 C_5-C_6	3	5	260.	110.	.0318	.808	800.	3560.	38.5	6740.	.87
EJ 41 C_5-C_6	3	1	.0222	.0094	.0120	.305	205.	912.	26.5	4640.	.41
EJ 41 C_5-C_6	3	4	60.	25.4	.0075	.191	97.5	434.	37.5	6570.	.87
GS 28 C_6-C_7		2	.016	.0068	.039/.029	.991/.737	242.	1070.	8.73	1530.	.47
GS 28 C_6-C_7		4	200.	84.7	.033/.040	.838/1.02	217.	965.	5.9	1030.	.13
HI 25 C_6-C_7		14	.009	.0038	.053/.022	1.35/.559	207.	921.	4.04	708.	.5
HI 25 C_6-C_7		16	341.	144.	.054/.091	1.37/2.31	283.	1260.	2.75	482.	.19

TABLE B2: STIFFNESS DATA SHEET

AXIAL (-Z)(COMPRESSION)

Specimen	Note	Test	Displacement Rate In/Min	Displacement Rate MM/Sec	Maximum Deformation In	Maximum Deformation MM	Maximum Load Lbs	Maximum Load N	Stiffness Lbs/In ($x10^3$)	Stiffness N/MM	Energy Loss Ratio A3/A1
SWE 23 C_7-T_1	3	2	.018	.0076	.032/x	.813/x	198.	881.	6.02	1050.	.31
SWE 23 C_7-T_1	3	3	130.	55.0	.042/x	1.067/x	387.	1720.	10.2	1750.	.30
SWE 25 C_7-T_1	3	2	.016	.0068	.025/.002	.635/.051	225.	999.	8.75	1530.	.28
SWE 25 C_7-T_1	3	3	212.	89.7	.038/x	.965/x	546.	2430.	15.2	2670.	.33
PW 35 C_7-T_1	3	2	.040	.0169	.014	.356	203.	900.8	16.25	2850.	.43
PW 35 C_7-T_1	3	6	177.	74.9	.0235	.597	430.	1910.	27.2	4770.	.92
EJ 41 C_7-T_1	3	1	.0111	.0047	.0063	.16	200.	890.	43.	7530.	.45
EJ 41 C_7-T_1	3	4	135.	57.2	.0125	.318	538.	2390.	27.8	4860.	.74

TABLE B3: STIFFNESS DATA SHEET

TEST - SHEAR +Ry (LATERAL)

Specimen	Note	Test	Displacement Rate In/Min	Displacement Rate MM/Sec	Maximum Deformation In	Maximum Deformation MM	Maximum Load Lbs	Maximum Load N	Stiffness Lbs/In ($x10^3$)	Stiffness N/MM	Energy Loss Ratio A3/A1
HI 25 $0-C_1$		9	.019	.00804	.075/.067	1.91/1.70	18.9	84.1	.226	39.5	.18
HI 25 $0-C_1$		11	168.	71.3	.074/.062	1.88/1.57	26.1	116.	.268	46.9	.17
GS 28 $0-C_1$		9	.021	.00889	.074/.073	1.88/1.85	15.	66.5	.169	29.6	.4
GS 28 $0-C_1$		11	118.	49.9	.076/.045	1.93/1.14	66.	293.	1.43	250.	.23
SWE 23 C_1-C_2		5	.016	.0068	.073/.055	1.85/1.4	51.	227.	691.	121.0	.22
SWE 23 C_1-C_2		6	153.	64.8	.05/.042	1.270/1.07	59.	262.	784.	137.	.53
EJ 41 C_1-C_2	3	8	.027	.011	.048	1.22	87.	387.	1980.	346.	.64
EJ 41 C_1-C_2	5										
SWE 25 C_2-C_3		9	.018	.0076	.096/.073	2.44/1.85	54.9	244.	1200.	210.	.54
SWE 25 C_2-C_3		11	115.	48.5	.081/.065	2.06/1.65	56.2	250.	821.	144.	.32
GS 28 C_2-C_3		9	.017	.0072	.070/.059	1.78/1.5	51.	227.	791.	139.	.21
GS 28 C_2-C_3		11	213.	90.2	.074/.064	1.88/1.63	71.6	318.	974.	171.	.19
SWE 23 C_3-C_4		1	.013	.0055	.076/.055	1.93/1.4	68.4	304.	1240.	216.	.27
SWE 23 C_3-C_4		3	153.	64.9	.056/.046	1.42/1.17	81.	360.	1620.	283.	.37
PW 35 C_3-C_4	3	12	.0243	.010	.049	1.25	30.	133.	890.	156.	.34
PW 35 C_3-C_4	5										
EJ 41 C_3-C_4	3	6	.0456	.019	.063	1.6	66.	294.	1430.	250.	.20
EJ 41 C_3-C_4	3	8	228.	96.5	.051	1.29	75.	334.	2000.	350.	.45

TABLE B3: STIFFNESS DATA SHEET

TEST - SHEAR +Ry (LATERAL)

Specimen	Note	Test	Displacement Rate In/Min	Displacement Rate MM/Sec	Maximum Deformation In	Maximum Deformation MM	Maximum Load Lbs	Maximum Load N	Stiffness Lbs/In ($x10^3$)	Stiffness N/MM	Energy Loss Ratio A3/A1
SWE 25 C_4-C_5		9	.017	.0072	.072/.060	1.83/1.52	69.3	308.	1110.	195.	.25
SWE 25 C_4-C_5		11	197.	83.4	.058/.055	1.47/1.4	10.5	47.	147.	25.8	.43
GS 28 C_4-C_5		9	.018	.0076	.069/.060	1.75/1.52	80.	356.	1310.	230.	.36
GS 28 C_4-C_5		11	146.	61.8	.055/.044	1.4/1.12	71.	316.	1400.	245.	.20
HI 25 C_4-C_5		1	.017	.0072	.068/.057	1.73/1.45	80.	356.	1480.	260.	.27
HI 25 C_4-C_5		3	142.	60.1	.055/.045	1.4/1.14	68.	302.	1430.	251.	.28
SWE 23 C_5-C_6		5	.015	.0068	.069/.057	1.75/1.45	77.7	346.	1340.	234.	.24
SWE 23 C_5-C_6	3	7	184.	77.8	.054/x	1.37/x	32.0	143.	592.	104.	.23
PW 35 C_5-C_6	3	12	.0216	.009	.055	1.4	80.	356.	1150.	201.	.05
PW 35 C_5-C_6	3	15	192.	81.3	.059	1.5	55.	245.	1700.	298.	.39
EJ 41 C_5-C_6	3	5	.0258	.011	.066	1.68	85.	378.	1480.	258.	.53
EJ 41 C_5-C_6	3	8	228.	96.5	.051	1.3	75.	334.	2000.	350.	.45
GS 28 C_6-C_7		5	.018	.0076	.072/.064	1.83/1.63	69.	307.	1000.	176.	.13
GS 28 C_6-C_7		7	184.	77.9	.050/.052	1.27/1.32	46.	205.	886.	155.	.2
HI 25 C_6-C_7		1	.015	.0064	.074/.045	1.88/1.14	78.	347.	1650.	289.	.4
HI 25 C_6-C_7		3	120.	50.8	.055/.032	1.4/.94	68.	302.	1970.	350.	.36

TABLE B3: STIFFNESS DATA SHEET

TEST - SHEAR +Ry (LATERAL)

Specimen	Note	Test	Displacement Rate In/Min	Displacement Rate MM/Sec	Maximum Deformation In	Maximum Deformation MM	Maximum Load Lbs	Maximum Load N	Stiffness Lbs/In $(x10^3)$	Stiffness N/MM	Energy Loss Ratio A3/A1
SWE 23 C_7-T_1		5	.011	.0047	.075/.039	1.91/.991	49.1	218.	985.	172.	.28
SWE 23 C_7-T_1		6	84.3	35.7	.053/.022	1.35/.559	46.0	205.	1210.	212.	.54
SWE 25 C_7-T_1		5	.018	.0076	.070/.063	1.78/1.6	78.1	347.	1110.	194.	.32
SWE 25 C_7-T_1		6	175.	74.2	.051/.051	1.3/1.3	63.2	28.1	1020.	178.	.68
PW 35 C_7-T_1	3	11	.0228	.010	.063	1.6	76.	338.	1300.	228.	.34
PW 35 C_7-T_1	3	14	222.	94.0	.0548	1.39	85.	378.	1830.	320.	.40
EJ 41 C_7-T_1	3	5	.003	.001	.0075	.191	94.	418.	2040.	357.	.45
EJ 41 C_7-T_1	3	8	240.	102.	.035	.889	53.8	240.	1630.	285.	.69

TABLE B4: STIFFNESS DATA SHEET

TEST - SHEAR -Ry (LATERAL)

Specimen	Note	Test	Displacement Rate In/Min	Displacement Rate MM/Sec	Maximum Deformation In	Maximum Deformation MM	Maximum Load Lbs	Maximum Load N	Stiffness Lbs/In ($x10^3$)	Stiffness N/MM	Energy Loss Ratio A3/A1
HI 25 $0-C_1$		10	.019	.00804	.074/.069	1.88/1.75	20.9	93.1	.207	36.3	.18
HI 25 $0-C_1$		12	185.	78.3	.075/.067	1.91/1.70	30.1	134.	.290	50.8	.19
GS 28 $0-C_1$		10	.019	.00804	.074/.068	1.88/1.73	4.36	19.4	.042	7.33	.13
GS 28 $0-C_1$		12	169.	71.5	.075/.065	1.91/1.65	4.64	20.6	.042	7.24	.16
SWE 23 C_1-C_2		5	.013	.0055	.069/.044	1.75/1.12	120.	534.	1860.	326.	.62
SWE 23 C_1-C_2	3	7	108.	45.7	.051/x	1.3/x	87.	387.	2120.	372.	.66
EJ 41 C_1-C_2	3	9	.025	.011	.0662	1.68	90.	400.	1500.	262.	.67
EJ 41 C_1-C_2	6/3	10	231.	97.8	.037	.94	83.	369.	2800.	490.	x
SWE 25 C_2-C_3		10	.016	.0067	.101/.065	2.57/1.65	69.6	310.	1730.	303.	.19
SWE 25 C_2-C_3		12	116.	49.3	.08/.064	2.03/1.63	55.7	248.	718.	126.	.09
GS 28 C_2-C_3		10	.019	.008	.071/.066	1.8/1.68	15.5	169.	179.	31.3	.15
GS 28 C_2-C_3		12	235.	99.5	.075/.072	1.91/1.83	28.	125.	282.	49.3	.27
SWE 23 C_3-C_4		2	.020	.0085	.071/.068	1.8/1.73	25.6	114.	317.	55.5	.16
SWE 23 C_3-C_4	5	4									
PW 35 C_3-C_4	3	13	.0255	.011	.051	1.3	30.	133.	942.	165.	.33
PW 35 C_3-C_4	3	14	237.	100.	.0512	1.3	43.5	193.	1500.	263.	.53
EJ 41 C_3-C_4	3	7	.0234	.010	.0662	1.68	66.	294.	1200.	210.	.35
EJ 41 C_3-C_4	3	8	242.	103.	.0473	1.2	52.5	234.	1550.	271.	.43

TABLE B4: STIFFNESS DATA SHEET

TEST - SHEAR -Ry (LATERAL)

Specimen	Note	Test	Displacement Rate In/Min	Displacement Rate MM/Sec	Maximum Deformation In	Maximum Deformation MM	Maximum Load Lbs	Maximum Load N	Stiffness Lbs/In ($x10^3$)	Stiffness N/MM	Energy Loss Ratio A3/A1
SWE 25 C_4-C_5		10	.019	.0080	.071/.067	1.8/1.7	13.	58.	163.	28.7	.19
SWE 25 C_4-C_5	6	12	216.	91.4	.068/.057	1.73/1.45	10.	44.	156.	27.4	x
GS 28 C_4-C_5		10	.019	.0080	.068/.063	1.73/1.6	52.	231.	749.	131.	.19
GS 28 C_4-C_5		12	176.	74.5	.053/.047	1.35/1.19	40.	178.	734.	129.	.25
HI 25 C_4-C_5		2	.017	.0072	.062/.057	1.58/1.45	56.	249.	997.	175.	.21
HI 25 C_4-C_5		4	150.	63.5	.053/.050	1.35/1.27	49.	218.	967.	169.	.25
SWE 23 C_5-C_6		6	.017	.0072	.068/.060	1.73/1.52	65.4	291.	1337.	234.	.25
SWE 23 C_5-C_6		8	202.	85.7	.054/.054	1.37/1.37	49.3	219.	939.	164.	.34
PW 35 C_5-C_6	3	13	.0185	.008	.055	1.4	67.	298.	1068.	187.	.42
PW 35 C_5-C_6	3	14	177.	74.9	.055	1.4	73.	325.	2425.	425.	.37
EJ 41 C_5-C_6	3	6	.0285	.012	.060	1.52	69.	307.	1442.	253.	.40
EJ 41 C_5-C_6	3	7	222.	94.0	.0485	2.76	65.	289.	2200.	385.	.43

TABLE B4: STIFFNESS DATA SHEET

TEST - SHEAR -Ry (LATERAL)

Specimen	Note	Test	Displacement Rate In/Min	Displacement Rate MM/Sec	Maximum Deformation In	Maximum Deformation MM	Maximum Load Lbs	Maximum Load N	Stiffness Lbs/In ($x10^3$)	Stiffness N/MM	Energy Loss Ratio A3/A1
GS 28 C_6-C_7		6	.016	.0068	.071/.058	1.8/1.47	67.	298.	1110.	194.	.19
GS 28 C_6-C_7		8	157.	66.5	.052/.046	1.32/1.17	50.	222.	1050.	183.	.18
HI 25 C_6-C_7		2	.014	.0059	.069/.046	1.75/1.17	66.6	296.	1370.	240.	.17
HI 25 C_6-C_7		4	199.	84.2	.057/.053	1.45/1.35	62.	276.	1380.	242.	.13
SWE 23 C_7-T_1		5	.015	.0064	.074/.053	1.88/1.35	59.6	265.	1090.	190.	.21
SWE 23 C_7-T_1		7	111.	46.9	.051/.051	1.3/1.3	60.4	269.	1150.	201.	.62
SWE 25 C_7-T_1		5	.020	.0085	.070/.069	1.78/1.75	76.6	341.	1120.	196.	.38
SWE 25 C_7-T_1		7	166.	70.2	.051/.054	1.3/1.37	65.7	292.	944.	165.	.67
PW 35 C_7-T_1	3	12	.0231	.010	.065	1.65	58.	258.	1140.	199.	.42
PW 35 C_7-T_1	3	13	231.	97.8	.055	1.4	73.	325.	1870.	327.	.34
EJ 41 C_7-T_1	3	6	.0204	.008	.045	1.14	103.	458.	2960.	518.	.32
EJ 41 C_7-T_1	3	7	240.	102.	.032.	.813	77.5	345.	2630.	460.	.75

TABLE B5: STIFFNESS DATA SHEET

TEST - SHEAR $+R_x$ (A-P)

Specimen	Note	Test	Displacement Rate In/Min	Displacement Rate MM/Sec	Maximum Deformation In	Maximum Deformation MM	Maximum Load Lbs	Maximum Load N	Stiffness Lbs/In ($x10^3$)	Stiffness N/MM	Energy Loss Ratio A3/A1
HI 25 $0-C_1$		5	.018	.00762	.074/.064	1.88/1.63	63.81	284.	.855	149.	.35
HI 25 $0-C_1$		7	172.	72.9	.073/.062	1.85/1.57	100.	446.	1.18	207.	.16
GS 28 $0-C_1$		5	.016	.00677	.074/.057	1.88/1.45	49.9	222.	.810	141.	.10
GS 28 $0-C_1$	2	7									
SWE 23 C_1-C_2		8	.013	.0055	.069/.044	1.75/1.12	63.5	282.	1360.	238.	.37
SWE 23 C_1-C_2		9	116.	49.2	.053/.031	1.346/.78	63.	280.	1600.	281.	.6
EJ 41 C_1-C_2	3	5	.024	.010	.070	1.78	84.	373.	1360.	238.	.6
EJ 41 C_1-C_2	5										
SWE 25 C_2-C_3		5	.013	.0055	.097/.067	2.46/1.70	65.9	293.	1000.	175.	.32
SWE 25 C_2-C_3		7	108.	45.7	.081/.060	2.06/1.52	55.7	248.	879.	154.	.29
GS 28 C_2-C_3		13	.0212	.0090	.072/.075	1.83/1.91	24.1	107.	262.	45.9	.17
GS 28 C_2-C_3		15	274.	116.	.078/.079	1.98/2.01	26.5	118.	273.	479.	.21
SWE 23 C_3-C_4		5	.015	.0064	.076/.055	1.93/1.4	121.	538.	2250.	393.	.21
SWE 23 C_3-C_4		7	177.	75.7	.055/.048	1.4/1.2	77.9	347.	1990.	349.	.38
PW 35 C_3-C_4	3	7	.0219	.009	.0465	1.18	55.	245.	1090.	191.	.49
PW 35 C_3-C_4	3	11	213.	90.2	.0445	1.13	107.	476.	2900.	508.	.47
EJ 41 C_3-C_4	3	10	.02	.008	.0635	1.61	69.	307.	1380.	241.	.46
EJ 41 C_3-C_4	3	13	206.	87.2	.0437	1.11	55.	245.	1380.	241.	.57

TABLE B5: STIFFNESS DATA SHEET

TEST - SHEAR + R_x (A-P)

Specimen	Note	Test	Displacement Rate In/Min	Displacement Rate MM/Sec	Maximum Deformation In	Maximum Deformation MM	Maximum Load Lbs	Maximum Load N	Stiffness Lbs/In ($x10^3$)	Stiffness N/MM	Energy Loss Ratio A3/A1
SWE 25 C_4-C_5		13	.019	.0080	.074/.066	1.88/1.68	35.	156.	459.	80.3	.28
SWE 25 C_4-C_5		15	206.	87.2	.057/.055	1.45/1.4	20.	89.	344.	60.2	.29
GS 28 C_4-C_5		13	.020	.0085	.071/.067	1.80/1.70	123.	547.	1850.	324.	.35
GS 28 C_4-C_5		15	188.	79.6	.054/.048	1.37/1.22	131.	583.	2690.	471.	.24
HI 25 C_4-C_5		5	.0156	.0066	.076/.051	1.93/1.3	70.	311.	1260.	221.	.13
HI 25 C_4-C_5		7	129.	54.6	.054/.043	1.37/1.09	51.	227.	1140.	200.	.11
SWE 23 C_5-C_6		9	.019	.0080	.069/.068	1.75/1.73	61.3	273.	883.	155.	.20
SWE 23 C_5-C_6		11	159.	67.0	.051/.053	1.3/1.35	57.2	255.	1150.	201.	.34
PW 35 C_5-C_6	3	6	.0507	.022	.0538	1.37	88.	391.	995.	174.	.73
PW 35 C_5-C_6	3	11	234.	99.1	.0505	1.29	51.5	229.	1550.	272.	.63
EJ 41 C_5-C_6	3	10	.021	.009	.053	1.35	100.	445.	2290.	401.	.48
EJ 41 C_5-C_6	3	11	204.	86.4	.0473	1.20	116.	516.	3150.	552.	.39
GS 28 C_6-C_7		9	.014	.0059	.071/.048	1.8/1.22	182.	810.	3780.	662.	.25
GS 28 C_6-C_7		11	141.	59.7	.052/.040	1.32/1.02	189.	841.	3870.	678.	.36
HI 25 C_6-C_7		5	.010	.0042	.075/.032	1.91/.813	91.	405.	3010.	527.	.37
HI 25 C_6-C_7		7	99.	41.9	.053/.028	1.35/.711	105.	467.	4060.	712.	.42

TABLE B5: STIFFNESS DATA SHEET

TEST - SHEAR $+R_x$ (A-P)

Specimen	Note	Test	Displacement Rate In/Min	Displacement Rate MM/Sec	Maximum Deformation In	Maximum Deformation MM	Maximum Load Lbs	Maximum Load N	Stiffness Lbs/In ($x10^3$)	Stiffness N/MM	Energy Loss Ratio A3/A1
SWE 23 C_7-T_1		8	.017	.0072	.070/.061	1.78/1.55	45.3	201.	551.9	96.7	.21
SWE 23 C_7-T_1		9	173.	73.2	.052/.049	1.32/1.25	48.9	218.	405.1	70.9	.39
SWE 25 C_7-T_1		8	.020	.0085	.065/.067	1.651/1.7	64.5	287.	837.	147.	.15
SWE 25 C_7-T_1		9	207.	87.6	.048/.0532	1.22/1.35	58.2	259.	777.	136.	.5
PW 35 C_7-T_1	3	8	.0162	.007	.044	1.12	91.	405.	2460.	431.	.49
PW 35 C_7-T_1	3	9	183.	77.5	.028	.711	114.	507.	3800.	665.	.15
EJ 41 C_7-T_1	3	12	.0162	.007	.025	.635	100.	445.	4180.	732.	.52
EJ 41 C_7-T_1	3	14	168	71.5	.0249	.633	113.	503.	5900.	1030.	.80

TABLE B6: STIFFNESS DATA SHEET

TEST - SHEAR $-R_x$ (A-P)

Specimen	Note	Test	Displacement Rate In/Min	Displacement Rate MM/Sec	Maximum Deformation In	Maximum Deformation MM	Maximum Load Lbs	Maximum Load N	Stiffness Lbs/In ($x10^3$)	Stiffness N/MM	Energy Loss Ratio A3/A1
HI 25 $0-C_1$	2	6									
HI 25 $0-C_1$		8	207.	87.7	.075/.075	1.91/1.91	34.5	154.	.409	71.6	.16
GS 28 $0-C_1$		6	.017	.00720	.070/.062	1.78/1.57	17.7	78.6	.205	35.8	.18
GS 28 $0-C_1$		8	192.	81.4	.075/.070	1.91/1.78	32.0	142.	.372	65.2	.10
SWE 23 C_1-C_2		8	.014	.0059	.069/.047	1.75/1.19	115.	512.	2340.	410.	.39
SWE 23 C_1-C_2		10	118.	49.9	.050/.041	1.27/1.04	112.	498.	2360.	413.	.59
EJ 41 C_1-C_2	3	6	.0225	.010	.0513	1.30	91.	405.	1820.	319.	.6
EJ 41 C_1-C_2	3	7	216.	91.4	.0355	.902	115.	508.	3450.	604.	.55
SWE 25 C_2-C_3		6	.043	.0182	.097/.074	2.46/1.88	42.0	187.	442.	77.5	.22
SWE 25 C_2-C_3		8	115.	48.7	.070/.064	1.78/1.63	58.4	260.	800.	140.	.34
GS 28 C_2-C_3	4	14	.019	.0080	x/.066	x/1.68	71.	316.	1690.	296.	.38
GS 28 $C_2 \cdot C_3$		16	227.	96.1	.096/.071	2.44/1.80	62.6	278.	690.	121.	.21
SWE 23 C_3-C_4		6	.018	.0076	.071/.061	1.8/1.55	35.9	160.	510.	89.4	.14
SWE 23 C_3-C_4		8	153.	64.7	.056/.048	1.42/1.22	32.1	143.	628.	110.	.24
PW 35 C_3-C_4	3	8	.046	.020	.0483	1.23	34.	151.	690.	121.	.48
PW 35 C_3-C_4	3	9	218.	92.3	.0468	1.19	53.	236.	1600.	280.	.46
EJ 41 C_3-C_4	3	11	.0207	.009	.0632	1.61	44.	196.	875.	153.	.32
EJ 41 C_3-C_4	3	12	228.	96.5	.0488	1.24	45.	200.	1200.	210.	.40

TABLE B6: STIFFNESS DATA SHEET

TEST - SHEAR $-R_x$ (A-P)

Specimen	Note	Test	Displacement Rate In/Min	Displacement Rate MM/Sec	Maximum Deformation In	Maximum Deformation MM	Maximum Load Lbs	Maximum Load N	Stiffness Lbs/In ($x10^3$)	Stiffness N/MM	Energy Loss Ratio A3/A1
SWE 25 C_4-C_5		14	.012	.0051	.072/.042	1.83/1.07	54.5	242.	1190.	209.	.50
SWE 25 C_4-C_5		16	108.	45.7	.058/.032	1.47/.813	43.5	193.	1280.	224.	.24
GS 28 C_4-C_5		14	.020	.0085	.070/.067	1.78/1.7	16.	71.	192.	33.7	.11
GS 28 C_4-C_5		16	200.	84.7	.053/.050	1.35/1.27	13.	58.	172.	30.2	.34
HI 25 C_4-C_5		6	.015	.0064	.069/.051	1.75/1.3	94.	418.	1880.	330.	.27
HI 25 C_4-C_5		8	139.	58.8	.054/.037	1.37/.94	80.	356.	2030.	355.	.12
SWE 23 C_5-C_6		10	.015	.0064	.068/.052	1.72/1.32	40.6	181.	854.	150.	.33
SWE 23 C_5-C_6	3	12	141.	80.7	.052/x	x	35.2	156.	1010.	177.	.06
PW 35 C_5-C_6	3	8	.051	.022	.0925	2.35	30.	133.	421.	736.	.65
PW 35 C_5-C_6	3	10	233.	98.4	.0823	2.09	37.5	167.	752.	132.	.43
EJ 41 C_5-C_6	3	9	.0228	.010	.065	1.65	27.	120.	638.	112.	.51
EJ 41 C_5-C_6	3	12	243.	102.	.0525	1.33	32.5	146.	750.	131.	.49
GS 28 C_6-C_7		10	.018	.0076	.065/.063	1.65/1.6	41.	182.	600.	105.	.16
GS 28 C_6-C_7		12	180.	76.2	.055/.048	1.4/1.22	32.	142.	613.	107.	.23
HI 25 C_6-C_7		6	.016	.0068	.070/.054	1.78/1.37	29.	129.	494.	86.5	.19
HI 25 C_6-C_7		8	161.	68.2	.048/.043	1.22/1.09	29.	129.	567.	99.2	.19

TABLE B6: STIFFNESS DATA SHEET

TEST - SHEAR $-R_x$ (A-P)

Specimen	Note	Test	Displacement Rate In/Min	Displacement Rate MM/Sec	Maximum Deformation In	Maximum Deformation MM	Maximum Load Lbs	Maximum Load N	Stiffness Lbs/In ($x10^3$)	Stiffness N/MM	Energy Loss Ratio A3/A1
SWE 23 C_7-T_1		8	.013	.0055	.069/.046	1.75/1.17	70.6	314.	1200.	210.	.46
SWE 23 C_7-T_1	3	10	167.	70.8	.051/x	1.3/x	67.7	301.	1140.	200.	.61
SWE 25 C_7-T_1		8	.017	.0072	.058/.052	1.47/1.31	126.	561.	2310.	405.	.49
SWE 25 C_7-T_1		10	107.	45.4	.047/.029	1.19/.681	12.4	55.	3900.	682.	.47
PW 35 C_7-T_1	3	7	.026	.011	.0658	1.67	39.	173.	715.	125.	.38
PW 35 C_7-T_1	3	10	234.	99.1	.0583	1.48	55.	245.	1130.	197.	.40
EJ 41 C_7-T_1	3	9	.044	.019	.0425	1.08	39.	173.	1160.	203.	.54
EJ 41 C_7-T_1	3	11	227.	96.1	.0385	.978	36.	160.	1000.	175.	.75

TABLE B7: STIFFNESS DATA SHEET

TEST - TORSION + M_z

Specimen	Note	Test	Displacement Rate Deg/Min	Displacement Rate Rad/Sec	Maximum Deformation Deg	Maximum Deformation Rad	Maximum Load In-Lbs	Maximum Load N-M	Stiffness In-Lbs/Deg	Stiffness N-M/Rad	Energy Loss Ratio A3/A1
GS 28 $0-C_1$		21	19.2	$5.59x10^{-3}$	9.64	.168	193.	858.	18.6	121.	.14
GS 28 $0-C_1$	6	23	6770.	1.97	7.81	.136	126.	560.	13.6	87.9	x
HI 25 $0-C_1$		21	20.8	$6.05x10^{-3}$	9.32	.163	77.4	344.	6.86	44.4	.24
HI 25 $0-C_1$		23	6760.	1.97	7.57	.132	45.2	201.	4.71	30.5	.08
SWE 23 C_1-C_2		12	18.2	$5.29x10^{-3}$	9.3	.16	7.	.79	.652	4.22	.24
SWE 23 C_1-C_2		14	6590.	1.92	8.4	.15	5.	.56	.663	4.29	.087
EJ 41 C_1-C_2		12	15.3	$4.4x10^{-3}$	9.9	.17	22.	2.5	3.	19.4	.73
EJ 41 C_1-C_2		13	14600.	4.2	8.0	.14	13.	1.5	5.5	35.6	.9
SWE 25 C_2-C_3		21	19.5	$5.66x10^{-3}$	9.8	.17	8.3	.95	.732	4.74	.38
SWE 25 C_2-C_3		24	6040.	1.76	6.6	.12	4.4	.5	.572	3.7	.46
GS 28 C_2-C_3		2	20.1	$5.85x10^{-3}$	10.1	.176	196.	22.1	20.	129.	.3
GS 28 C_2-C_3		4	8110.	2.36	8.4	.147	153.	17.3	19.2	124.	.081
SWE 23 C_3-C_4		14	20.8	$6.05x10^{-3}$	10.2	.178	108.	12.2	10.8	70.2	.29
SWE 23 C_3-C_4		16	7850.	2.28	8.5	.148	94.	10.6	11.7	75.9	.13
PW 35 C_3-C_4		16	20.7	$6.0x10^{-3}$	9.8	.17	148.	16.7	23.	149.	.47
PW 35 C_3-C_4		17	18900.	5.5	9.8	.17	156.	17.6	31.	201.	.42
EJ 41 C_3-C_4		24	20.1	$5.8x10^{-3}$	10.0	.17	226.	25.5	32.5	210.	.52
EJ 41 C_3-C_4		25	15600.	4.5	7.6	.13	172.	19.4	26.5	172.	.3

TABLE B7: STIFFNESS DATA SHEET

TEST - TORSION + M_z

Specimen	Note	Test	Displacement Rate Deg/Min	Rad/Sec	Maximum Deformation Deg	Rad	Maximum Load In-Lbs	N-M	Stiffness In-Lbs/Deg	N-M/Rad	Energy Loss Ratio A3/A1
SWE 25 C_4-C_5		6	18.3	$5.32x10^{-3}$	9.3	.162	230.	25.9	15.5	101.	.46
SWE 25 C_4-C_5		8	6720.	1.95	8.4	.147	200.	22.6	1.21	7.82	.2
GS 28 C_4-C_5		2	20.7	$6.02x10^{-3}$	10.1	.176	218.	24.6	14.8	95.7	.25
GS 28 C_4-C_5		4	8160.	2.37	8.43	.147	136.	15.4	5.6	36.2	.08
HI 25 C_4-C_5		14	21.1	$6.14x10^{-3}$	9.9	.173	227.	25.7	23.8	154.	.44
HI 25 C_4-C_5		16	7740.	2.25	8.0	.14	163.	18.5	19.3	125.	.26
SWE 23 C_5-C_6		14	18.8	$5.47x10^{-3}$	9.3	.162	128.	14.4	13.7	88.9	.28
SWE 23 C_5-C_6		16	6960.	2.02	8.7	.152	130.	14.7	14.4	93.3	.096
PW 35 C_5-C_6		17	21.	$6.1x10^{-3}$	10.	.17	92.	10.4	17.	110.	.58
PW 35 C_5-C_6		18	19500.	5.7	9.9	.17	100.	11.3	30.	194.	.6
EJ 41 C_5-C_6		22	20.4	$5.9x10^{-3}$	9.9	.17	290.	32.8	43.	278.	.46
EJ 41 C_5-C_6		23	15000.	4.4	7.3	.13	144.	16.3	34.	220.	.23
GS 28 C_6-C_7		14	21.5	$6.25x10^{-3}$	7.2	.126	178.	20.1	24.7	160.	.22
GS 28 C_6-C_7		16	77500.	2.25	4.72	.0824	89.4	10.1	20.5	132.	.17
HI 25 C_6-C_7		10	19.5	$5.68x10^{-3}$	4.07	.071	221.	25.	56.5	366.	.077
HI 25 C_6-C_7	6	12	66100.	1.92	4.19	.0731	8.94	1.01	2.03	13.1	x

TABLE B7: STIFFNESS DATA SHEET

TEST - TORSION + M_z

Specimen	Note	Test	Displacement Rate		Maximum Deformation		Maximum Load		Stiffness		Energy Loss Ratio A3/A1
			Deg/Min	Rad/Sec	Deg	Rad	In-Lbs	N-M	In-Lbs/ Deg	N-M/ Rad	
SWE 23 C_7-T_1		11	19.6	5.7×10^{-3}	9.4	.164	21.4	2.41	2.26	14.6	.14
SWE 23 C_7-T_1		12	6990.	2.07	7.96	.139	18.3	2.07	2.06	13.3	.031
SWE 25 C_7-T_1		11	20.4	5.93×10^{-3}	9.9	.173	28.6	3.23	2.41	15.6	.16
SWE 25 C_7-T_1		12	7220.	2.13	7.9	.138	17.2	1.94	1.58	10.2	.23
PW 35 C_7-T_1		16	20.7	5.5×10^{-3}	9.9	.17	190.	2.4	29.5	191.	.74
PW 35 C_7-T_1		17	18600.	5.5	9.8	.17	218.	24.6	64.	414.	.31
EJ 41 C_7-T_1		25	20.7	$6.\times10^{-3}$	8.1	.14	280.	31.6	50.	324.	.54
EJ 41 C_7-T_1		26	14700.	4.3	7.7	.13	270.	30.5	75.	486.	.29

TABLE B8: STIFFNESS DATA SHEET

TEST - TORSION - M_z

Specimen	Note	Test	Displacement Rate Deg/Min	Displacement Rate Rad/Sec	Maximum Deformation Deg	Maximum Deformation Rad	Maximum Load In-Lbs	Maximum Load N-M	Stiffness In-Lbs/Deg	Stiffness N-M/Rad	Energy Loss Ratio A3/A1
HI 25 $0-C_1$		22	20.2	5.88×10^{-3}	9.41	.64	95.7	426.	10.7	69.5	.26
HI 25 $0-C_1$		24	7220.	2.1	7.64	.133	58.8	262.	7.67	49.6	.03
GS 28 $0-C_1$		22	20.0	5.82×10^{-3}	9.76	.17	180.	801.	17.5	114.	.2
GS 28 $0-C_1$	6	24	6610.	1.92	7.54	.132	105.	427.	17.	110.	x
SWE 23 C_1-C_2		11	19.	5.5×10^{-3}	9.7	.17	9.7	1.1	.838	5.42	.32
SWE 23 C_1-C_2		13	6750.	1.96	8.6	.15	12.7	1.44	1.1	7.1	.31
EJ 41 C_1-C_2		11	15.6	4.5×10^{-3}	10.	.17	46.	5.2	6.	38.8	.81
EJ 41 C_1-C_2		14	17400.	5.1	9.8	.17	32.	3.6	8.5	55.	.6
SWE 25 C_2-C_3		22	19.3	5.6×10^{-3}	9.6	.17	7.2	.82	.77	4.98	.54
SWE 25 C_2-C_3		23	5870.	1.71	6.6	.12	4.3	.47	.57	3.69	.25
GS 28 C_2-C_3		1	20.4	5.93×10^{-3}	10.1	.18	157.	17.7	16.1	104.	.5
GS 28 C_2-C_3		3	7920.	2.3	8.4	.15	110.	12.4	12.	77.9	.12
SWE 23 C_3-C_4		13	21.	6.11×10^{-3}	10.2	.18	131.9	14.9	13.3	86.2	.44
SWE 23 C_3-C_4		15	7410.	2.15	8.1	.14	104.	11.8	11.	71.2	.09
PW 35 C_3-C_4		15	20.	5.8×10^{-3}	9.9	.17	136.	15.4	23.	149.	.45
PW 35 C_3-C_4		18	21000.	6.1	10.	.17	184.	20.8	28.	181.	.35
EJ 41 C_3-C_4		23	30.	8.7×10^{-3}	10.	.17	216.	24.4	30.5	197.	.63
EJ 41 C_3-C_4		26	15000.	4.4	7.7	.13	140.	15.8	25.	162.	.47

TABLE B8: STIFFNESS DATA SHEET

TEST - TORSION $-M_z$

Specimen	Note	Test	Displacement Rate Deg/Min	Displacement Rate Rad/Sec	Maximum Deformation Deg	Maximum Deformation Rad	Maximum Load In-Lbs	Maximum Load N-M	Stiffness In-Lbs/Deg	Stiffness N-M/Rad	Energy Loss Ratio A3/A1
SWE 25 C_4-C_5		5	18.4	5.35×10^{-3}	9.4	.16	231.	26.1	5.64	36.5	.38
SWE 25 C_4-C_5		7	7040.	2.05	8.6	.15	197.	22.2	22.3	144.	.095
GS 28 C_4-C_5		1	19.2	5.58×10^{-3}	10.1	.176	182.	20.5	21.7	140.	.36
GS 28 C_4-C_5		3	7480.	2.18	8.	.14	61.6	6.96	13.1	85.	.005
HI 25 C_4-C_5		13	20.8	6.65×10^{-3}	9.8	.17	153.	17.3	13.	84.	.30
HI 25 C_4-C_5		15	7490.	2.18	8.	.14	72.1	8.15	7.07	45.8	.075
SWE 23 C_5-C_6		13	18.9	5.5×10^{-3}	9.4	.164	116.	13.1	11.2	72.7	.33
SWE 23 C_5-C_6		15	6880.	2.	8.68	.151	81.3	9.16	8.69	56.2	.68
PW 35 C_5-C_6		16	21.	6.1×10^{-3}	10.	.17	150.	16.9	24.	220.	.55
PW 35 C_5-C_6		19	18900.	5.5	9.7	.17	176.	19.9	35.	227.	.53
EJ 41 C_5-C_6		21	20.4	5.9×10^{-3}	9.8	.17	280.	31.6	32.5	210.	.71
EJ 41 C_5-C_6		24	16200.	4.7	7.7	.13	260.	29.4	34.	220.	.23
GS 28 C_6-C_7		13	23.2	6.75×10^{-3}	7.8	.136	219.	24.7	30.3	196.	.17
GS 28 C_6-C_7	6	15	7550.	2.2	4.6	.0803	109.	12.3	30.5	198.	x
HI 25 C_6-C_7		9	20.6	5.99×10^{-3}	4.1	.072	164.	18.7	39.7	257.	.041
HI 25 C_6-C_7		11	7490.	2.18	4.12	.072	89.4	10.2	24.2	157.	.04

TABLE B8: STIFFNESS DATA SHEET

TEST - TORSION $-M_z$

Specimen	Note	Test	Displacement Rate Deg/Min	Displacement Rate Rad/Sec	Maximum Deformation Deg	Maximum Deformation Rad	Maximum Load In-Lbs	Maximum Load N-M	Stiffness In-Lbs/Deg	Stiffness N-M/Rad	Energy Loss Ratio A3/A1
SWE 23 C_7-T_1		11	16.9	4.9×10^{-3}	9.8	.17	21.	2.37	2.3	14.9	.28
SWE 23 C_7-T_1		13	7320.	2.13	8.1	.14	22.3	2.52	2.52	16.3	.14
SWE 25 C_7-T_1		11	20.6	5.99×10^{-3}	9.98	.17	31.	3.5	3.36	21.8	.28
SWE 25 C_7-T_1		13	7600.	2.21	8.1	.14	19.6	2.21	1.96	12.7	.052
PW 35 C_7-T_1		15	20.4	5.9×10^{-3}	9.7	.17	230.	26.	32.	207.	.68
PW 35 C_7-T_1		18	37200.	10.8	9.8	.17	234.	26.4	53.3	345.	.41
EJ 41 C_7-T_1		24	20.4	5.9×10^{-3}	8.	.14	260.	29.4	50.	324.	.65
EJ 41 C_7-T_1		27	16200.	4.7	7.7	.13	270.	30.5	50.	324.	.41

TABLE B9: STIFFNESS DATA SHEET

TEST - BENDING $+M_y$ (A-P)

Specimen	Note	Test	Displacement Rate Deg/Min	Displacement Rate Rad/Sec	Maximum Deformation Deg	Maximum Deformation Rad	Maximum Load In-Lbs	Maximum Load N-M	Stiffness In-Lbs/ Deg	Stiffness N-M/ Rad	Energy Loss Ratio A3/A1
HI 25 $0\text{-}C_1$		17	1.16	$.337\times10^{-3}$	3.115	.055	1.53	.173	1.48	9.58	.31
HI 25 $0\text{-}C_1$		19	3070.	1.44	5.65	.099	45.	5.08	.16	1.06	.92
GS 28 $0\text{-}C_1$		17	1.16	$.337\times10^{-3}$	3.115	.055	4.88	.551	.362	2.28	.32
GS 28 $0\text{-}C_1$		19	4930.	.88	3.14	.055	12.2	1.38	10.5	68.4	.29
SWE 23 $C_1\text{-}C_2$		19	1.06	$.308\times10^{-3}$	2.99/2.68	.052/.047	.78	.088	.26	1.67	.081
SWE 23 $C_1\text{-}C_2$		21	1540.	.448	3.18/2.70	.056/.047	1.06	.120	2.86	18.5	.44
EJ 41 $C_1\text{-}C_2$		20	1.41	$.41\times10^{-3}$	2.80	.049	6.0	.68	20.0	130.	.55
EJ 41 $C_1\text{-}C_2$		21	4100.	1.19	2.75	.048	4.0	.45	65.0	424.	.86
SWE 25 $C_2\text{-}C_3$		13	2.53	$.736\times10^{-3}$	2.75/3.23	.048/.056	8.5	.96	2.2	14.3	.26
SWE 25 $C_2\text{-}C_3$		16	7440.	2.16	3.91/4.84	.068/.084	19.3	2.18	2.3	14.9	.59
GS 28 $C_2\text{-}C_3$		21	1.16	$.337\times10^{-3}$	2.93/2.88	.050/.050	19.9	2.25	6.2	40.1	.34
GS 28 $C_2\text{-}C_3$		23	1660.	.483	3.02/2.82	.052/.049	29.7	3.36	7.7	49.9	.26
SWE 23 $C_3\text{-}C_4$		21	1.27	$.369\times10^{-3}$	3.00/3.14	.052/.055	.94	1.06	0.2	1.3	.30
SWE 23 $C_3\text{-}C_4$	3	23	1900.	.552	3.17/x	.055/x	.89	.101	2.17	14.	.33
PW 35 $C_3\text{-}C_4$	3	24	1.53	$.45\times10^{-3}$	3.00	.052	17.0	1.92	5.25	34.	.57
PW 35 $C_3\text{-}C_4$	3	27	4430.	1.29	3.03	.053	20.0	2.26	8.75	56.6	.30
EJ 41 $C_3\text{-}C_4$	3	19	1.52	$.44\times10^{-3}$	2.95	.051	7.5	.85	3.75	24.3	.56
EJ 41 $C_3\text{-}C_4$	3	22	4400.	1.28	2.88	.050	13.0	1.47	4.5	29.1	.85

TABLE B9: STIFFNESS DATA SHEET

TEST - BENDING $+M_y$ (A-P)

Specimen	Note	Test	Displacement Rate Deg/Min	Displacement Rate Rad/Sec	Maximum Deformation Deg	Maximum Deformation Rad	Maximum Load In-Lbs	Maximum Load N-M	Stiffness In-Lbs/Deg	Stiffness N-M/Rad	Energy Loss Ratio A3/A1
SWE 25 C_4-C_5	5	21									
SWE 25 C_4-C_5	5	23									
GS 28 C_4-C_5	6	21	1.14	$.332 \times 10^{-3}$	2.97/2.84	.052/.050	11.9	1.35	1.09	7.04	x
GS 28 C_4-C_5		22	1750.	.510	3.06/2.92	.053/.051	6.04	.682	1.18	7.62	.053
HI 25 C_4-C_5		17	1.32		2.96/2.75		3.2		.85	5.63	.27
HI 25 C_4-C_5		19	1780.	.517	2.98/2.96	.052/.052	5.66	.639	.96	6.23	.16
SWE 23 C_5-C_6		21	1.17	$.340 \times 10^{-3}$	3.04/3.04	.053/.053	3.22	.138	.31	2.03	.26
SWE 23 C_5-C_6	5										
PW 35 C_5-C_6	1										
PW 35 C_5-C_6	1										
EJ 41 C_5-C_6	3	17	1.64	$.48 \times 10^{-3}$	3.23	.056	58.	6.55	25.5	165.	.60
EJ 41 C_5-C_6	3	20	4500.	1.31	2.75	.048	47.5	5.37	18.0	117.	.65
GS 28 C_6-C_7		21	1.11	$.323 \times 10^{-3}$	2.93/2.80	.051/.049	13.2	1.49	3.05	19.8	.16
GS 28 C_6-C_7		23	1670.	.486	3.19/2.87	.056/.050	14.1	1.60	2.45	15.9	.41
HI 25 C_6-C_7	1										
HI 25 C_6-C_7	1										

TABLE B9: STIFFNESS DATA SHEET

TEST - BENDING $+M_y$ (A-P)

Specimen	Note	Test	Displacement Rate Deg/Min	Displacement Rate Rad/Sec	Maximum Deformation Deg	Maximum Deformation Rad	Maximum Load In-Lbs	Maximum Load N-M	Stiffness In-Lbs/Deg	Stiffness N-M/Rad	Energy Loss Ratio A3/A1
SWE 23 C_7-T_1		14	1.09	$.317\times10^{-3}$	2.85/2.73	.049/.047	5.36	.605	0.663	4.292	.75
SWE 23 C_7-T_1	5	16									
SWE 25 C_7-T_1		14	1.21	$.352\times10^{-3}$	3.03/3.03	.053/.053	6.89	.778	1.69	11.	.69
SWE 25 C_7-T_1		16	1500.	.437	2.87/2.39	.050/.042	6.01	.679	1.79	11.6	69
PW 35 C_7-T_1	3	23	1.54	$.45\times10^{-3}$	2.92	.051	25.	2.82	13.5	87.4	.59
PW 35 C_7-T_1	3	26	4300.	1.26	2.98	.052	36.5	4.12	10.0	64.7	.52
EJ 41 C_7-T_1	3	21	1.52	$.44\times10^{-3}$	2.98	.052	59.0	6.67	40.0	259.	.55
EJ 41 C_7-T_1	3	22	4650.	1.35	2.53	.044	40.	4.52	26.5	172.	.35

TABLE B10: STIFFNESS DATA SHEET

TEST - BENDING $-M_y$ (A-P)

Specimen	Note	Test	Displacement Rate Deg/Min	Displacement Rate Rad/Sec	Maximum Deformation Deg	Maximum Deformation Rad	Maximum Load In-Lbs	Maximum Load N-M	Stiffness In-Lbs/Deg	Stiffness N-M/Rad	Energy Loss Ratio A3/A1
HI 25 $0-C_1$		18	1.17	$.341\times10^{-3}$	3.13	.55	1.8	.203	.276	1.79	.63
HI 25 $0-C_1$		20	660	.192	5.45	.85	45.1	201.	3.30	20.1	.81
GS 28 $0-C_1$		18	1.23	$.358\times10^{-3}$	3.13	.55	5.03	.568	.724	4.70	.37
GS 28 $0-C_1$	6	20	4880.	1.42	3.15	.55	18.2	80.8	.226	1.46	x
SWE 23 C_1-C_2		20	1.32	$.384\times10^{-3}$	3.02/2.90	.053/.051	7.88	.89	2.61	16.9	.45
SWE 23 C_1-C_2		22	1570.	.458	3.07/2.75	.054/.048	8.90	1.01	3.17	20.5	.43
EJ 41 C_1-C_2	3	19	1.44	$.42\times10^{-3}$	2.80	.049	7.5	.85	5.5	35.6	.79
EJ 41 C_1-C_2	3	22	4100.	1.19	3.70	.065	16.5	1.86	8.5	55.0	.30
SWE 25 C_2-C_3		14	2.55	$.741\times10^{-3}$	2.76/3.24	.048/.057	25.1	2.84	8.28	53.6	.33
SWE 25 C_2-C_3		15	6890.	2.00	3.70/4.48	.065/.079	42.3	4.79	7.20	46.6	.47
GS 28 C_2-C_3		22	1.10	$.319\times10^{-3}$	2.85/2.76	.050/.048	82.5	9.35	28.1	182.	.33
GS 28 C_2-C_3		24	1670.	.484	3.02/2.78	.053/.049	87.8	9.95	31.1	201.	.32
SWE 23 C_3-C_4		22	1.32	$.384\times10^{-3}$	3.02/3.36	.053/.059	4.37	.49	1.27	8.21	.33
SWE 23 C_3-C_4		24	2080.	.605	3.03/3.40	.053/.059	5.79	.65	1.75	11.3	.25
PW 35 C_3-C_4	3	25	1.53	$.45\times10^{-3}$	3.05	.053	26.5	2.99	11.0	71.2	.57
PW 35 C_3-C_4	3	26	4580.	1.33	3.00	.052	32.5	3.67	15.0	97.1	.48
EJ 41 C_3-C_4	3	20	1.52	$.44\times10^{-3}$	2.93	.051	26.0	2.94	11.0	71.2	.72
EJ 41 C_3-C_4	3	21	4280.	1.24	3.25	.057	35.0	3.95	16.5	107.	.66

TABLE B10: STIFFNESS DATA SHEET

TEST - BENDING $-M_y$ (A-P)

Specimen	Note	Test	Displacement Rate Deg/Min	Displacement Rate Rad/Sec	Maximum Deformation Deg	Maximum Deformation Rad	Maximum Load In-Lbs	Maximum Load N-M	Stiffness In-Lbs/Deg	Stiffness N-M/Rad	Energy Loss Ratio A3/A1
SWE 25 C_4-C_5		22	1.28	$.372\times10^{-3}$	3.02/3.21	.053/.056	2.07	.234	.64	4.15	.64
SWE 25 C_4-C_5		24	1820.	.531	3.04/3.4	.053/.059	5.78	.653	.63	4.05	.4
GS 28 C_4-C_5		23	.88	$.26\times10^{-3}$	2.96/2.20	.052/.038	32.	3.61	10.3	66.7	.39
GS 28 C_4-C_5		24	1230.	.357	3.03/2.04	.053/.036	35.	3.95	11.7	75.9	.41
HI 25 C_4-C_5		18	1.18	$.344\times10^{-3}$	2.87/3.00	.050/.052	17.9	2.02	6.23	40.3	.35
HI 25 C_4-C_5		20	1730.	.502	2.88/2.93	.050/.051	23.	2.6	7.49	48.5	.28
SWE 23 C_5-C_6		22	1.19	$.346\times10^{-3}$	3.02/3.07	.053/.054	6.14	.696	1.9	12.3	.31
SWE 23 C_5-C_6		24	1920.	.559	3.04/3.30	.053/.058	8.14	.920	2.49	16.1	.25
PW 35 C_5-C_6	1										
PW 35 C_5-C_6	1										
EJ 41 C_5-C_6	3	18	1.71	$.50\times10^{-3}$	2.58	.045	65.0	7.34	28.5	185.	.61
EJ 41 C_5-C_6	3	19	4730.	1.37	2.90	.051	85.0	9.6	37.5	243.	.49
GS 28 C_6-C_7		22	1.1	$.320\times10^{-3}$	2.97/2.76	.052/.048	48.3	5.46	17.3	112.	.36
GS 28 C_6-C_7		24	1620.	.471	2.98/2.83	.052/.049	47.6	5.38	14.7	95.1	.42
HI 25 C_6-C_7	1										
HI 25 C_6-C_7	1										

TABLE B10: STIFFNESS DATA SHEET

TEST - BENDING $-M_y$ (A-P)

Specimen	Note	Test	Displacement Rate Deg/Min	Displacement Rate Rad/Sec	Maximum Deformation Deg	Maximum Deformation Rad	Maximum Load In-Lbs	Maximum Load N-M	Stiffness In-Lbs/Deg	Stiffness N-M/Rad	Energy Loss Ratio A3/A1
SWE 23 C_7-T_1		14	1.11	$.323\times10^{-3}$	2.83/2.81	.050/.049	2.0	.226	2.45	15.8	.56
SWE 23 C_7-T_1		15	5140.	1.49	2.89/2.72	.051/.048	6.56	.743	1.37	8.84	.25
SWE 25 C_7-T_1		15	1.24	$.361\times10^{-3}$	3.03/3.10	.053/.054	3.31	.374	.073	4.73	.44
SWE 25 C_7-T_1		17	1750.	.518	3.09/2.89	.054/.050	5.45	.616	1.52	9.85	.45
PW 35 C_7-T_1	3	24	1.50	$.44\times10^{-3}$	2.88	.050	16.0	1.81	14.5	93.9	.78
PW 35 C_7-T_1	3	25	4250.	1.24	2.82	.049	17.5	1.98	7.3	47.3	.52
EJ 41 C_7-T_1	3	20	1.5	$.44\times10^{-3}$	3.0	.052	41.5	4.69	20.0	130.	.37
EJ 41 C_7-T_1	3	23	4280.	1.37	2.50	.044	26.0	2.94	10.5	68.	.53

TABLE B11: STIFFNESS DATA SHEET

TEST - BENDING $+M_x$ (Lat)

Specimen	Note	Test	Displacement Rate Deg/Min	Displacement Rate Rad/Sec	Maximum Deformation Deg	Maximum Deformation Rad	Maximum Load In-Lbs	Maximum Load N-M	Stiffness In-Lbs/Deg	Stiffness N-M/Rad	Energy Loss Ratio A3/A1
HI 25 $0-C_1$		13	1.16	$.338\times10^{-3}$	3.12	.055	121.	13.7	36.2	234	.27
HI 25 $0-C_1$	6	15	4820.	1.40	3.13	.055	156.	17.6	35.6	232	x
GS 28 $0-C_1$		13	1.67	$.339\times10^{-3}$	3.12	.055	62.	7.05	15.1	97.6	.24
GS 28 $0-C_1$	6	15	4770.	1.39	3.13	.055	92.7	10.5	17.3	112	x
SWE 23 C_1-C_2		15	1.16	$.337\times10^{-3}$	2.99/2.90	.052/.051	5.70	.644	1.48	9.57	.25
SWE 23 C_1-C_2		17	1890.	.548	3.06/3.17	.053/.055	10.0	1.13	2.59	16.8	.45
EJ 41 C_1-C_2	3	15	1.12	$.33\times10^{-3}$	3.05	.053	38.5	4.35	15.3	90.0	.73
EJ 41 C_1-C_2	3	18	4130.	1.20	2.95	.051	58.0	6.55	16.5	107.	.60
SWE 25 C_2-C_3		17	2.59	$.753\times10^{-3}$	2.75/3.31	.048/.057	17.3	1.95	4.25	27.5	.53
SWE 25 C_2-C_3		19	6850.	1.99	3.69/4.54	.064/.078	35.6	4.02	6.97	45.1	.65
GS 28 C_2-C_3		17	1.04	$.302\times10^{-3}$	2.82/2.58	.049/.045	9.75	1.10	2.48	16.1	.20
GS 28 C_2-C_3		19	1770.	.515	3.08/3.02	.054/.053	11.8	1.33	2.48	16.1	.18
SWE 23 C_3-C_4		17	1.21	$.352\times10^{-3}$	2.99/3.01	.052/.053	6.01	.679	1.71	11.1	.22
SWE 23 C_3-C_4		19	1660.	.482	3.00/3.10	.052/.054	9.36	1.06	2.60	16.9	.3
PW 35 C_3-C_4	3	21	1.4	$.41\times10^{-3}$	2.85	.050	4.0	.45	.75	4.9	.64
PW 35 C_3-C_4	3	22	4200.	1.22	2.75	.048	13.0	1.47	7.5	48.6	.47
EJ 41 C_3-C_4	3	15	1.5	$.44\times10^{-3}$	2.88	.050	62.5	7.06	29.0	188.	.51
EJ 41 C_3-C_4	3	16	4400.	1.28	2.90	.051	80.0	9.04	41.0	265.	.36

TABLE B11: STIFFNESS DATA SHEET

TEST - BENDING $+M_x$ (Lat)

Specimen	Note	Test	Displacement Rate Deg/Min	Displacement Rate Rad/Sec	Maximum Deformation Deg	Maximum Deformation Rad	Maximum Load In-Lbs	Maximum Load N-M	Stiffness In-Lbs/Deg	Stiffness N-M/Rad	Energy Loss Ratio A3/A1
SWE 25 C_4-C_5		17	.070	$.204 \times 10^{-3}$	3.00/1.76	.052/.031	0.69	.078	.358	2.32	.2
SWE 25 C_4-C_5		19	1490.	.432	3.04/2.50	.053/.044	1.09	.123	.315	2.04	.24
GS 28 C_4-C_5	2	17									
GS 28 C_4-C_5		20	1130.	.330	3.09/1.96	.054/.034	25.8	2.91	6.05	39.2	.068
HI 25 C_4-C_5		21	1.14	$.324 \times 10^{-3}$	2.86/2.86	.050/.050	3.15	.356	0.925	5.99	.23
HI 25 C_4-C_5		23	1800.	.523	2.99/2.98	.052/.052	5.05	.57	.094	6.06	.4
SWE 23 C_5-C_6		17	1.08	$.314 \times 10^{-3}$	3.05/2.73	.053/.048	4.13	.467	1.33	8.62	.23
SWE 23 C_5-C_6		19	1680.	.489	3.06/3.16	.053/.055	7.91	.894	2.41	15.6	.13
PW 35 C_5-C_6	1										
PW 35 C_5-C_6	1										
EJ 41 C_5-C_6	3	14	1.48	$.43 \times 10^{-3}$	2.60	.045	65.0	7.34	32.0	207.	.61
EJ 41 C_5-C_6	3	15	3830.	1.11	2.50	.044	100.	11.30	52.5	340.	.42
GS 28 C_6-C_7		19	1.14	$.33 \times 10^{-3}$	2.95/2.84	.051/.049	11.9	1.35	3.16	20.4	.21
GS 28 C_6-C_7		21	1770.	.514	3.16/2.84	.055/.05	19.	2.14	6.04	39.1	.21
HI 25 C_6-C_7	1										
HI 25 C_6-C_7	1										

TABLE B11: STIFFNESS DATA SHEET

TEST - BENDING $+M_x$ (Lat)

Specimen	Note	Test	Displacement Rate Deg/Min	Displacement Rate Rad/Sec	Maximum Deformation Deg	Maximum Deformation Rad	Maximum Load In-Lbs	Maximum Load N-M	Stiffness In-Lbs/Deg	Stiffness N-M/Rad	Energy Loss Ratio A3/A1
SWE 23 C_7-T_1		17	1.13	$.327 \times 10^{-3}$	2.85/2.82	.050/.050	3.56	.402	1.19	7.71	.25
SWE 23 C_7-T_1	3	18	7210.	2.10	2.86/x	.049/x	2.35	.265	.411	2.66	.88
SWE 25 C_7-T_1		18	1.0	$.291 \times 10^{-3}$	3.02/2.50	.053/.044	2.62	.296	.98	6.31	.12
SWE 25 C_7-T_1		20	1770.	.515	3.08/2.92	.054/.051	7.43	.839	2.29	14.8	.25
PW 35 C_7-T_1	3	20	1.44	$.42 \times 10^{-3}$	2.90	.051	14.5	1.64	10.5	68.	.58
PW 35 C_7-T_1	3	21	4500.	1.31	2.88	.050	20.0	2.26	20.	130.	.55
EJ 41 C_7-T_1	3	16	1.32	$.38 \times 10^{-3}$	1.80	.031	68.5	7.74	60.	388.	.62
EJ 41 C_7-T_1	3	18	4130.	1.20	1.88	.033	71.0	8.02	64.	414.	.46

TABLE B12: STIFFNESS DATA SHEET

TEST - BENDING $-M_x$ (Lat)

Specimen	Note	Test	Displacement Rate Deg/Min	Displacement Rate Rad/Sec	Maximum Deformation Deg	Maximum Deformation Rad	Maximum Load In-Lbs	Maximum Load N-M	Stiffness In-Lbs/Deg	Stiffness N-M/Rad	Energy Loss Ratio A3/A1
HI 25 $0-C_1$		14	1.17	$.342 \times 10^{-3}$	3.14	.055	60.4	6.82	15.0	97.2	.25
HI 25 $0-C_1$		16	4385	1.42	3.17	.056	73.5	8.3	17.9	116.	.003
GS 28 $0-C_1$		14	1.17	$.34 \times 10^{-3}$	3.13	.055	31.16	3.52	5.94	38.4	.23
GS 28 $0-C_1$		16	4965	1.45	3.16	.055	45	5.08	7.62	49.4	.01
SWE 23 C_1-C_2		16	1.16	$.34 \times 10^{-3}$	3.02/2.92	.053/.051	30.7	3.47	9.44	61.	.43
SWE 23 C_1-C_2		18	1940.	.565	3.06/3.31	.053/.058	30.4	3.43	9.41	60.9	.31
EJ 41 C_1-C_2	3	16	1.41	$.41 \times 10^{-3}$	3.0	.052	50.0	5.65	27.50	178.	.66
EJ 41 C_1-C_2	3	17	4050.	1.18	3.15	.055	55.0	6.21	41.	259.	.42
SWE 25 C_2-C_3		18	2.53	$.737 \times 10^{-3}$	2.72/3.34	.047/.058	4.39	.496	.715	4.63	.72
SWE 25 C_2-C_3		20	7710.	2.25	3.89/4.89	.067/.084	16.2	1.83	2.12	13.7	.62
GS 28 C_2-C_3	3	18	1.18	$.343 \times 10^{-3}$	2.92/x	.051/x	30.7	3.47	9.48	61.4	.4
GS 28 C_2-C_3		20	1840.	.534	3.06/3.01	.053/.053	42.7	4.83	12.3	79.7	.39
SWE 23 C_3-C_4		18	1.25	$.364 \times 10^{-3}$	3.04/3.19	.053/.056	6.29	.711	1.73	11.2	.50
SWE 23 C_3-C_4		20	1800.	.524	3.06/3.23	.053/.056	8.93	1.01	2.49	16.1	.37
PW 35 C_3-C_4	3	20	1.5	$.44 \times 10^{-3}$	2.85	.050	61.5	6.95	37.5	243.	.70
PW 35 C_3-C_4	3	23	4200.	1.22	2.85	.050	86.0	9.72	55.	356.	.38
EJ 41 C_3-C_4	3	14	1.6	$.47 \times 10^{-3}$	2.75	.048	65.0	7.34	30.	194.	.47
EJ 41 C_3-C_4	3	18	4400.	1.28	3.00	.052	80.0	9.04	45.	291.	.34

TABLE B12: STIFFNESS DATA SHEET

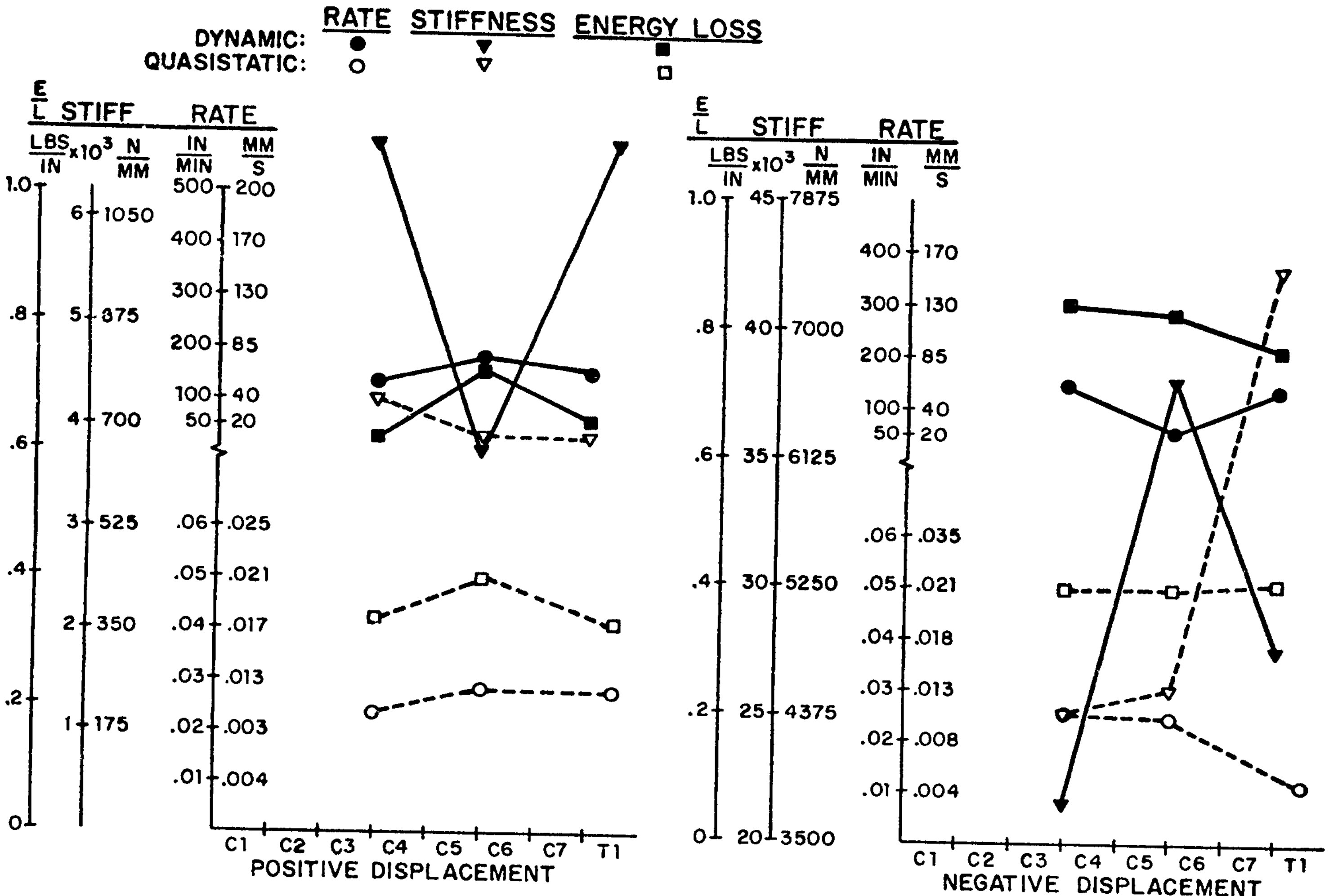
TEST - BENDING $-M_x$ (Lat)

Specimen	Note	Test	Displacement Rate Deg/Min	Displacement Rate Rad/Sec	Maximum Deformation Deg	Maximum Deformation Rad	Maximum Load In-Lbs	Maximum Load N-M	Stiffness In-Lbs/Deg	Stiffness N-M/Rad	Energy Loss Ratio A3/A1
SWE 25 C_4-C_5		18	1.10	$.320x10^{-3}$	2.99/2.67	.052/.046	2.08	.235	.730	4.73	.38
SWE 25 C_4-C_5	3	20	1770.	.516	3.0/x	.052	3.59	.406	.727	4.70	.06
GS 28 C_4-C_5		18	1.16	$.338x10^{-3}$	2.95	.052	30.3	3.42	7.37	47.7	.2
GS 28 C_4-C_5		19	1770.	.515	3.01	.053	35.6	4.02	10.2	66.1	.36
HI 25 C_4-C_5		22	1.16	$.338x10^{-3}$	2.77/2.89	.048/.050	8.61	.973	2.61	16.9	.63
HI 25 C_4-C_5		24	1740.	.506	2.84/2.90	.050/.051	12.4	1.4	3.95	25.6	.38
SWE 23 C_5-C_6		18	1.15	$.335x10^{-3}$	3.02/2.92	.053/.051	7.03	.79	2.21	14.3	.42
SWE 23 C_5-C_6		20	1710.	.498	3.04/3.38	.053/.059	8.81	1.00	2.57	16.7	.19
PW 35 C_5-C_6	1										
PW 35 C_5-C_6	1										
EJ 41 C_5-C_6	3	13	1.48	$.43x10^{-3}$	2.95	.051	60.0	6.78	42.	272.	.66
EJ 41 C_5-C_6	3	16	4280.	1.24	2.75	.048	34.5	3.90	41.	265.	.64
GS 28 C_6-C_7		18	1.13	$.329x10^{-3}$	2.95/2.84	.051/.050	31.2	3.52	10.2	66.	.32
GS 28 C_6-C_7		20	1650.	.479	3.01/2.86	.053/.050	5.01	.566	1.64	10.6	.22
HI 25 C_6-C_7	1										
HI 25 C_6-C_7	1										

TABLE B12: STIFFNESS DATA SHEET

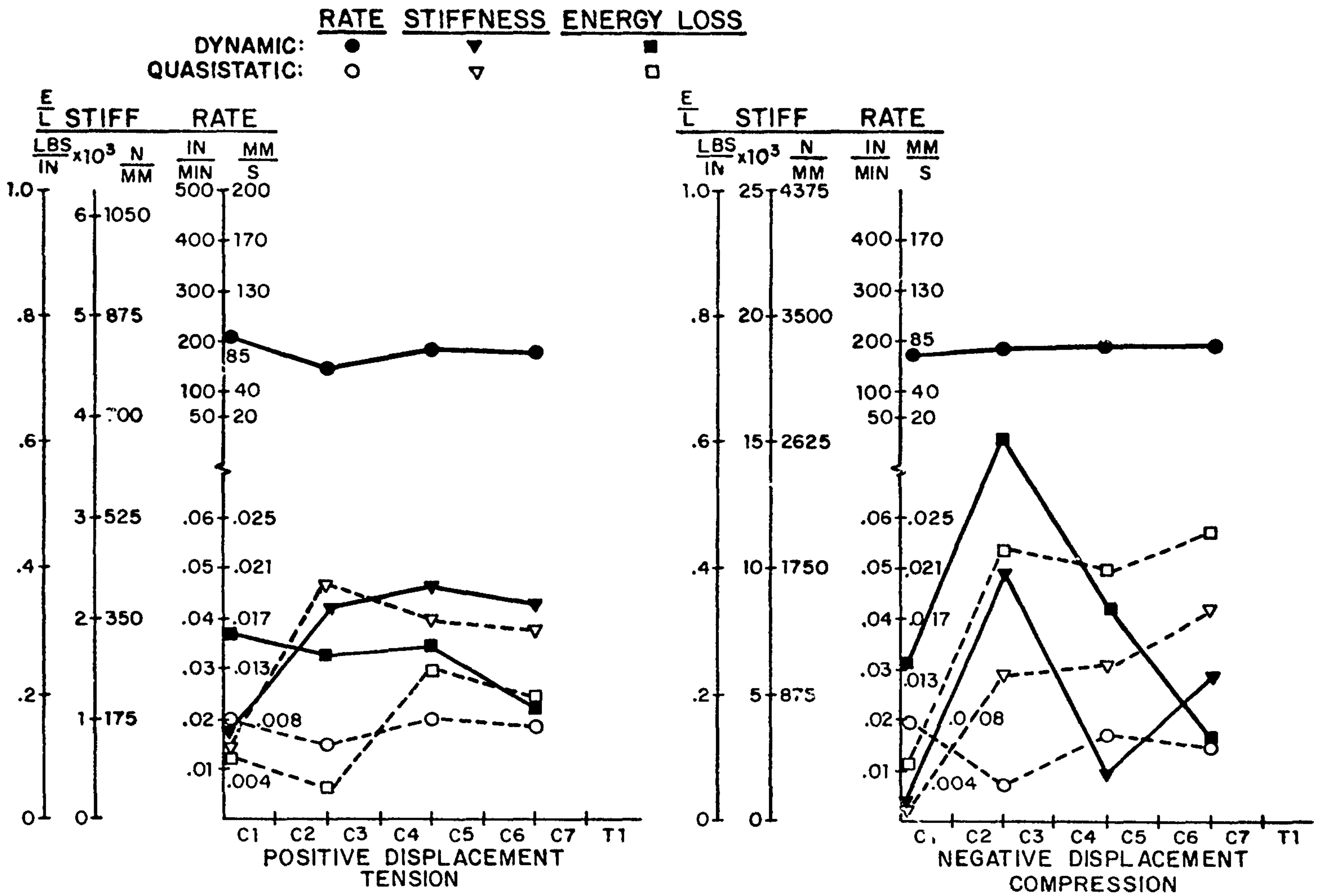
TEST - BENDING $-M_x$ (Lat)

Specimen	Note	Test	Displacement Rate Deg/Min	Displacement Rate Rad/Sec	Maximum Deformation Deg	Maximum Deformation Rad	Maximum Load In-Lbs	Maximum Load N-M	Stiffness In-Lbs/Deg	Stiffness N-M/Rad	Energy Loss Ratio A3/A1
SWE 23 C_7-T_1		17	1.14	$.333 \times 10^{-3}$	2.85/2.73	.050/.048	.785	.089	.137	.884	.27
SWE 23 C_7-T_1		19	6400.	1.86	2.84/2.61	.049/.045	.61	.066	.162	1.05	.087
SWE 25 C_7-T_1		19	1.11	$.323 \times 10^{-3}$	3.10/2.78	.054/.049	6.56	.741	2.06	13.3	.38
SWE 25 C_7-T_1		21	1920.	.560	2.98/3.44	.052/.060	8.77	.991	2.60	16.9	.30
PW 35 C_7-T_1	3	19	1.44	$.42 \times 10^{-3}$	2.8	.049	33.0	3.73	21.5	139.	.66
PW 35 C_7-T_1	3	22	4500.	1.31	2.88	.050	42.5	4.80	23.3	151.	.40
EJ 41 C_7-T_1	3	15	1.14	$.33 \times 10^{-3}$	2.95	.051	53.5	6.04	30.0	194.	.59
EJ 41 C_7-T_1	3	19	4500.	1.31	2.0	.035	18.25	2.06	21.0	136.	.42



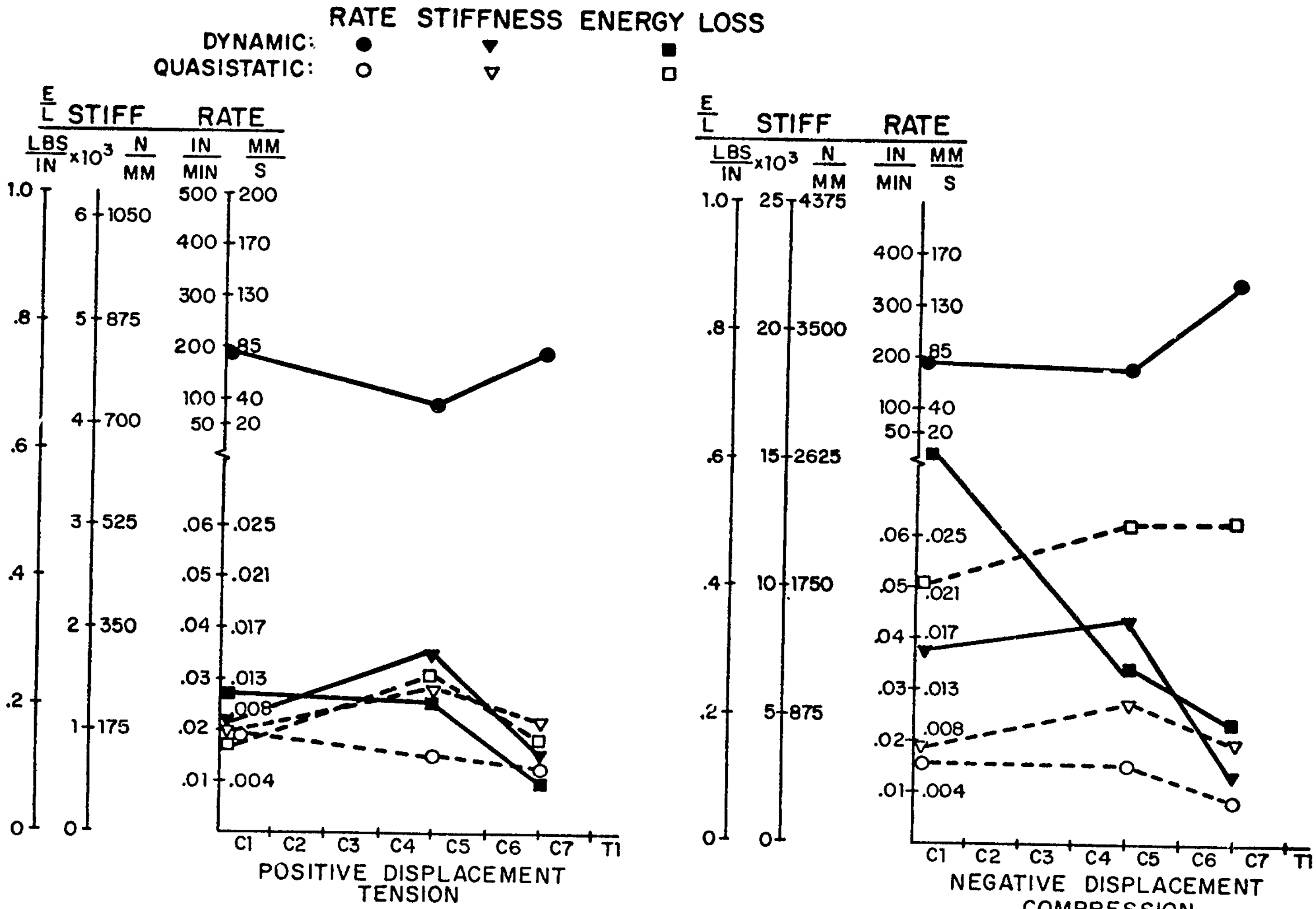
SPECIMEN-**EJ 41** TEST-**AXIAL ±Z**

FIGURE B1: DATA FROM STIFFNESS TEST ANALYSIS



SPECIMEN- GS 28 TEST- AXIAL ± Z

FIGURE B1: DATA FROM STIFFNESS TEST ANALYSIS



SPECIMEN-HI 25 TEST-AXIAL ±Z

FIGURE B1: DATA FROM STIFFNESS TEST ANALYSIS

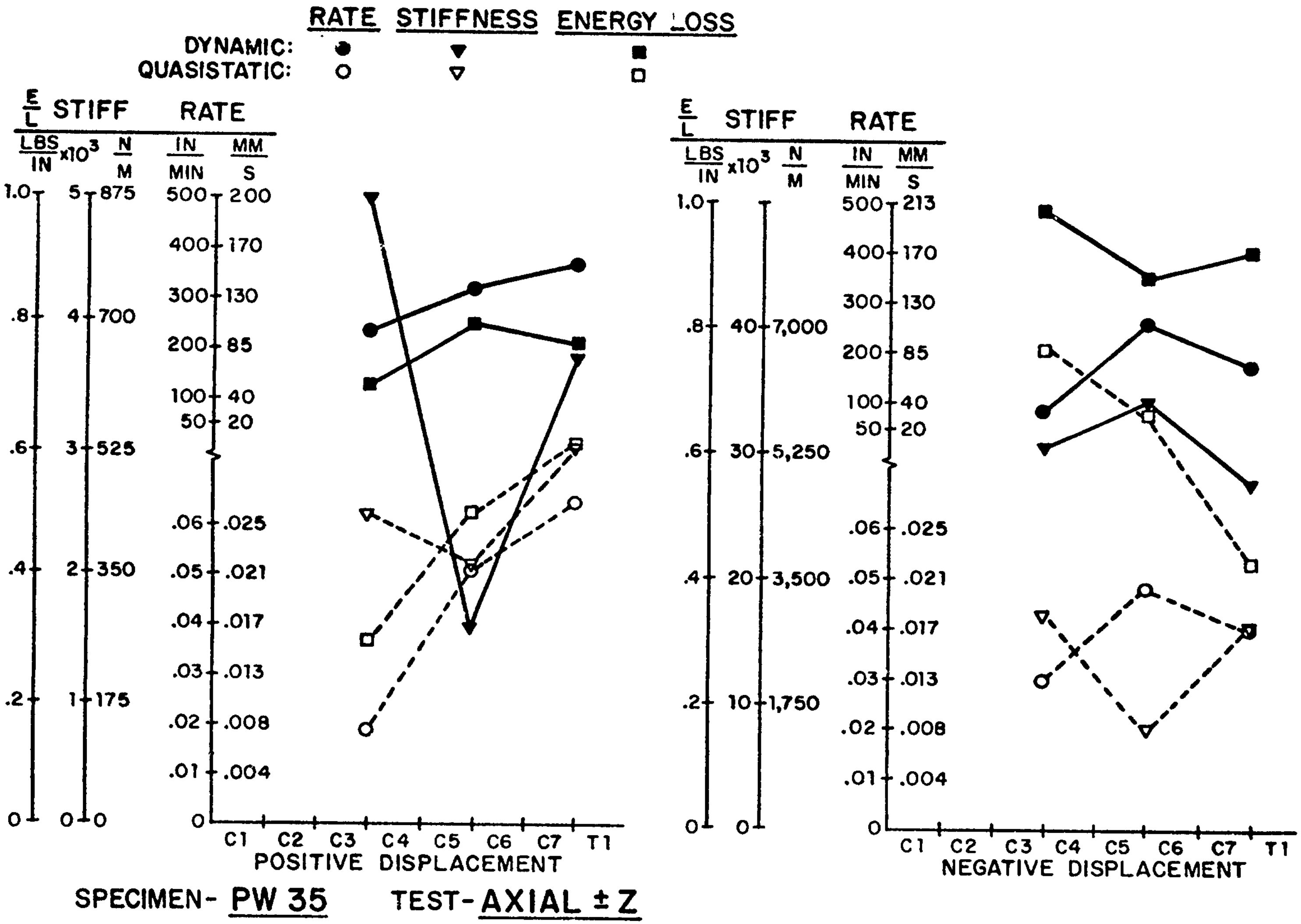
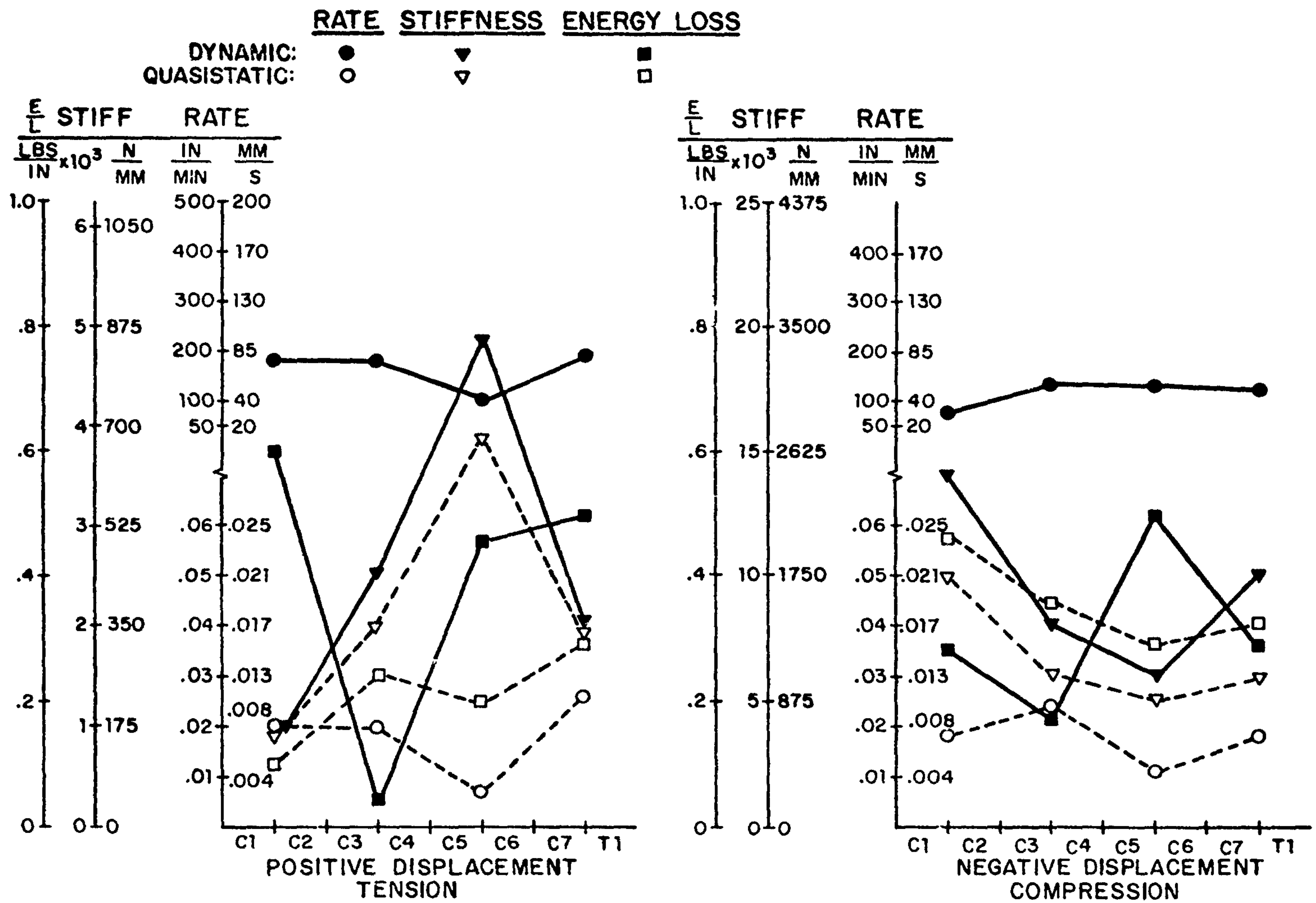
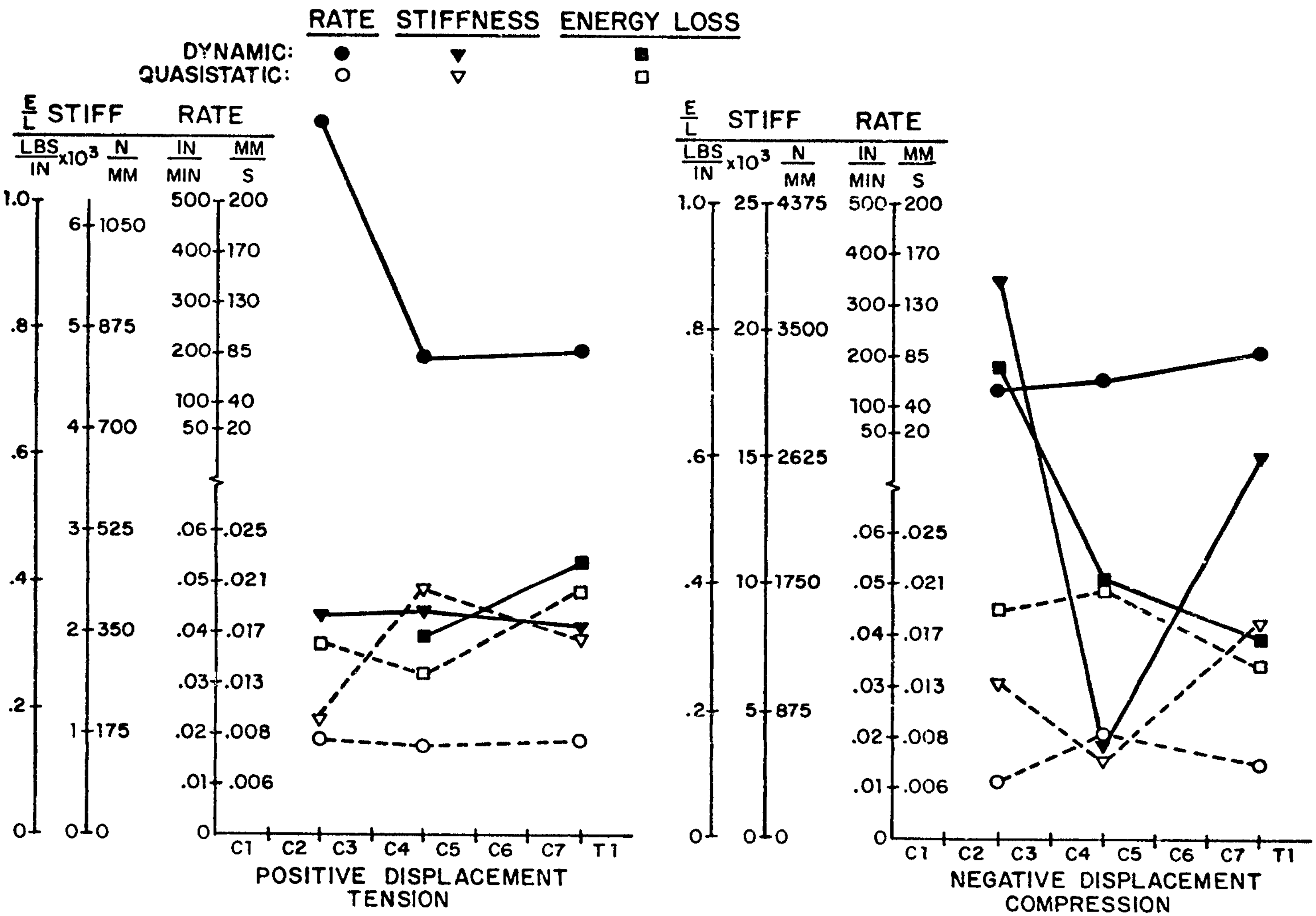


FIGURE B1: DATA FROM STIFFNESS TEST ANALYSIS



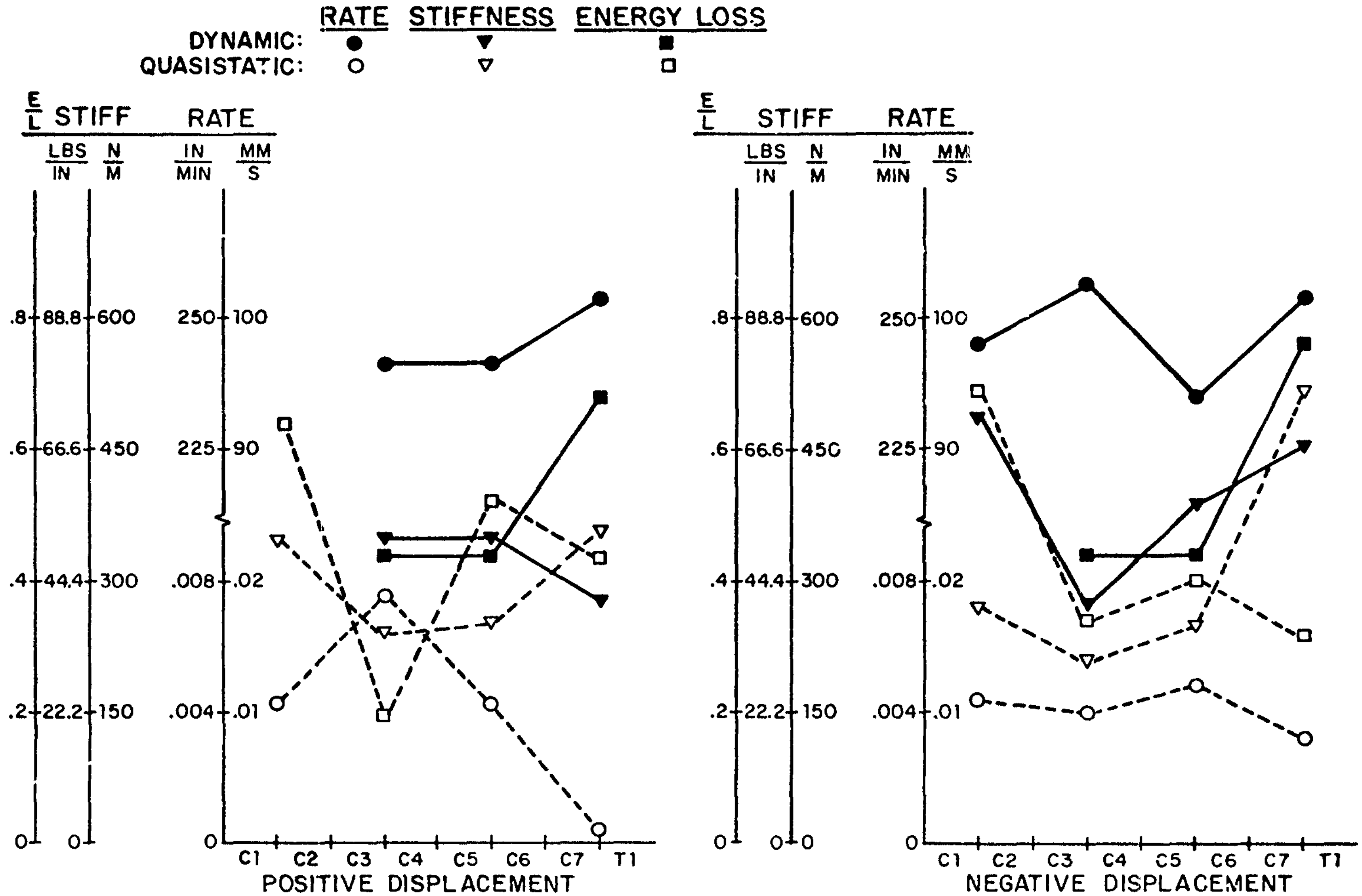
SPECIMEN- **SWE 23** TEST- **AXIAL ±Z**

FIGURE B1: DATA FROM STIFFNESS TEST ANALYSIS



SPECIMEN-SWE 25 TEST-AXIAL ±Z

FIGURE B1: DATA FROM STIFFNESS TEST ANALYSIS



SPECIMEN-EJ 41 TEST-SHEAR ±Y

FIGURE B2: DATA FROM STIFFNESS TEST ANALYSIS

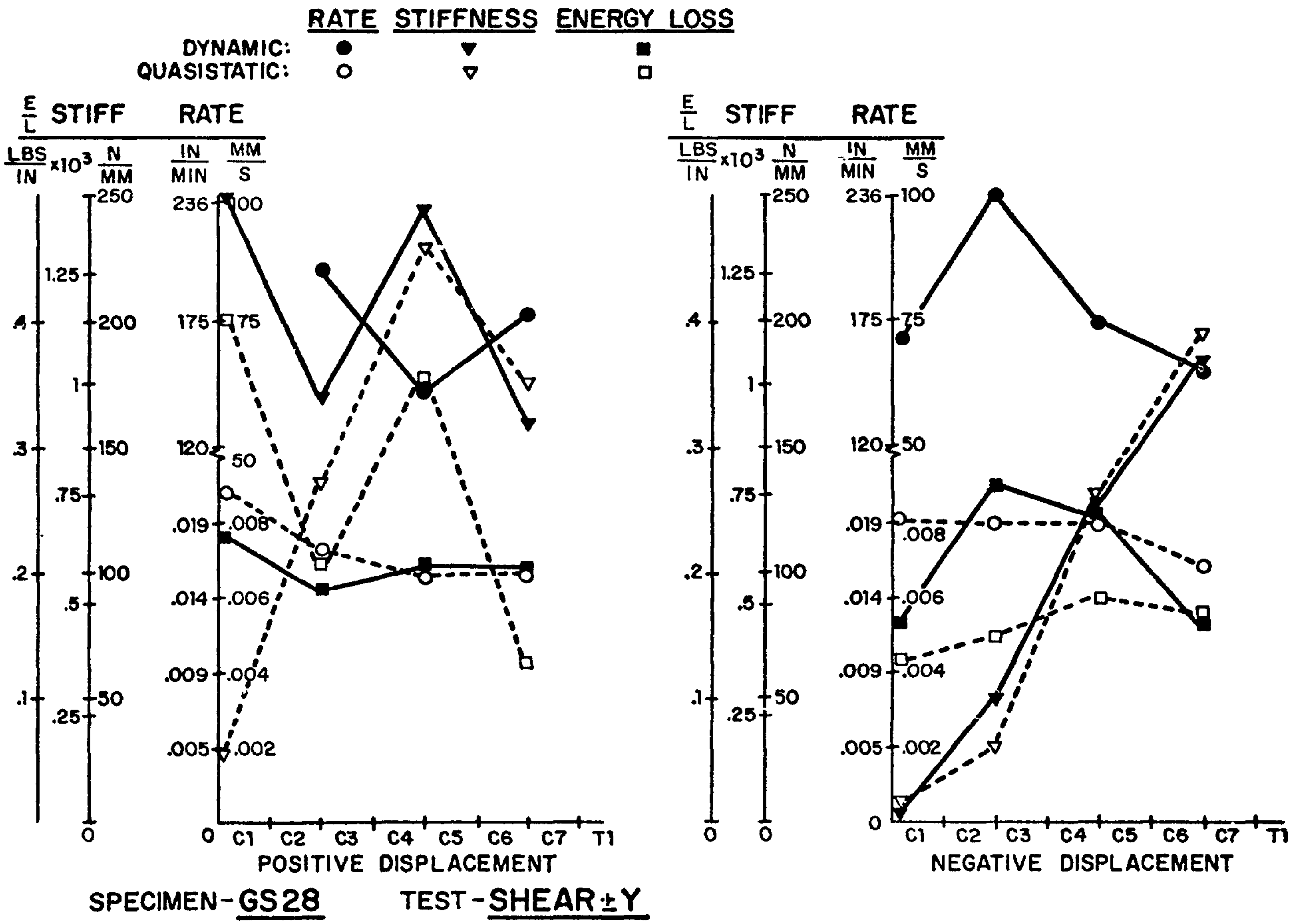
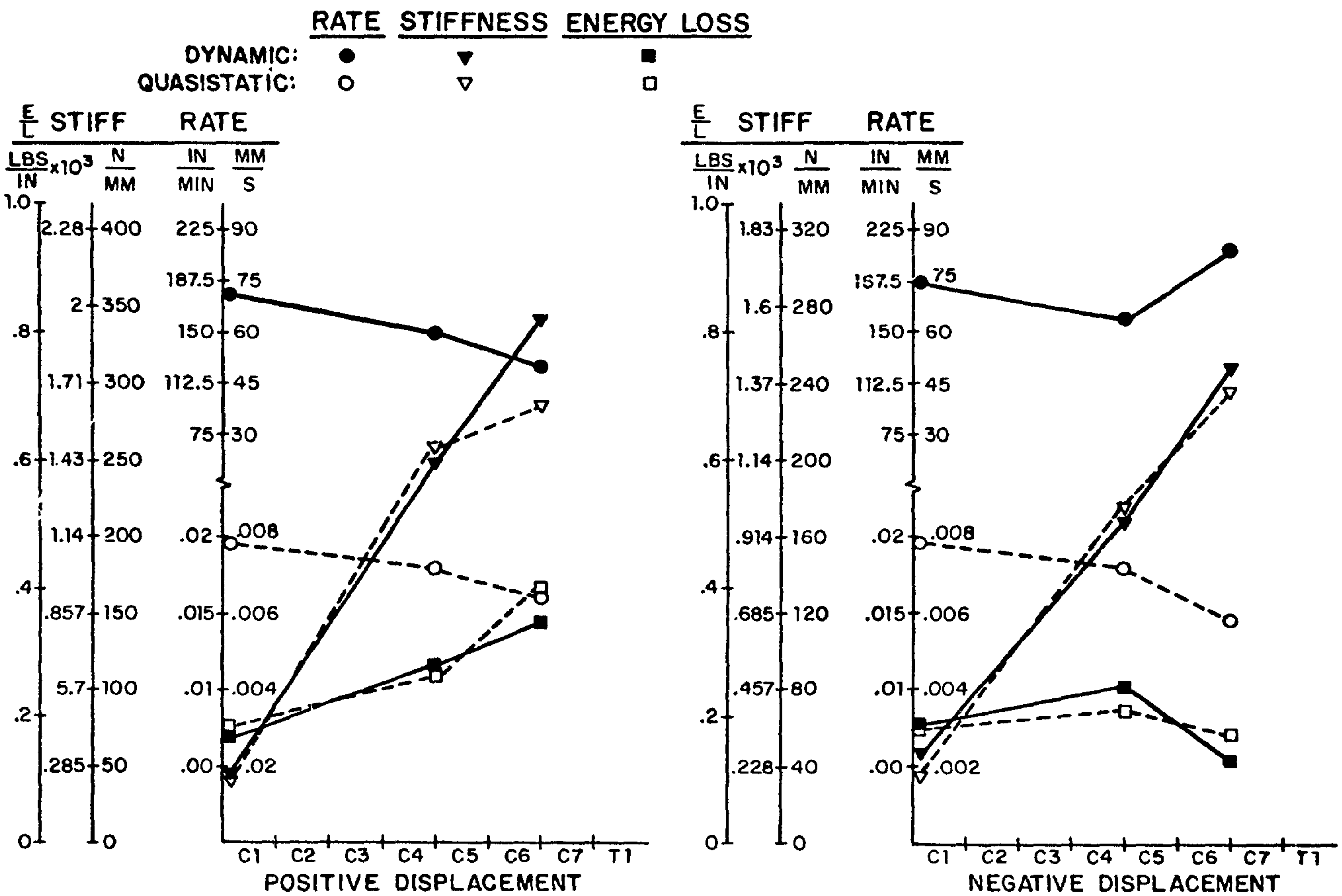
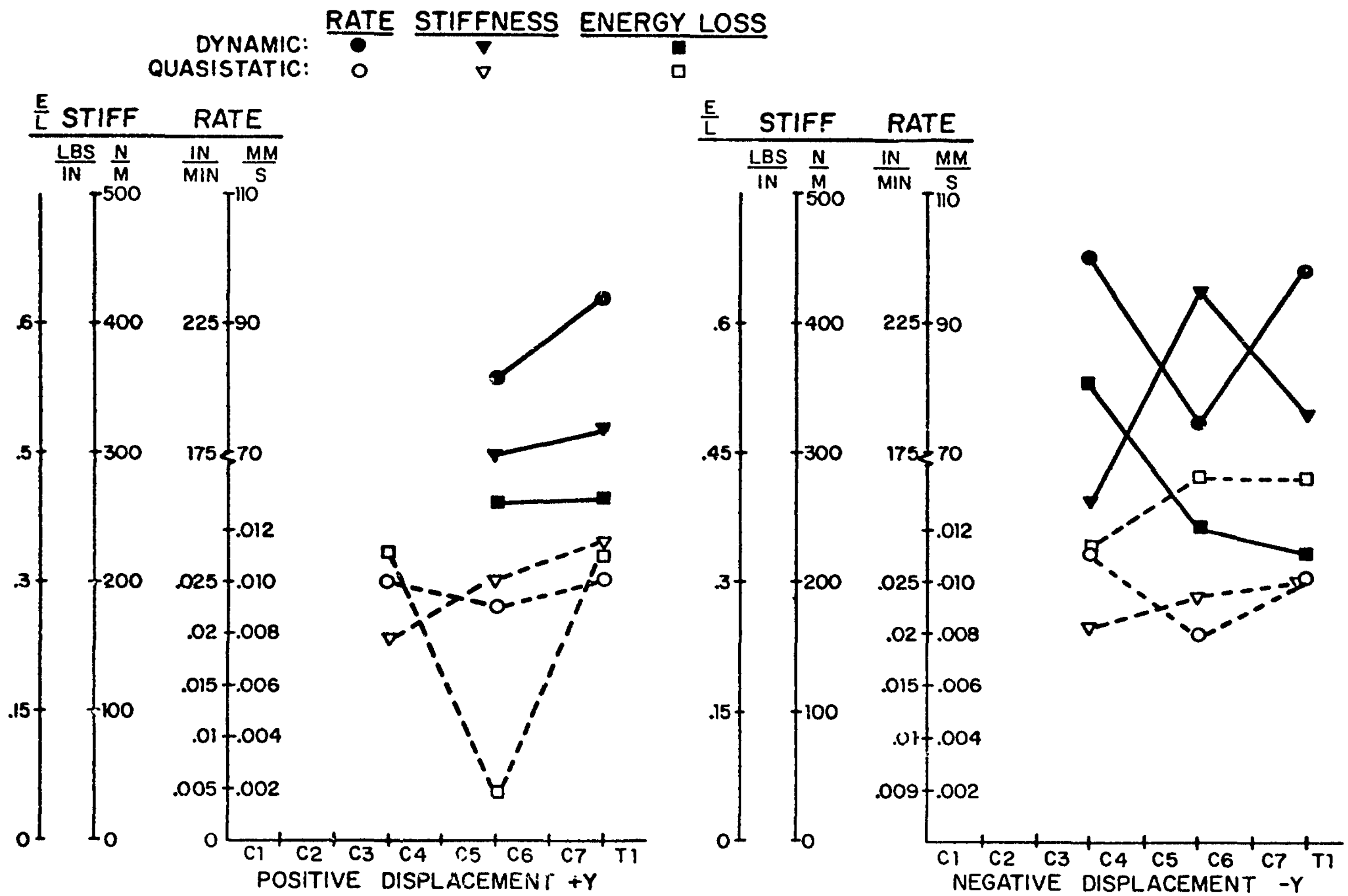


FIGURE B2: DATA FROM STIFFNESS TEST ANALYSIS



SPECIMEN- HI 25 TEST- SHEAR ±Y

FIGURE B2: DATA FROM STIFFNESS TEST ANALYSIS



SPECIMEN-PW 35 TEST-SHEAR ±Y

FIGURE B2: DATA FROM STIFFNESS TEST ANALYSIS

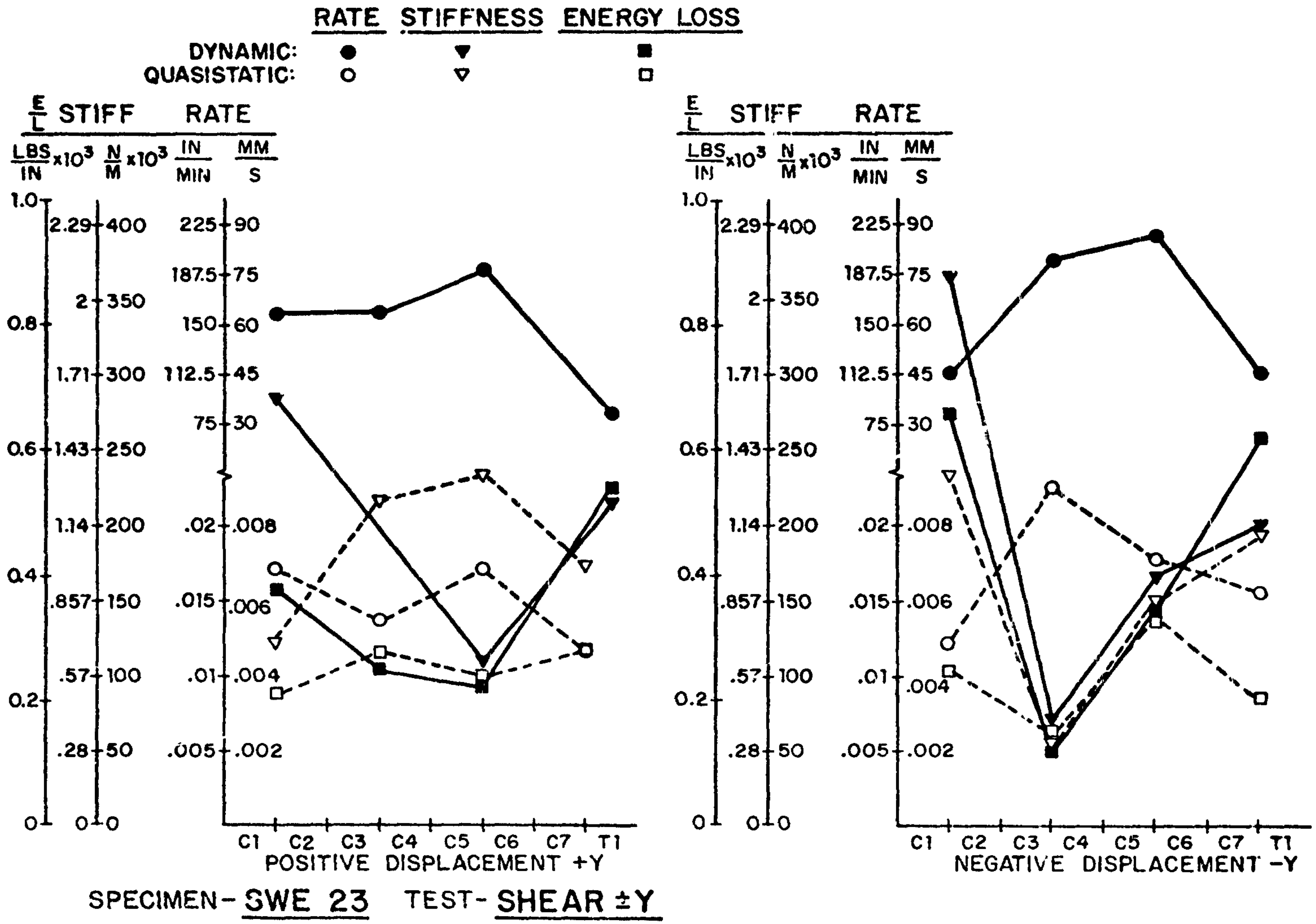
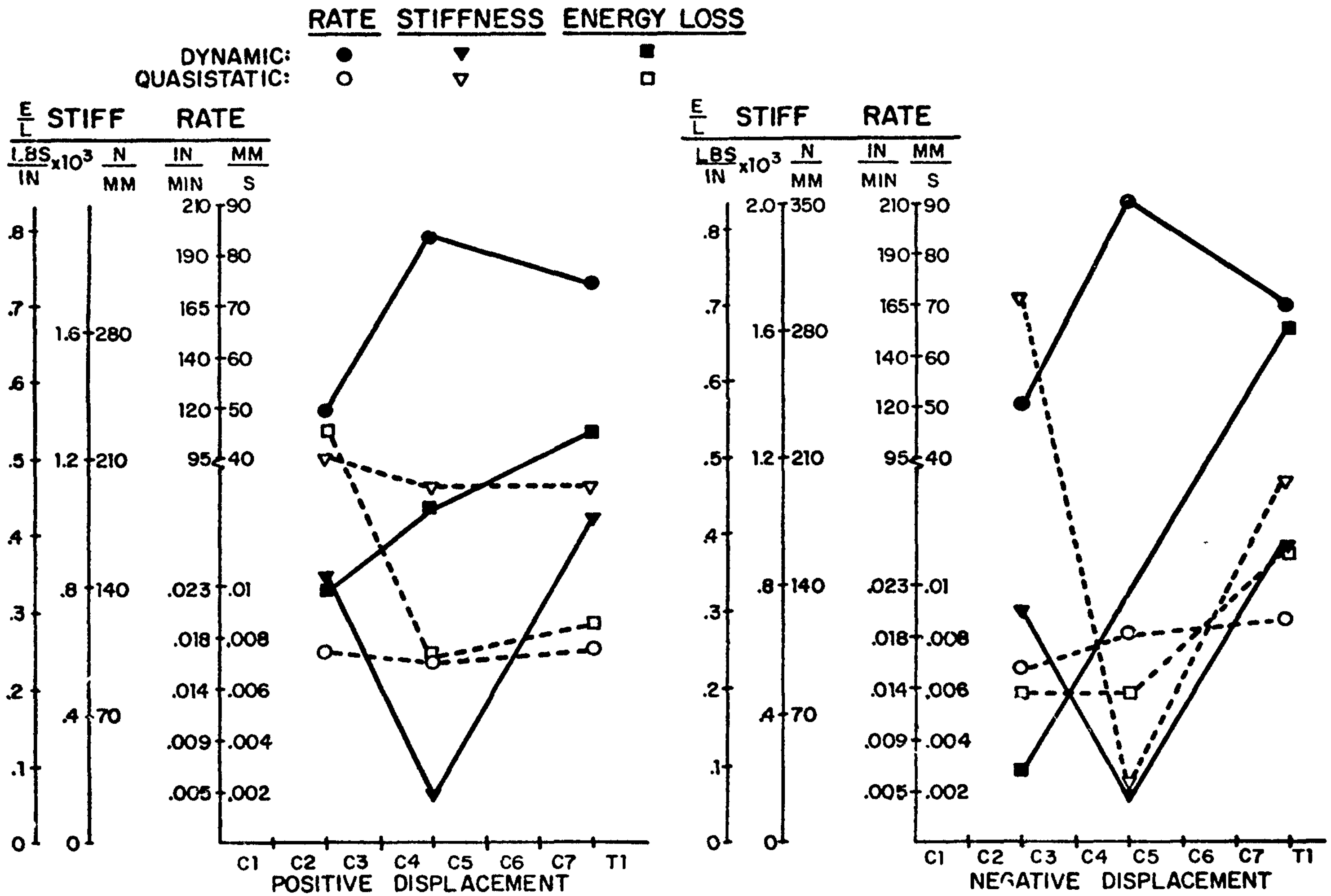


FIGURE B2: DATA FROM STIFFNESS TEST ANALYSIS



SPECIMEN-**SWE 25** TEST-**SHEAR ±Y**

FIGURE B2: DATA FROM STIFFNESS TEST ANALYSIS

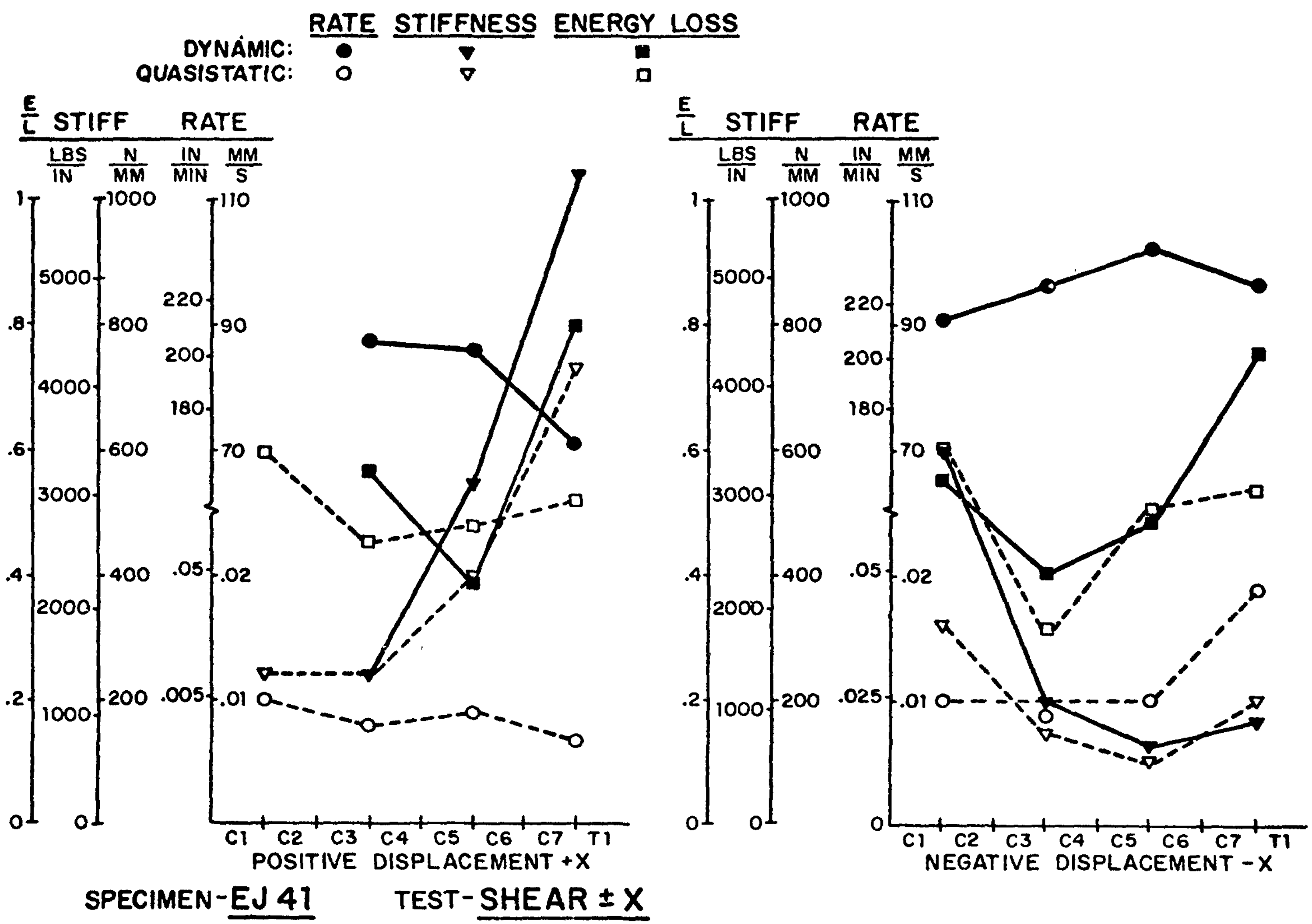
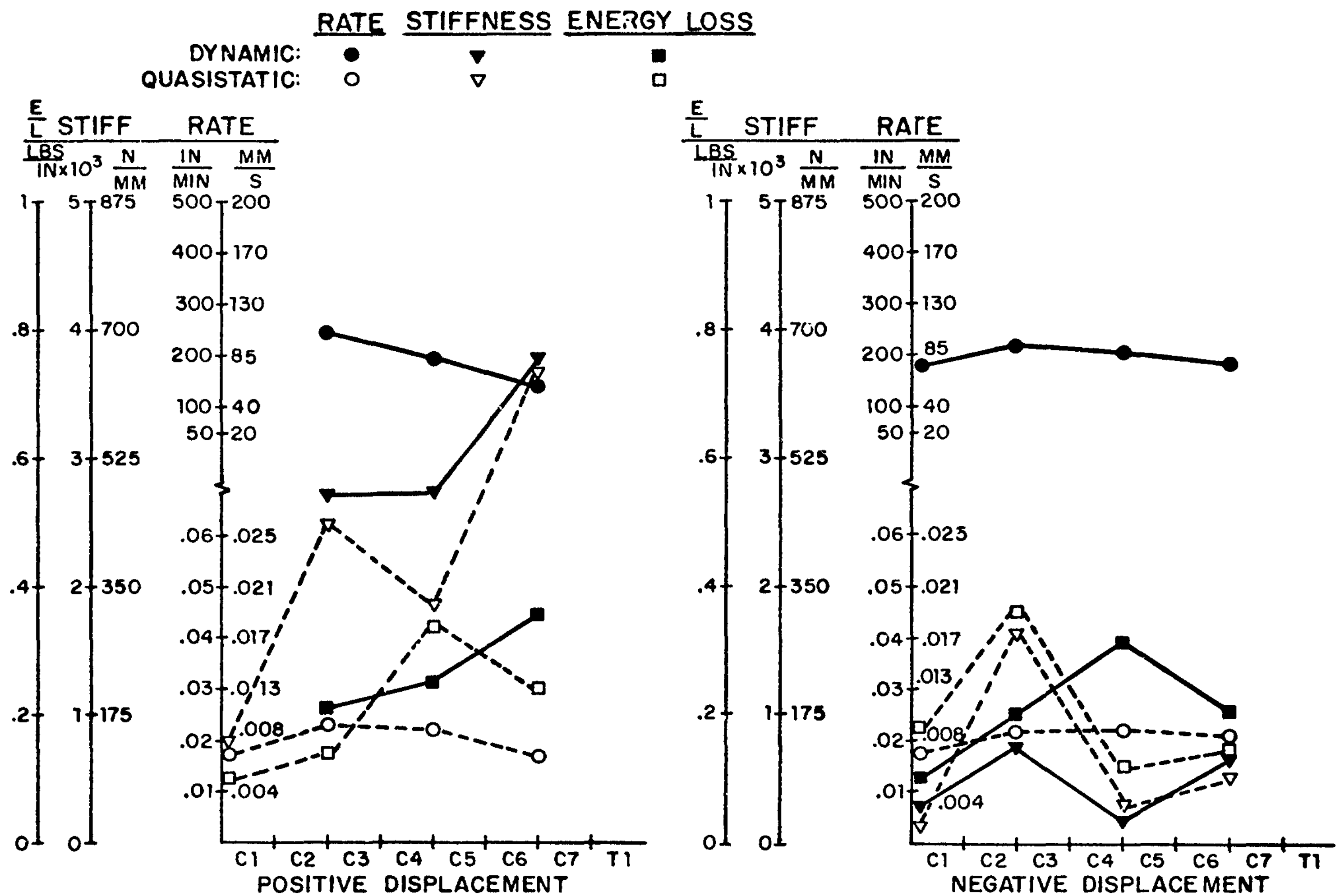


FIGURE B3: DATA FROM STIFFNESS TEST ANALYSIS



SPECIMEN-**GS 28** TEST-**SHEAR ±X**

FIGURE B3: DATA FROM STIFFNESS TEST ANALYSIS

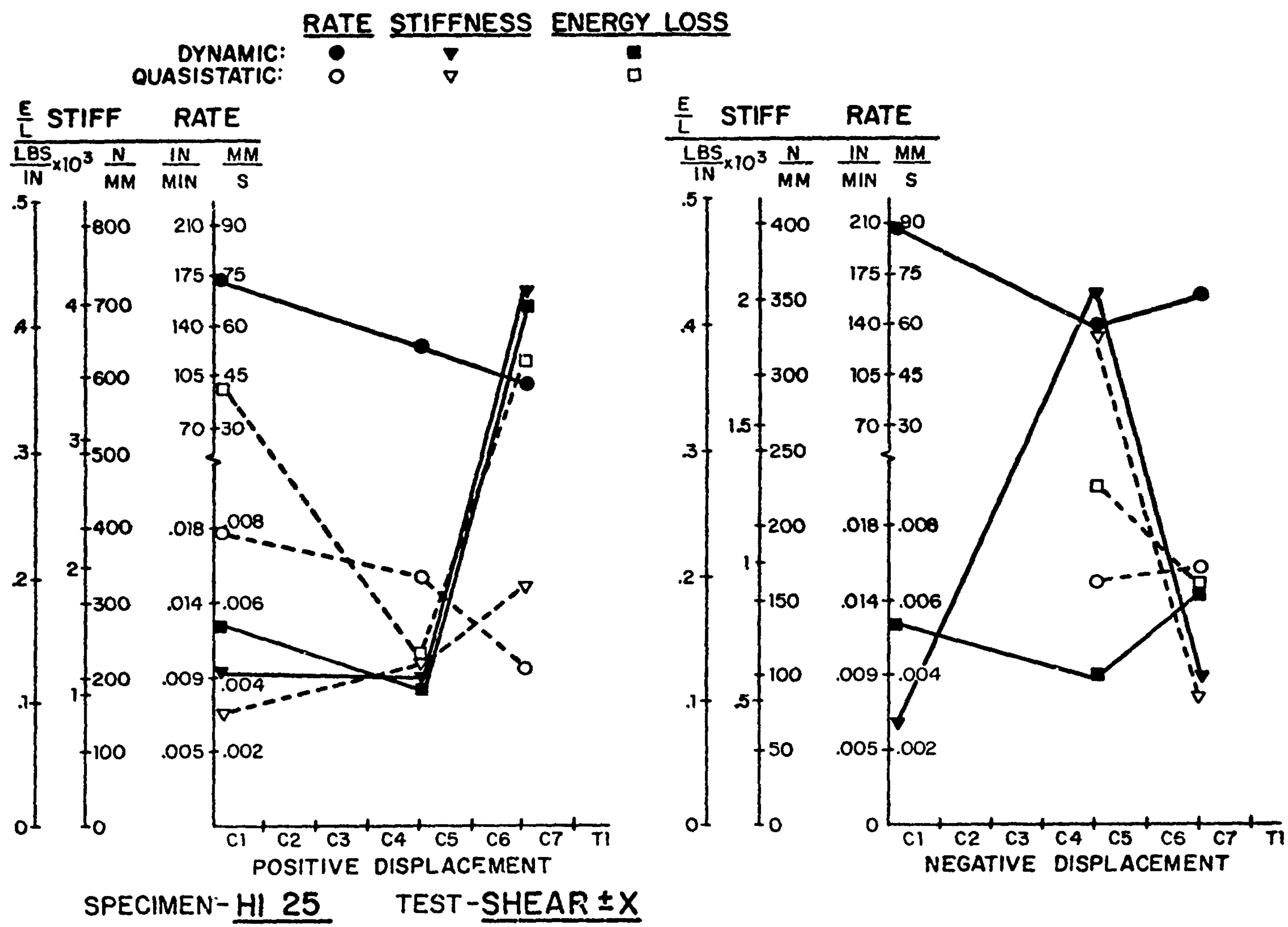


FIGURE B3: DATA FROM STIFFNESS TEST ANALYSIS

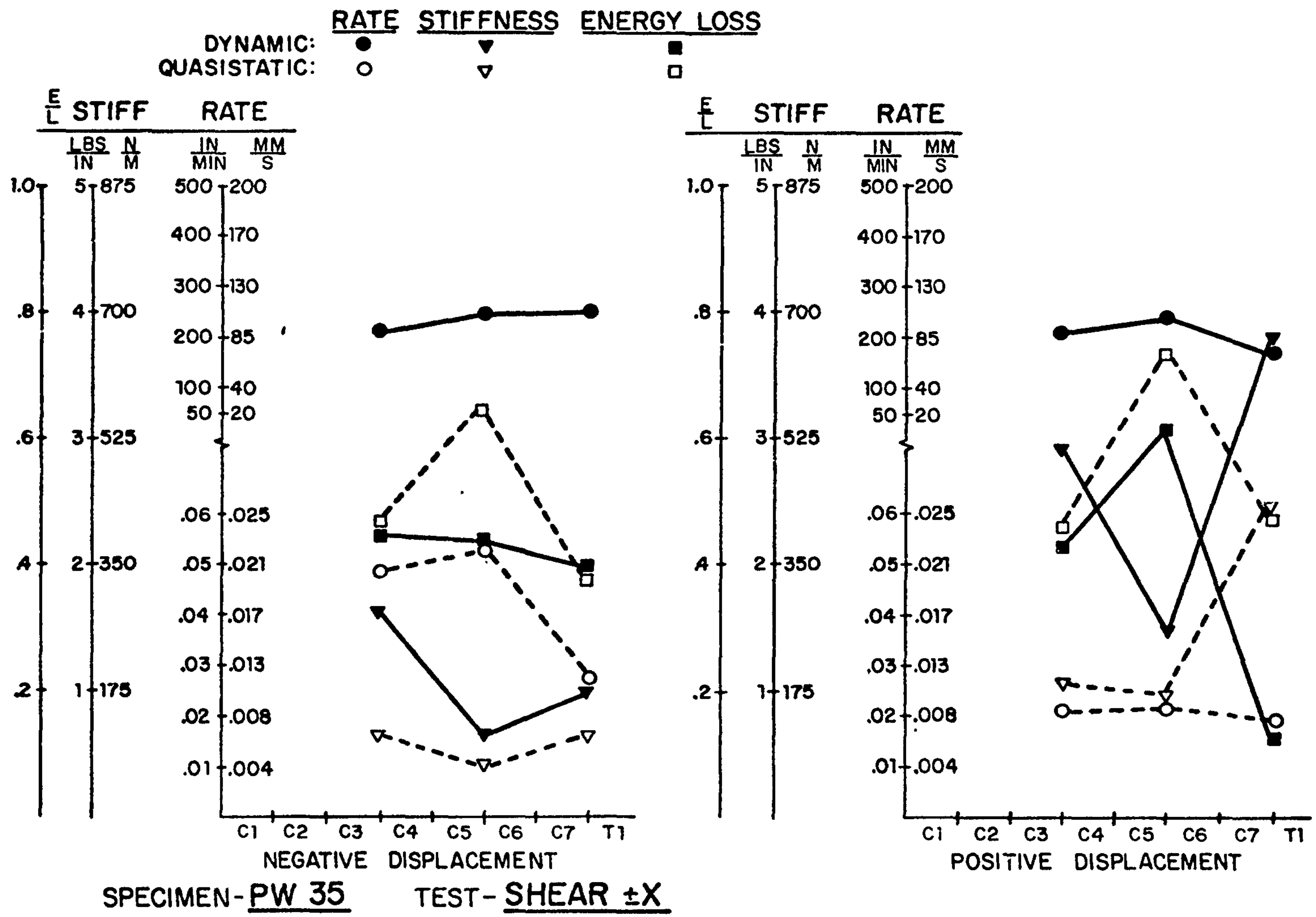


FIGURE B3: DATA FROM STIFFNESS TEST ANALYSIS

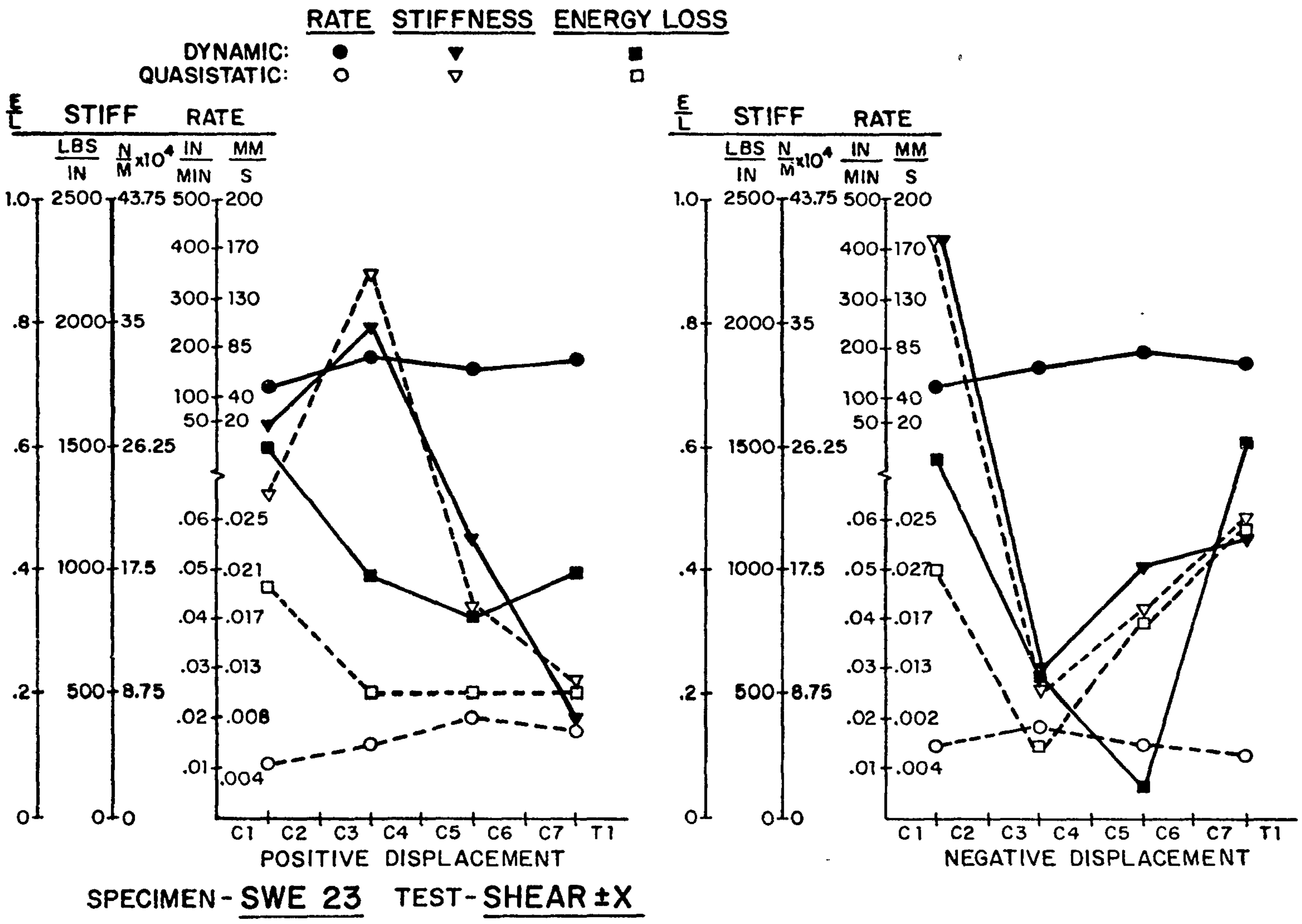
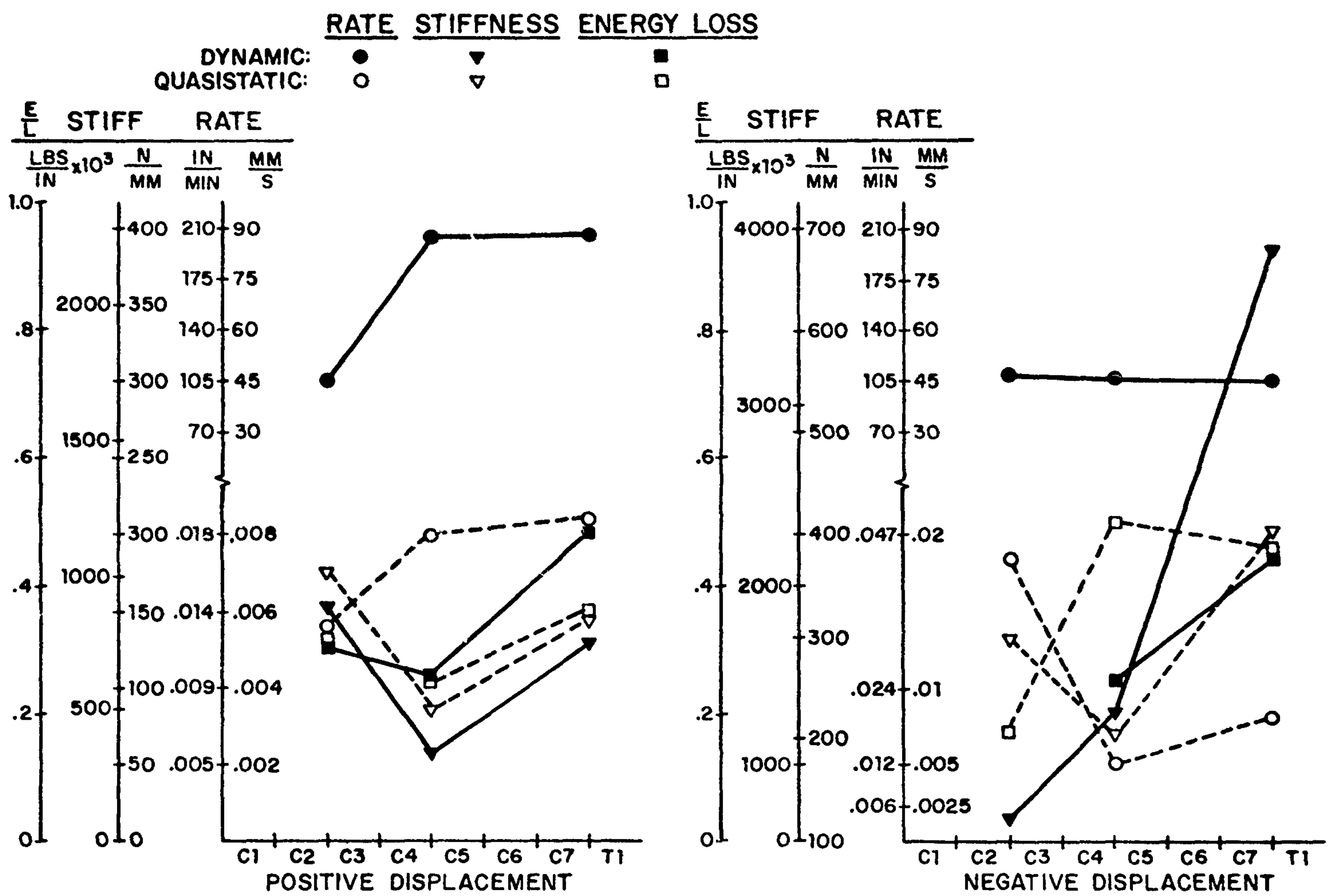


FIGURE B3: DATA FROM STIFFNESS TEST ANALYSIS



SPECIMEN- SWE 25 TEST- SHEAR ±X

FIGURE B3: DATA FROM STIFFNESS TEST ANALYSIS

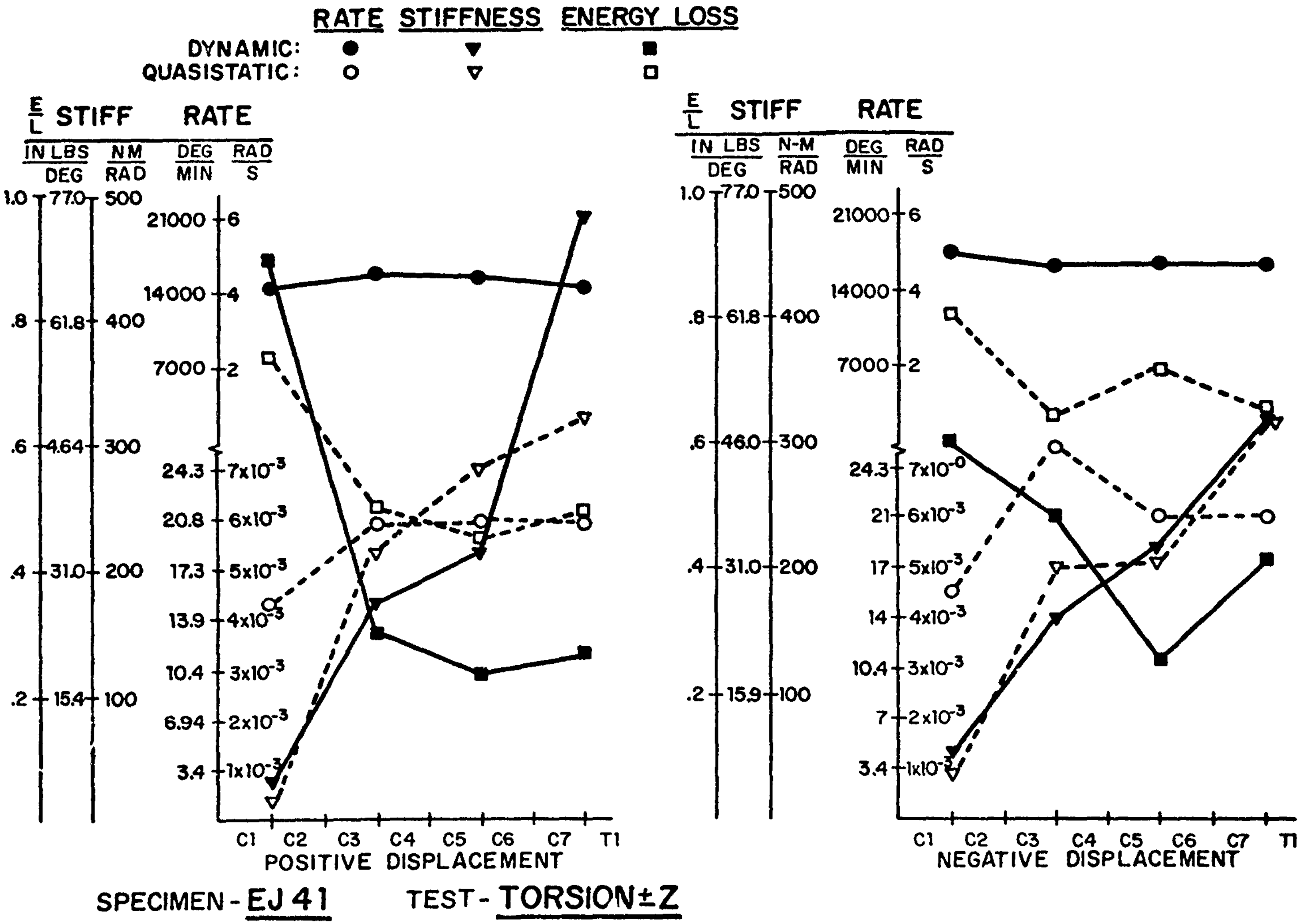


FIGURE B4: DATA FROM STIFFNESS TEST ANALYSIS

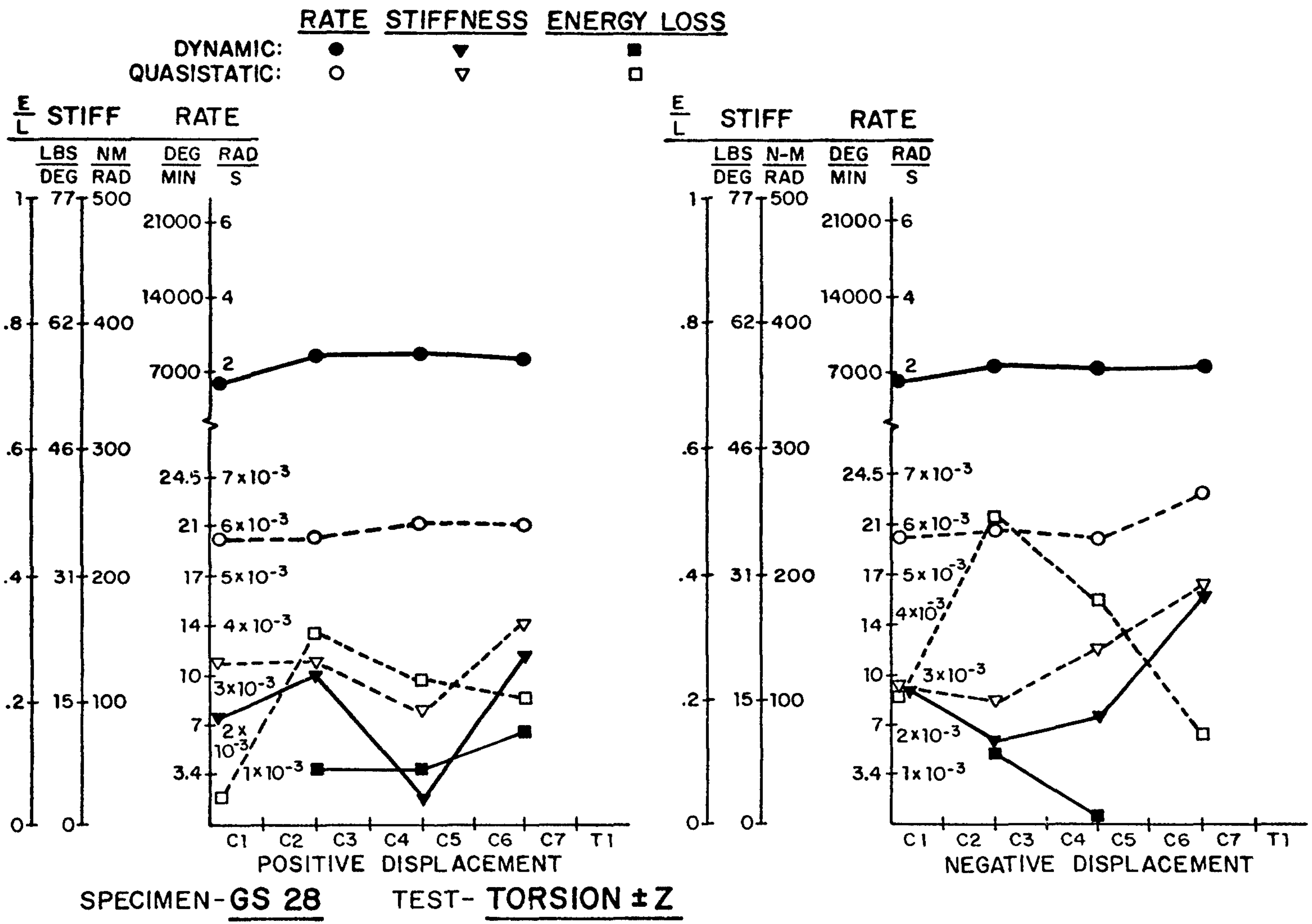
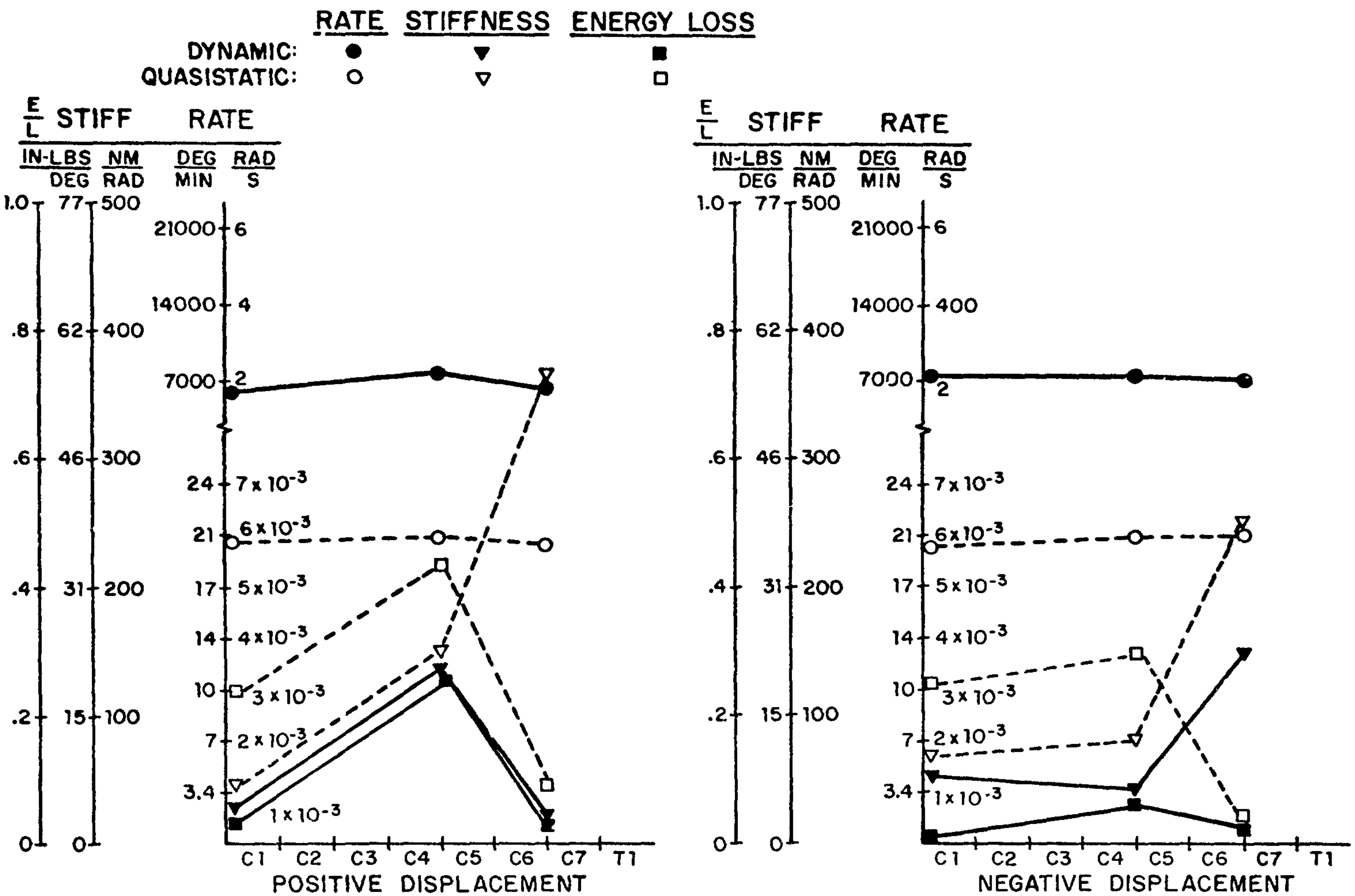


FIGURE B4: DATA FROM STIFFNESS TEST ANALYSIS



SPECIMEN- HI 25 TEST- TORSION ±Z

FIGURE B4: DATA FROM STIFFNESS TEST ANALYSIS

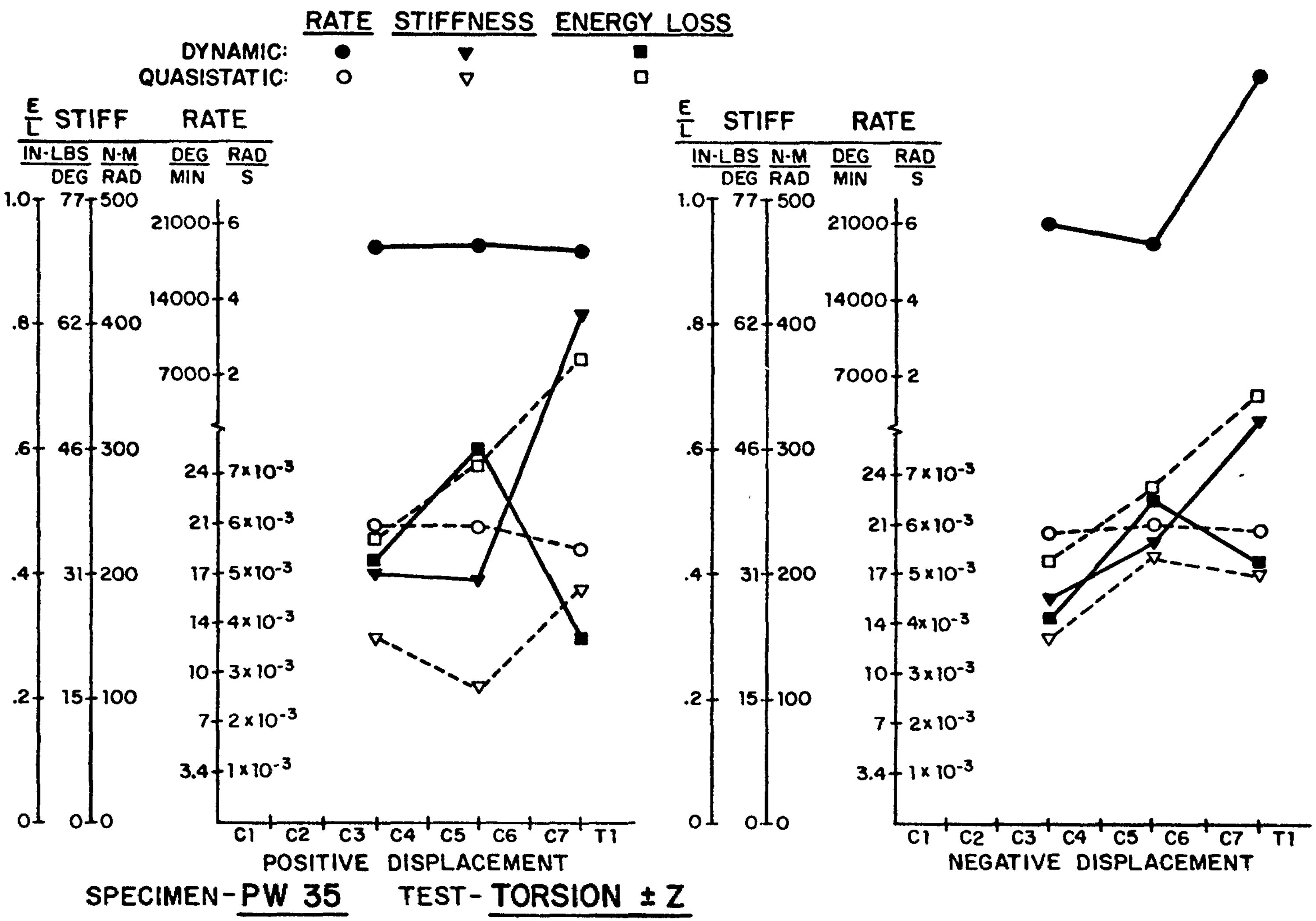


FIGURE B4: DATA FROM STIFFNESS TEST ANALYSIS

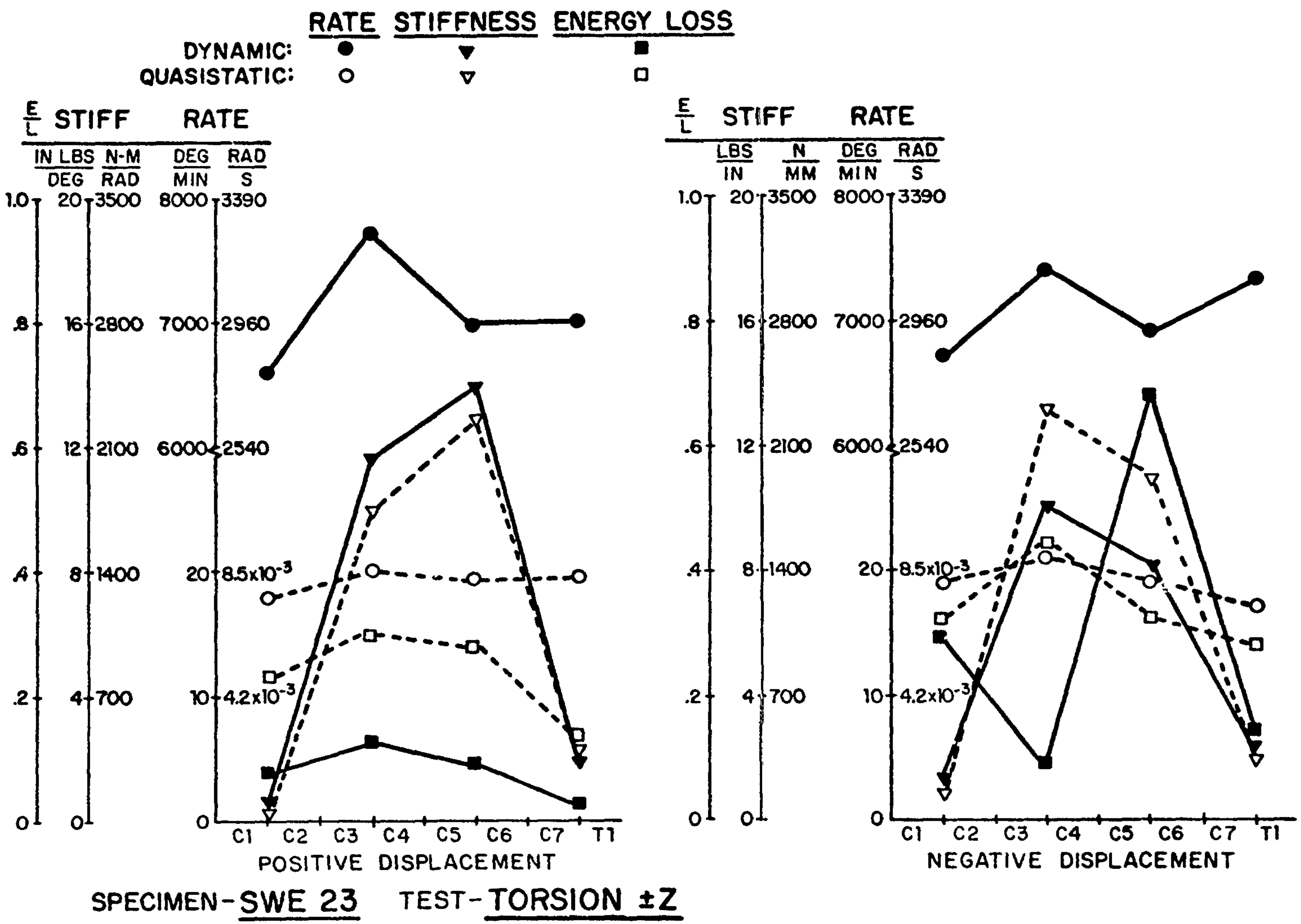
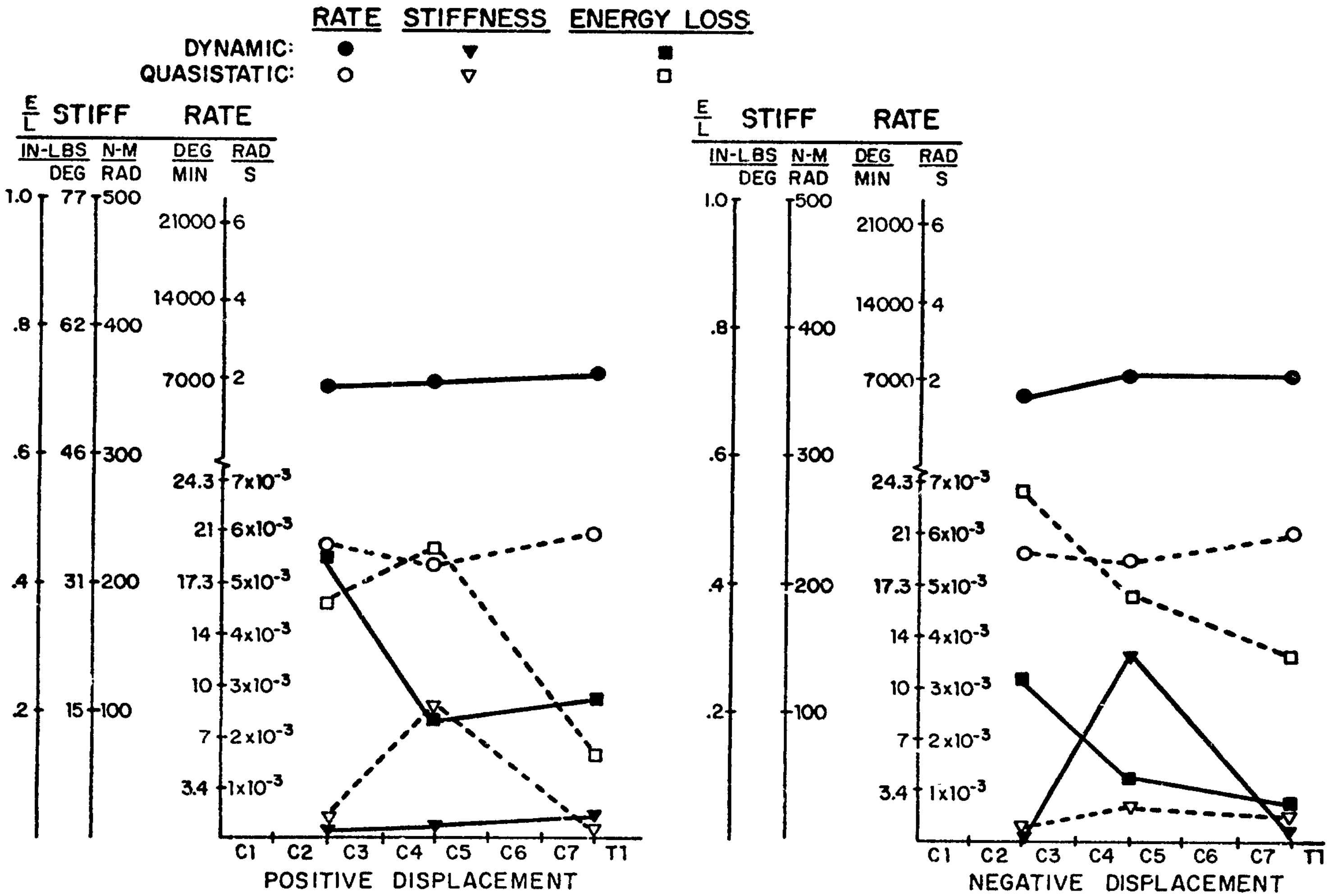
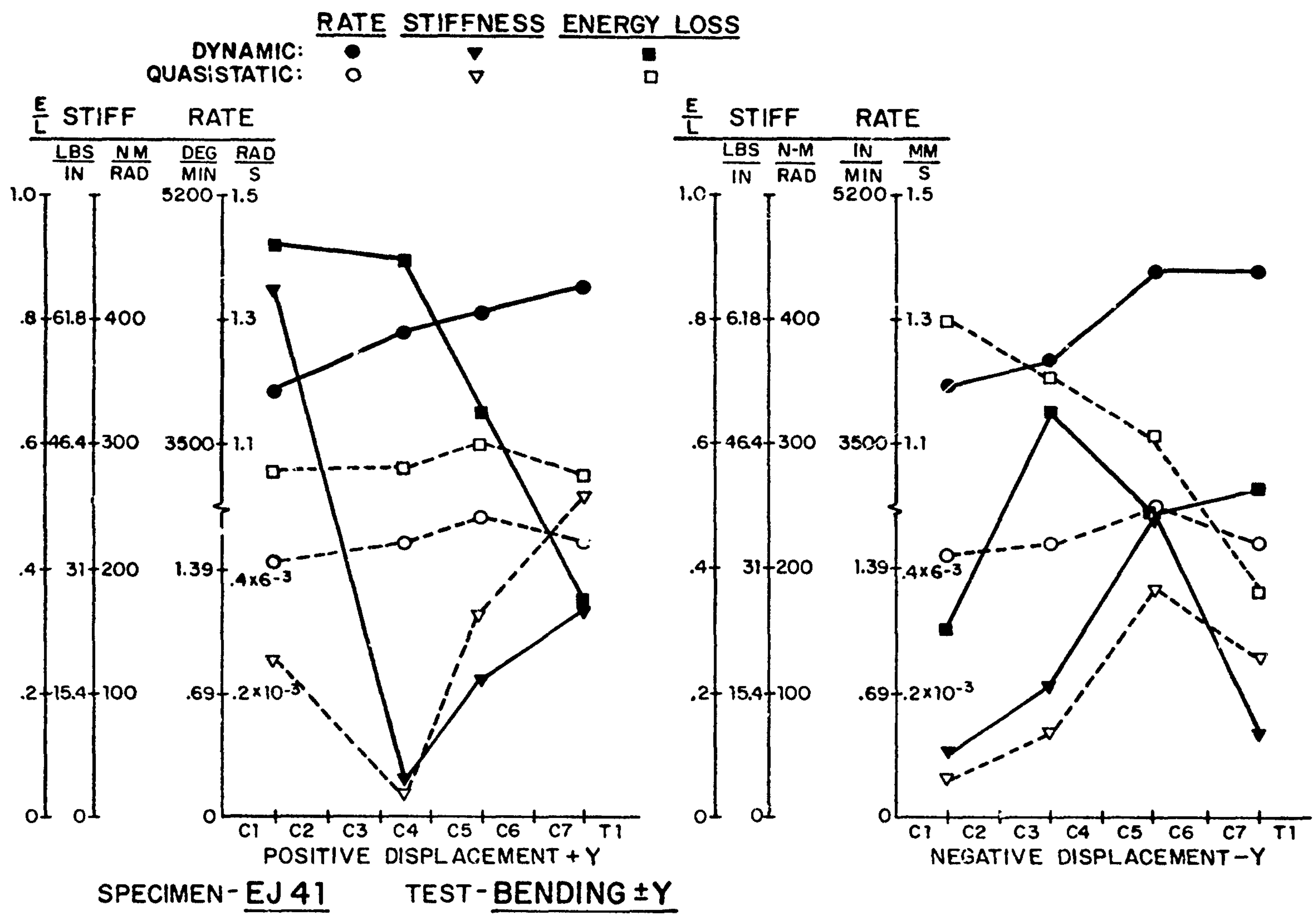


FIGURE B4: DATA FROM STIFFNESS TEST ANALYSIS



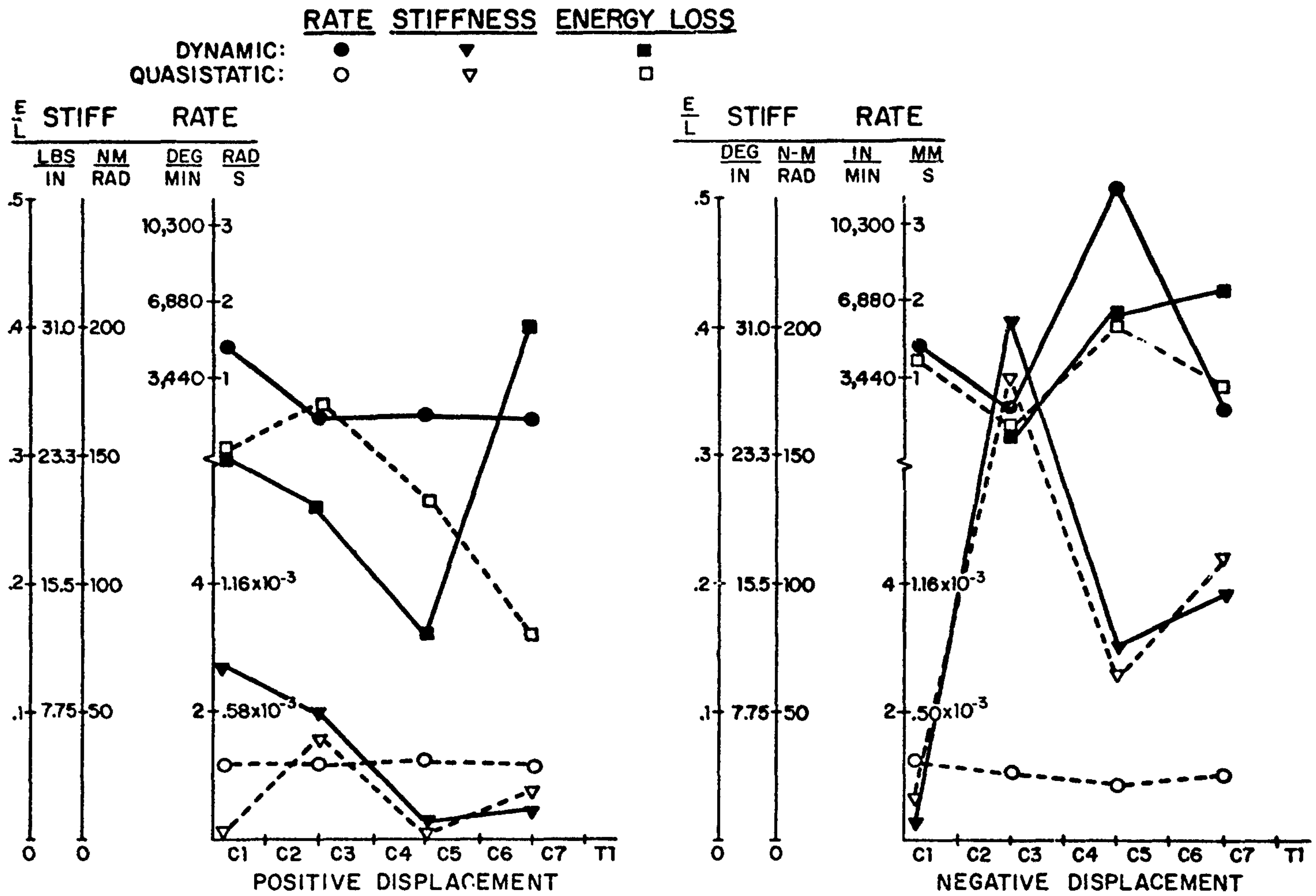
SPECIMEN-SWE 25 TEST-TORSION ±Z

FIGURE B4: DATA FROM STIFFNESS TEST ANALYSIS



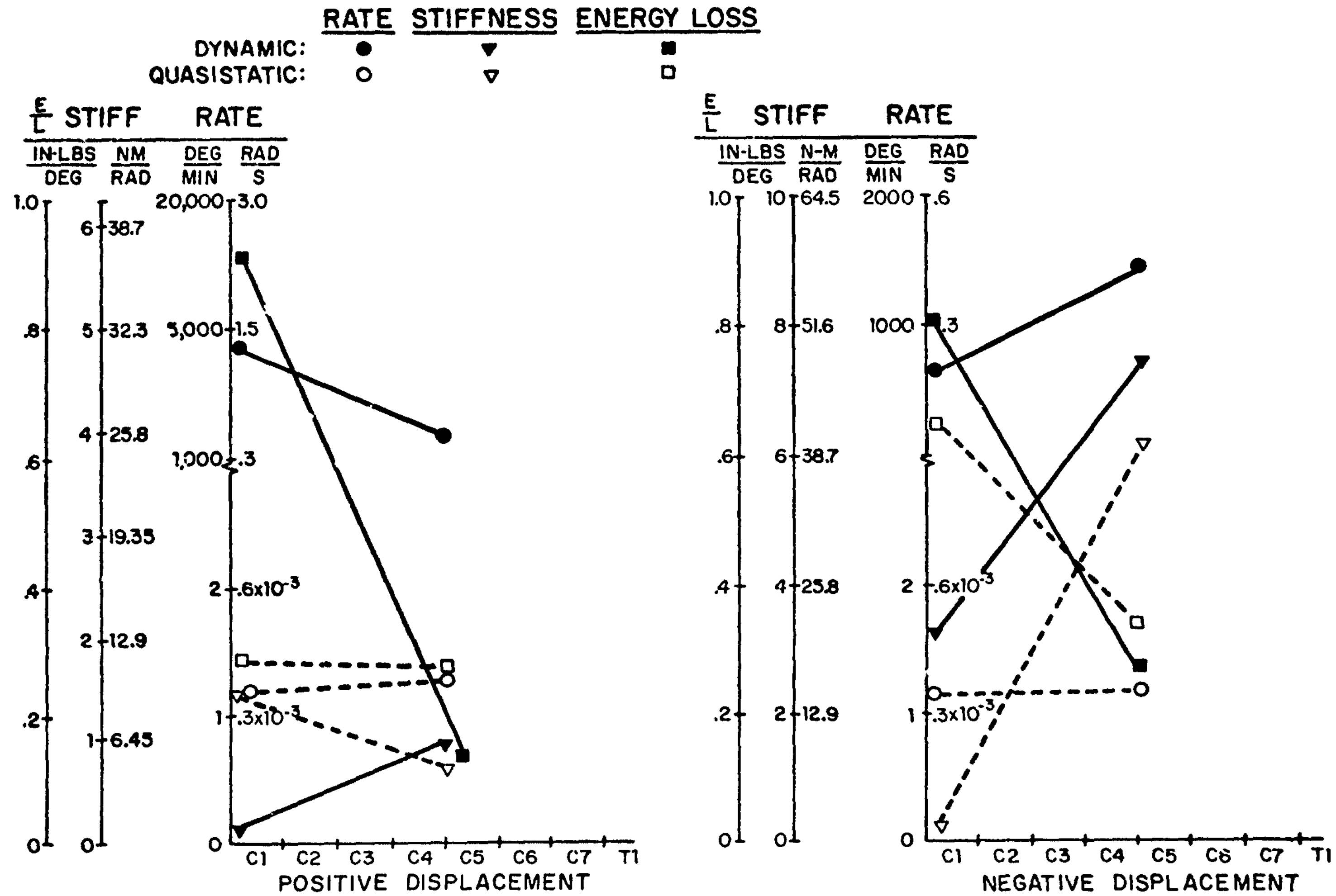
SPECIMEN - EJ 41 TEST - BENDING ±Y

FIGURE B5: DATA FROM STIFFNESS TEST ANALYSIS



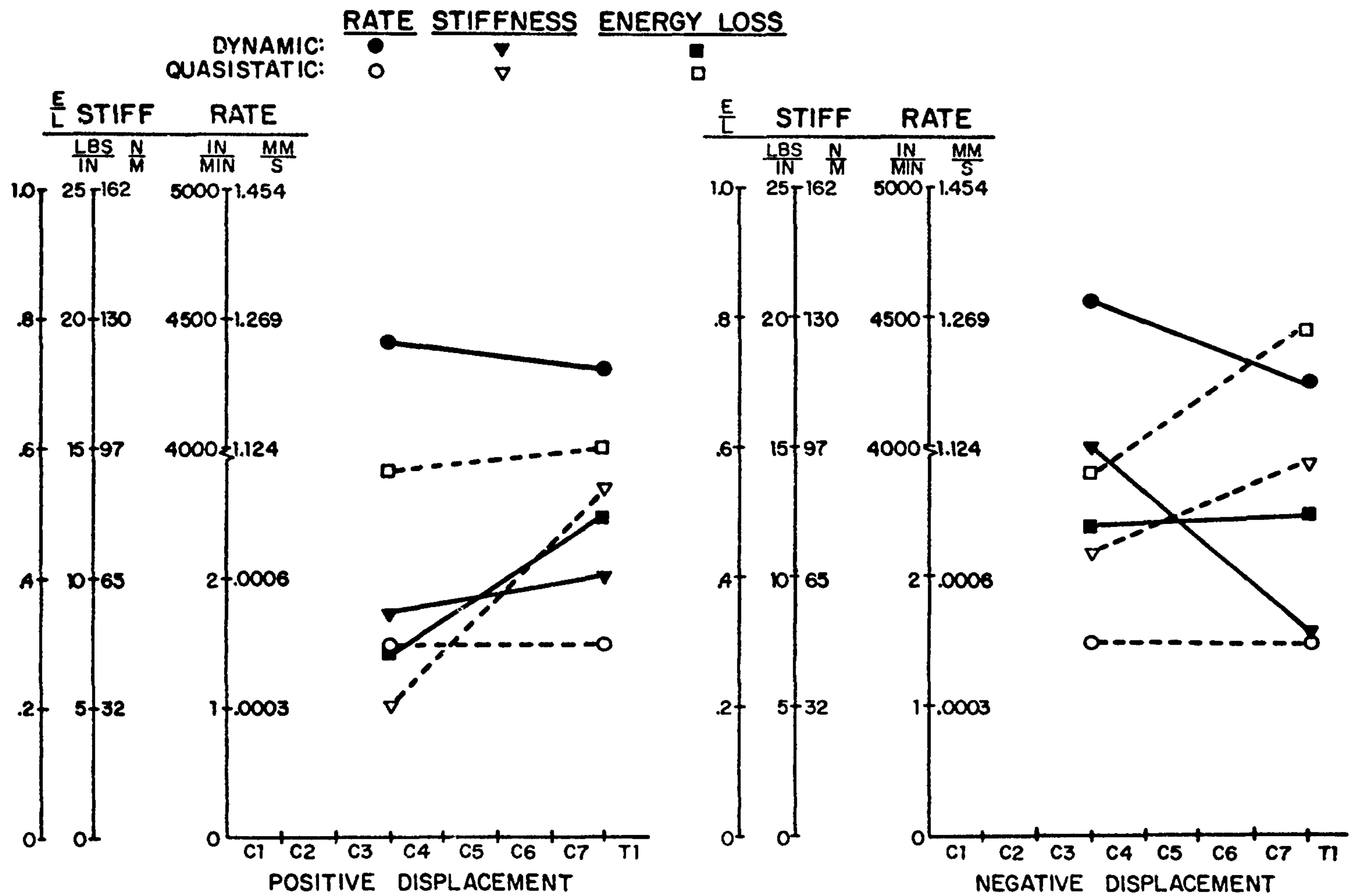
SPECIMEN- GS28 TEST- BENDING ± Y

FIGURE B5: DATA FROM STIFFNESS TEST ANALYSIS



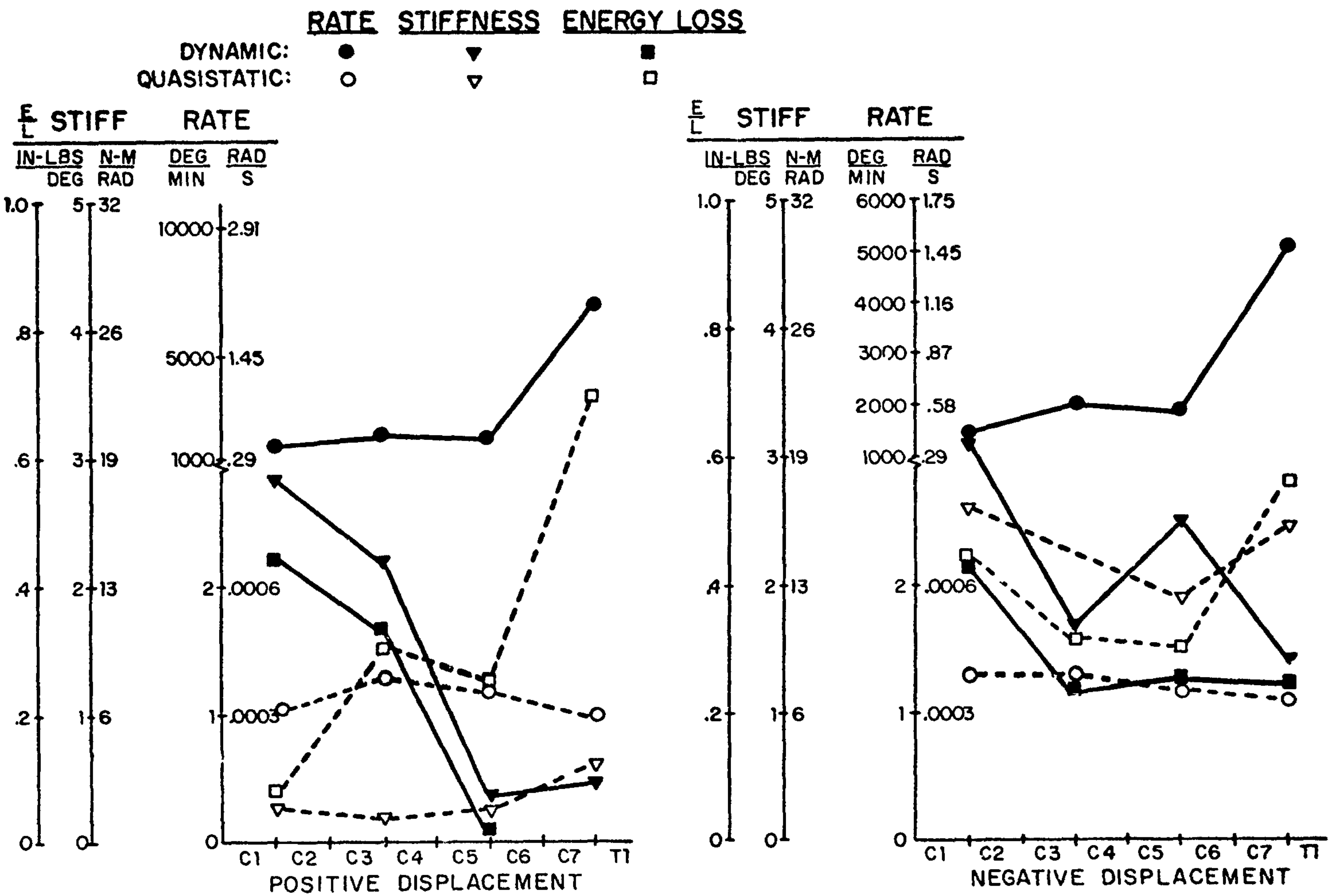
SPECIMEN-HI 25 TEST-BENDING ± Y

FIGURE B5: DATA FROM STIFFNESS TEST ANALYSIS



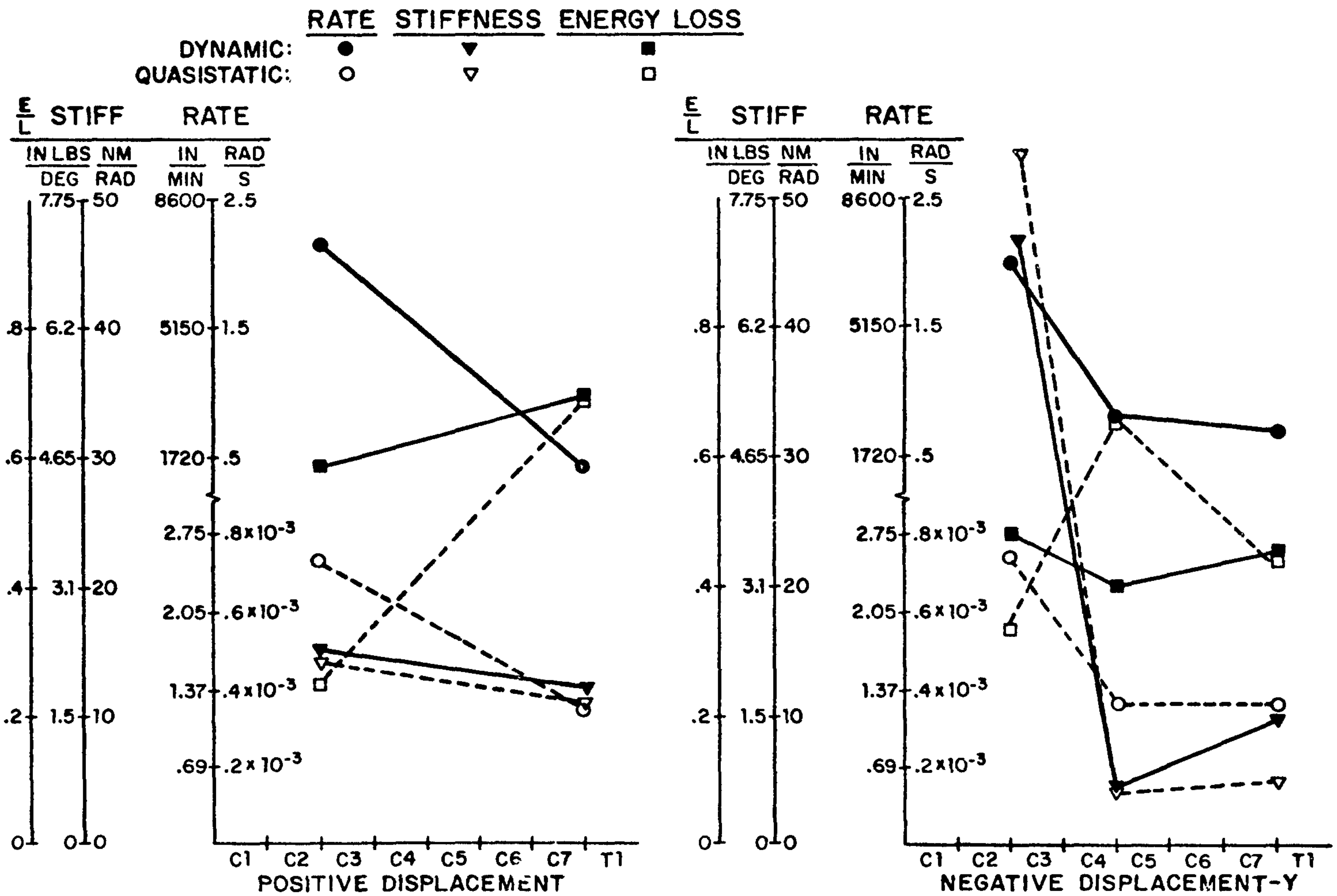
SPECIMEN-PW 35 TEST-BENDING ±Y

FIGURE B5: DATA FROM STIFFNESS TEST ANALYSIS



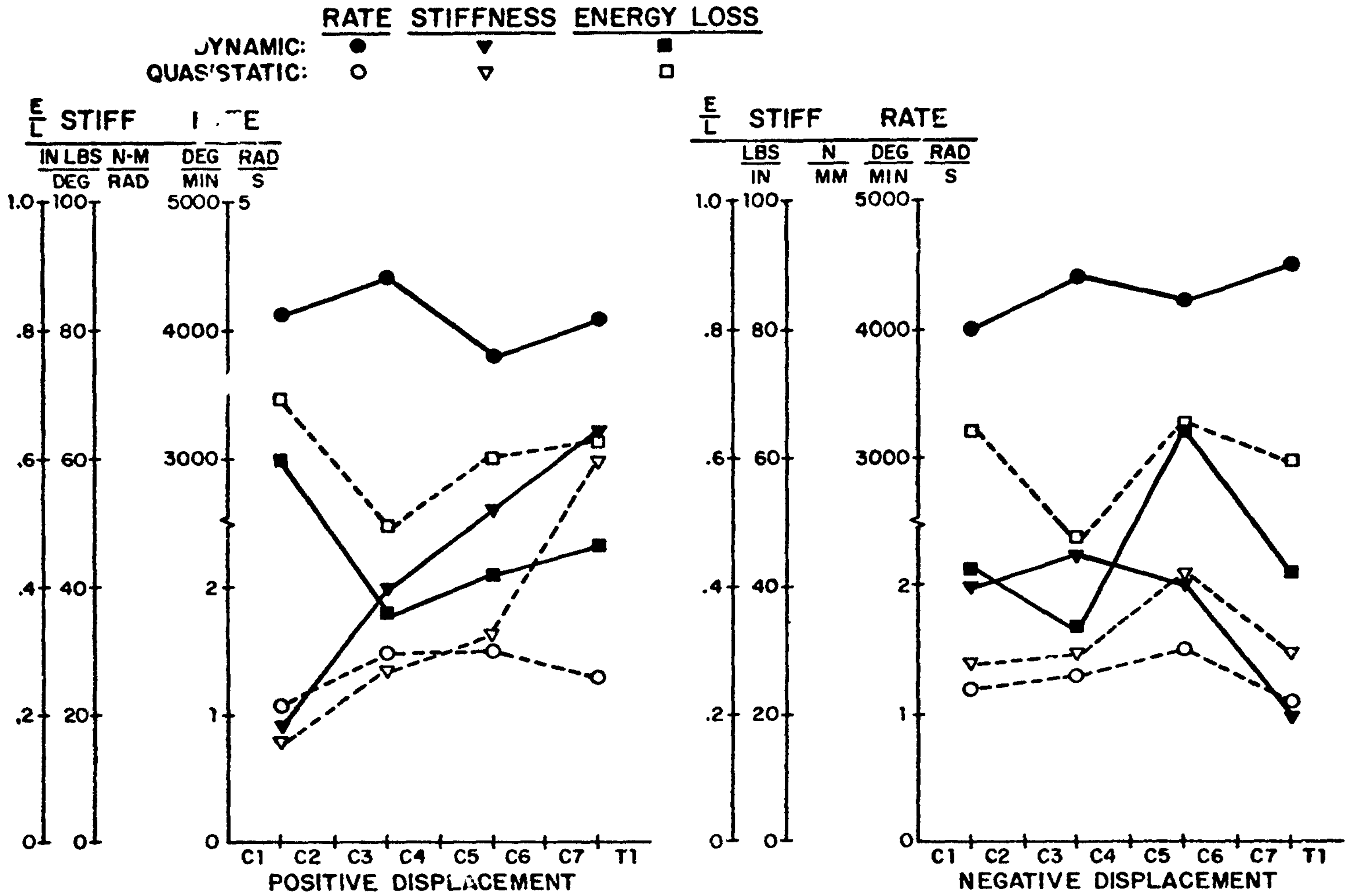
SPECIMEN-SWE 23 TEST-BENDING ±Y

FIGURE B5: DATA FROM STIFFNESS TEST ANALYSIS



SPECIMEN-**SWE 25** TEST- **BENDING ±Y**

FIGURE B5: DATA FROM STIFFNESS TEST ANALYSIS



SPECIMEN-EJ 41 TEST-BENDING ±X

FIGURE B6: DATA FROM STIFFNESS TEST ANALYSIS

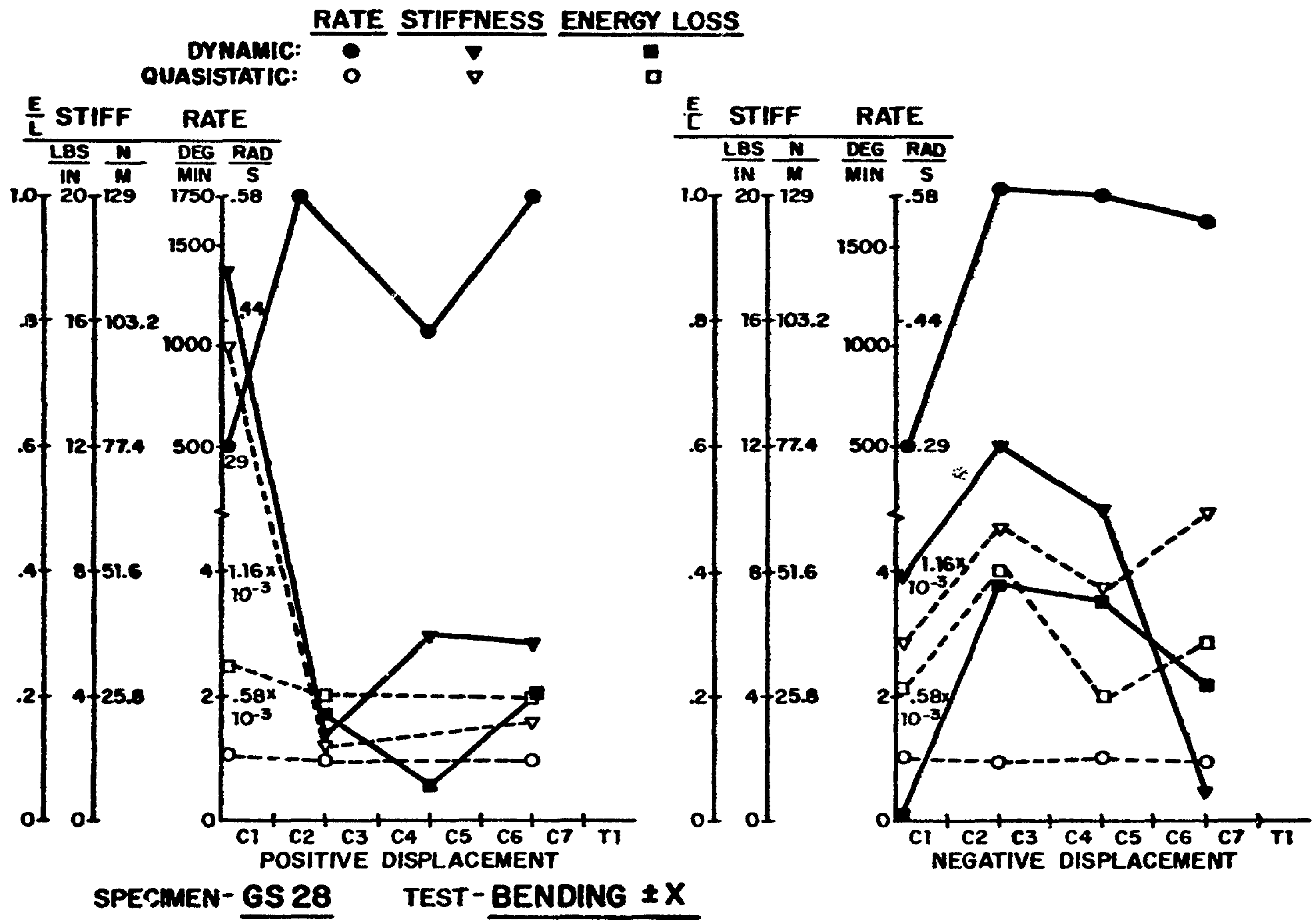


FIGURE B6: DATA FROM STIFFNESS TEST ANALYSIS

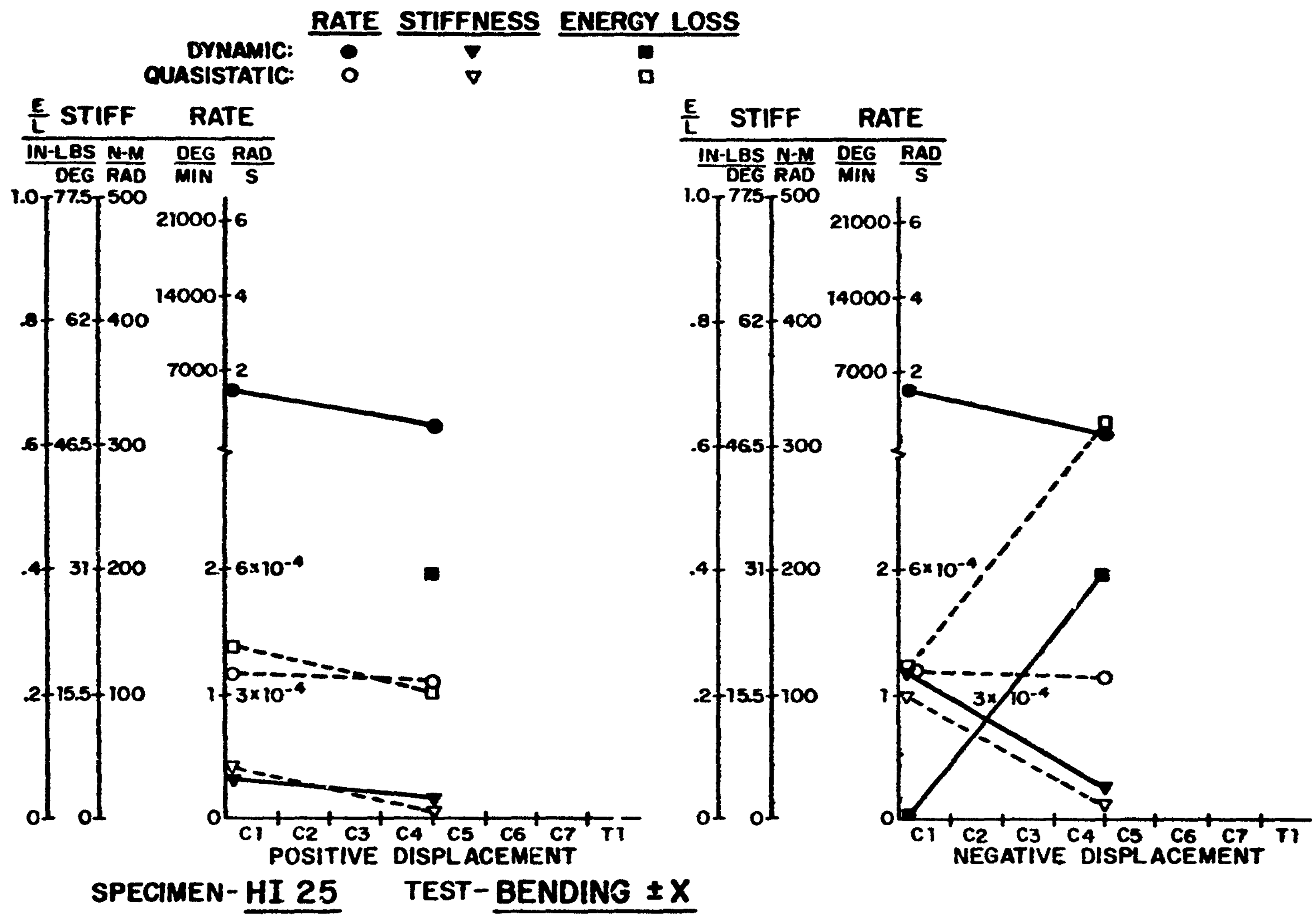
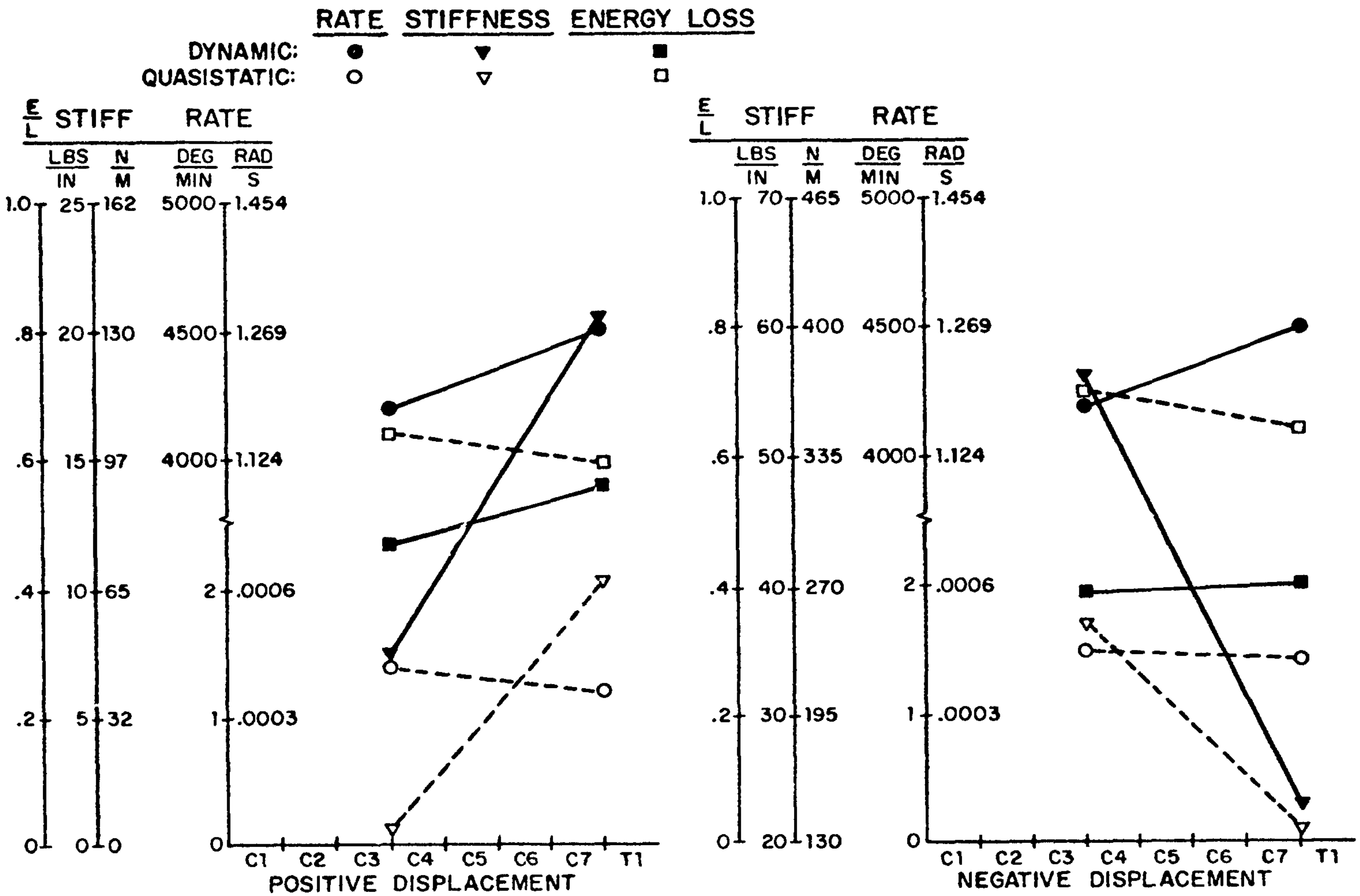


FIGURE B6: DATA FROM STIFFNESS TEST ANALYSIS



SPECIMEN- **PW 35** TEST- **BENDING ±X**

FIGURE B6: DATA FROM STIFFNESS TEST ANALYSIS

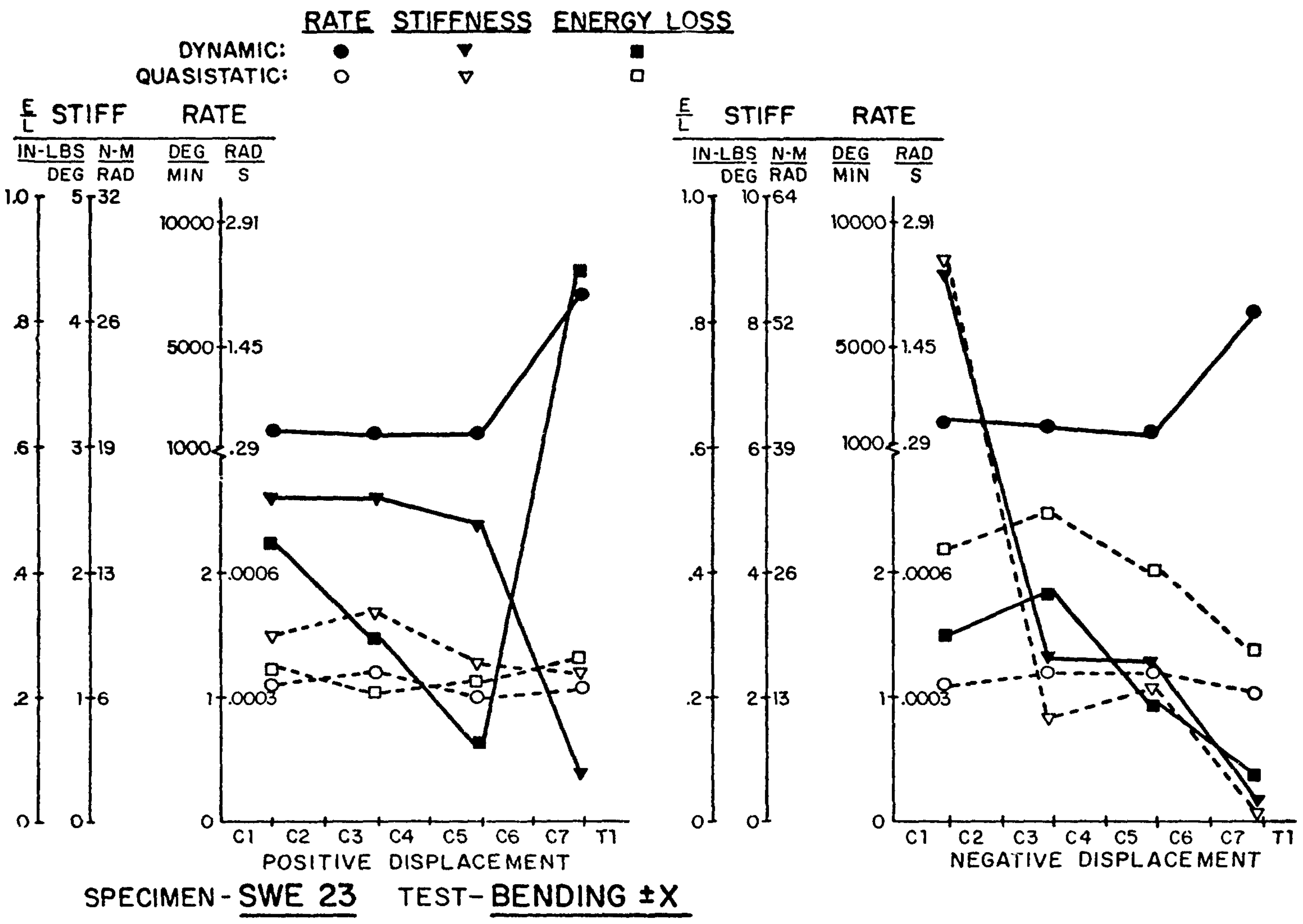


FIGURE B6: DATA FROM STIFFNESS TEST ANALYSIS

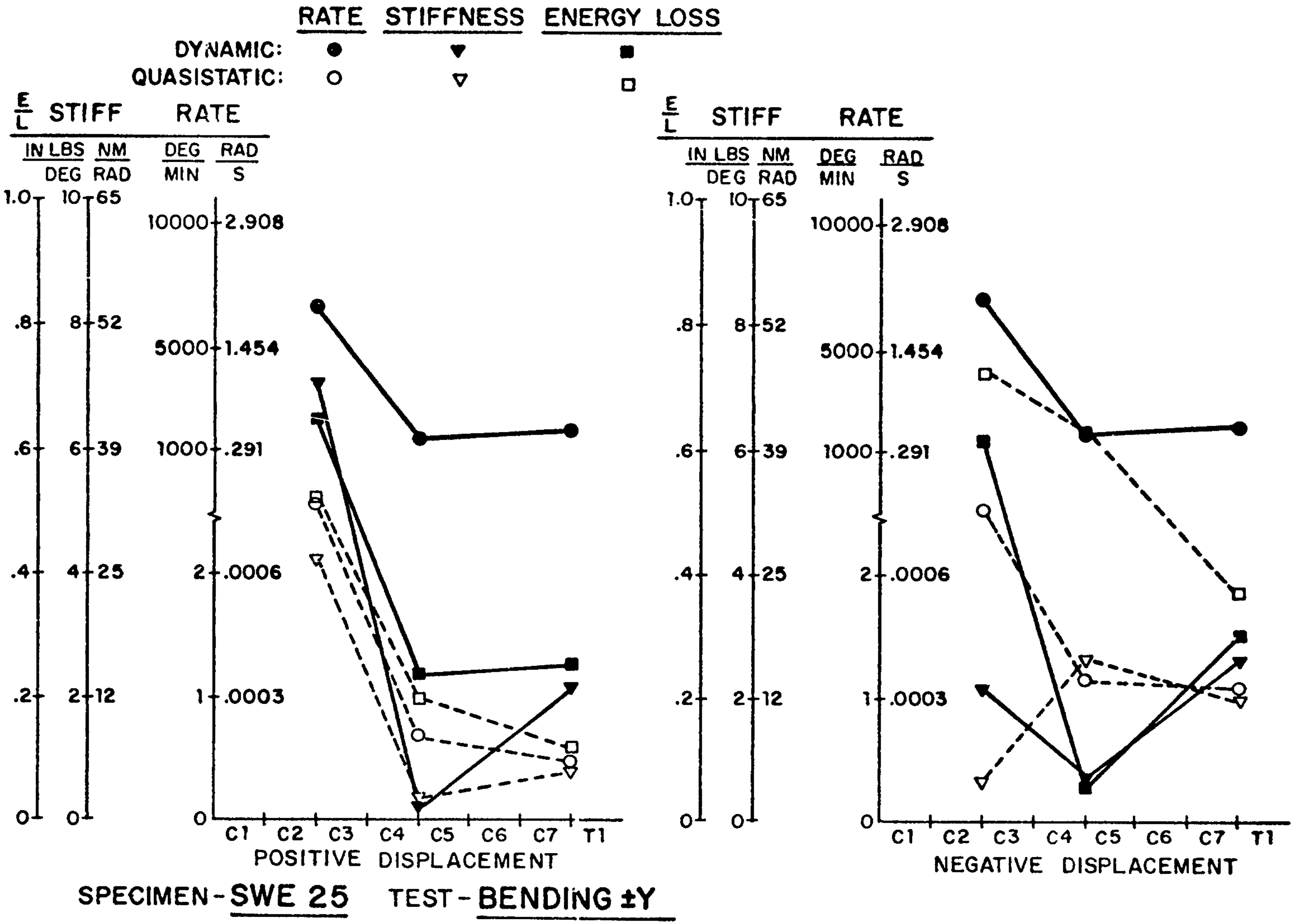


FIGURE B6: DATA FROM STIFFNESS TEST ANALYSIS

APPENDIX C

Appendix C consists of the data derived from the work on geometrical measurements. Tables C-1 through C-38 are the coordinates of the points measured in accordance with Figure 16. Examples of the coordinates plotted by computer graphics are in Figure C5. Tables C-39 through C-44 are calculated projected areas from the data. Figures C2 and C4 are plots of these areas. Other data, such as the normal vectors to the facet and centrum, are included also.

TABLE C-1. COORDINATES OF VERTEBRA C1
FOR SPECIMEN EJ 41

POINT	SUPERIOR X	SUPERIOR Y	SUPERIOR Z	INFERIOR X	INFERIOR Y	INFERIOR Z
1	1.6	0.4	3.6	-0.8	1.9	-5.7
2	1.6	0.4	3.6	-0.8	1.9	-5.7
3	1.6	0.4	3.6	-1.8	4.3	-4.0
4	1.6	0.4	3.6	-1.8	4.3	-4.0
5	1.6	0.4	3.6	-1.3	5.4	-1.5
6	1.6	0.4	3.6	-1.3	5.4	-1.5
7	1.6	0.4	3.6	-1.3	1.9	1.6
8	1.6	0.4	3.6	-1.3	1.9	1.6
9	1.6	0.4	3.6	-1.3	-1.6	0.9
10	1.6	0.4	3.6	-1.3	-1.6	0.9
11	1.6	0.4	3.6	-2.2	-3.6	-2.3
12	1.6	0.4	3.6	-2.2	-3.6	-2.3
13	1.6	0.4	3.6	-0.8	-1.0	-6.3
14	1.6	0.4	3.6	-0.8	-1.0	-6.3
15	-5.0	12.4	1.9	-5.4	-7.1	-7.3
16	-5.4	20.9	6.0	-4.9	-17.1	-12.3
17	-21.4	23.0	7.3	-13.3	-24.0	-13.8
18	-16.8	16.3	1.8	-19.4	-19.0	-9.3
19	-11.7	15.2	0.7	-17.3	-9.6	-5.6
20	-11.5	19.8	2.8	-11.3	-14.8	-9.4
21	-6.7	-11.7	2.7	-6.7	8.8	-9.9
22	-18.4	-16.2	3.5	-18.8	11.9	-7.2
23	-19.7	-23.9	7.7	-17.7	22.1	-12.8
24	-9.2	-24.3	7.6	-9.3	22.1	-14.1
25	-2.4	-15.8	6.2	-4.9	16.0	-11.2
26	-10.8	-18.8	4.2	-12.7	16.4	-10.1
27	-23.3	19.2	-0.8	-21.5	-17.0	-3.8
28	-34.7	13.6	-0.4	-33.7	-12.5	-5.2
29	-37.8	0.8	4.5	-36.1	0.1	-4.3
30	-33.8	-12.8	1.6	-32.3	13.4	-5.9
31	-14.4	42.0	-2.2	-11.3	-42.6	-3.1
32	-47.3	0.9	0.7	-47.3	0.9	0.7
33	-47.3	0.9	0.7	-47.3	0.9	0.7
34	-10.5	-43.5	-3.2	-14.8	42.8	-2.1

TABLE C-2. COORDINATES OF VERTEBRA C2
FOR SPECIMEN EJ 41

POINT	SUPERIOR X	SUPERIOR Y	SUPERIOR Z	INFERIOR X	INFERIOR Y	INFERIOR Z
1	0.6	-2.1	22.4	3.7	-0.2	-22.5
2	0.6	-2.1	22.4	4.5	-4.2	-21.8
3	0.6	1.7	19.3	2.9	-8.1	-17.5
4	0.6	1.7	19.3	-4.0	-9.4	-16.3
5	1.8	1.1	16.0	-8.2	-7.9	-15.8
6	1.8	1.1	16.0	-9.3	-2.5	-15.9
7	3.5	0.4	14.5	-10.5	4.1	-16.5
8	3.5	0.4	14.5	-5.1	7.6	-16.7
9	3.3	-3.0	13.7	0.7	8.6	-18.6
10	3.3	-3.0	13.7	3.6	5.6	-21.9
11	2.2	-6.0	16.1	0.5	4.6	-20.0
12	2.2	-6.0	16.1	1.7	-3.9	-19.6
13	0.7	-5.7	20.0	-4.8	-5.6	-16.5
14	0.7	-5.7	20.0	-6.5	3.2	-16.5
15	1.8	5.3	8.4	-11.5	-21.9	-14.4
16	2.9	12.8	5.0	-15.4	-26.4	-16.2
17	-0.6	18.0	3.2	-18.2	-23.9	-19.5
18	-14.6	16.2	1.7	*	*	*
19	-11.7	6.5	6.4	-14.2	-16.0	-18.0
20	-5.4	12.5	5.9	-14.5	-21.5	-16.5
21	2.2	-11.7	10.7	-15.8	21.7	-14.1
22	-8.0	-11.4	9.9	-16.2	14.1	-16.6
23	-15.1	-20.9	3.6	-20.4	14.1	-19.8
24	-5.3	-27.3	4.9	*	*	*
25	3.1	-22.3	5.1	-20.3	23.1	-15.8
26	-4.3	-19.2	7.5	-18.3	18.6	-16.7
27	-17.9	12.7	-0.4	-19.8	-16.7	-18.5
28	-32.5	-4.5	-0.8	-32.8	-9.5	-17.5
29	-32.5	-4.5	-0.8	-33.9	1.6	-16.5
30	-17.0	-19.2	2.1	-23.8	11.6	-18.5
31	-8.2	27.1	-16.8	-2.8	-27.9	-16.5
32	-44.7	-2.4	-11.5	-43.1	-10.4	-12.4
33	-43.1	-10.3	-12.4	-44.7	-2.4	-11.5
34	-2.8	-27.9	-16.5	-8.2	27.1	-16.8

* Not able to measure

TABLE C-3. COORDINATES OF VERTEBRA C3
FOR SPECIMEN EJ 41

POINT	SUPERIOR X	SUPERIOR Y	SUPERIOR Z	INFERIOR X	INFERIOR Y	INFERIOR Z
1	6.4	1.0	5.2	7.5	0.3	-8.2
2	5.7	4.6	5.5	6.7	-5.0	-7.3
3	5.0	8.6	9.2	3.3	-8.9	-5.3
4	2.9	9.7	12.2	-3.2	-8.9	-4.6
5	-6.9	9.1	12.4	-5.4	-6.8	-5.7
6	-6.7	-0.8	8.8	-6.1	-0.8	-5.9
7	-5.8	-9.8	11.4	-7.1	6.9	-4.3
8	-0.4	-11.7	10.7	-4.3	9.9	-2.3
9	5.2	-9.7	11.1	0.3	10.2	-2.4
10	6.9	-4.9	5.3	5.3	7.3	-5.8
11	3.1	-4.1	6.7	2.2	5.0	-4.3
12	2.4	4.9	7.0	3.0	-3.0	-5.3
13	-4.0	5.6	8.8	-2.2	-3.9	-4.3
14	-4.0	-4.8	8.2	-2.7	3.7	-3.7
15	-14.2	23.8	13.4	-5.7	-23.0	-2.6
16	-17.9	23.5	7.8	-9.7	-26.4	-6.3
17	-18.4	17.7	3.6	-14.2	-21.8	-10.1
18	-14.4	13.6	8.3	-13.7	-16.5	-9.3
19	-12.9	17.9	10.9	-9.1	-16.9	-4.8
20	-15.3	19.2	8.2	-10.7	-21.0	-6.3
21	-10.6	-24.0	11.2	-0.0	0.0	0.0 *
22	-10.1	-17.3	9.3	-0.0	0.0	0.0 *
23	-13.9	-13.6	3.8	-0.0	0.0	0.0 *
24	-14.7	-19.1	2.5	-0.0	0.0	0.0 *
25	-14.4	-25.0	6.3	-0.0	0.0	0.0 *
26	-12.3	-20.3	6.4	-0.0	0.0	0.0 *
27	-18.1	10.8	4.7	-17.7	-12.4	-7.1
28	-24.9	-1.4	2.4	-26.3	-5.5	-8.2
29	-24.9	-1.4	2.4	-26.4	2.8	-7.8
30	-17.0	-11.7	3.0	-17.7	11.1	-6.3
31	-5.0	28.8	0.9	-1.3	-27.9	-0.2
32	-38.4	4.3	-12.5	-38.0	-4.8	-9.3
33	-38.0	-4.8	-9.3	-37.3	4.4	-12.2
34	-0.7	-28.3	-0.0	-2.2	27.7	1.6

* Facet Broken

TABLE C-4. COORDINATES OF VERTEBRA C4 FOR SPECIMEN EJ 41

POINT	SUPERIOR X	SUPERIOR Y	SUPERIOR Z	INFERIOR X	INFERIOR Y	INFERIOR Z
1	7.0	0.1	5.7	7.8	-0.9	-8.4
2	6.2	5.3	5.6	7.0	-6.1	-7.1
3	5.1	8.6	8.5	5.2	-9.7	-3.4
4	2.3	9.9	11.2	0.3	-11.6	-2.0
5	-4.8	8.2	12.2	-4.2	-10.6	-2.5
6	-5.2	0.3	8.2	-6.0	0.4	-5.5
7	-5.5	-8.9	11.5	-4.4	8.2	-4.0
8	-0.3	-11.9	11.5	-1.0	10.2	-3.7
9	5.7	-11.3	9.6	3.9	10.1	-5.7
10	5.8	-7.4	5.8	7.3	5.6	-7.5
11	2.7	-3.8	6.5	4.7	3.9	-6.6
12	3.0	5.2	6.9	3.8	-4.5	-5.3
13	-1.9	4.6	8.1	-3.9	-4.4	-3.6
14	-1.8	-4.1	7.9	-2.7	4.2	-3.9
15	-12.4	22.6	7.3	-6.6	-24.3	0.5
16	-9.0	25.1	10.8	-12.1	-26.7	-4.8
17	-5.2	22.0	12.4	-15.8	-20.3	-6.0
18	-8.9	15.2	11.1	-13.3	-15.1	-3.3
19	-12.7	17.0	7.6	-8.9	-19.6	-0.4
20	-9.1	20.0	9.5	-11.1	-21.7	-1.3
21	-6.7	-23.3	15.6	-5.3	23.7	-1.6
22	-9.2	-17.8	13.4	-9.0	17.2	-3.1
23	-13.1	-15.8	10.2	-13.1	14.0	-6.2
24	-14.5	-22.9	8.8	-12.4	21.5	-5.1
25	-11.0	-25.7	11.9	-9.5	25.9	-4.1
26	-10.7	-21.2	11.8	-10.7	20.4	-3.2
27	-13.5	11.7	8.0	-17.2	-13.0	-5.1
28	-23.3	0.5	6.8	-27.0	-3.5	-5.9
29	-23.3	0.5	6.8	-26.6	5.3	-6.5
30	-14.5	-12.1	9.4	-15.9	12.7	-5.6
31	-0.9	30.6	0.4	-2.6	-31.3	3.8
32	-38.1	8.2	-8.7	-38.8	-9.7	-7.9
33	-39.8	-8.0	-6.7	-37.4	7.2	-9.8
34	-2.6	-30.9	3.8	-0.9	30.6	0.4

TABLE C-5. COORDINATES OF VERTEBRA C5
FOR SPECIMEN EJ 41

POINT	SUPERIOR X	SUPERIOR Y	SUPERIOR Z	INFERIOR X	INFERIOR Y	INFERIOR Z	
1	7.3	0.8	5.0	7.4	0.1	-7.3	
2	5.9	8.3	7.0	6.1	-6.6	-4.2	
3	4.9	10.1	11.1	2.0	-9.9	-2.3	
4	-4.8	10.4	11.7	-2.5	-9.9	-2.2	
5	-6.9	4.9	7.9	-6.9	-7.0	-4.4	
6	-6.0	-0.7	7.4	-7.7	0.1	-5.2	
7	-6.0	-9.8	9.4	-7.4	9.1	-3.7	
8	-0.7	-13.7	10.9	-3.3	11.1	-2.7	
9	5.1	-12.0	10.3	2.0	11.1	-4.2	
10	7.5	-6.6	5.4	5.8	7.0	-6.4	
11	3.4	-5.3	5.9	2.6	6.0	-5.1	
12	4.1	4.9	6.1	2.3	-4.1	-4.1	
13	-3.6	5.6	6.9	-3.0	-4.1	-4.1	
14	-3.8	-7.3	6.9	-2.9	5.1	-3.4	
15	-6.5	23.1	15.1	-7.9	-24.4	0.0	
16	-10.1	26.6	11.8	-10.2	-26.8	-3.4	
17	-14.8	18.9	8.7	-13.4	-24.8	-5.7	
18	-11.1	12.4	11.8	-15.3	-19.8	-6.2	
19	-8.6	18.8	14.7	-14.3	-12.2	-4.2	
20	-11.3	20.7	11.7	-12.4	-20.0	-2.7	
21	-6.0	-25.9	11.2	-0.0	0.0	0.0	*
22	-8.7	-18.8	11.6	-0.0	0.0	0.0	
23	-13.0	-16.7	7.5	-0.0	0.0	0.0	
24	-13.3	-23.4	5.3	-0.0	0.0	0.0	
25	-9.4	-27.2	7.3	-0.0	0.0	0.0	
26	-10.3	-21.9	8.5	-0.0	0.0	0.0	
27	-16.5	9.2	7.3	-18.8	-10.4	-5.3	
28	-23.5	-1.2	5.0	-28.5	-3.4	-6.1	
29	-23.5	-1.2	5.0	-28.5	4.2	-5.4	
30	-16.6	-10.6	6.2	-19.0	10.9	-4.0	
31	-1.5	29.2	3.2	-1.7	-29.8	-0.2	
32	-41.3	7.6	-7.5	-44.5	-6.5	-6.7	
33	-43.8	-5.9	-7.2	-41.9	7.3	-7.7	
34	-0.8	-30.8	0.0	-1.5	29.2	3.2	

* Facet Broken

TABLE C-6. COORDINATES OF VERTEBRA C6
FOR SPECIMEN EJ 41

POINT	SUPERIOR X	SUPERIOR Y	SUPERIOR Z	INFERIOR X	INFERIOR Y	INFERIOR Z
1	7.8	-0.1	4.6	6.5	1.3	-6.2
2	6.4	8.0	5.2	5.7	-5.1	-6.6
3	4.0	12.1	10.6	2.5	-10.2	-6.0
4	-0.5	12.3	12.5	-4.0	-9.2	-4.4
5	-6.3	8.2	9.0	-8.4	-5.7	-4.6
6	-5.9	-0.9	7.3	-8.3	1.3	-5.6
7	-6.5	-7.4	8.4	-8.6	6.9	-4.6
8	-0.8	-13.4	11.9	-2.4	13.2	-3.6
9	3.8	-13.3	9.4	4.7	13.3	-3.6
10	5.5	-9.0	4.8	6.4	8.8	-4.1
11	3.2	-6.8	5.1	2.5	6.6	-4.6
12	3.2	5.6	5.5	3.3	-3.3	-5.1
13	-2.3	5.3	6.6	-4.0	-2.2	-4.1
14	-2.2	-6.2	6.2	-3.7	2.9	-2.7
15	-7.5	22.9	16.6	-10.7	-19.8	2.3
16	-12.3	24.9	11.7	-16.0	-23.7	2.8
17	-15.7	18.9	7.2	-20.0	-21.2	-3.6
18	-12.6	12.9	11.9	-17.8	-13.4	-5.2
19	-8.9	16.7	15.0	-13.5	-15.0	0.6
20	-11.7	19.8	12.5	-15.4	-18.2	-0.6
21	-6.6	-26.4	14.5	-10.5	20.7	3.7
22	-9.2	-19.2	14.6	-14.0	15.3	-1.0
23	-11.8	-13.2	12.4	-17.2	15.3	-6.1
24	-14.2	-21.8	8.0	-15.5	24.8	-2.9
25	-10.9	-26.8	9.9	-11.5	25.3	3.1
26	-11.1	-21.8	11.7	-14.0	20.4	-0.1
27	-15.2	10.0	7.2	-21.6	-9.7	-4.0
28	-23.1	0.4	6.8	-33.5	-2.1	-3.2
29	-23.1	0.4	6.8	-33.5	3.8	-5.1
30	-15.3	-10.7	8.4	-20.4	10.9	-4.1
31	-1.6	30.3	4.1	-1.5	-28.7	2.9
32	-46.7	5.7	-1.2	-46.7	0.3	1.0
33	-46.5	0.8	1.3	-46.7	5.7	-1.2
34	-1.5	-28.7	2.9	-2.4	31.2	3.9

TABLE C-7 COORDINATES OF VERTEBRA C7
FOR SPECIMEN EJ 41

POINT	SUPERIOR X	SUPERIOR Y	SUPERIOR Z	INFERIOR X	INFERIOR Y	INFERIOR Z
1	9.1	0.2	5.3	7.2	-0.4	-7.2
2	7.9	6.0	5.8	4.8	-8.8	-7.0
3	4.6	12.3	7.1	1.8	-13.2	-6.2
4	-1.4	15.8	10.4	-4.3	-14.6	-4.2
5	-6.4	12.2	10.1	-7.7	-7.5	-4.2
6	-5.6	1.5	7.9	-7.0	-0.4	-5.9
7	-6.3	-6.1	9.4	-7.7	7.1	-5.3
8	-3.6	-11.7	11.4	-4.7	13.5	-4.7
9	3.2	-11.4	7.1	0.8	14.7	-7.2
10	7.7	-5.9	5.8	5.9	7.7	-7.7
11	4.7	-3.3	6.0	2.7	6.2	-6.3
12	4.6	4.8	5.4	1.7	-7.0	-5.5
13	-2.3	4.8	6.3	-3.3	-6.1	-4.2
14	-2.2	-4.0	7.0	-2.7	5.7	-5.2
15	-9.2	25.4	17.3	-12.5	-21.2	4.1
16	-13.4	24.7	10.7	-14.8	-25.1	1.8
17	-14.5	18.8	6.2	-19.6	-21.7	-3.2
18	-11.4	15.4	14.0	-20.9	-12.8	-5.7
19	-9.7	19.0	15.5	-16.6	-14.1	0.9
20	-11.6	20.8	12.6	-17.6	-18.9	-0.2
21	-10.6	-18.5	16.1	-11.2	21.9	0.9
22	-12.2	-11.6	15.6	-13.3	15.6	0.7
23	-15.8	-14.5	8.5	-13.6	14.6	-6.7
24	-17.7	-23.2	15.3	-18.2	21.6	-6.2
25	-13.3	-22.9	18.1	-14.7	26.0	-2.7
26	-13.7	-17.8	13.0	-15.2	19.6	-1.7
27	-16.7	11.4	7.0	-23.2	-10.2	-4.5
28	-22.8	0.2	7.1	-32.7	-3.3	-5.7
29	-22.8	0.2	7.1	-32.7	4.6	-7.2
30	-18.7	-8.7	8.0	-21.5	12.0	-6.7
31	-1.3	35.0	0.2	-10.8	-37.9	5.6
32	-55.2	1.1	-2.2	-55.2	1.1	-2.2
33	-55.2	1.1	-2.2	-55.2	1.1	-2.2
34	-10.8	-37.9	-5.6	-1.3	35.0	0.2

TABLE C-8. COORDINATES OF VERTEBRA T1
FOR SPECIMEN EJ 41

POINT	SUPERIOR X	Y	Z	INFERIOR X	Y	Z
1	7.8	-1.5	6.5	9.7	-0.0	-7.4
2	6.4	5.4	6.6	8.2	-6.7	-7.5
3	3.3	10.4	6.8	2.4	-16.6	-6.5
4	-3.9	13.7	10.8	-5.6	-16.7	-4.5
5	-8.2	6.6	10.3	-9.0	-9.6	-6.5
6	-6.3	-1.1	8.4	-6.6	-0.3	-7.5
7	-8.0	-9.5	10.2	-8.6	9.2	-6.9
8	-5.0	-15.3	10.9	-4.9	16.1	-6.9
9	-1.5	-15.0	7.4	3.4	14.7	-9.6
10	5.0	-10.4	6.6	8.1	7.8	-8.5
11	1.8	-6.3	7.3	3.9	4.4	-6.7
12	1.8	3.4	6.9	3.6	-3.8	-6.2
13	-2.5	3.4	6.9	-2.9	-3.8	-6.4
14	-3.0	-5.6	7.3	-3.0	5.8	-6.6
15	-10.8	21.4	17.2	-17.6	-15.2	-0.0
16	-13.7	24.6	12.5	-16.5	-20.9	-1.1
17	-17.3	18.5	7.3	-18.0	-22.8	-4.9
18	-17.9	11.6	8.6	-22.6	-11.6	-9.4
19	-13.5	13.2	15.9	-19.9	-10.2	-2.6
20	-14.4	17.7	13.2	-19.9	-15.7	-3.9
21	-12.8	-24.3	18.2	-16.6	12.1	-1.0
22	-15.2	-15.1	16.9	-20.6	9.9	-8.0
23	-19.3	-12.8	9.5	-19.7	16.8	-8.7
24	-19.6	-21.0	8.6	-15.6	22.2	-6.3
25	-17.7	-24.9	12.6	-15.2	18.1	-1.5
26	-17.0	-19.3	12.9	-18.3	14.6	-4.5
27	-20.4	9.0	5.5	-26.0	-9.2	-8.4
28	-25.7	0.3	5.2	-35.9	-0.1	-12.5
29	-25.7	0.3	5.2	-35.9	-0.1	-12.5
30	-21.3	-10.5	6.6	-24.0	9.1	-9.1
31	-18.1	39.7	11.8	-18.0	-39.4	10.8
32	-55.9	0.1	-6.0	-55.9	0.1	-6.0
33	-55.9	0.1	-6.0	-55.9	0.1	-6.0
34	-20.0	-40.0	9.5	-18.0	41.7	12.5

TABLE C-9. COORDINATES OF VERTEBRA C2
FOR SPECIMEN GS 28

POINT	SUPERIOR X	SUPERIOR Y	SUPERIOR Z	INFERIOR X	INFERIOR Y	INFERIOR Z
1	5.5	2.9	10.4	15.9	-3.8	-12.9
2	5.5	2.7	10.2	14.3	-8.8	-9.9
3	1.0	8.0	11.3	10.9	-10.6	-9.3
4	1.2	7.8	11.3	3.6	-11.9	-10.8
5	-4.3	9.3	15.0	0.4	-11.9	-14.6
6	-4.0	9.0	15.2	-0.3	-5.6	-15.9
7	-14.2	4.7	13.3	-0.5	-0.1	-17.8
8	-4.8	6.0	20.0	0.0	2.2	-15.4
9	-3.4	0.8	17.8	2.7	3.9	-13.9
10	-3.1	0.4	17.5	13.1	3.4	-14.5
11	1.6	0.3	13.4	9.6	0.8	-13.5
12	1.6	0.3	13.4	10.7	-7.0	-10.7
13	0.1	4.1	15.5	4.6	-7.0	-12.1
14	0.1	4.3	15.6	2.8	-1.2	-13.7
15	-6.2	11.1	1.0	-3.2	-25.8	-12.5
16	2.7	15.3	0.8	-5.0	-32.0	-12.0
17	2.9	21.5	-3.5	-6.8	-33.3	-16.6
18	-7.7	21.4	-10.3	-6.2	-29.1	-22.0
19	-11.1	13.5	-8.3	-3.5	-23.8	-16.1
20	-4.3	16.4	-3.4	-4.9	-28.7	-16.4
21	0.6	-12.1	7.0	-5.3	15.0	-21.7
22	-6.7	-12.0	4.7	-5.8	8.1	-25.0
23	-8.9	-18.4	1.0	-5.9	9.9	-29.5
24	-5.2	-26.1	2.7	-7.5	12.2	-27.5
25	5.2	-20.7	7.7	-7.1	16.7	-26.3
26	-2.4	-18.4	6.1	-6.7	13.0	-25.1
27	-13.6	9.0	-12.2	-8.1	-22.0	-21.2
28	-23.7	-2.3	-14.2	-17.7	-10.9	-23.8
29	-22.9	-9.0	-13.4	-17.9	-4.1	-24.3
30	-14.6	-18.1	-7.1	-8.0	6.1	-26.4
31	2.8	26.4	-20.4	5.0	-33.7	-5.8
32	-36.3	-6.7	-25.5	-32.0	-15.3	-32.6
33	-36.2	-10.1	-24.4	-32.0	-8.5	-33.2
34	4.2	-32.9	-3.6	4.1	24.1	-21.1
35	-9.3	10.3	12.6	6.3	-11.9	-9.1
36	-9.0	-1.3	15.1	5.2	4.6	-13.6

TABLE C-10. COORDINATES OF VERTEBRA C3
FOR SPECIMEN GS 28

POINT	SUPERIOR X	SUPERIOR Y	SUPERIOR Z	INFERIOR X	INFERIOR Y	INFERIOR Z
1	6.5	-0.6	5.5	11.2	1.2	-9.0
2	3.2	9.5	8.2	9.7	-3.9	-8.1
3	-0.7	10.8	10.8	6.4	-5.9	-6.9
4	-6.9	8.6	11.3	-0.9	-7.3	-8.2
5	-11.0	4.8	7.6	-4.3	-3.9	-10.0
6	-8.1	-0.5	5.7	-4.6	1.0	-9.2
7	-8.8	-8.3	6.8	-6.3	7.3	-9.0
8	-5.2	-10.9	8.9	-2.6	7.9	-6.9
9	1.5	-10.6	8.7	4.8	8.4	-6.6
10	3.9	-3.8	6.2	8.5	7.0	-7.9
11	1.0	-3.5	6.5	4.6	5.8	-7.5
12	-0.6	4.3	6.3	5.7	-0.8	-7.9
13	-3.9	2.0	5.4	-0.3	-2.9	-8.5
14	-3.4	-5.8	5.1	-1.8	5.5	-7.2
15	-15.9	17.2	8.0	-3.1	-23.9	-6.7
16	-18.6	24.2	8.5	-5.5	-25.1	-13.6
17	-20.0	22.9	2.2	-8.2	-20.7	-17.8
18	-16.6	16.0	-0.1	-7.5	-16.3	-15.4
19	-17.0	12.7	4.7	-5.8	-16.4	-11.1
20	-16.2	19.3	4.3	-5.0	-22.7	-11.8
21	-10.6	-20.2	5.0	-10.6	18.9	-3.7
22	-12.1	-16.7	-1.8	-14.2	18.0	-12.4
23	-13.2	-22.7	-4.9	-14.6	24.7	-14.6
24	-13.8	-27.3	0.4	-11.3	28.0	-7.8
25	-11.9	-27.6	3.6	-9.7	26.8	-2.5
26	-10.7	-27.7	-0.5	-11.9	22.1	-7.8
27	-17.1	10.3	2.0	-17.1	-16.1	-17.4
28	-24.3	0.8	0.1	-19.7	-5.0	-13.5
29	-24.5	-5.5	0.0	-29.3	-0.1	-18.2
30	-15.3	-12.5	-0.6	-29.6	10.3	-19.9
31	-4.6	28.1	2.3	3.5	-30.2	-3.4
32	-35.3	-0.3	-14.3	-33.3	-6.0	-17.6
33	-33.9	-5.0	-12.7	-34.8	-1.6	-16.7
34	3.3	-29.9	-2.2	-3.6	31.6	1.7
35	-4.8	9.3	10.3	2.1	-7.9	-7.3
36	-2.0	-11.8	9.5	-0.4	9.2	-5.5

TABLE C-11. COORDINATES OF VERTEBRA C4
FOR SPECIMEN GS 28

POINT	SUPERIOR X	SUPERIOR Y	SUPERIOR Z	INFERIOR X	INFERIOR Y	INFERIOR Z
1	7.8	1.0	3.8	10.1	0.5	-8.3
[illegible]	4.6	8.9	5.0	8.8	-6.1	-8.8
3	3.0	10.4	10.3	5.8	-9.6	-7.9
4	-9.6	9.6	9.4	-3.0	-12.0	-8.7
5	-9.0	8.5	7.7	-6.6	-7.7	-11.1
6	-5.5	-2.6	5.6	-7.3	-1.1	-10.2
7	-6.4	-6.7	6.8	-7.4	7.0	-8.6
8	-5.3	-9.9	9.1	-4.6	6.6	-6.7
9	3.8	-9.5	9.4	1.1	7.2	-5.1
10	6.0	-7.6	5.2	5.0	6.2	-6.4
11	2.0	-3.8	6.1	1.9	2.2	-6.2
12	2.0	4.4	5.3	2.3	-1.7	-6.4
13	-4.8	5.1	4.6	-2.9	-3.5	-7.7
14	-2.9	-5.3	5.7	-4.4	3.4	-7.6
15	-9.7	23.0	13.3	-7.3	-24.0	-6.8
16	-13.8	25.7	6.8	-5.5	-31.8	-10.2
17	-15.9	22.2	1.5	-11.5	-27.2	-15.0
18	-15.5	16.2	2.1	-12.0	-20.2	-13.6
19	-12.8	15.4	9.6	-10.2	-16.4	-9.8
20	-14.3	19.9	6.5	-9.0	-24.6	-10.6
21	-6.3	-24.8	12.0	-8.7	20.6	0.9
22	-12.5	-16.9	5.1	-12.2	12.5	-5.1
23	-10.6	-18.3	0.7	-15.5	17.7	-10.4
24	-9.5	-24.9	2.4	-12.4	25.6	-10.2
25	-6.9	-26.4	7.5	-9.5	27.0	-5.9
26	-9.3	-21.9	5.3	-13.5	18.8	-4.8
27	-13.9	12.8	7.2	-14.9	-13.8	-11.0
28	-19.2	4.2	0.7	-22.5	-8.8	-13.9
29	-19.9	-2.0	0.5	-24.7	-0.2	-15.1
30	-11.2	-11.9	4.1	-15.3	11.9	-9.0
31	-2.6	34.4	-4.6	5.6	-29.7	-5.2
32	-35.0	3.6	-18.5	-32.5	-9.8	-21.4
33	-34.1	-6.5	-16.2	-34.4	1.1	-21.8
34	4.4	-29.5	1.2	-1.4	31.0	-4.5
35	-3.7	11.1	11.5	2.1	-10.2	-7.1
36	-1.8	-10.6	10.5	-1.7	6.5	-5.9

TABLE C-12. COORDINATES OF VERTEBRA C5 FOR SPECIMEN GS 28

POINT	SUPERIOR X	SUPERIOR Y	SUPERIOR Z	INFERIOR X	INFERIOR Y	INFERIOR Z
1	4.8	0.1	5.1	13.1	0.6	-9.2
2	3.3	6.7	6.9	9.4	-7.7	-8.7
3	-1.1	10.5	12.5	4.4	-8.7	-6.2
4	-3.2	10.3	11.8	-2.1	-8.0	-7.5
5	-11.3	8.6	9.6	-5.7	-5.6	-10.6
6	-8.2	0.3	5.6	-3.9	0.3	-9.7
7	-9.8	-8.8	7.9	-4.1	8.8	-9.4
8	-8.2	-10.6	10.3	-0.9	11.6	-7.0
9	-4.0	-11.0	11.2	1.7	11.3	-5.6
10	1.1	-9.3	6.3	9.0	8.4	-7.2
11	-0.7	-4.9	5.1	5.6	5.1	-6.5
12	-6.3	5.7	5.4	6.3	-2.5	-6.8
13	-4.0	5.8	4.6	-0.3	-3.1	-8.1
14	-4.1	-4.5	4.5	-0.3	5.1	-7.6
15	-8.4	23.8	13.0	-8.8	-20.1	-2.7
16	-6.9	29.4	9.6	-8.2	-28.8	-8.4
17	-9.6	28.8	5.2	12.6	-25.1	-13.0
18	-12.5	22.4	5.8	-11.2	-15.9	-14.3
19	-10.3	19.6	12.7	-10.3	-16.1	-4.1
20	-9.9	24.9	9.1	-11.0	-21.5	-8.5
21	-12.4	-17.6	11.5	-3.0	24.7	-2.0
22	-16.3	-12.8	7.5	-5.3	18.0	-6.3
23	-16.4	-15.9	3.4	-8.1	18.6	-11.7
24	-16.2	-24.7	5.8	-5.2	28.9	-11.7
25	-13.7	-25.2	10.6	-2.7	29.6	-7.1
26	-14.6	-20.1	7.4	-4.8	23.8	-7.3
27	-14.3	15.6	7.7	-17.8	-7.4	-10.1
28	-22.2	5.9	-0.2	-21.0	1.3	10.9
29	-22.8	0.9	-1.3	-19.0	8.3	-11.9
30	-16.3	-9.6	3.4	-11.8	15.2	-10.2
31	3.9	30.3	2.1	-2.4	-29.2	-0.7
32	-33.6	7.2	-15.7	-33.8	-0.5	-23.8
33	-32.2	4.6	-16.1	-32.0	11.3	-24.4
34	-4.0	-30.5	5.1	3.0	28.9	-1.7
35	-4.1	12.1	12.8	1.5	-10.8	-6.1
36	-5.5	-13.1	16.8	2.4	10.6	-6.4

TABLE C-13. COORDINATES OF VERTEBRA C6
FOR SPECIMEN GS 28

POINT	SUPERIOR X	SUPERIOR Y	SUPERIOR Z	INFERIOR X	INFERIOR Y	INFERIOR Z
1	8.5	1.5	5.3	11.3	-1.1	-10.0
2	3.3	10.3	6.9	9.0	-8.5	-10.6
3	-0.1	12.6	12.2	5.5	-11.2	-10.0
4	-6.7	12.5	9.8	-2.0	-11.0	-6.5
5	-8.7	8.7	6.9	-6.8	-7.4	-7.7
6	-9.0	2.4	3.5	-6.3	-2.0	-8.2
7	-9.0	-5.5	4.5	-6.4	7.4	-6.1
8	-4.2	-10.9	11.0	-2.8	10.0	-4.7
9	2.3	-11.5	9.6	3.5	10.6	-7.3
10	4.2	-7.7	5.4	9.2	8.2	-9.7
11	1.5	-4.8	4.4	5.7	4.3	-8.0
12	2.3	6.9	7.1	4.9	-6.8	-8.6
13	-6.4	7.7	5.3	-2.9	-5.5	-6.0
14	-6.0	-3.6	4.3	-1.9	2.7	-5.7
15	-9.6	24.8	13.0	-6.5	-26.3	3.0
16	-10.5	30.3	5.9	-9.2	-29.8	-4.1
17	-12.8	25.3	5.2	-11.7	-27.7	-9.4
18	-14.4	19.8	5.4	-13.2	-21.0	-11.8
19	-13.8	17.1	9.5	-12.0	-19.1	-4.9
20	-11.9	22.8	8.2	-12.1	-23.4	-5.7
21	-9.5	-24.9	10.6	-7.9	19.4	1.4
22	-12.3	-18.1	8.5	-13.2	15.0	-2.3
23	-12.0	-18.6	3.6	-14.6	17.9	-6.9
24	-11.3	-23.0	1.9	-9.6	28.5	-3.6
25	-9.2	-28.2	4.5	-6.5	23.8	2.7
26	-10.5	-22.4	4.8	-11.2	20.7	-1.2
27	-13.9	13.1	9.1	-17.0	-12.1	-6.8
28	-20.8	5.4	1.2	-24.1	-3.8	-6.7
29	-20.4	-4.2	0.8	-24.3	4.0	-5.4
30	-14.4	-11.0	4.3	-16.8	8.4	-6.3
31	0.4	32.8	6.2	1.1	-20.6	5.2
32	-42.5	4.7	-17.8	-44.7	-3.0	-13.2
33	-40.1	-0.5	-19.0	-47.8	3.7	-10.8
34	-0.4	-30.9	2.2	-2.3	32.4	3.3
35	-2.9	12.6	11.8	0.4	-12.8	-7.1
36	-3.0	-11.7	10.7	0.9	11.1	-5.9

TABLE C-14. COORDINATES OF VERTEBRA C7
FOR SPECIMEN GS 28

POINT	SUPERIOR X	SUPERIOR Y	SUPERIOR Z	INFERIOR X	INFERIOR Y	INFERIOR Z
1	9.5	-2.1	7.7	9.5	2.2	-11.1
2	3.6	8.5	8.7	9.4	-8.8	-11.5
3	0.6	11.4	11.0	4.3	-12.0	-11.6
4	-10.1	8.6	11.3	-2.1	-10.8	-12.2
5	-11.2	5.4	9.3	-7.0	-5.6	-10.7
6	-9.3	-1.9	6.6	-7.0	2.0	-9.9
7	-9.7	-11.7	7.5	6.8	8.7	-6.4
8	-7.0	-15.2	8.8	-1.3	15.5	-6.0
9	1.9	-12.2	6.9	3.7	15.9	-7.4
10	4.8	-9.6	6.9	7.4	11.5	-9.3
11	1.7	-5.8	5.4	3.4	6.5	-6.8
12	2.0	3.1	8.1	5.6	-2.3	-9.8
13	-5.5	4.8	8.7	-2.8	-5.2	-7.5
14	-3.9	-5.4	5.3	-0.9	8.4	-7.3
15	-12.6	22.1	18.9	-11.0	-20.5	-4.0
16	-12.8	26.0	11.6	-11.5	-25.3	-9.1
17	-15.2	19.9	9.2	-17.3	-17.2	-13.6
18	-15.8	12.7	13.0	-17.9	-10.4	-12.4
19	-14.1	17.8	17.4	-13.7	-12.5	-3.8
20	-14.5	20.6	13.8	-13.6	-17.6	-6.3
21	-14.4	-21.9	11.2	-9.6	22.4	4.2
22	-16.3	-15.9	8.0	-12.2	14.4	0.8
23	-15.6	-22.4	2.6	-16.4	18.4	-7.9
24	-14.8	-27.6	5.0	-8.4	28.2	-2.7
25	-12.6	-29.6	11.6	-6.4	27.7	3.4
26	-14.8	-22.0	7.7	-11.6	21.8	0.3
27	-17.1	8.3	11.5	-23.1	-5.4	-11.0
28	-24.3	2.4	5.2	-26.9	-1.8	-13.4
29	-25.0	-5.2	3.7	-28.4	5.5	-11.5
30	-19.0	-10.7	5.9	-19.8	11.9	-8.0
31	-6.1	36.3	13.7	-5.0	-35.2	-0.7
32	-51.2	4.9	-14.8	-46.8	-1.7	-22.6
33	-53.9	-1.5	-16.1	-49.2	7.7	-19 5
34	-7.2	-42.5	1.6	-1.3	37.6	5.7
35	-2.9	12.3	14.1	1.5	-14.1	-13.0
36	-1.7	-16.3	10.5	0.4	18.0	-4.9

TABLE C-15. COORDINATES OF VERTEBRA C4 FOR SPECIMEN HI 23

POINT	SUPERIOR X	SUPERIOR Y	SUPERIOR Z	INFERIOR X	INFERIOR Y	INFERIOR Z
1	7.5	1.1	4.5	11.6	-1.2	-8.5
2	5.6	7.9	4.1	9.3	-7.6	-7.0
3	2.2	10.7	7.3	4.7	-9.6	-4.7
4	-5.9	10.4	8.0	-2.7	-10.9	-5.4
5	-6.8	5.5	5.4	-4.7	-7.2	-7.6
6	-6.6	2.1	4.1	-3.6	-2.1	-8.1
7	-7.3	-7.1	6.1	-4.6	3.6	-8.6
8	-5.1	-9.7	9.7	-2.1	8.1	-6.7
9	1.0	-10.0	10.4	6.6	6.4	-7.6
10	4.8	-7.4	6.1	10.1	3.5	-8.3
11	2.2	-4.3	5.2	7.0	2.6	-6.5
12	2.5	3.9	5.4	4.5	-5.9	-5.8
13	-2.6	5.9	4.0	-1.7	-6.3	-6.4
14	-3.0	-3.9	4.8	-0.1	2.3	-7.9
15	-11.2	21.6	4.0	-6.8	-17.5	-4.5
16	-14.4	24.2	-0.4	-5.7	-26.1	-3.9
17	-14.6	19.9	-3.5	-7.2	-29.1	-8.5
18	-12.5	15.1	-2.1	-11.6	-22.9	-11.9
19	-10.6	14.1	1.5	-8.3	-15.9	-7.4
20	-12.2	18.1	-0.3	-8.7	-22.5	-6.6
21	-9.3	-15.3	5.1	-8.9	12.4	-8.0
22	-10.5	-16.0	1.7	-10.5	11.2	-11.6
23	-10.9	-20.4	1.1	-12.4	15.4	-16.0
24	-10.3	-23.8	3.3	-10.9	21.5	-14.4
25	-8.7	-21.9	7.0	-9.0	21.4	-9.8
26	-9.7	-20.1	3.5	-10.4	16.8	-11.6
27	-12.8	10.7	0.2	-13.4	-14.0	-9.2
28	-18.8	2.5	-0.3	-18.9	-7.6	-11.0
29	-19.0	-4.4	-0.7	-19.6	0.1	-12.3
30	-13.8	-10.3	2.2	-13.5	8.4	-11.7
31	-3.6	27.4	-4.2	-1.6	-27.6	1.5
32	-32.2	0.2	-12.8	-31.2	-7.7	-14.0
33	-30.3	-4.4	-12.3	-32.4	-2.7	-12.6
34	0.0	-27.1	1.9	-4.6	26.2	-4.5
35	-2.8	11.6	8.2	-1.1	-10.4	-4.3
36	-2.5	-9.3	9.7	-2.5	8.3	-5.6

TABLE C-16. COORDINATES OF VERTEBRA C5 FOR SPECIMEN HI 23

POINT	SUPERIOR X	SUPERIOR Y	SUPERIOR Z	INFERIOR X	INFERIOR Y	INFERIOR Z
1	8.9	2.7	5.6	7.9	-1.3	-9.1
2	5.5	10.2	5.7	5.1	-7.9	-8.7
3	2.8	11.9	9.1	1.6	-10.2	-7.6
4	-4.8	11.7	9.6	-6.3	-9.6	-7.8
5	-6.8	9.1	7.6	-7.8	-5.7	-8.4
6	-4.9	2.3	5.1	-6.9	-0.9	-6.6
7	-6.0	-7.4	6.9	-7.7	5.0	-7.6
8	-5.8	-12.7	8.7	-4.4	8.1	-5.7
9	3.1	-9.6	8.0	2.7	8.4	-7.9
10	5.3	-6.4	3.2	5.9	5.3	-9.0
11	0.2	-8.4	3.7	4.3	1.7	-7.7
12	4.8	5.8	5.6	3.7	-6.5	-7.6
13	-2.2	6.1	3.9	-2.4	-3.3	-6.2
14	-5.0	-7.6	4.5	-2.5	2.6	-6.5
15	-10.6	20.2	7.1	-6.2	-26.6	-4.2
16	-10.8	25.8	6.8	-12.1	-25.7	-10.9
17	-12.3	22.7	3.6	-13.5	-20.6	-11.9
18	-13.2	19.1	3.6	-13.5	-14.3	-9.2
19	-9.6	14.6	9.0	-9.2	-19.7	-5.2
20	-12.0	16.1	5.0	-10.9	-20.1	-7.2
21	-8.6	-17.9	8.1	-12.5	15.8	-3.2
22	-13.5	-12.4	4.8	-13.6	10.9	-6.7
23	-13.0	-16.1	0.9	-16.3	17.6	-9.7
24	-9.9	-23.1	3.4	-13.5	22.9	-8.6
25	-5.9	-22.6	8.0	-11.7	22.1	-3.4
26	-9.5	-17.9	5.5	-13.5	18.7	-5.4
27	-12.3	12.4	6.1	-16.7	-12.5	-9.2
28	-19.8	4.5	4.0	-22.7	-5.6	-7.7
29	-21.4	-1.5	3.9	-23.5	2.0	-7.0
30	-14.1	-8.6	5.1	-17.1	8.9	-7.7
31	-2.4	28.4	0.5	-3.0	-29.1	-1.7
32	-35.7	4.7	-4.9	-40.5	-6.9	-6.0
33	-36.5	1.0	-4.4	-40.3	0.5	-5.4
34	-8.2	-29.6	-5.0	-4.0	25.1	1.3
35	-1.0	11.0	10.0	-1.6	-11.1	-6.4
36	-1.1	-10.1	10.0	-1.2	7.5	-6.6

TABLE C-17. COORDINATES OF VERTEBRA C6
FOR SPECIMEN HI 23

POINT	SUPERIOR X	SUPERIOR Y	SUPERIOR Z	INFERIOR X	INFERIOR Y	INFERIOR Z
1	8.2	1.0	6.9	7.8	-1.4	-10.2
2	4.1	12.4	7.8	4.5	-9.3	-10.0
3	1.4	13.1	11.5	2.0	-11.4	-9.1
4	-4.9	12.3	10.2	-5.3	-10.1	-8.9
5	-6.7	8.4	8.6	-7.2	-6.5	-10.2
6	-5.3	1.1	7.7	-6.9	-1.4	-10.9
7	-6.8	-7.6	9.5	-7.8	5.1	-10.5
8	-4.4	-11.2	11.5	-5.4	7.8	-9.3
9	2.9	-10.6	11.1	2.3	10.5	-10.9
10	7.1	-6.7	8.0	5.6	7.7	-10.6
11	3.6	-2.9	6.6	2.7	5.7	-9.0
12	2.3	8.1	6.5	2.8	-4.8	-8.6
13	-3.3	6.4	7.4	-3.2	-5.5	-8.4
14	-3.0	-4.8	8.1	-3.4	3.7	-8.6
15	-10.9	16.2	12.7	-10.3	-18.3	-7.4
16	-10.6	24.6	12.5	-[illegible]6	-25.2	-6.0
17	-13.5	25.5	7.5	-16.3	-25.8	-11.3
18	-15.3	19.3	5.6	-16.5	-20.7	-15.2
19	-13.4	13.6	8.7	-12.0	-15.1	-10.7
20	-13.8	19.8	9.3	-13.0	-20.7	-12.6
21	-9.4	-13.9	11.8	-11.1	16.7	-6.1
22	-12.0	-14.7	7.6	-12.8	10.7	-9.9
23	-12.2	-16.9	4.0	-15.1	13.1	-14.3
24	-7.8	-25.6	7.7	-16.4	21.0	-13.9
25	-5.2	-25.2	11.5	-15.3	25.0	-6.3
26	-9.2	-20.8	8.4	-13.4	18.5	-9.9
27	-15.1	12.6	6.4	-16.6	-12.0	-13.2
28	-19.8	7.2	4.5	-23.5	-4.7	-13.2
29	-20.3	-0.7	3.3	-24.5	1.1	-12.5
30	-14.8	-12.1	6.9	-18.8	7.8	-12.7
31	-2.7	29.3	5.2	-2.3	-28.0	-6.2
32	-45.5	5.5	-8.7	-46.5	-2.7	-17.6
33	-46.0	-0.8	-7.1	-45.6	2.8	-17.6
34	-2.4	-27.8	-0.2	-2.7	24.7	-6.0
35	-1.4	14.3	12.0	-1.1	-11.4	-8.6
36	-0.3	-11.4	13.0	-1.0	9.2	-9.9

TABLE C-18. COORDINATES OF VERTEBRA C7
FOR SPECIMEN HI 23

	SUPERIOR			INFERIOR		
POINT	X	Y	Z	X	Y	Z
1	9.4	0.6	7.8	8.2	-0.8	-9.5
2	7.7	9.6	8.0	5.1	-9.1	-9.3
3	2.0	13.6	9.1	3.7	-12.6	-8.9
4	-6.4	11.2	10.3	-3.2	-11.1	-7.3
5	-7.4	6.7	8.5	-5.8	-7.9	-7.0
6	-7.4	0.7	7.1	-6.4	-0.9	-8.7
7	-8.7	-6.9	8.5	-6.6	5.4	-6.6
8	-5.0	-11.3	9.3	-2.7	10.6	-6.7
9	2.6	-8.9	8.1	3.6	11.0	-8.4
10	7.2	-5.3	7.4	6.6	7.4	-9.3
11	3.5	-4.2	5.6	3.3	4.2	-7.5
12	4.1	5.1	6.4	2.6	-6.2	-7.9
13	-3.4	4.3	5.4	-2.2	-5.1	-7.4
14	-3.0	-3.3	5.4	-3.0	4.1	-6.9
15	-13.6	12.3	12.1	-14.1	-14.9	-2.5
16	-11.9	22.6	16.2	-12.7	-23.3	-2.7
17	-15.8	26.4	13.7	-15.8	-25.4	-5.2
18	-15.6	24.0	7.6	-18.2	-12.4	-12.3
19	-14.2	15.4	6.3	-15.8	-10.4	-6.4
20	-13.3	20.8	9.7	-15.4	-18.1	-6.2
21	-12.9	-11.8	10.9	-14.1	15.7	-0.9
22	-13.4	-12.1	6.7	-17.4	9.0	-6.4
23	-13.7	-18.0	6.6	-20.2	8.4	-10.2
24	-14.4	-25.5	10.5	-21.2	20.0	-9.3
25	-10.7	-25.4	15.7	-17.4	23.6	-4.4
26	-12.2	-20.0	10.4	-17.0	16.2	-7.0
27	-16.0	8.9	7.0	-19.5	-8.8	-10.4
28	-20.0	3.6	7.6	-23.2	-4.1	-10.7
29	-19.6	-3.8	7.3	-24.0	2.3	-9.4
30	-14.6	-8.6	8.7	-21.2	6.0	-9.2
31	-2.1	41.0	4.3	-3.9	-35.0	0.0
32	-51.5	2.7	-8.5	-51.4	-5.1	-13.8
33	-50.5	-2.3	-7.0	-51.3	-0.6	-15.2
34	-7.7	-34.7	5.6	-2.8	39.8	0.9
35	-2.1	14.1	11.4	0.0	-14.4	-8.2
36	-2.7	-12.4	8.6	1.0	13.2	-8.5

TABLE C-19. COORDINATES OF VERTEBRA C1
FOR SPECIMEN PW 35

POINT	SUPERIOR X	SUPERIOR Y	SUPERIOR Z	INFERIOR X	INFERIOR Y	INFERIOR Z
1	-0.0	0.2	4.2	0.8	1.4	-6.7
2	-0.0	0.2	4.2	0.8	1.4	-6.7
3	-0.0	0.2	4.2	-0.2	4.4	-6.2
4	-0.0	0.2	4.2	-0.2	4.4	-6.2
5	-0.0	0.2	4.2	-1.4	5.4	-1.7
6	-0.0	0.2	4.2	-1.4	5.4	-1.7
7	-0.0	0.2	4.2	-1.4	2.4	0.8
8	-0.0	0.2	4.2	-1.4	2.4	0.8
9	-0.0	0.2	4.2	-1.2	-1.6	0.8
10	-0.0	0.2	4.2	-1.2	-1.6	0.8
11	-0.0	0.2	4.2	-0.2	-2.6	-3.2
12	-0.0	0.2	4.2	-0.2	-2.6	-3.2
13	-0.0	0.2	4.2	0.3	-1.6	-6.2
14	-0.0	0.2	4.2	0.3	-1.6	-6.2
15	-5.0	16.4	8.2	-2.2	-9.1	-10.2
16	-12.8	25.3	3.7	-7.7	-22.1	-15.7
17	-25.1	24.7	4.8	-15.2	-23.1	-16.2
18	-19.3	18.0	0.3	-19.7	-18.6	-12.2
19	-7.8	12.4	2.4	-16.2	-10.6	-9.2
20	-12.3	21.4	2.4	-11.7	-16.1	-12.2
21	-4.2	-11.1	6.2	-2.7	11.4	-9.2
22	-12.9	-16.9	0.0	-14.2	10.9	-8.2
23	-20.5	-13.4	0.4	-18.2	17.4	-10.2
24	-26.1	-19.4	7.1	-15.2	24.9	-14.7
25	-9.8	-22.8	7.9	-6.7	25.4	-16.2
26	-13.0	-19.7	2.7	-10.2	17.9	-11.9
27	-26.2	19.1	-3.5	-21.1	-17.6	-6.2
28	-38.8	1.8	3.2	-35.2	-0.1	-7.2
29	-38.8	1.8	3.2	-35.2	-0.1	-7.2
30	-26.5	-15.0	-1.9	-21.2	19.4	-7.2
31	-12.7	45.4	-7.2	-16.7	-42.8	-4.7
32	-44.2	0.1	-1.9	-45.3	-1.6	-1.7
33	-44.2	0.1	-1.9	-45.3	-1.6	-1.7
34	-19.4	-42.8	-4.4	-12.7	45.4	-7.2

TABLE C-20. COORDINATES OF VERTEBRA C2 FOR SPECIMEN PW 35

POINT	SUPERIOR X	SUPERIOR Y	SUPERIOR Z	INFERIOR X	INFERIOR Y	INFERIOR Z
1	4.2	-2.4	10.2	5.8	0.5	-14.6
2	4.2	-2.4	10.2	5.3	-4.0	-14.1
3	3.4	1.6	11.8	1.8	-7.0	-10.6
4	3.4	1.6	11.8	-5.2	-8.0	-8.1
5	1.6	3.0	14.0	-10.2	-4.0	-10.1
6	1.6	3.0	14.0	-9.2	-0.5	-9.6
7	1.6	1.5	17.6	-9.7	5.0	-9.6
8	1.6	1.5	17.6	-4.7	8.5	-8.6
9	1.7	-1.0	18.5	1.3	8.0	-11.6
10	1.7	-1.0	18.5	5.3	5.0	-14.6
11	1.7	-4.0	17.5	0.8	4.5	-10.6
12	1.7	-4.0	17.5	1.3	-2.0	-10.6
13	2.7	-5.0	13.9	-3.7	-2.5	-8.6
14	2.7	-5.0	13.9	-4.7	3.5	-8.6
15	3.0	17.1	3.3	-12.2	-20.0	-6.6
16	-6.2	22.9	3.0	-14.2	-25.0	-7.6
17	-14.7	15.3	2.6	-18.2	-23.0	-12.6
18	-5.1	6.9	9.4	-18.7	-17.0	-15.6
19	2.1	7.6	6.9	-14.2	-15.0	-9.6
20	-4.8	15.9	5.3	-15.7	-19.0	-10.6
21	3.1	-18.9	3.2	-12.2	21.0	-6.6
22	0.4	-11.0	6.6	-14.2	14.0	-10.6
23	-10.8	-13.7	5.0	-18.7	14.0	-14.6
24	-13.1	-21.2	5.8	-20.2	19.0	-15.6
25	-1.0	-25.5	1.7	-18.2	23.0	-11.6
26	-5.8	-19.1	4.3	-16.7	19.0	-10.6
27	-16.9	14.8	0.8	-22.2	-14.0	-12.6
28	-40.9	-0.7	1.3	-39.8	0.0	-10.1
29	-40.9	-0.7	1.3	-39.8	0.0	-10.1
30	-17.4	-16.3	0.8	-23.2	13.0	-13.1
31	-6.2	29.0	-11.6	-7.7	-28.0	-12.6
32	-45.9	4.3	-9.1	-45.8	-5.0	-8.6
33	-45.8	-4.7	-9.7	-46.3	4.0	-9.1
34	-7.3	-29.0	-12.7	-6.2	29.0	-11.6

TABLE C-21. COORDINATES OF VERTEBRA C3
FOR SPECIMEN PW 35

POINT	SUPERIOR X	SUPERIOR Y	SUPERIOR Z	INFERIOR X	INFERIOR Y	INFERIOR Z
1	6.8	0.3	5.9	7.1	-0.7	-7.6
2	3.7	7.2	6.0	4.7	-6.3	-5.7
3	0.1	10.3	9.8	1.8	-8.2	-3.6
4	-5.2	10.1	11.2	-1.7	-8.7	-2.6
5	-7.3	6.5	9.8	-6.2	-6.4	-4.8
6	-6.9	-0.3	7.2	-6.2	-0.3	-5.6
7	-7.5	-5.6	9.0	-6.8	5.6	-5.5
8	-6.3	-9.1	11.3	-2.3	8.7	-3.0
9	-1.5	-10.6	10.9	2.6	7.5	-4.3
10	4.4	-7.3	7.3	5.9	4.1	-6.8
11	2.4	-4.5	6.6	2.5	2.5	-4.8
12	2.1	4.7	6.1	2.5	-3.4	-4.6
13	-3.4	4.5	7.0	-1.5	-3.4	-3.6
14	-2.9	-4.6	6.6	-3.3	3.5	-4.1
15	-11.2	19.4	10.2	-7.6	-22.6	0.6
16	-14.2	23.9	7.1	-11.9	-24.9	-3.7
17	-17.3	21.1	3.8	-14.9	-20.8	-8.3
18	-17.0	14.6	1.8	-11.9	-15.3	-5.6
19	-12.5	13.4	6.4	-9.9	-16.0	-2.8
20	-14.2	13.4	5.9	-11.7	-20.4	-4.2
21	-10.5	-16.8	11.0	-10.4	16.1	-2.6
22	-13.4	-13.1	5.8	-13.9	13.6	-6.7
23	-15.8	-18.0	2.3	-16.3	19.1	-9.6
24	-14.6	-23.7	6.8	-12.9	24.1	-5.5
25	-11.3	-22.6	11.4	-10.8	22.3	-2.6
26	-12.9	-19.0	7.1	-13.0	19.0	-5.5
27	-16.8	10.9	2.5	-16.0	-14.2	-5.6
28	-25.3	-0.6	1.6	-27.2	-4.4	-8.6
29	-25.3	-0.6	1.6	-27.2	2.1	-8.3
30	-15.5	-12.3	3.1	-19.0	11.6	-6.7
31	-1.5	27.4	1.5	-0.6	-27.4	2.7
32	-38.3	4.5	-9.5	-37.1	-6.5	-9.1
33	-35.9	-6.1	-9.7	-38.6	4.3	-9.6
34	-0.3	-27.5	2.8	-1.5	27.4	1.5

TABLE C-22. COORDINATES OF VERTEBRA C4
FOR SPECIMEN PW 35

POINT	SUPERIOR X	SUPERIOR Y	SUPERIOR Z	INFERIOR X	INFERIOR Y	INFERIOR Z
1	5.8	0.0	5.6	7.4	0.1	-8.4
2	5.7	5.5	5.5	5.4	-6.8	-6.3
3	1.9	9.4	9.2	0.4	-9.9	-2.6
4	-4.9	9.4	11.6	-5.4	-9.4	-4.0
5	-6.9	5.0	-9.3	-6.3	-5.7	-4.6
6	-6.7	-1.3	7.9	-6.3	-1.9	-5.1
7	-6.3	-6.3	10.3	-7.9	4.5	-5.0
8	-4.2	-9.1	12.7	-5.5	7.7	-3.2
9	1.2	-10.7	11.1	-0.5	7.6	-4.0
10	4.1	-6.6	6.3	5.4	5.6	-7.4
11	2.3	-3.2	6.3	2.9	3.3	-5.4
12	1.5	3.2	6.2	3.3	-3.4	-5.2
13	-1.9	2.5	6.8	3.3	-3.4	-5.2
14	-1.3	-4.5	7.4	3.3	-3.4	-5.2
15	-11.2	21.8	13.2	-6.2	-20.7	2.7
16	-16.4	22.8	7.7	-7.6	-24.9	1.8
17	-17.9	16.9	5.3	-12.6	-24.9	-4.2
18	-14.6	12.3	8.6	-14.4	-20.4	-9.8
19	-10.2	16.6	13.5	-12.2	-16.4	-3.2
20	-13.7	18.0	9.3	-10.6	-20.9	-0.7
21	-6.2	-19.2	15.6	-8.0	21.0	-0.2
22	-10.3	-14.3	11.6	-13.6	12.9	-5.9
23	-13.5	-18.2	8.1	-17.2	17.0	-9.3
24	-11.9	-24.3	10.6	-14.7	24.0	-7.7
25	-7.4	-23.6	15.0	-10.7	24.6	-3.1
26	-10.1	-19.6	11.6	-13.0	18.9	-4.1
27	-15.9	9.8	7.4	-18.5	-14.0	-3.2
28	-25.0	-2.2	5.4	-26.1	-6.9	-6.5
29	-25.0	-2.2	5.4	-27.0	2.6	-6.8
30	-15.7	-12.5	8.2	-17.7	11.4	-5.5
31	-2.9	27.1	-0.1	-0.5	-28.9	2.5
32	-37.2	3.9	-10.2	-36.5	-9.9	-13.0
33	-36.5	-9.9	-13.0	-37.2	3.9	-10.2
34	-0.5	-29.2	2.5	-2.9	27.1	-0.1

TABLE C-23. COORDINATES OF VERTEBRA C5 FOR SPECIMEN PW 35

POINT	SUPERIOR X	SUPERIOR Y	SUPERIOR Z	INFERIOR X	INFERIOR Y	INFERIOR Z
1	6.0	1.4	3.4	7.5	-0.1	-6.0
2	3.8	6.8	4.0	5.4	-5.8	-5.4
3	2.8	9.3	4.9	0.9	-8.4	-3.2
4	1.2	10.9	7.9	-4.9	-8.0	-3.9
5	-5.1	10.9	10.8	-5.8	-3.8	-5.0
6	-7.0	5.9	7.4	-5.9	-0.4	-4.9
7	-6.1	-4.3	8.0	-6.2	5.8	-4.4
8	-5.1	-9.0	11.4	-4.5	8.5	-2.9
9	2.4	-9.2	11.2	1.5	8.5	-3.9
10	3.7	-6.3	6.3	5.7	6.0	-5.5
11	3.4	-3.0	5.2	1.9	3.6	-3.5
12	2.9	4.4	4.2	2.3	-2.7	-4.0
13	-3.0	3.4	5.4	-2.2	-2.7	-3.2
14	-3.7	-3.7	6.5	-2.1	2.8	-3.5
15	-8.8	22.0	11.4	-8.3	-20.3	3.4
16	-10.7	25.4	9.2	-8.7	-24.6	2.9
17	-14.9	25.0	5.2	-13.1	-25.2	-4.2
18	-16.7	21.5	3.6	-15.2	-18.2	-5.6
19	-14.9	13.6	6.3	-12.8	-15.3	-3.2
20	-12.9	18.4	6.4	-12.4	-21.5	0.0
21	-7.3	-20.2	16.7	-9.1	19.8	1.0
22	-9.4	-14.0	14.0	-13.4	14.7	-4.9
23	-12.7	-14.8	10.8	-16.1	21.0	-6.7
24	-14.1	-19.5	9.8	-13.5	26.0	-5.3
25	-12.2	-23.8	11.6	-10.5	24.9	0.0
26	-10.7	-18.7	12.2	-13.1	19.9	-2.4
27	-16.6	10.5	4.9	-16.7	-14.2	-4.3
28	-25.0	-1.0	4.4	-28.4	-5.1	-8.9
29	-25.0	-1.0	4.4	-28.4	3.4	-8.0
30	-14.4	-12.0	8.8	-18.0	13.2	-5.2
31	-5.0	31.4	-2.4	-1.5	-30.2	3.0
32	-40.2	4.3	-13.6	-38.4	-6.3	-13.3
33	-39.2	-7.3	-12.8	-39.4	4.9	-13.4
34	-1.2	-30.3	3.2	-5.0	31.4	-2.4

TABLE C-24. COORDINATES OF VERTEBRA C6
FOR SPECIMEN PW 35

POINT	SUPERIOR X	SUPERIOR Y	SUPERIOR Z	INFERIOR X	INFERIOR Y	INFERIOR Z
1	6.7	0.6	5.5	6.6	-0.1	-6.5
2	2.6	8.1	6.6	5.8	-7.4	-5.5
3	-0.3	11.5	10.8	0.8	-9.7	-4.5
4	-5.5	10.2	10.1	-3.4	-8.4	-4.7
5	-7.1	5.6	7.6	-5.4	-6.3	-5.5
6	-5.9	-0.3	6.7	-5.1	-0.4	-5.8
7	-6.1	-5.8	7.9	-5.4	6.8	-5.8
8	-4.1	-9.7	10.1	-2.1	10.3	-5.3
9	0.4	-10.8	12.0	2.2	10.3	-6.5
10	4.4	-8.1	7.0	6.6	6.5	-5.5
11	2.7	-4.3	6.1	3.3	4.8	-5.8
12	2.5	1.8	5.8	2.9	-4.2	-4.7
13	-2.4	3.5	5.9	-2.9	-4.2	-4.5
14	-2.2	-4.2	6.2	-2.8	4.8	-5.3
15	-10.3	21.7	13.7	-7.3	-19.7	3.5
16	-14.2	26.0	8.6	-7.8	-26.2	1.9
17	-16.6	20.8	5.4	-10.8	-27.4	-2.9
18	-15.5	15.8	6.2	-13.3	-20.1	-4.5
19	-12.8	13.7	10.5	-9.8	-16.7	0.9
20	-13.1	21.4	9.8	-10.3	-22.4	0.5
21	-7.9	-21.1	15.6	-9.8	19.3	0.0
22	-8.3	-17.8	15.2	-11.6	15.0	-0.6
23	-11.4	-15.4	11.2	-15.8	14.3	-6.0
24	-13.7	-21.1	9.5	-17.3	19.6	-8.5
25	-9.5	-24.3	14.9	-17.3	24.0	-8.5
26	-10.7	-20.3	12.3	-14.1	20.0	-3.5
27	-16.3	10.2	7.8	-18.6	-12.2	-3.5
28	-24.9	-1.1	5.7	-28.5	-7.5	-7.5
29	-24.9	-1.1	5.7	-28.8	1.3	-8.1
30	-14.1	-12.6	9.1	-18.3	11.6	-6.0
31	-6.3	29.8	1.5	-1.2	-30.2	5.1
32	-37.3	0.8	-16.5	-39.3	-9.1	-13.5
33	-39.3	-9.1	-13.5	-37.3	0.8	-16.5
34	-1.1	-31.3	5.2	-6.3	29.8	1.5

TABLE C-25. COORDINATES OF VERTEBRA C7
FOR SPECIMEN PW 35

POINT	SUPERIOR X	SUPERIOR Y	SUPERIOR Z	INFERIOR X	INFERIOR Y	INFERIOR Z
1	7.3	0.5	6.7	7.3	-0.1	-7.3
2	4.7	7.2	7.2	6.4	-8.0	-7.3
3	-1.4	12.5	10.0	4.2	-11.9	-7.5
4	-5.9	11.0	11.0	-1.9	-11.9	-5.0
5	-7.9	7.0	9.2	-7.1	-9.0	-5.1
6	-7.2	-0.2	7.7	-6.8	-1.1	-7.2
7	-7.7	-7.2	9.2	-7.8	6.0	-6.4
8	-5.7	-10.5	1.1	-4.2	10.5	-5.4
9	-0.6	-12.0	13.1	2.4	11.4	-7.4
10	6.0	-5.9	7.7	7.1	6.0	-7.5
11	2.6	-3.8	7.7	2.8	4.2	-6.1
12	3.3	4.0	7.2	2.8	-4.1	-5.8
13	-3.1	4.0	7.5	-2.9	-4.1	-5.3
14	-3.0	-4.5	7.8	-3.4	4.4	-5.8
15	-12.0	19.9	15.3	-13.8	-19.9	-1.3
16	-15.4	26.4	11.7	-15.5	-26.4	-3.8
17	-17.9	20.8	5.9	-17.4	-21.9	-7.2
18	-16.6	15.7	8.2	-17.1	-15.4	-6.9
19	-15.1	14.0	12.3	-14.9	-15.4	-2.9
20	-15.1	20.7	9.9	-15.6	-20.5	-3.8
21	-9.8	-23.0	18.1	-13.8	18.0	-0.6
22	-12.4	-17.6	15.4	-15.9	13.0	-3.2
23	-14.5	-19.3	10.0	-19.7	12.2	-9.8
24	-12.8	-25.5	11.5	-18.2	23.0	-6.0
25	-10.2	-27.2	16.6	-15.1	25.0	-1.9
26	-11.5	-22.4	14.4	-16.9	17.0	-4.3
27	-18.9	10.4	7.9	-19.7	-12.5	-8.2
28	-25.2	-1.2	5.2	-31.6	-6.7	-13.3
29	-25.2	-1.2	5.2	-31.7	0.8	-13.8
30	-16.7	-12.1	9.4	-21.8	9.0	-9.5
31	-9.8	35.9	3.2	-4.8	-35.7	5.5
32	-52.1	-3.6	-16.4	-52.1	-3.6	-16.4
33	-52.1	-3.6	-16.4	-52.1	-3.6	-16.4
34	-4.2	-35.7	5.6	-8.6	36.0	3.5

TABLE C-26. COORDINATES OF VERTEBRA T1
FOR SPECIMEN PW 35

POINT	SUPERIOR X	SUPERIOR Y	SUPERIOR Z	INTERIOR X	INTERIOR Y	INTERIOR Z
1	10.0	-0.9	6.5	7.8	-3.9	-8.5
2	8.2	6.7	7.1	1.1	-14.4	-8.6
3	3.1	10.4	8.2	-7.7	-13.8	-7.3
4	-2.2	11.7	11.8	-10.1	-8.2	-6.9
5	-6.3	8.0	11.7	-10.1	-8.2	-6.9
6	-4.2	-0.6	9.0	-8.0	-0.4	-7.1
7	-5.6	-7.5	10.8	-9.4	8.2	-6.4
8	-3.5	-12.3	12.4	-4.4	13.1	-7.5
9	3.1	-12.6	8.1	2.7	14.1	-8.6
10	7.8	-8.8	6.9	6.3	9.6	-8.4
11	4.9	-5.6	7.4	2.5	6.0	-7.0
12	4.0	3.4	7.8	2.0	-5.4	-7.3
13	-0.1	3.4	8.5	-5.1	-4.4	-6.5
14	-0.3	-4.5	8.0	-4.7	5.2	-6.5
15	-10.7	21.3	18.1	-17.5	-18.3	0.7
16	-14.7	25.6	13.2	-18.7	-23.4	-2.0
17	-16.4	17.7	9.7	-22.7	-19.6	-6.5
18	-16.9	12.5	9.7	-21.7	-11.4	-7.0
19	-13.2	12.8	15.7	-18.3	-12.7	-0.4
20	-13.7	16.8	14.1	-20.2	-18.4	-2.7
21	-9.2	-24.3	17.7	-17.3	16.4	1.5
22	-12.0	-16.0	15.3	-19.6	11.6	-1.6
23	-15.1	-12.4	11.8	-22.2	12.5	-8.0
24	-16.1	-19.3	10.3	-22.2	23.1	-5.0
25	-15.4	-25.8	11.4	-16.9	22.0	2.0
26	-13.7	-21.6	14.3	-20.2	16.4	-1.5
27	-17.0	8.5	7.2	-24.2	-10.8	-8.5
28	-24.2	-1.1	5.6	-33.2	-3.5	-11.2
29	-24.2	-1.1	5.6	-34.0	2.5	-10.8
30	-18.1	-11.3	7.8	-25.0	9.1	-8.6
31	-18.5	40.5	10.4	-14.9	-43.4	12.0
32	-54.5	-1.9	-14.8	-54.5	-1.9	-14.8
33	-54.5	-1.9	-14.8	-54.5	-1.9	-14.8
34	-12.3	-43.3	11.3	-19.1	41.4	10.5

TABLE C-27. COORDINATES OF VERTEBRA C3 FOR SPECIMEN SWE 23

POINT	SUPERIOR X	Y	Z	INFERIOR X	Y	Z
1	7.3	-0.7	4.8	10.1	-0.1	-10.2
2	4.8	7.0	8.8	6.8	-6.4	-6.5
3	0.8	9.9	11.0	2.9	-9.0	-5.2
4	-5.7	9.2	10.7	-4.0	-9.1	-6.4
5	-8.6	7.0	6.5	-5.2	-5.7	-11.3
6	-9.3	-1.4	5.5	-3.2	0.7	-10.8
7	-8.9	-8.4	7.0	-4.4	8.5	-11.8
8	-3.9	-9.1	9.6	-2.2	11.3	-8.4
9	2.9	-9.5	10.6	5.5	8.5	-7.7
10	5.9	-6.8	7.1	9.1	5.3	-10.1
11	1.0	-5.1	5.3	5.5	4.7	-7.7
12	1.5	1.9	4.1	4.6	-4.5	-7.6
13	-4.8	2.2	3.6	-1.2	-4.2	-8.7
14	-4.4	-4.7	5.1	0.0	5.3	-8.7
15	-11.5	20.4	8.3	-4.1	-17.7	-4.7
16	-13.5	24.9	7.1	-6.4	-25.3	-9.7
17	-14.6	22.1	0.7	-10.5	-24.1	-13.0
18	-17.5	11.7	-4.0	-12.8	-17.8	-14.4
19	-12.0	12.8	3.7	-6.7	-13.4	-9.6
20	-13.6	19.7	4.4	-8.5	-19.6	-9.7
21	-9.6	-20.5	8.7	-1.8	20.5	-3.4
22	-12.8	-15.4	2.0	-6.4	14.4	-11.3
23	-12.9	-20.5	-4.2	-12.1	19.0	-16.2
24	-11.8	-24.7	2.8	-10.1	26.0	-12.0
25	-9.2	-24.3	9.0	-6.1	25.5	-4.5
26	-10.2	-18.9	3.7	-9.6	21.1	-9.4
27	-15.3	8.1	-2.3	-10.5	-10.8	-12.7
28	-21.6	2.3	-2.0	-18.2	-3.9	-15.3
29	-20.7	-2.3	-1.0	-18.8	4.0	-15.9
30	-11.5	-10.8	0.4	-12.9	11.6	-13.5
31	0.9	29.7	-2.8	5.1	-27.9	-2.0
32	-30.9	3.0	-13.8	-30.3	-2.7	-19.3
33	-31.5	-5.0	-12.0	-30.0	2.3	-20.3
34	4.2	-29.3	1.0	0.9	27.2	-4.9
35	-2.3	10.0	11.3	-1.5	-9.8	-4.5
36	-2.1	-9.5	10.0	1.0	10.8	-6.2

TABLE C-28. COORDINATES OF VERTEBRA C4
FOR SPECIMEN SWE 23

POINT	SUPERIOR X	SUPERIOR Y	SUPERIOR Z	INFERIOR X	INFERIOR Y	INFERIOR Z
1	6.0	-1.4	5.1	9.8	1.6	-9.0
2	3.5	6.8	8.6	9.5	-4.6	-10.4
3	0.4	8.7	11.2	5.5	-8.6	-9.4
4	-5.8	8.1	13.1	-2.2	-8.2	-9.7
5	-7.7	4.3	8.8	-4.3	-4.5	-10.8
6	-6.5	-0.3	6.3	-4.0	0.5	-10.3
7	-9.6	-7.6	6.7	-4.5	7.6	-8.3
8	-7.0	-12.2	9.9	-1.8	11.2	-7.4
9	1.0	-13.2	7.8	7.4	9.5	-8.0
10	4.7	-8.6	5.0	10.5	6.2	-8.1
11	0.9	-6.3	4.2	5.8	5.9	-7.0
12	1.6	3.5	6.6	4.8	-2.6	-7.7
13	-3.2	3.3	6.1	0.9	-2.6	-8.1
14	-3.4	-4.6	4.2	0.0	5.3	-7.2
15	-7.6	14.4	16.3	-7.2	-17.9	-6.9
16	-10.1	21.8	17.0	-5.3	-24.9	-8.9
17	-15.3	20.5	9.4	-7.9	23.8	-13.8
18	-15.8	14.3	3.6	-10.2	-18.2	-16.6
19	-12.2	11.1	8.9	-9.9	-12.0	-12.5
20	-11.1	18.2	10.9	-7.0	-19.0	-10.8
21	-6.0	-20.4	9.7	-7.6	15.3	-2.9
22	-11.7	-15.1	5.6	-12.2	16.0	-9.1
23	-13.1	-18.7	0.7	-12.9	21.8	-9.6
24	-12.4	-27.2	1.9	-8.8	27.6	-3.8
25	-7.2	-27.6	7.6	-4.8	10.1	0.3
26	-9.3	-21.8	4.3	-9.4	20.5	-4.6
27	-15.1	8.6	6.3	-12.5	-10.3	-12.0
28	-23.1	1.8	0.6	-18.8	-3.1	-13.7
29	-21.5	-4.5	-1.0	-19.6	4.2	-12.9
30	-14.7	-12.7	4.5	-13.9	11.6	-8.9
31	3.8	31.6	5.6	5.4	-28.3	-6.3
32	-30.0	2.8	-7.5	-30.9	-4.0	-27.3
33	-31.7	-2.8	-7.1	-29.7	7.1	-19.4
34	2.2	-30.4	-3.4	2.5	31.6	6.1
35	-2.7	8.4	13.0	0.3	-9.3	-8.6
36	-4.9	-12.8	9.9	2.0	13.4	-6.4

TABLE C-29. COORDINATES OF VERTEBRA C5 FOR SPECIMEN SWE 23

POINT	SUPERIOR X	SUPERIOR Y	SUPERIOR Z	INFERIOR X	INFERIOR Y	INFERIOR Z
1	5.8	0.3	7.4	13.2	-0.2	-11.0
2	4.1	5.9	7.8	8.5	-5.8	-9.7
3	1.9	9.8	9.5	4.7	-8.1	-6.5
4	-6.9	11.2	10.1	-3.8	-9.5	-8.2
5	-9.3	5.8	6.2	-4.0	-7.0	-9.8
6	-9.3	0.0	5.2	-4.9	0.0	-8.8
7	-10.5	-7.4	6.9	-3.4	7.6	-9.5
8	-8.9	-11.3	10.1	-1.8	10.8	-7.9
9	-0.6	-13.3	10.8	5.0	10.9	-6.7
10	3.3	-9.1	7.1	8.6	8.0	-7.9
11	-0.8	-6.0	6.9	5.1	5.9	5.3
12	1.9	7.6	6.8	4.4	-2.2	-5.4
13	-5.9	4.8	5.9	-2.4	-4.0	-7.1
14	-6.5	-5.6	5.7	-1.9	6.0	-6.9
15	-7.4	21.0	13.6	-8.4	-20.2	-4.1
16	-8.8	25.9	11.9	-10.7	-25.8	-8.3
17	-13.3	24.6	6.2	-14.5	-19.2	-14.2
18	-14.3	19.7	4.8	-12.0	-14.0	-10.9
19	-13.3	14.8	8.3	-8.8	-13.5	-5.6
20	-12.5	19.6	8.8	-11.8	-18.6	-8.3
21	-11.8	-20.5	12.7	-4.5	22.1	-3.5
22	-14.1	-15.0	10.8	-6.4	16.2	-6.5
23	-16.4	-14.9	5.6	-11.3	17.9	-13.2
24	-16.3	-22.0	4.3	-7.9	27.4	-11.4
25	-14.3	-27.7	9.5	-5.9	27.4	-6.2
26	-14.0	-19.4	8.9	-7.9	23.0	-8.7
27	-14.5	10.8	7.5	-16.6	-8.8	-9.1
28	-22.8	2.5	1.3	-20.6	-1.5	-12.2
29	-23.3	-2.9	1.4	-19.6	3.8	-11.5
30	-17.0	-11.1	5.7	-11.7	12.5	-9.9
31	2.9	31.7	2.8	6.9	-30.9	-4.9
32	-38.4	4.3	-19.3	-32.4	-0.7	-20.2
33	-35.1	-2.6	-18.4	-27.2	8.5	-23.1
34	- 4.0	-31.5	-3.6	7.2	25.5	-6.3
35	-3.5	12.6	10.5	0.9	-11.1	-7.4
36	-4.3	-13.1	10.5	2.2	11.5	-6.6

TABLE C-30. COORDINATES OF VERTEBRA C6
FOR SPECIMEN SWE 23

POINT	SUPERIOR X	SUPERIOR Y	SUPERIOR Z	INFERIOR X	INFERIOR Y	INFERIOR Z
1	7.5	-1.2	6.3	8.5	0.4	-11.5
2	5.8	7.7	6.5	5.7	-11.8	-13.2
3	2.4	11.2	9.9	2.1	-13.4	-10.1
4	-2.1	11.8	11.2	-6.9	-12.6	-9.5
5	-6.3	9.8	9.8	-8.1	-8.2	-10.0
6	-5.5	1.9	7.6	-6.6	-2.6	-12.9
7	-6.9	-8.6	9.5	-6.6	9.7	-7.2
8	-4.0	-11.5	10.9	-4.0	15.1	-5.7
9	1.7	-10.2	8.0	5.6	13.2	-10.4
10	5.7	-8.0	6.0	8.1	10.0	-9.7
11	1.4	-5.0	5.8	4.2	5.2	-7.5
12	2.4	4.9	5.7	1.7	-5.6	-7.1
13	-2.2	5.2	6.4	-3.9	-5.8	-7.5
14	-2.9	-6.1	6.2	-1.7	5.8	-8.1
15	-7.0	22.8	14.7	-11.4	-21.7	-2.6
16	-10.1	26.8	9.9	-15.5	-28.4	-7.2
17	-10.6	22.0	9.7	-17.0	-20.2	-11.8
18	-11.9	14.4	11.0	-15.1	-14.3	-10.6
19	-8.3	16.4	15.3	-12.5	-15.4	-5.4
20	-9.6	21.5	11.8	-14.4	-20.7	-7.2
21	-11.3	-14.8	13.6	-8.2	19.9	-1.9
22	-14.5	-12.4	9.3	-10.8	12.4	-5.8
23	-14.8	-17.7	7.9	-13.7	17.8	-11.7
24	-14.3	-24.4	9.4	-12.0	26.2	-9.2
25	-11.4	-23.8	13.9	-10.5	27.1	-4.6
26	-12.8	-18.3	10.9	-10.8	20.2	-7.0
27	-13.8	11.7	10.6	-16.8	-8.6	-7.9
28	-20.6	6.7	8.4	-24.1	-1.9	-12.3
29	-22.1	-0.5	8.7	-24.9	3.8	-10.7
30	-15.3	-9.1	9.8	-17.5	10.2	-7.1
31	1.2	33.1	4.7	7.1	-24.6	-1.9
32	-43.7	6.7	-5.3	-44.9	1.7	-13.5
33	-42.3	2.9	-4.6	-41.9	6.6	-15.3
34	-3.1	-30.6	3.6	5.0	22.2	-8.1
35	-1.4	14.2	12.6	-0.8	-14.5	-7.9
36	-2.0	-12.9	12.3	0.2	14.6	-6.5

TABLE C-31. COORDINATES OF VERTEBRA C7
FOR SPECIMEN SWE 23

POINT	SUPERIOR X	SUPERIOR Y	SUPERIOR Z	INFERIOR X	INFERIOR Y	INFERIOR Z
1	8.7	-1.3	8.2	9.5	1.5	-9.3
2	4.0	10.4	8.5	6.7	-10.2	-9.6
3	0.6	11.9	8.2	4.3	-12.7	-10.3
4	-9.5	11.1	8.8	-5.2	-11.7	-7.8
5	-11.4	7.0	6.5	-7.1	-4.6	-7.8
6	-10.6	-1.0	7.5	-5.6	1.2	-8.6
7	-10.1	-7.3	9.1	-6.2	9.2	-7.9
8	-7.1	-13.0	10.2	-4.2	13.3	-7.2
9	0.6	-13.8	8.7	3.6	16.1	-7.8
10	4.1	-11.4	7.9	6.1	14.1	-8.5
11	-0.5	-5.9	6.1	4.4	8.3	-6.9
12	1.6	4.0	7.0	4.8	-5.1	-7.7
13	-5.2	4.7	7.3	-2.2	-4.0	-7.2
14	-6.7	-5.7	7.2	-3.0	8.8	-6.9
15	-13.9	16.9	12.6	-10.7	-15.2	1.0
16	-14.5	24.5	11.5	-11.4	-23.7	-2.9
17	-15.9	22.5	5.9	-16.8	-16.5	-10.2
18	-16.2	14.1	3.6	-18.1	-7.6	-12.8
19	-15.6	10.5	10.4	-10.7	-10.1	-1.8
20	-15.4	18.0	8.5	-15.5	-14.2	-5.5
21	-12.5	-23.2	14.6	-10.4	19.8	-0.6
22	-14.9	-11.8	10.5	-15.7	13.4	-4.2
23	-16.4	-13.5	5.7	-18.2	14.4	-13.0
24	-16.6	-25.2	6.6	-13.5	27.1	-7.0
25	-14.6	-28.8	11.8	-10.1	23.0	-2.2
26	-15.3	-20.9	9.0	-15.1	19.5	-6.5
27	-18.6	6.7	6.8	-20.7	-4.1	-9.5
28	-22.2	2.5	6.9	-25.6	1.8	-10.0
29	-22.2	-3.0	6.8	-25.1	5.3	-9.7
30	-16.8	-7.5	7.4	-17.4	11.3	-5.6
31	-9.4	36.0	3.2	-5.8	-31.6	-7.0
32	-53.5	7.9	-13.0	-48.4	0.3	-22.5
33	-51.3	-2.0	-14.3	-49.9	10.1	-17.4
34	-10.3	-38.2	2.4	-4.6	37.1	-1.3
35	-0.5	10.7	9.9	0.0	-12.5	-9.3
36	-2.5	-15.4	9.3	0.9	16.8	-7.5

TABLE C-32. COORDINATES OF VERTEBRA T1
FOR SPECIMEN SWE 23

POINT	SUPERIOR X	SUPERIOR Y	SUPERIOR Z	INFERIOR X	INFERIOR Y	INFERIOR Z
1	7.6	-0.7	8.2	11.1	2.3	-9.3
2	6.1	9.2	9.2	7.7	-8.1	-11.9
3	1.6	11.0	10.2	3.7	-14.4	-12.4
4	-7.2	8.9	12.2	-5.4	-13.7	-14.3
5	-8.9	4.6	10.5	-10.7	-7.7	-12.8
6	-7.8	-0.1	8.8	-9.3	1.8	-9.8
7	-10.5	-10.3	10.9	-7.3	15.2	-8.6
8	-6.9	-13.8	11.1	-4.2	18.6	-8.6
9	-1.1	14.5	7.7	3.8	18.1	-8.1
10	3.4	-11.8	6.9	8.6	12.8	-9.8
11	2.0	-7.5	7.3	2.9	11.1	-10.1
12	2.9	5.0	8.4	4.0	-7.1	-10.8
13	-2.7	4.2	9.1	-4.7	-4.8	-10.9
14	-3.4	-7.7	7.8	-3.2	9.3	-9.7
15	-12.1	14.4	18.1	-15.5	-14.0	-5.1
16	-12.9	24.0	13.9	-15.0	-17.5	-9.5
17	-18.2	19.5	9.4	-19.6	-13.7	-13.7
18	-18.8	9.0	8.8	-21.1	-4.9	-15.3
19	-13.9	9.5	17.1	-18.2	-8.2	-6.1
20	-14.0	15.6	13.1	-19.7	-10.4	-8.9
21	-14.2	-18.6	16.2	-13.0	16.0	-0.8
22	-17.1	-10.8	12.3	-19.4	10.6	-5.5
23	-19.3	-11.9	4.3	-18.9	14.9	-14.4
24	-17.0	-20.8	8.5	-15.9	22.3	-10.2
25	-14.8	-22.4	12.7	-11.4	22.0	-5.5
26	-15.8	-16.9	10.8	-17.1	18.2	-7.4
27	-18.0	7.3	10.5	-18.9	-3.8	-8.6
28	-22.2	3.2	5.1	-21.7	0.5	-11.8
29	-22.1	-0.5	5.3	-21.1	6.5	-11.7
30	-17.3	-7.5	7.7	-18.1	12.1	-2.1
31	-11.3	31.0	16.9	-16.5	-36.5	2.0
32	-49.9	7.9	-13.8	-43.9	1.6	-29.3
33	-51.0	-2.1	-15.6	-44.1	8.0	-26.9
34	-14.8	-35.3	14.2	-15.5	35.0	5.3
35	-0.9	11.4	11.5	-0.4	-14.7	-11.8
36	-1.1	-17.3	9.5	0.8	17.2	-7.1

TABLE C-33. COORDINATES OF VERTEBRA C2
FOR SPECIMEN SWE 25

POINT	SUPERIOR X	SUPERIOR Y	SUPERIOR Z	INFERIOR X	INFERIOR Y	INFERIOR Z
1	-0.6	5.6	12.5	16.1	-5.4	-13.5
2	-1.6	5.5	12.1	13.8	-10.7	-11.3
3	-4.4	6.9	14.5	11.7	-11.2	-10.1
4	-4.3	7.1	13.3	6.4	-12.4	-11.0
5	-9.8	6.2	14.8	2.2	-9.7	-13.6
6	-9.5	6.8	14.7	2.3	-5.6	-16.5
7	-13.0	5.9	15.5	1.2	-0.7	-18.3
8	-12.9	6.3	15.5	1.6	2.4	-17.4
9	-12.1	-0.5	17.5	8.2	4.3	-14.7
10	-11.5	-0.1	17.8	11.7	3.5	-14.1
11	-6.6	-1.1	16.1	9.8	-0.8	-13.6
12	-7.3	-1.4	16.0	10.5	-5.4	-12.0
13	-4.0	-0.7	15.5	3.7	-6.2	-14.5
14	-3.8	-1.0	15.3	3.3	-0.4	-16.1
15	1.1	12.2	5.5	-4.1	-24.1	-13.9
16	4.7	18.9	1.4	-5.5	-27.6	-14.0
17	-0.8	22.9	-3.7	-4.6	-30.9	-19.5
18	-9.4	16.8	-6.9	-4.5	-23.4	-23.7
19	-6.7	10.9	2.0	-3.4	-19.0	-19.0
20	-3.4	15.3	-0.6	-11.3	-25.1	-20.7
21	5.1	-9.6	9.6	-0.1	16.3	-20.6
22	-2.8	-6.6	9.1	-2.7	8.1	-22.0
23	-8.8	-18.0	-0.3	-2.9	6.5	-28.6
24	-3.0	-25.0	2.2	-3.7	15.4	-30.5
25	3.3	-22.5	4.6	-4.7	18.8	-26.6
26	-1.5	-16.1	5.1	-4.0	13.0	-25.7
27	-11.7	12.4	-10.2	-7.8	-17.0	-22.3
28	-23.1	-2.5	-15.1	-16.3	-8.2	-22.6
29	-22.2	-9.4	-14.1	-18.2	-3.7	-24.0
30	-12.4	-16.6	-7.0	-8.1	4.4	-22.8
31	3.7	26.7	-16.6	5.9	-34.3	-7.3
32	-38.7	-10.2	-38.2	-30.7	-24.4	-36.2
33	-36.9	-20.3	-33.8	-29.6	-5.1	-41.0
34	3.7	-34.0	-5.0	3.3	23.9	-20.5
35	-9.4	8.0	13.2	7.0	-11.0	-11.0
36	-9.7	-2.0	15.0	7.4	4.4	-15.3

TABLE C-34. COORDINATES OF VERTEBRA C3 FOR SPECIMEN SWE 25

POINT	SUPERIOR X	SUPERIOR Y	SUPERIOR Z	INFERIOR X	INFERIOR Y	INFERIOR Z
1	7.1	1.0	5.5	10.3	-0.8	-10.8
2	4.3	6.7	7.5	6.8	-6.5	-10.3
3	-1.0	10.9	11.6	3.6	-9.2	-7.6
4	-7.2	10.8	11.5	-2.5	-9.1	-7.7
5	-7.2	8.9	11.2	-5.1	-6.5	-9.7
6	-7.7	1.3	5.1	-4.6	-1.1	-10.4
7	-9.0	-3.3	7.7	-2.8	7.9	-7.8
8	-8.3	-7.1	11.0	-0.1	8.4	-7.5
9	-4.2	-6.9	9.8	5.1	8.3	-7.3
10	3.4	-6.2	8.6	7.6	6.8	-8.2
11	-2.3	1.4	-1.9	3.1	3.0	-8.7
12	1.9	3.1	9.0	3.0	-4.1	-7.5
13	-5.1	3.9	5.6	-1.3	-3.1	-8.5
14	-4.4	-2.7	7.7	-2.1	4.6	-7.4
15	-8.8	20.3	12.2	-9.7	-24.8	-8.3
16	-10.7	25.1	10.6	-11.5	-25.8	-12.5
17	-13.1	25.0	4.8	-14.0	-21.3	-15.5
18	-5.4	10.3	1.4	-13.6	-13.3	-13.8
19	-11.8	15.3	5.6	-10.2	-15.9	-7.9
20	-10.2	19.0	4.9	-12.8	-19.5	-11.1
21	-16.7	-20.8	7.4	-4.0	18.0	-2.0
22	-16.9	-14.3	7.1	-8.4	13.8	-6.8
23	-19.0	-11.9	0.9	-10.2	19.3	-11.1
24	-20.1	-18.9	-2.8	-4.0	26.5	-7.2
25	-19.5	-22.6	1.8	-2.6	24.7	-4.4
26	-16.8	-18.0	1.9	-8.9	19.3	-5.8
27	-18.4	10.2	4.7	-15.6	-6.5	-14.2
28	-22.5	5.4	1.8	-20.9	-2.7	-14.0
29	-25.3	0.4	1.1	-22.4	1.3	-12.9
30	-15.8	-10.1	-1.8	-10.9	12.9	-9.1
31	3.0	25.8	6.7	-3.0	-26.7	-5.0
32	-37.7	3.2	-19.4	-32.5	-3.3	-21.0
33	-38.4	-2.8	-17.4	-35.6	2.8	-21.1
34	-14.6	-25.0	-11.8	5.7	29.5	-2.8
35	-4.2	10.1	12.8	-0.2	-9.3	-7.0
36	-3.5	-9.5	11.9	2.9	8.4	-7.1

TABLE C-35. COORDINATES OF VERTEBRA C4
FOR SPECIMEN SWE 25

POINT	SUPERIOR X	SUPERIOR Y	SUPERIOR Z	INFERIOR X	INFERIOR Y	INFERIOR Z
1	7.9	0.7	6.1	10.8	-0.2	-10.3
2	5.8	6.2	7.3	7.2	-5.7	-10.9
3	2.4	7.9	10.2	4.6	-6.5	-8.9
4	-6.7	8.0	12.0	-4.1	-7.4	-7.8
5	-8.3	6.0	8.8	-5.3	-4.2	-10.2
6	-7.4	-0.7	6.1	-4.6	1.2	-10.4
7	-7.7	-7.9	9.0	-5.9	6.7	-9.0
8	-5.0	-9.9	10.1	-4.2	9.1	-8.0
9	0.5	-10.5	9.4	6.5	7.3	-9.1
10	2.8	-7.0	5.8	9.9	5.1	-9.9
11	0.8	-6.7	4.8	4.8	4.2	-7.7
12	2.3	3.6	5.9	5.0	-3.1	-9.5
13	-4.7	2.1	6.4	-1.6	-3.0	-7.9
14	-5.2	-5.8	6.0	-1.7	4.1	-7.1
15	-10.8	14.5	14.7	-7.8	-22.6	-7.0
16	-8.6	24.2	14.2	-12.2	-23.1	-16.7
17	-12.0	23.9	8.0	-13.6	-15.6	-18.8
18	-15.7	17.2	5.8	-11.7	-13.9	-10.4
19	-13.1	13.4	12.0	-9.4	-19.3	-9.1
20	-10.4	19.9	12.3	-11.7	-18.3	-13.0
21	-9.2	-21.9	12.0	-7.9	18.0	0.6
22	-14.2	-14.2	6.9	-12.3	14.1	-6.8
23	-14.8	-21.1	2.4	-12.6	21.1	-10.6
24	-13.6	-25.5	3.7	-7.5	27.2	-4.7
25	-11.3	-26.2	8.2	-6.2	23.7	0.0
26	-13.0	-21.1	6.2	-10.3	20.9	-3.1
27	-15.5	10.5	8.0	-15.8	-11.7	-11.9
28	-22.1	2.4	5.1	-23.7	-2.5	-10.8
29	-22.5	-3.3	5.9	-23.6	5.9	-8.3
30	-15.4	-11.9	5.3	-16.3	14.1	-8.4
31	0.5	30.3	4.5	-0.5	-30.0	-6.4
32	-36.4	8.2	-10.1	-36.7	-1.9	-15.1
33	-36.6	-3.2	-9.9	-35.3	9.0	-14.1
34	1.0	-32.0	-2.9	-0.1	29.6	-0.3
35	-3.5	8.7	12.6	-1.1	-7.1	-8.8
36	-3.0	-10.8	10.8	0.9	8.2	-6.2

TABLE C-36. COORDINATES OF VERTEBRA C5
FOR SPECIMEN SWE 25

	SUPERIOR			INFERIOR		
POINT	X	Y	Z	X	Y	Z
1	8.4	1.4	3.2	10.4	-0.2	-7.6
2	5.8	8.2	5.9	7.8	-8.5	-8.7
3	2.8	10.1	10.2	3.5	-11.3	-7.9
4	-6.2	9.5	8.0	-5.8	-9.9	-8.0
5	-6.7	5.3	4.6	-6.8	-5.9	-8.7
6	-6.6	2.0	4.0	-6.0	-0.8	-8.4
7	-8.1	-5.0	6.5	-5.7	4.3	-7.5
8	-4.8	-9.8	8.3	-2.4	8.8	-6.1
9	1.4	-10.4	6.5	4.6	8.4	-4.9
10	3.9	-5.8	2.5	8.2	5.9	-7.4
11	1.1	-3.5	1.7	4.8	4.2	-6.4
12	-0.8	8.3	-3.1	4.3	-5.1	-6.6
13	-2.0	4.3	2.0	-2.1	-4.6	-5.9
14	-2.4	-2.5	2.6	-1.7	2.2	-5.6
15	-7.2	25.7	13.7	-10.2	-15.1	-3.6
16	-9.2	28.4	8.1	-8.3	-26.1	-2.7
17	-11.8	22.5	5.0	-11.7	-27.3	-12.3
18	-12.4	15.6	7.5	-14.1	-18.5	-13.0
19	-10.6	15.9	12.0	-12.8	-13.4	-8.8
20	-10.7	21.7	8.8	-10.7	-21.6	-6.9
21	-13.2	-14.9	8.7	-7.3	15.4	2.3
22	-20.3	-14.4	0.6	-11.9	13.4	-6.3
23	*	*	*	9.3	23.8	-6.5
24	*	*	*	6.6	27.6	-3.5
25	*	*	*	-4.0	26.0	1.7
26	-13.0	-19.3	2.6	-7.3	22.4	-1.0
27	-15.7	23.4	9.2	-17.5	-10.2	-8.5
28	-23.6	16.7	5.1	-22.6	-2.9	-7.8
29	--	--	--	-21.8	5.8	-8.1
30	-15.2	-9.6	5.7	-17.1	9.7	-5.4
31	2.0	30.2	4.9	4.3	-27.6	-2.6
32	-25.5	9.3	-11.4	-32.0	-6.9	-18.7
33	-33.5	0.8	-13.0	-33.4	5.4	-13.4
34	-1.5	-28.4	-3.5	6.7	23.2	2.4
35	-1.2	11.4	10.6	-2.0	-11.8	-5.0
36	-2.4	-10.1	7.5	-0.5	8.0	-4.3

*Not available due to digitizing error

TABLE C-37. COORDINATES OF VERTEBRA C7
FOR SPECIMEN SWE 25

	SUPERIOR			INFERIOR		
POINT	X	Y	Z	X	Y	Z
1	6.2	-0.1	7.2	7.9	0.0	-8.3
2	5.2	5.2	7.3	5.1	-8.5	-9.2
3	1.7	9.5	8.0	2.4	-12.9	-8.6
4	-2.0	10.7	12.9	-4.6	-10.1	-8.1
5	-9.0	7.9	10.7	-8.5	-3.9	-7.8
6	-7.1	-0.5	6.7	-6.7	0.4	-7.9
7	-9.6	-9.0	9.3	-5.9	9.1	-5.3
8	-3.8	-15.0	9.4	-0.5	12.5	-4.9
9	-0.1	-12.2	5.6	3.5	14.1	-6.0
10	3.4	-10.4	5.3	7.3	7.6	-7.5
11	0.2	-6.6	5.3	2.9	5.7	-4.9
12	1.5	4.5	6.5	1.4	-5.2	-6.7
13	-4.4	4.5	7.0	-3.6	-2.1	-6.7
14	-4.4	-7.2	5.7	-3.6	4.4	-6.4
15	-11.5	20.3	18.0	-15.5	-19.0	-5.6
16	-14.3	26.5	15.0	-20.3	-25.5	-6.9
17	-14.6	24.7	11.3	-20.9	-20.5	-10.9
18	-15.8	19.5	8.6	-19.0	-9.7	-9.6
19	-16.0	13.6	15.4	-17.7	-12.7	-5.8
20	-13.9	20.1	12.8	-17.9	-17.7	-8.5
21	-15.2	-21.8	14.2	-14.0	22.1	-0.9
22	-19.1	-12.1	12.8	-15.9	13.0	-4.4
23	-19.7	-10.4	6.3	-17.1	15.5	-8.8
24	-18.9	-19.6	4.8	-15.9	26.3	-4.5
25	-19.2	-27.6	11.4	-14.9	26.9	-1.1
26	-17.8	-16.5	7.4	-16.2	20.2	-4.0
27	-20.3	8.6	11.4	-22.8	-6.0	-9.8
28	-23.7	2.8	8.6	-30.2	-0.4	-9.4
29	-24.5	-2.5	7.7	-28.9	5.2	-10.5
30	-19.9	-8.6	8.5	-19.0	12.5	-8.6
31	-6.9	31.4	17.3	-4.8	-27.0	-2.7
32	-55.0	7.3	-6.9	52.3	1.2	-15.0
33	-56.2	1.0	-6.8	-51.3	8.5	-15.8
34	-12.3	-31.8	11.9	-0.3	28.9	2.3
35	0.4	10.3	8.4	-0.5	-10.6	-8.1
36	-0.7	-12.7	6.5	0.6	13.2	-4.5

TABLE C-38. COORDINATES OF VERTEBRA T1
FOR SPECIMEN SWE 25

POINT	SUPERIOR X	SUPERIOR Y	SUPERIOR Z	INFERIOR X	INFERIOR Y	INFERIOR Z
1	7.3	-6.5	5.1	9.6	1.0	-10.5
2	5.7	3.7	7.0	7.6	-13.4	-13.2
3	2.2	10.0	8.3	2.9	-15.2	-13.4
4	-4.8	9.4	11.4	-6.8	-11.3	-10.5
5	-8.8	2.8	8.5	-8.9	-10.3	-10.4
6	-7.3	-3.4	5.6	-6.5	-2.2	-11.1
7	-7.3	-15.1	8.2	-8.8	7.3	-6.6
8	-3.7	-19.0	7.8	-3.7	13.0	-8.6
9	2.8	-17.4	4.1	3.0	15.0	-8.7
10	6.3	-12.4	5.7	7.1	8.9	-9.2
11	2.6	-10.9	3.7	4.1	5.7	-8.4
12	1.9	1.1	5.2	3.9	-6.9	-10.0
13	-3.4	0.6	5.0	-2.9	-5.6	-9.6
14	-3.4	-10.5	4.2	-3.7	4.1	-8.7
15	-13.2	16.1	16.5	-15.7	-18.7	-6.2
16	-17.6	23.7	13.4	-16.0	-23.5	-10.7
17	-20.8	17.1	7.1	-19.6	-17.7	-15.8
18	-16.8	7.0	11.5	-20.2	-11.0	-15.6
19	-14.9	12.1	14.6	-17.9	-12.1	-6.3
20	-15.8	16.1	11.1	-18.2	-16.5	-10.0
21	-13.3	-29.3	13.1	-13.9	14.9	-3.4
22	-15.1	-22.6	10.1	-19.5	18.6	-6.3
23	-20.9	-23.6	2.6	-20.4	23.1	-11.4
24	-21.3	-31.1	7.9	-18.0	31.1	-6.1
25	-18.6	-32.6	9.9	-16.4	31.3	-1.8
26	-16.4	-29.3	6.2	-18.7	24.7	-4.2
27	-17.1	6.5	12.4	-26.8	-0.2	-11.3
28	-24.7	0.8	6.5	-32.5	6.7	-14.6
29	-25.5	-7.1	4.3	-30.4	13.2	-14.9
30	-17.9	-15.2	8.7	-21.7	18.6	-10.7
31	-17.0	28.0	16.4	-19.3	-21.8	0.2
32	-57.0	1.9	-12.8	-51.4	9.2	-26.2
33	-55.6	-4.3	-16.1	-50.0	13.5	-25.9
34	-17.5	-25.1	7.9	-21.7	40.3	7.6
35	-0.8	10.8	9.7	-0.3	-15.5	-12.1
36	-0.7	-18.5	6.3	-1.3	15.1	-8.7

Specimen: EJ 41

TABLE C-39: PROJECTED VERTEBRAE AREAS (MM^2)

Vert.	Superior/ Inferior	XY Plane			XZ Plane			YZ PLANE		
		A_C[1]	A_R[2]	A_L[3]	A_C[1]	A_R[2]	A_L[3]	A_C[1]	A_R[2]	A_L[3]
C1	S	0.00	140.98	94.68	0.00	64.56	71.96	0.00	24.20	27.34
	I	9.36	168.32	149.67	5.55	82.77	63.99	65.60	44.14	24.62
C2	S	24.72	196.72	170.78	4.60	76.44	70.36	69.06	39.96	28.86
	I	225.99	112.54	188.55	18.74	63.94	78.82	92.30	162.89	237.06
C3	S	269.00	38.25	38.68	10.36	12.28	19.66	84.64	58.37	52.33
	I	229.53	53.02	*	13.67	5.14	*	79.55	48.61	*
C4	S	238.98	46.41	44.38	37.51	3.04	5.16	81.82	39.92	34.68
	I	249.75	56.12	45.69	14.64	15.49	9.08	87.88	49.17	26.19
C5	S	323.29	46.25	51.61	45.90	17.74	10.32	59.14	46.20	50.39
	I	273.24	50.69	*	19.07	12.75	*	66.20	48.67	*
C6	S	302.82	51.17	57.41	45.19	15.41	2.42	84.31	58.17	63.37
	I	289.28	57.23	45.32	13.75	27.56	4.98	54.99	48.54	65.63
C7	S	319.02	50.43	35.78	37.16	25.81	5.16	83.61	71.23	69.16
	I	339.67	57.79	54.96	9.29	1.03	11.35	64.00	75.35	71.23
T1	S	330.03	54.60	52.04	15.42	8.04	15.11	85.23	85.51	87.58
	I	464.51	36.13	34.88	22.75	17.59	20.07	90.83	80.52	64.72

[1] A_C = Area of the centrum
[2] A_R = Area of the right facet
[3] A_L = Area of the left facet
* = Facet was broken

Specimen: GS 28

TABLE C-40: PROJECTED VERTEBRAE AREAS (MM^2)

Vert.	Superior/ Inferior	XY Plane A_C [1]	XY Plane A_R [2]	XY Plane A_L [3]	XZ Plane A_C [1]	XZ Plane A_R [2]	XZ Plane A_L [3]	YZ PLANE A_C [1]	YZ PLANE A_R [2]	YZ PLANE A_L [3]
C1	S									
	I									
C2	S	60.44	128.84	105.27	35.67	22.19	94.61	60.46	59.39	78.33
	I	216.12	11.08	13.21	60.83	6.36	19.51	73.45	33.73	58.88
C3	S	262.15	20.41	15.60	98.46	22.50	26.89	51.88	69.39	64.53
	I	206.78	35.27	25.48	31.06	8.03	8.57	40.83	89.49	61.86
C4	S	252.73	15.00	40.27	108.31	27.07	6.01	68.35	61.43	84.15
	I	262.06	54.67	47.11	38.28	41.08	22.32	84.25	99.93	73.14
C5	S	255.58	33.54	25.82	131.01	12.36	25.78	65.72	68.10	51.40
	I	279.97	33.51	33.45	28.56	21.32	19.02	96.20	82.39	106.44
C6	S	319.03	6.25	25.75	139.90	18.54	21.97	78.35	58.09	61.58
	I	327.55	56.63	35.22	33.85	22.34	19.01	119.91	73.91	92.29
C7	S	374.73	14.06	13.82	110.47	13.75	18.39	73.45	74.57	71.68
	I	369.60	45.42	50.34	76.60	45.45	32.35	135.17	106.45	100.68
T1	S									
	I									

[1] A_C = Area of the centrum
[2] A_R = Area of the right facet
[3] A_L = Area of the left facet

Specimen: HI 23

TABLE C-41: PROJECTED VERTEBRAE AREAS (MM^2)

Vert.	Superior/ Inferior	XY Plane A_C [1]	XY Plane A_R [2]	XY Plane A_L [3]	XZ Plane A_C [1]	XZ Plane A_R [2]	XZ Plane A_L [3]	YZ PLANE A_C [1]	YZ PLANE A_R [2]	YZ PLANE A_L [3]
C1	S									
	I									
C2	S									
	I									
C3	S									
	I									
C4	S	250.40	12.60	23.91	91.11	2.05	13.47	54.53	33.69	47.43
	I	234.51	25.97	42.75	44.15	4.78	15.59	57.42	57.61	66.55
C5	S	274.11	30.37	38.56	105.99	22.45	3.28	87.93	50.56	59.26
	I	235.74	28.88	44.14	24.34	10.48	15.44	69.53	53.59	60.09
C6	S	290.60	37.09	38.34	86.05	24.61	8.80	53.10	64.07	61.29
	I	257.87	40.04	43.83	30.04	22.61	25.70	62.59	81.37	59.71
C7	S	332.13	27.53	24.95	89.44	14.48	25.36	76.76	76.19	88.70
	I	271.31	68.37	45.24	24.01	17.64	8.94	59.89	87.39	82.29
T1	S									
	I									

[1] A_C = Area of the centrum
[2] A_R = Area of the right facet
[3] A_L = Area of the left facet

Specimen: PW 35

TABLE C-42: PROJECTED VERTEBRAE AREAS (MM^2)

Vert.	Superior/ Inferior	XY Plane A_C [1]	XY Plane A_R [2]	XY Plane A_L [3]	XZ Plane A_C [1]	XZ Plane A_R [2]	XZ Plane A_L [3]	YZ PLANE A_C [1]	YZ PLANE A_R [2]	YZ PLANE A_L [3]
C1	S	0.00	110.07	131.18	0.00	112.24	53.53	0.00	71.38	53.26
	I	15.65	160.12	166.00	3.10	81.50	82.62	62.50	20.25	21.25
C2	S	19.19	154.73	176.47	3.23	37.58	68.09	63.28	24.15	46.29
	I	211.75	44.00	51.25	7.00	16.52	14.75	96.12	61.94	51.50
C3	S	238.40	36.50	45.02	33.25	10.37	12.76	50.14	60.27	50.34
	I	187.63	40.83	38.62	10.23	7.11	1.32	69.47	49.06	47.54
C4	S	207.71	46.78	53.17	37.36	5.14	7.87	60.91	47.47	57.06
	I	206.66	45.41	61.27	16.82	10.91	13.96	59.67	65.87	63.25
C5	S	208.32	41.49	50.58	42.23	4.18	8.24	65.78	41.77	51.97
	I	189.78	43.81	46.37	7.87	20.26	14.75	56.39	60.71	56.23
C6	S	224.49	30.44	44.97	43.34	8.26	.01	41.36	33.26	61.81
	I	219.88	41.35	44.55	13.42	10.32	7.23	36.25	56.68	52.25
C7	S	279.19	25.10	39.16	39.98	12.38	12.86	35.42	58.83	66.51
	I	293.94	26.35	48.32	13.94	1.01	2.97	61.45	44.55	69.77
T1	S	297.43	48.51	48.72	18.88	7.22	5.59	84.99	60.78	73.86
	I	412.33	42.15	48.30	16.53	8.59	8.49	56.21	64.21	81.13

[1] A_C = Area of the centrum
[2] A_R = Area of the right facet
[3] A_L = Area of the left facet

Specimen: SWE 23

TABLE C-43: PROJECTED VERTEBRAE AREAS (MM^2)

Vert.	Superior/ Inferior	XY Plane A_C [1]	XY Plane A_R [2]	XY Plane A_L [3]	XZ Plane A_C [1]	XZ Plane A_R [2]	XZ Plane A_L [3]	YZ PLANE A_C [1]	YZ PLANE A_R [2]	YZ PLANE A_L [3]
C1	S									
	I									
C2	S									
	I									
C3	S	267.85	22.42	44.48	162.74	23.77	18.76	50.96	71.82	86.32
	I	227.01	71.44	63.31	47.70	43.75	19.40	88.72	93.24	67.26
C4	S	254.16	62.51	59.56	126.53	19.26	33.05	57.70	78.53	87.33
	I	244.44	61.89	26.05	40.08	3.51	18.90	63.66	77.92	75.28
C5	S	302.63	36.58	45.74	93.08	9.06	7.08	47.44	70.89	59.55
	I	266.27	46.53	46.16	37.45	8.76	13.81	133.79	78.39	76.42
C6	S	261.06	34.41	31.82	74.67	4.35	10.35	62.08	54.68	45.80
	I	381.86	45.64	47.36	99.54	7.13	12.14	167.83	88.96	77.15
C7	S	399.25	43.75	20.14	68.57	4.91	4.09	66.52	98.14	82.68
	I	366.80	53.54	72.33	40.98	28.00	35.82	74.45	96.90	121.14
		345.22	29.82	72.35	58.82	12.87	15.43	64.79	83.01	98.34
T1	S	544.52	46.33	28.87	85.52	52.00	30.99	61.60	95.54	78.34
	I									

[1] A_C = Area of the centrum
[2] A_R = Area of the right facet
[3] A_L = Area of the left facet

Specimen: SWE 25

TABLE C-44: PROJECTED VERTEBRAE AREAS (MM^2)

Vert.	Superior/ Inferior	XY Plane			XZ Plane			YZ PLANE		
		A_C[1]	A_R[2]	A_L[3]	A_C[1]	A_R[2]	A_L[3]	A_C[1]	A_R[2]	A_L[3]
C1	S									
	I									
C2	S	124.70	165.42	102.19	33.63	60.55	86.96	44.44	71.33	70.17
	I	185.08	29.70	77.79	49.00	11.87	75.86	70.66	85.92	67.94
C3	S	217.68	25.25	31.12	209.35	23.42	26.87	137.67	73.50	70.38
	I	210.61	48.18	37.68	38.80	35.65	11.38	66.83	64.74	69.50
C4	S	227.40	37.08	43.37	110.92	11.48	22.36	53.74	66.52	71.47
	I	212.17	44.90	27.90	41.83	27.81	13.94	70.64	88.96	72.80
C5	S	258.64	n/a	32.63	179.90	n/a	18.66	170.79	n/a	76.51
	I	272.03	52.88	48.81	36.53	29.88	19.58	73.33	101.32	112.72
C6	S									
	I									
C7	S	286.01	30.86	26.75	84.31	33.13	20.25	78.80	105.56	67.98
	I	304.27	23.28	42.48	52.64	4.68	15.33	84.79	61.08	55.56
T1	S	355.76	58.40	62.52	97.67	41.16	24.25	108.19	59.80	80.79
	I	420.42	60.14	28.65	70.50	17.82	20.72	72.34	85.92	88.18

[1] A_C = Area of the centrum
[2] A_R = Area of the right facet
[3] A_L = Area of the left facet

TABLE C-45: NORMAL UNIT VECTOR TO CENTRUM

Specimen: EJ 41

Vertebra	Surface	X	Y	Z
C1	Sup			
	Inf	-0.95	0.06	-0.30
C2	Sup	0.90	-0.22	0.37
	Inf	-0.41	-0.08	-0.91
C3	Sup	0.26	-0.05	0.96
	Inf	-0.20	0.06	-0.98
C4	Sup	0.24	-0.02	0.97
	Inf	-0.22	-0.00	-0.98
C5	Sup	0.10	0.00	0.99
	Inf	0.00	0.08	-1.00
C6	Sup	0.20	-0.03	0.98
	Inf	-0.12	0.08	-0.99
C7	Sup	0.13	0.08	0.99
	Inf	-0.26	-0.07	-0.96
T1	Sup	0.00	0.04	1.00
	Inf	0.03	-0.02	-1.00

TABLE C-46: NORMAL UNIT VECTOR TO CENTRUM

Specimen: GS 28

Vertebra	Surface	X	Y	Z
C1	Sup			
	Inf			
C2	Sup	0.57	0.29	0.77
	Inf	0.09	0.05	-0.99
C3	Sup	0.09	-0.05	0.99
	Inf	0.06	0.11	-0.99
C4	Sup	0.20	0.00	0.98
	Inf	0.08	0.16	-0.98
C5	Sup	0.22	-0.07	0.97
	Inf	0.04	0.08	-1.00
C6	Sup	0.04	-0.16	0.99
	Inf	-0.15	0.11	-0.98
C7	Sup	0.03	-0.09	1.00
	Inf	-0.16	0.29	-0.94
T1	Sup			
	Inf			

TABLE C-47: NORMAL UNIT VECTOR TO CENTRUM

Specimen: HI 23

Vertebra	Surface	X	Y	Z
C1	Sup			
	Inf			
C2	Sup			
	Inf			
C3	Sup			
	Inf			
C4	Sup	0.06	0.06	1.00
	Inf	0.00	-0.11	-0.99
C5	Sup	0.12	-0.04	0.99
	Inf	-0.06	0.06	-1.00
C6	Sup	0.12	0.04	-0.99
	Inf	0.0	0.0	-1.00
C7	Sup	0.04	0.00	1.00
	Inf	-0.21	0.00	-0.98
T1	Sup			
	Inf			

TABLE C-48: NORMAL UNIT VECTOR TO CENTRUM

Specimen: PW 35

Vertebra	Surface	X	Y	Z
C1	Sup	0.0	0.0	0.0
	Inf	-0.98	0.14	-0.12
C2	Sup	0.95	-0.12	0.30
	Inf	-0.37	-0.06	-0.93
C3	Sup	0.16	-0.03	0.99
	Inf	-0.24	-0.13	-0.96
C4	Sup	0.15	0.10	0.98
	Inf	-0.58	-0.06	-0.81
C5	Sup	0.18	0.13	0.98
	Inf	-0.17	-0.05	-0.98
C6	Sup	0.03	0.04	1.00
	Inf	-0.03	-0.09	-1.00
C7	Sup	0.05	0.04	1.00
	Inf	-0.09	-0.06	-0.99
T1	Sup	0.17	-0.07	0.98
	Inf	-0.11	0.00	-0.99

TABLE C-49: NORMAL VECTOR TO CENTRUM

Specimen: SWE 23

Vertebra	Surface	X	Y	Z
C1	Sup			
	Inf			
C2	Sup			
	Inf			
C3	Sup	0.12	0.04	0.99
	Inf	0.09	-0.05	-0.99
C4	Sup	0.17	-0.23	0.96
	Inf	0.06	0.23	-0.97
C5	Sup	-0.05	0.05	1.00
	Inf	-0.08	0.04	-1.00
C6	Sup	0.22	-0.04	0.97
	Inf	-0.17	0.17	-0.97
C7	Sup	0.00	0.18	0.98
	Inf	-0.09	0.00	-1.00
T1	Sup	0.16	0.00	0.99
	Inf	0.08	0.17	-0.98

TABLE C-50: NORMAL UNIT VECTOR TO CENTRUM

Specimen: SWE 25

Vertebra	Surface	X	Y	Z
C1	Sup			
	Inf			
C2	Sup			
	Inf	0.13	-0.47	-0.87
C3	Sup	0.20	-0.30	0.93
	Inf	-0.14	0.14	-0.98
C4	Sup	0.18	0.00	0.98
	Inf	-0.06	0.11	-0.99
C5	Sup	0.12	0.18	0.98
	Inf	0.00	0.12	-0.99
C6	Sup			
	Inf			
C7	Sup	0.19	-0.08	0.98
	Inf	-0.10	0.20	-0.98
T1	Sup	0.22	0.00	0.98
	Inf	-0.12	0.21	-0.97

TABLE C-51: NORMAL UNIT VECTOR TO THE FACET PLANE

Specimen: EJ 41

Vertebra	Surface		X	Y	Z		X	Y	Z
C1	Sup	L[1]	-0.39	-0.82	0.42	R[2]	0.02	0.36	0.93
	Inf	L	-0.14	-0.32	-0.93	R	-0.22	0.44	-0.87
C2	Sup	L	-0.11	0.36	0.93	R	-0.27	-0.22	0.94
	Inf	L	0.43	0.36	-0.83	R	0.63	-0.17	-0.76
C3	Sup	L	-0.72	-0.40	0.56	R	-0.90	0.03	0.44
	Inf	L	-0.0	-0.0*	-0.0	R	0.67	0.11	-0.74
C4	Sup	L	0.57	-0.07	-0.82	R	-0.66	-0.02	0.75
	Inf	L	0.43	0.08	-0.90	R	0.63	0.29	-0.72
C5	Sup	L	-0.67	0.26	0.70	R	-0.66	-0.21	0.72
	Inf	L	-0.0	-0.0*	-0.0	R	0.71	0.13	-0.69
C6	Sup	L	-0.75	0.00	0.66	R	-0.70	-0.16	0.70
	Inf	L	-0.68	0.73	0.08	R	0.53	0.01	0.85
C7	Sup	L	-0.89	-0.06	0.46	R	-0.47	0.60	0.64
	Inf	L	0.71	0.01	-0.70	R	0.71	0.10	-0.70
T1	Sup	L	-0.84	0.20	0.50	R	-0.83	-0.05	0.55
	Inf	L	0.80	-0.32	-0.51	R	0.90	0.21	-0.34

1L = Left
2R = Right

*FRACTURED

TABLE C-52: NORMAL UNIT VECTOR TO THE FACET PLANE

Specimen: GS 28

Vertebra	Surface		X	Y	Z		X	Y	Z
C1	Sup	L[1]				R[2]			
	Inf	L				R			
C2	Sup	L	-0.41	0.64	0.64	R	-0.51	0.09	0.85
	Inf	L	0.94	-0.31	-0.16	R	0.58	0.58	-0.58
C3	Sup	L	-0.85	-0.51	0.17	R	-0.94	0.31	0.16
	Inf	L	0.95	0.00	-0.32	R	0.93	-0.12	-0.35
C4	Sup	L	0.87	0.00	0.50	R	0.94	-0.16	0.31
	Inf	L	0.85	0.17	0.51	R	0.87	0.29	0.39
C5	Sup	L	-0.87	0.35	0.35	R	0.91	0.13	0.39
	Inf	L	0.94	0.19	-0.28	R	0.92	-0.28	-0.28
C6	Sup	L	-0.87	0.22	0.44	R	-0.94	-0.24	0.24
	Inf	L	0.91	0.1	-0.4	R	0.78	-0.20	-0.59
C7	Sup	L	-0.94	0.24	0.24	R	-0.98	0.00	0.20
	Inf	L	0.86	0.12	-0.49	R	0.83	-0.50	-0.25
T1	Sup	L				R			
	Inf	L				R			

1L = Left
2R = Right

TABLE C-53: NORMAL UNIT VECTOR TO THE FACET PLANE

Specimen: HI 23

Vertebra	Surface		X	Y	Z		X	Y	Z
C1	Sup	L[1]				R[2]			
	Inf	L				R			
C2	Sup	L				R			
	Inf	L				R			
C3	Sup	L				R			
	Inf	L				R			
C4	Sup	L	-0.87	-0.22	0.44	R	-0.89	0.00	0.45
	Inf	L	0.74	0.25	-0.62	R	0.85	-0.17	-0.51
C5	Sup	L	-0.80	0.27	0.53	R	-0.85	-0.17	0.51
	Inf	L	0.74	0.25	-0.62	R	0.78	-0.20	-0.59
C6	Sup	L	-0.86	0.00	0.51	R	-0.87	-0.22	0.44
	Inf	L	0.81	0.32	-0.49	R	0.82	-0.14	-0.55
C7	Sup	L	-0.99	0.12	0.00	R	-0.99	0.16	0.0
	Inf	L	0.91	0.08	-0.41	R	0.78	-0.08	-0.62
T1	Sup	L				R			
	Inf	L				R			

1L = Left
2R = Right

TABLE C-54: NORMAL UNIT VECTOR TO THE FACET PLANE

Specimen: PW 35

Vertebra	Surface		X	Y	Z		X	Y	Z
C1	Sup	L[1]	-0.38	-0.66	0.64	R[2]	-0.29	0.82	0.49
	Inf	L	0.13	-0.47	0.87	R	-0.11	0.48	-0.87
C2	Sup	L	-0.07	0.36	0.93	R	0.15	0.06	0.99
	Inf	L	0.74	0.09	-0.67	R	-0.64	0.53	-0.56
C3	Sup	L	-0.73	-0.24	0.63	R	-0.85	0.21	0.49
	Inf	L	0.77	0.01	-0.64	R	0.77	-0.06	-0.64
C4	Sup	L	-0.73	-0.10	0.68	R	-0.74	0.18	0.65
	Inf	L	0.72	-0.10	-0.69	R	0.72	0.05	-0.70
C5	Sup	L	0.69	0.07	0.72	R	-0.71	0.06	0.70
	Inf	L	0.71	-0.18	-0.68	R	0.84	0.03	-0.55
C6	Sup	L	-0.80	0.01	0.60	R	-0.72	0.03	0.69
	Inf	L	0.74	-0.10	-0.66	R	0.79	0.14	-0.60
C7	Sup	L	0.83	0.16	0.54	R	-0.88	-0.13	0.45
	Inf	L	0.81	0.08	-0.58	R	0.85	0.02	-0.53
T1	Sup	L	0.84	0.10	0.53	R	-0.74	-0.04	0.67
	Inf	L	0.86	0.14	-0.50	R	0.81	0.00	-0.59

1L = Left
2R = Right

TABLE C-55: NORMAL UNIT VECTOR TO THE FACET PLANE

Specimen: SWE 23

Vertebra	Surface		X	Y	Z		X	Y	Z
C1	Sup	L[1]				R[2]			
	Inf	L				R			
C2	Sup	L				R			
	Inf	L				R			
C3	Sup	L	-0.91	0.10	0.40	R	-0.96	0.19	-0.19
	Inf	L	0.70	0.12	-0.70	R	0.74	-0.18	0.65
C4	Sup	L	-0.78	-0.39	0.49	R	-0.76	0.0	-0.65
	Inf	L	0.94	0.16	-0.31	R	0.8	0.0	-0.6
C5	Sup	L	-0.80	0.0	0.60	R	-0.88	0.15	0.44
	Inf	L	0.88	-0.15	-0.44	R	0.83	-0.21	-0.52
C6	Sup	L	-0.78	0.20	0.59	R	-0.89	0.00	0.45
	Inf	L	0.82	-0.14	-0.55	R	0.89	0.00	-0.45
C7	Sup	L	-0.96	0.00	0.27	R	-0.89	0.09	0.45
	Inf	L	0.86	0.00	-0.51	R	0.88	-0.07	-0.47
T1	Sup	L	-0.79	0.00	0.61	R	-0.93	-0.12	0.35
	Inf	L	0.89	0.11	-0.44	R	0.91	-0.18	-0.37

1L = Left
2R = Right

TABLE C-56: NORMAL UNIT VECTOR TO THE FACET PLANE

Specimen: SWE 25

Vertebra	Surface		X	Y	Z		X	Y	Z
C1	Sup	L[1]				R[2]			
	Inf	L				R			
C2	Sup	L	-0.59	0.46	0.66	R	-0.51	0.11	0.85
	Inf	L	1.00	0.00	0.00	R	0.95	0.00	-0.32
C3	Sup	L	-0.84	-0.49	0.21	R	-0.94	0.00	0.35
	Inf	L	0.83	0.00	-0.55	R	0.77	-0.33	-0.55
C4	Sup	L	-0.84	0.24	0.48	R	0.89	0.00	0.45
	Inf	L	0.91	0.35	-0.23	R	0.87	-0.29	-0.39
C5	Sup	L	-0.89	0.25	0.38	R		NA	
	Inf	L	0.90	0.20	0.40	R	0.86	-0.29	-0.43
C6	Sup	L				R			
	Inf	L				R			
C7	Sup	L	-0.93	0.00	0.37	R	-0.94	-0.10	0.31
	Inf	L	0.71	0.0	-0.71	R	0.89	0.00	-0.45
T1	Sup	L	-0.79	0.00	0.61	R	-0.57	0.46	0.68
	Inf	L	0.88	0.15	-0.44	R	0.83	0.15	-0.53

1L = Left
2R = Right

TABLE C-57: MOUNTING BASE CENTER COORDINATES

Specimen: EJ 41

Vertebra	SUPERIOR/ INFERIOR	X	Y	Z
C1	Inf	-23.7	1.4	17.0
C2	Sup	- 5.5	- 4.6	-24.2
C3	Inf	-16.3	6.6	20.0
C4	Sup	-21.4	5.2	-17.0
C5	Inf	-22.4	4.6	23.1
C6	Sup	-19.0	3.5	-18.8
C7	Inf	-20.7	-0.8	21.1
T1	Sup	-18.9	-0.1	-22.2

TABLE C-58: MOUNTING BASE CENTER COORDINATES

Specimen: GS 28

Vertebra	SUPERIOR/ INFERIOR	X	Y	Z
C1				
C2	Inf	-1.14	-0.15	-0.56
C3	Sup	-1.22	0.09	-0.36
C4	Inf	-0.21	-0.23	-0.47
C5	Sup	-0.62	-0.06	-0.15
C6	Inf	-1.27	-0.35	-0.10
C7	Sup	-1.26	-0.21	-0.64
T1				

TABLE C-59: MOUNTING BASE CENTER COORDINATES

Specimen: HI 28

Vertebra	SUPERIOR/ INFERIOR	X	Y	Z
C1				
C2				
C3				
C4	Inf	0.44	-0.22	-0.13
C5	Sup	-0.02	0.11	-0.60
C6	Inf	-1.53	-0.17	-0.49
C7	Sup	-1.30	0.11	0.63
T1				

TABLE C-60: MOUNTING BASE COORDINATES

Specimen: PW 35

Vertebra	SUPERIOR/ INFERIOR	X	Y	Z
C1				
C2				
C3	Inf	-15.9	1.1	24.9
C4	Sup	- 6.3	1.7	-22.3
C5	Inf	- 3.5	0.3	26.5
C6	Sup	- 4.6	-2.6	-24.6
C7	Inf	-23.9	-1.5	26.0
T1	Sup	-26.5	-1.0	-21.9

TABLE C-61: MOUNTING BASE CENTER COORDINATES

Specimen: SWE 23

Vertebra	SUPERIOR/ INFERIOR	X	Y	Z
C1				
C2				
C3	Inf	0.12	0.14	0.09
C4	Sup	0.17	-0.14	-0.24
C5	Inf	-0.21	0.21	0.19
C6	Sup	-0.49	0.37	-0.36
C7	Inf	-2.07	0.18	0.36
T1	Sup	-1.52	-0.09	-0.68

TABLE C-62: MOUNTING BASE COORDINATES

Specimen: SWE 25

Vertebra	SUPERIOR/ INFERIOR	X	Y	Z
C1				
C2	Inf	-0.79	0.96	-1.29
C3	Sup	-0.26	2.77	1.01
C4	Inf	0.99	1.54	0.22
C5	Sup	-0.41	-0.13	0.16
C6				
C7	Inf	-3.03	0.48	-0.07
T1	Sup	-2.30	-0.08	-1.27

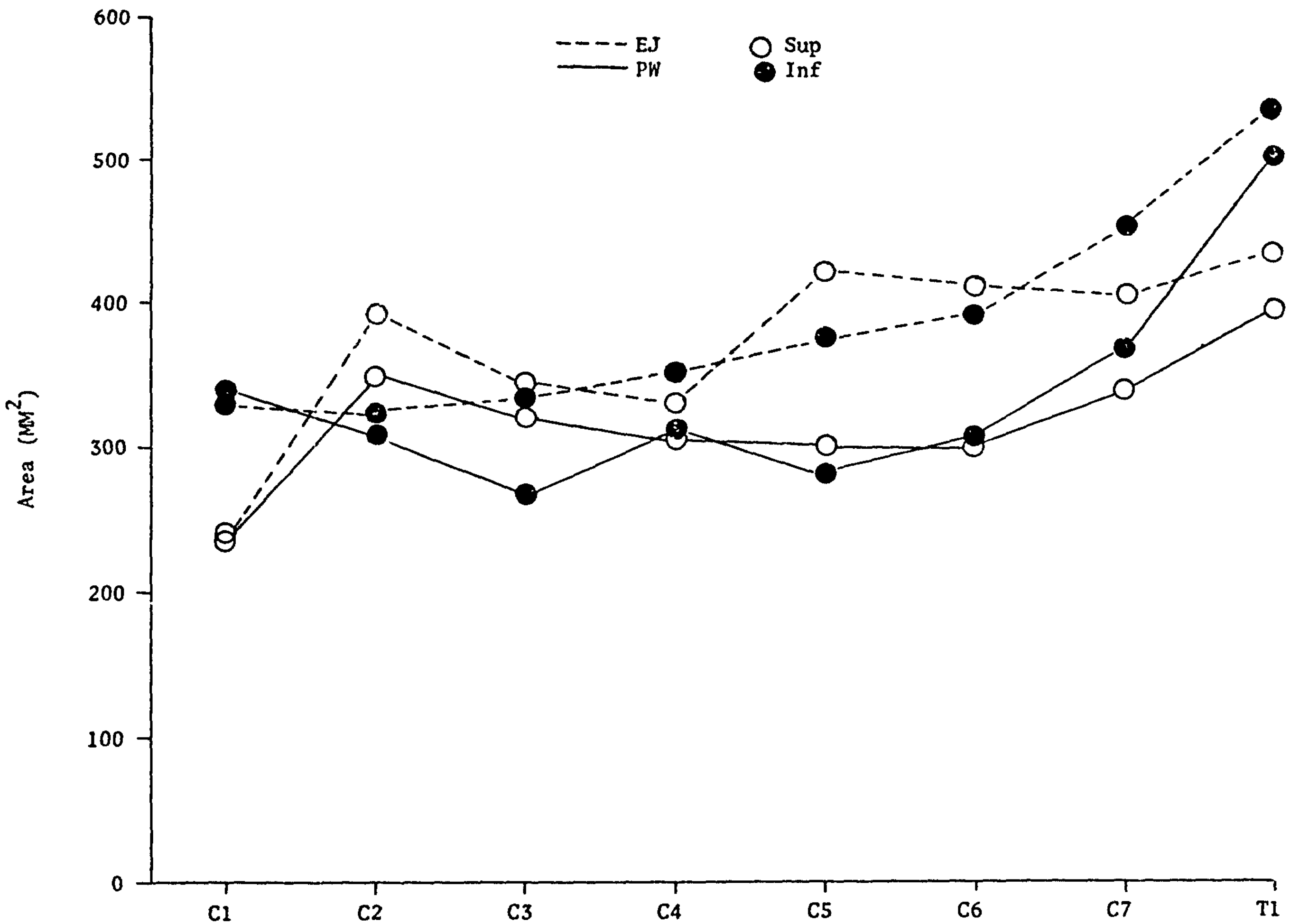


Figure C1A: Combined Projected Area: X-Y Plane

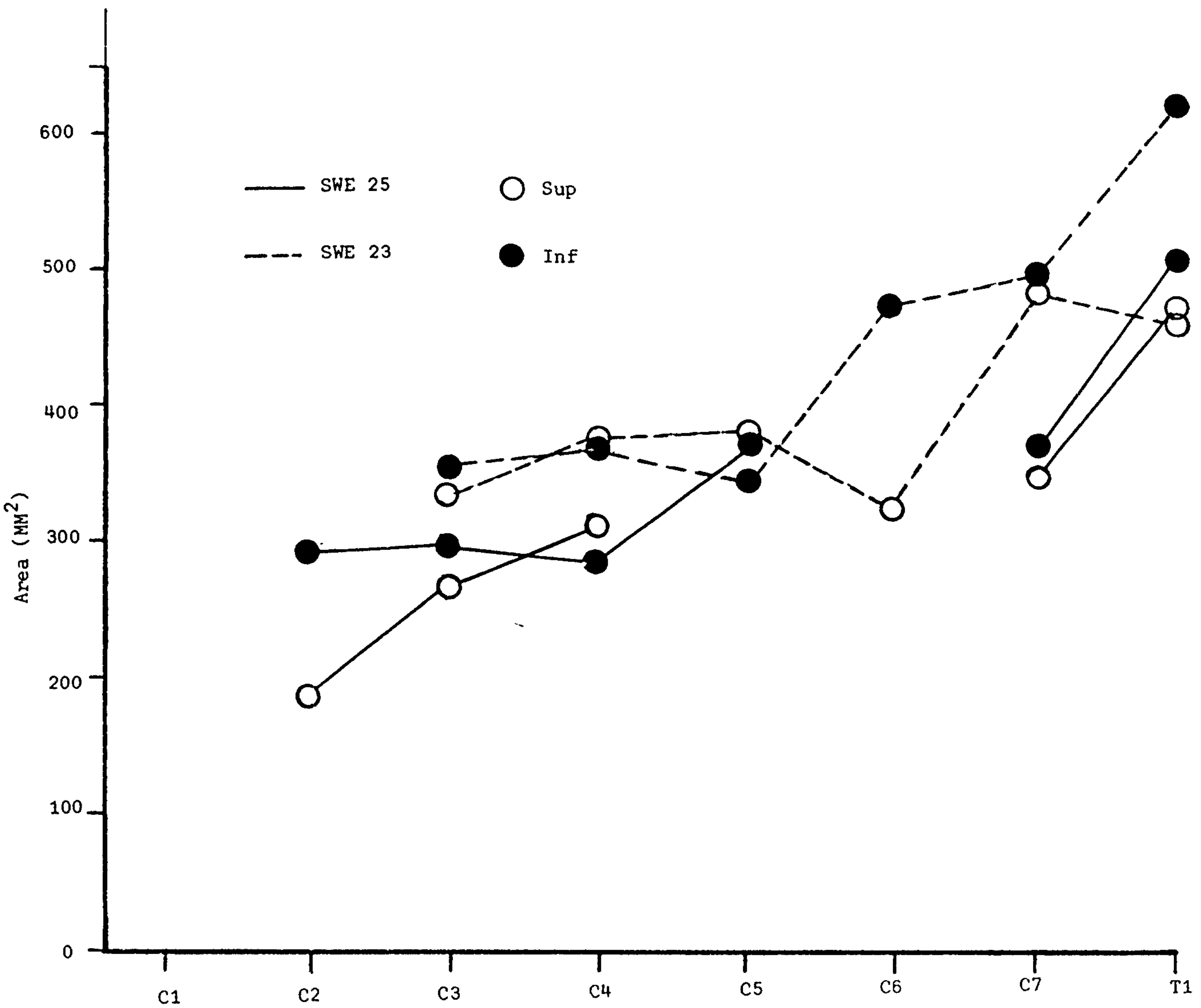


Figure C1B: Combined Projected Area: X-Y Plane

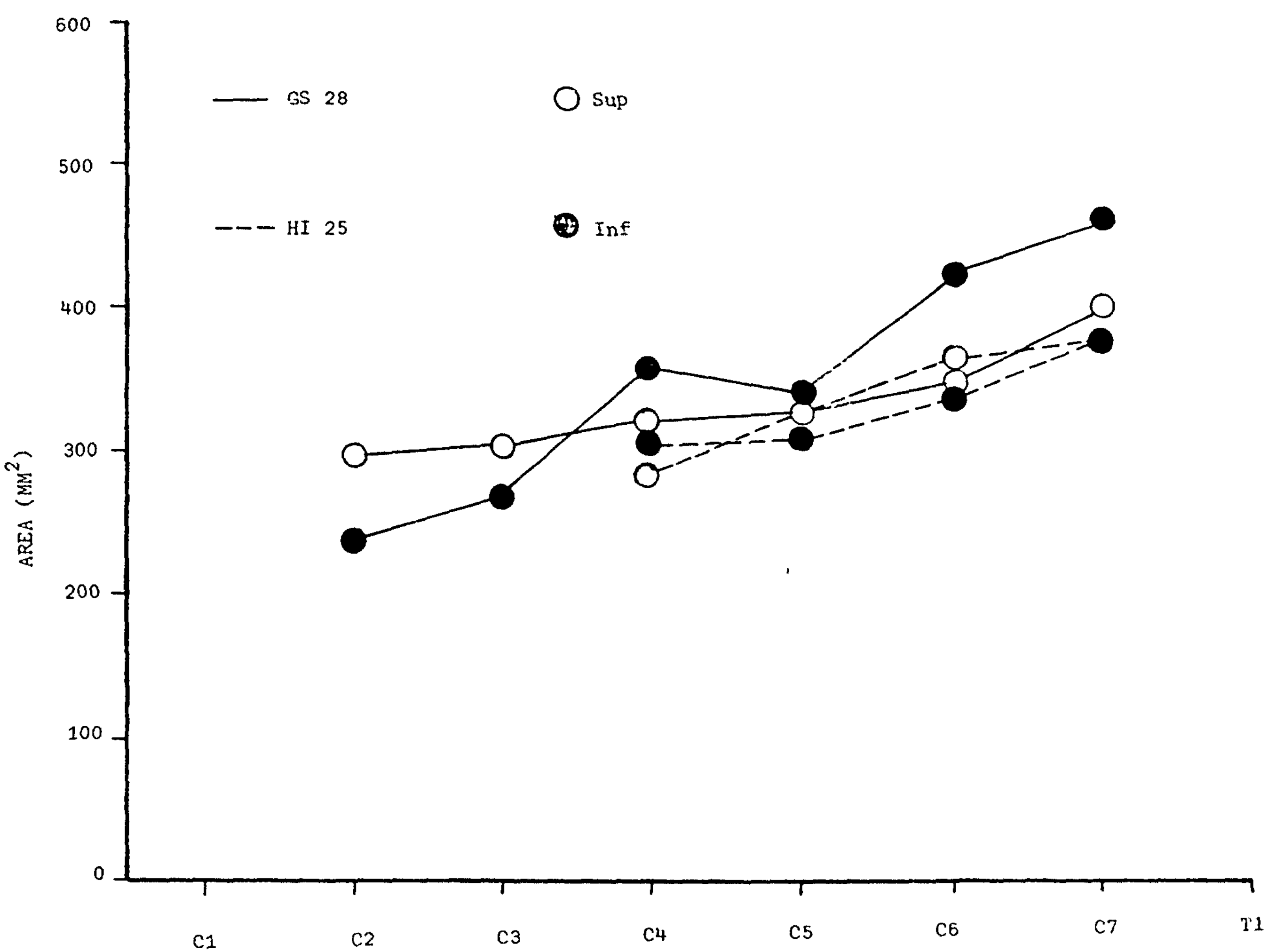


Figure C1C: Combined Projected Area: X-Y Plane

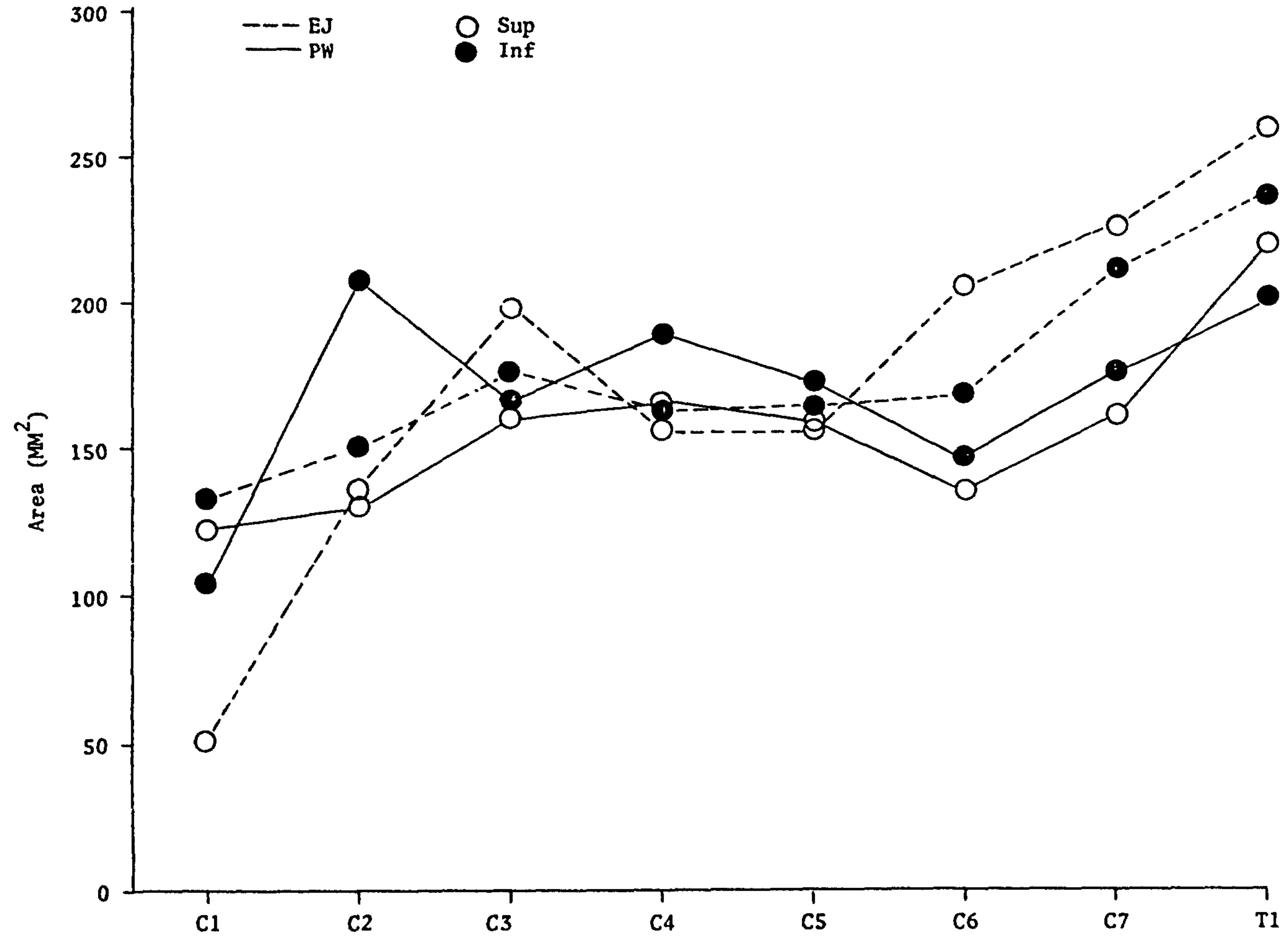


Figure C2A: Combined Projected Area: Y-Z Plane

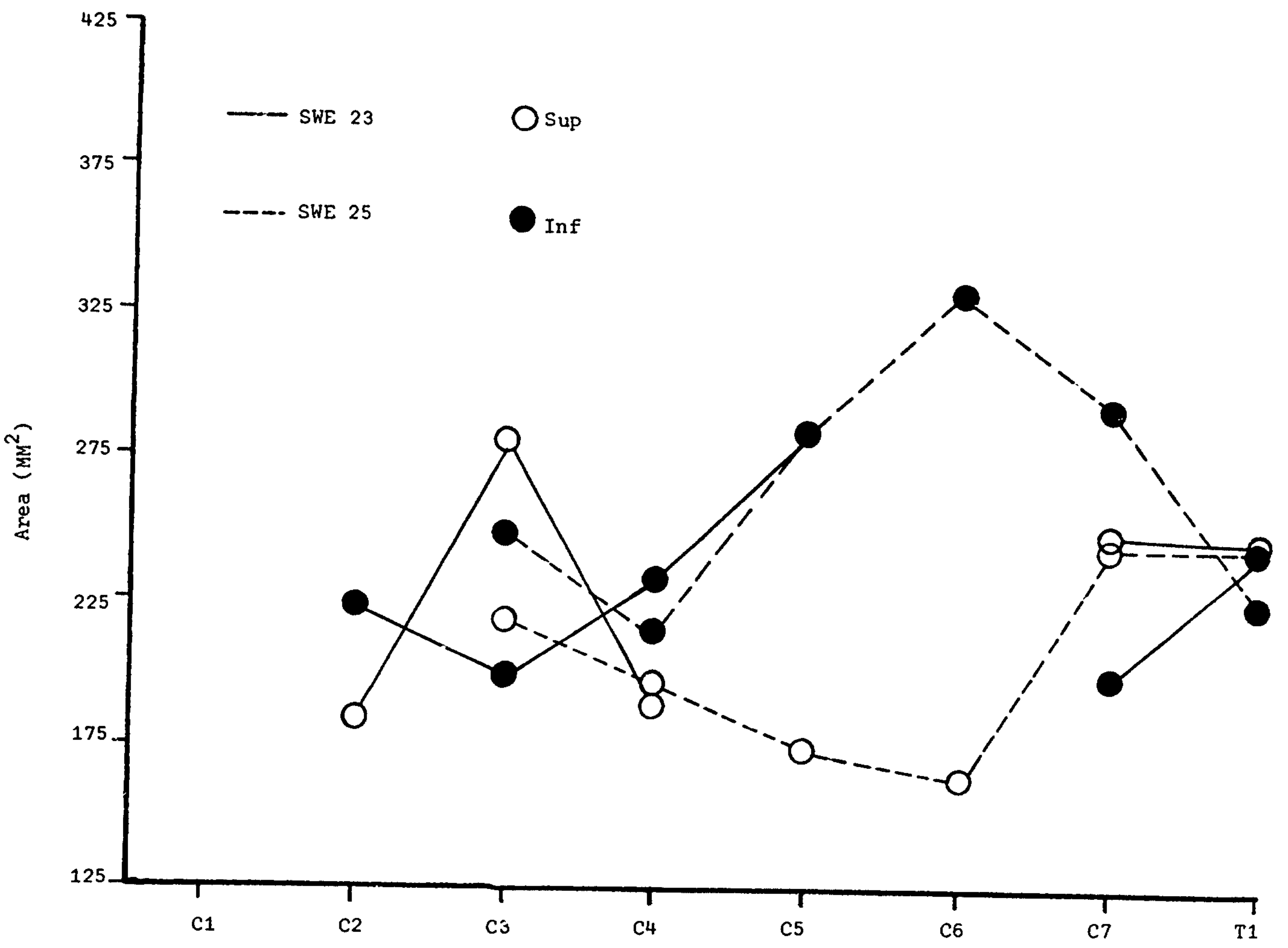


Figure C2B: Combined Projected Area: Y-Z Plane

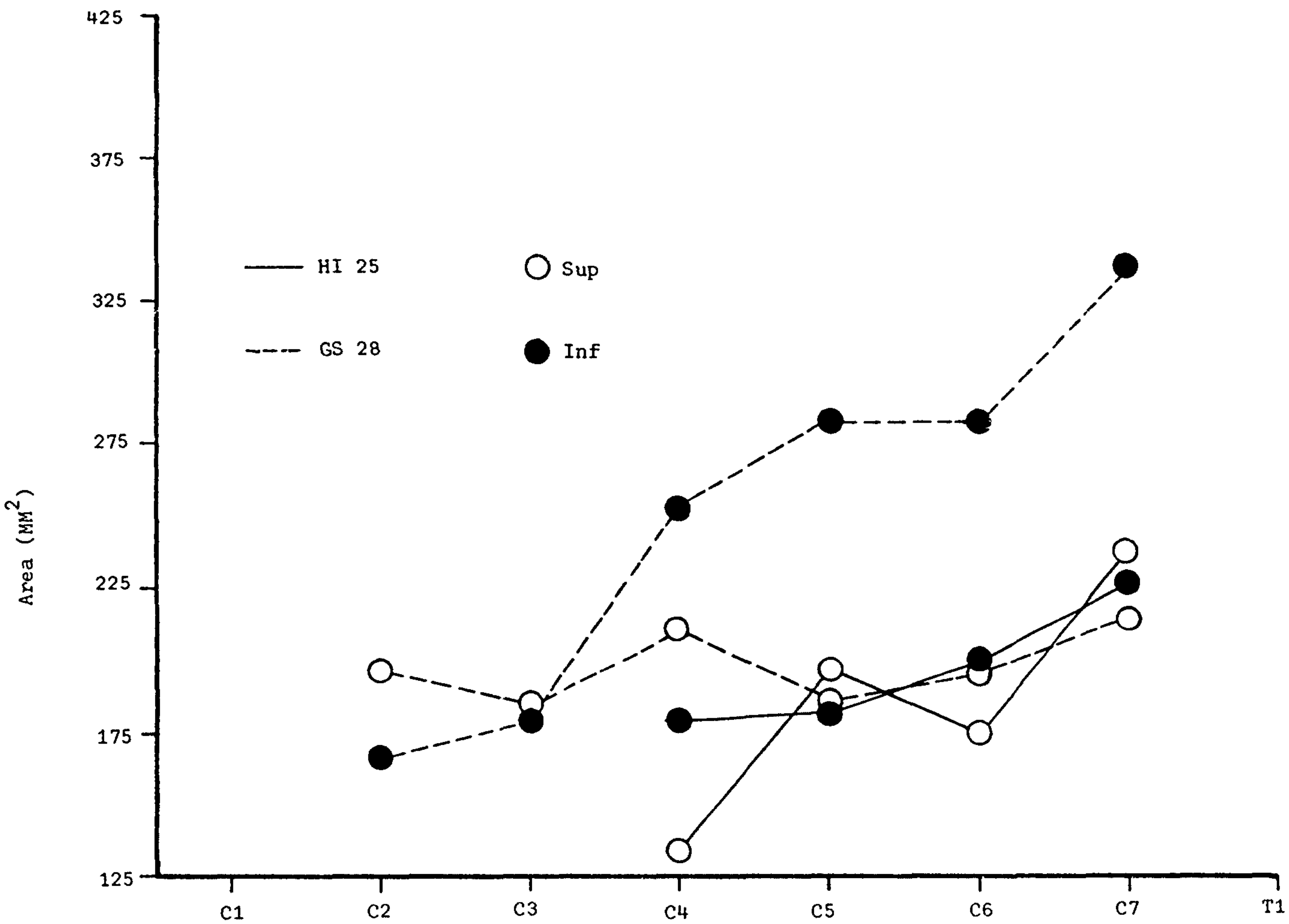


Figure C2C: Combined Projected Area: Y-Z Plane

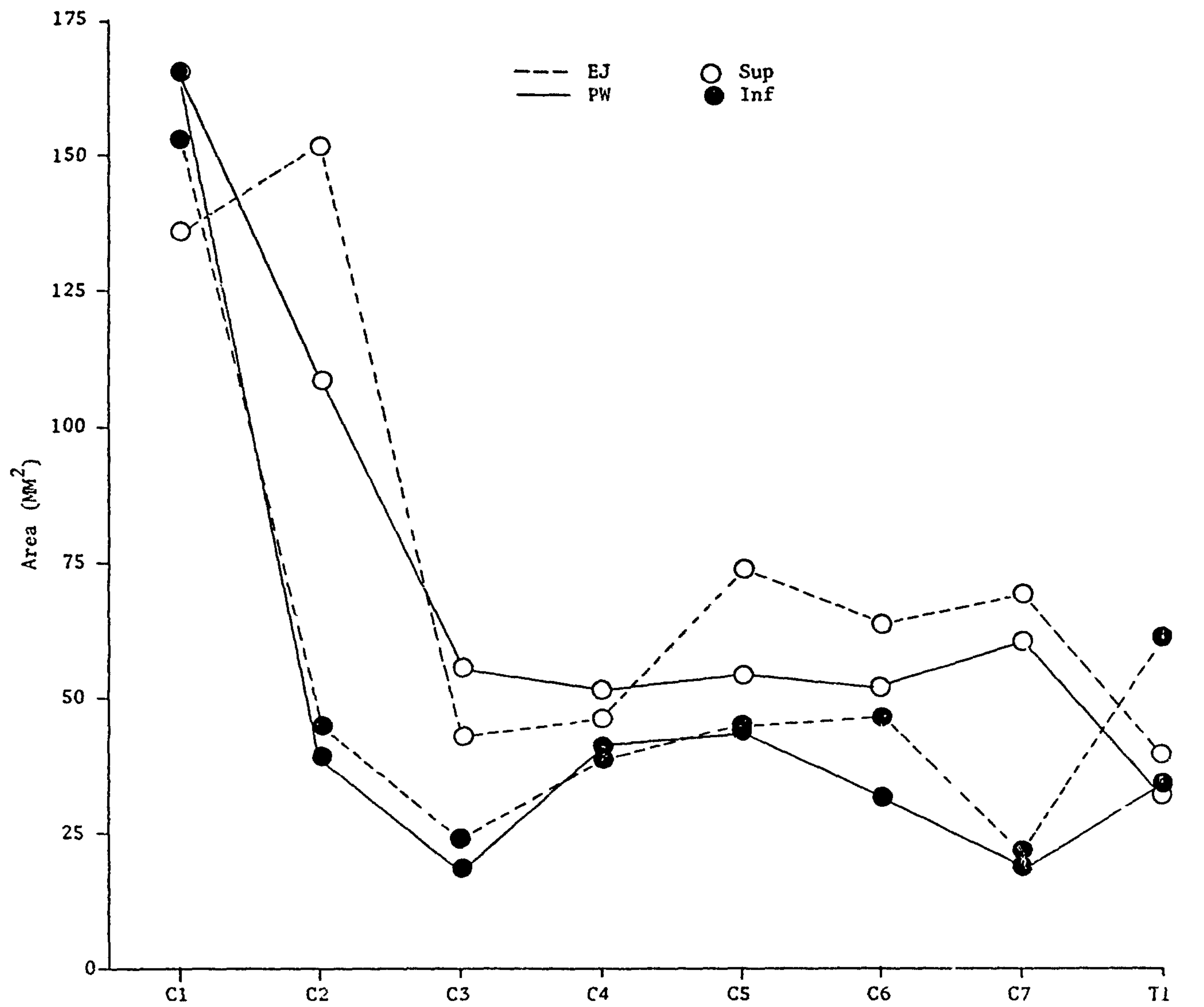


Figure C3A: Combined Projected Area: X-Z Plane

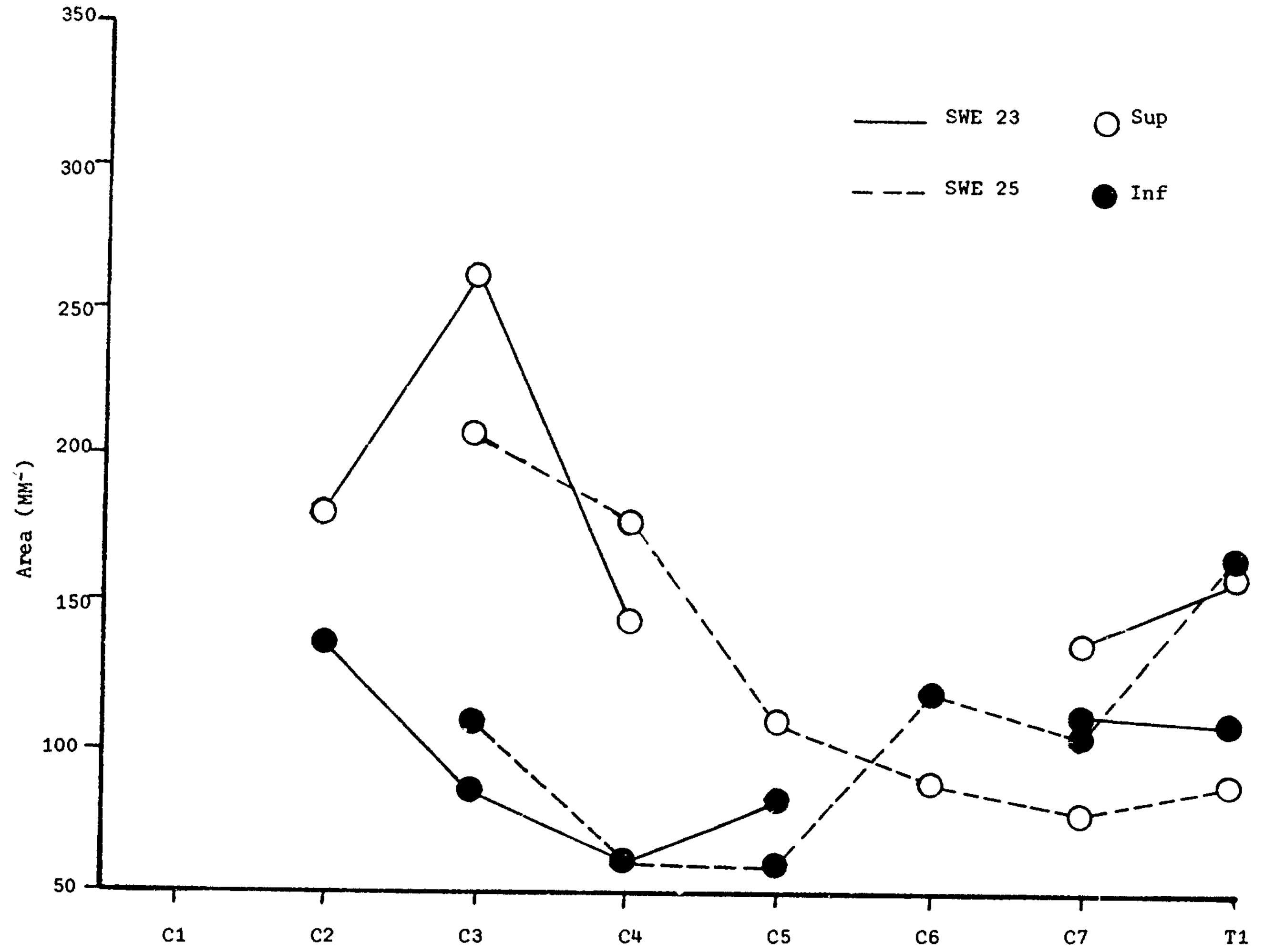


Figure C3B: Combined Projected Area: X-Z Plane

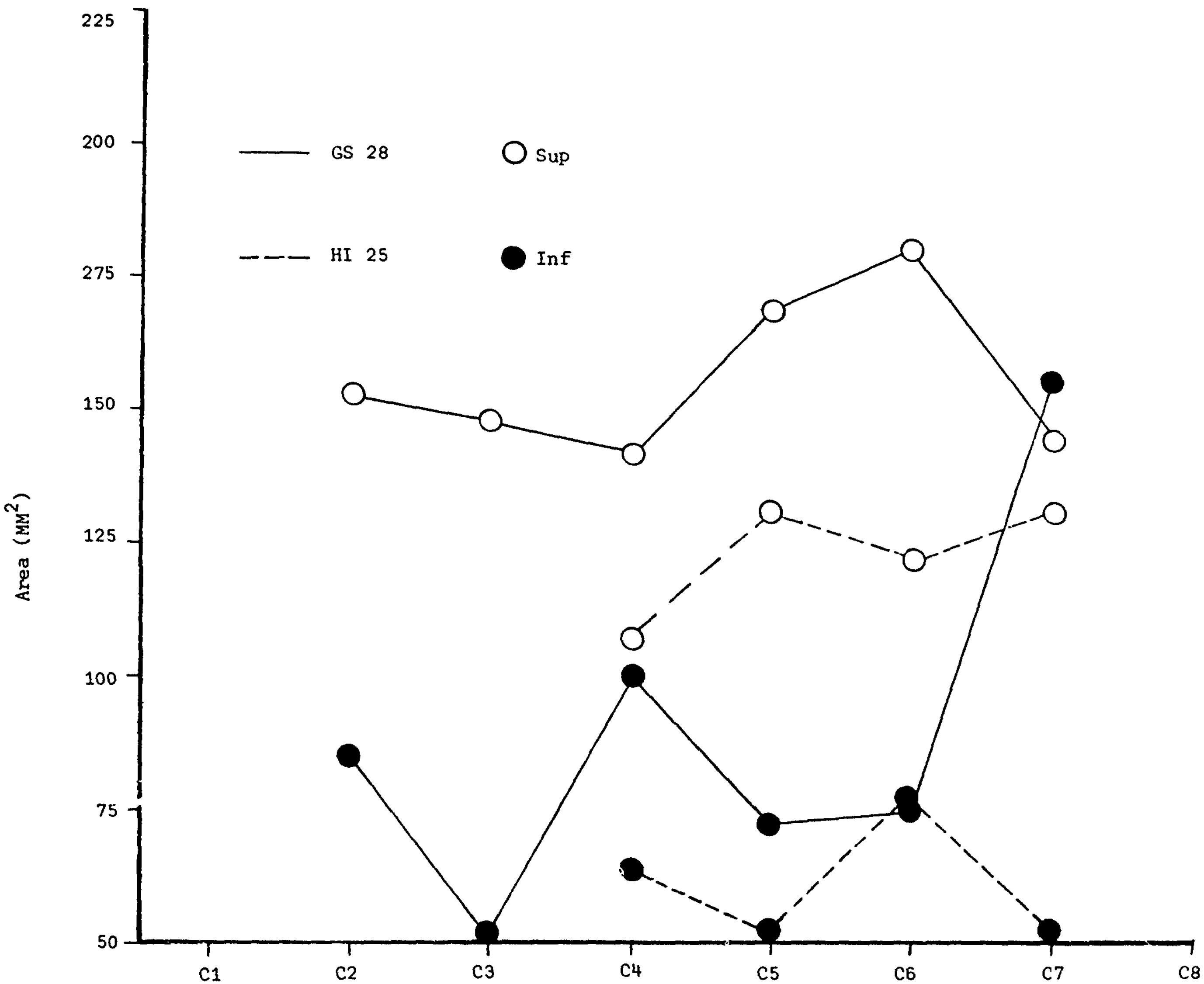


Figure C3C: Combined Projected Area: X-Z Plane

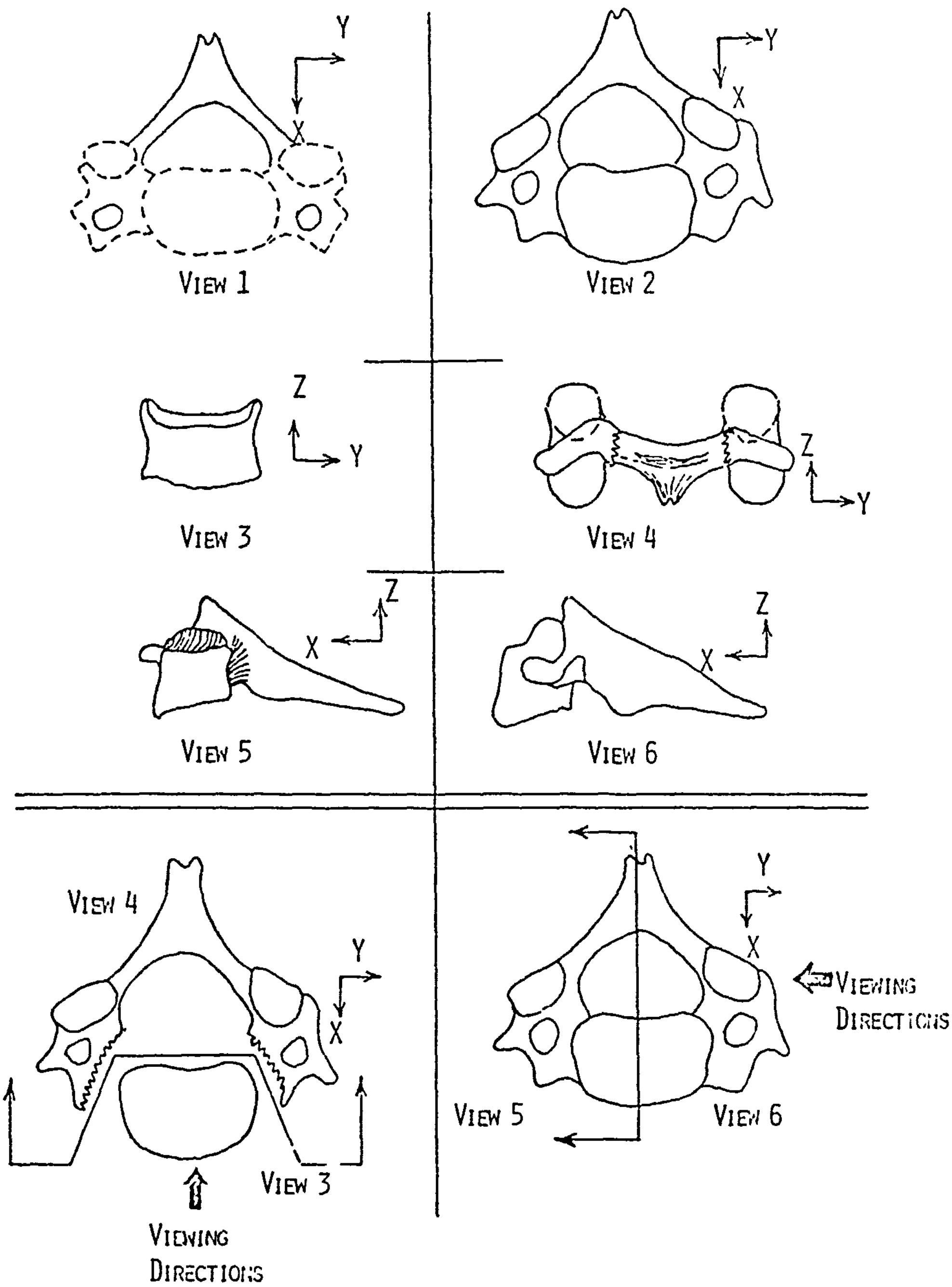


FIGURE C4: KEY TO VERTEBRA PLOTS C6-C101

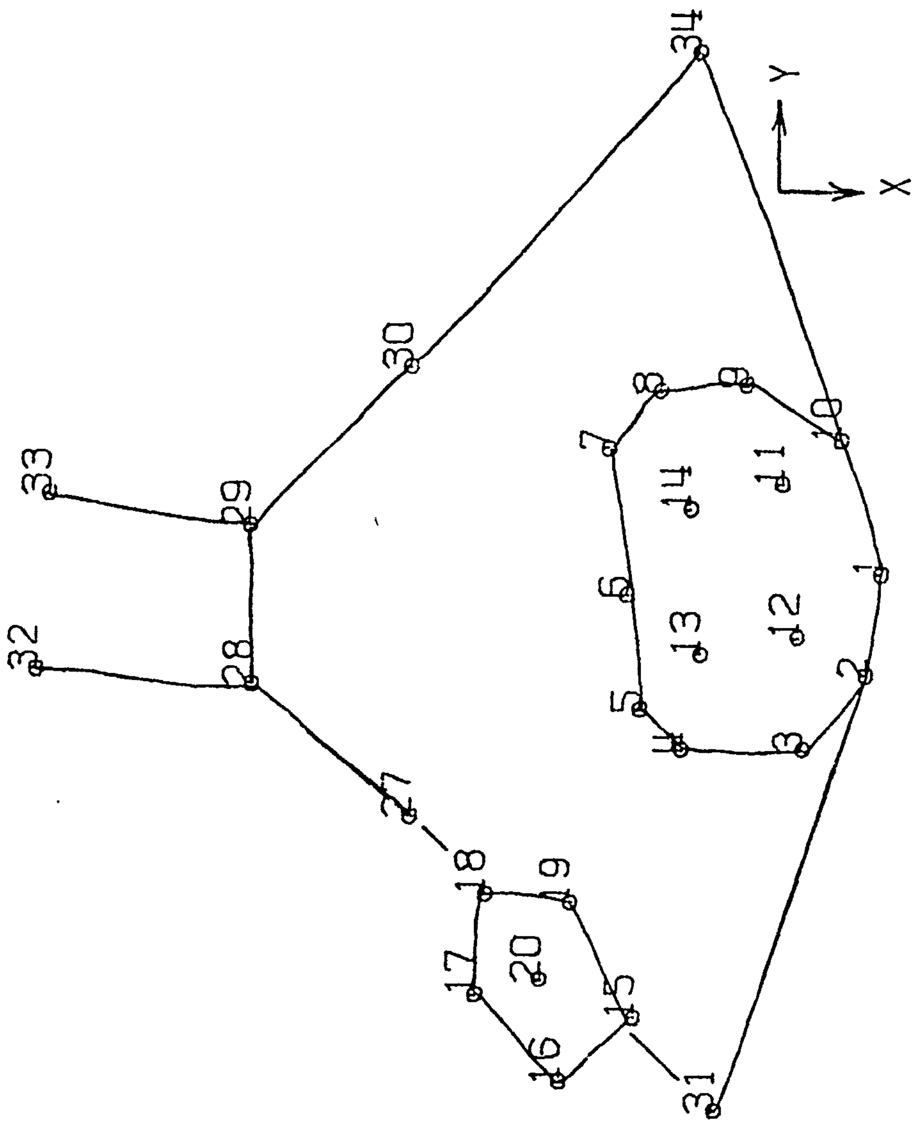


FIGURE C5: EJ 41 C3 VIEW 1

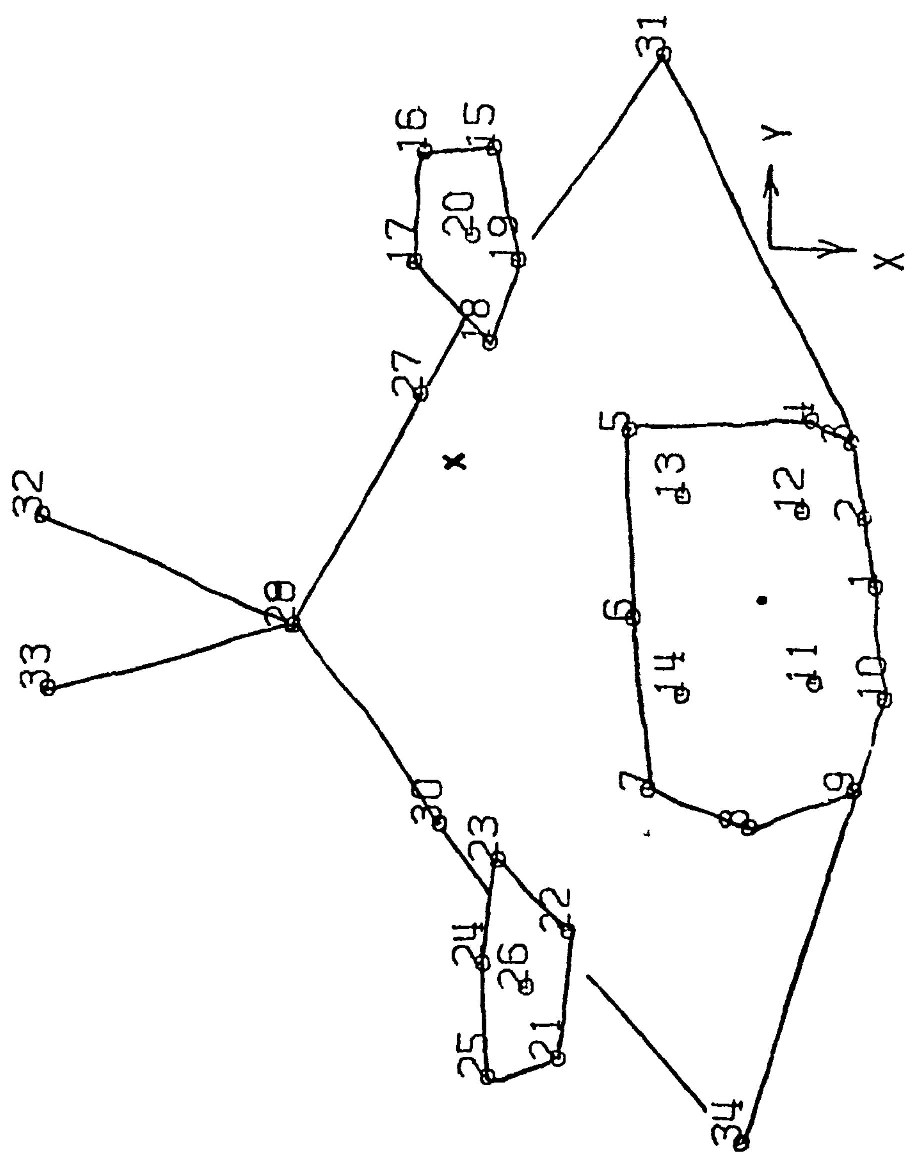


FIGURE C5: EJ 41 C3 VIEW 2

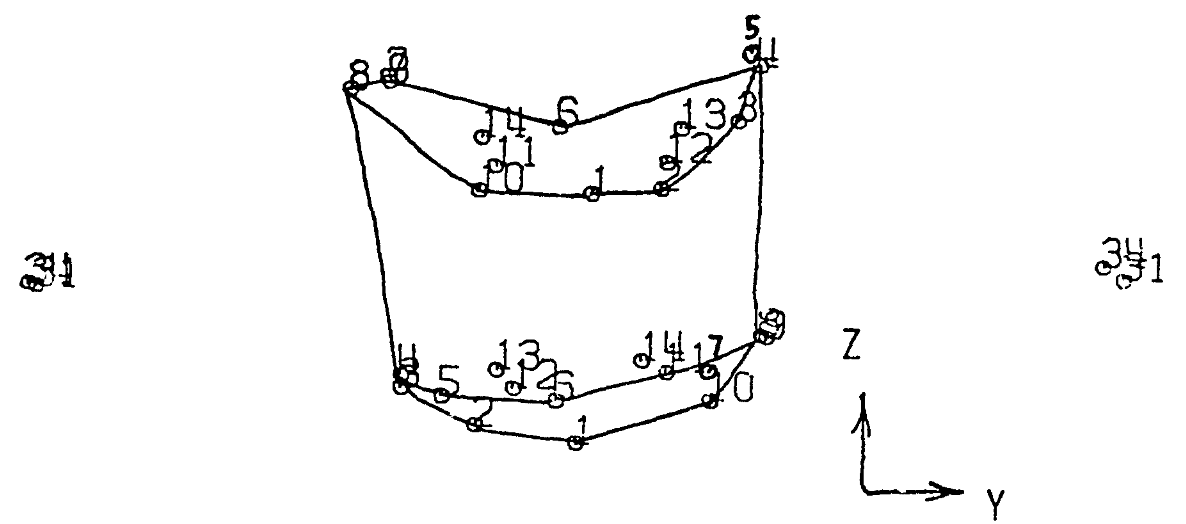


FIGURE C5: EJ 41 C3 VIEW 3

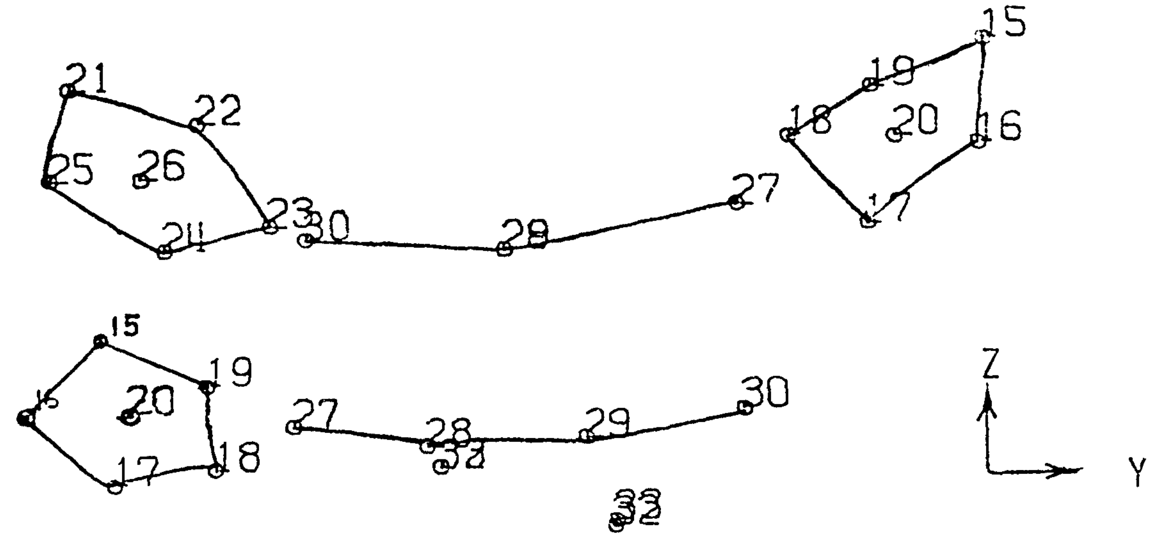


FIGURE C5: EJ 41 C3 VIEW 4

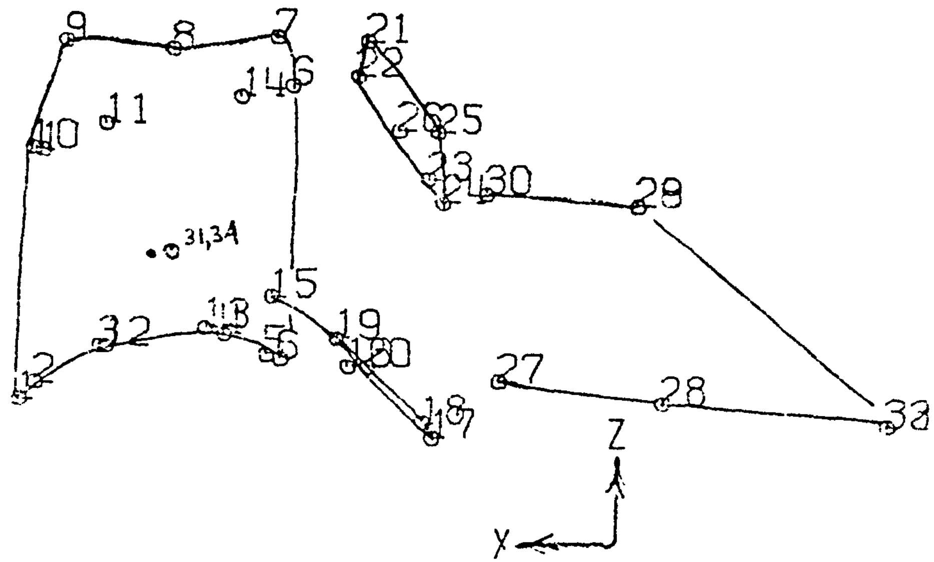


FIGURE C5: EJ 41 C3 VIEW 5

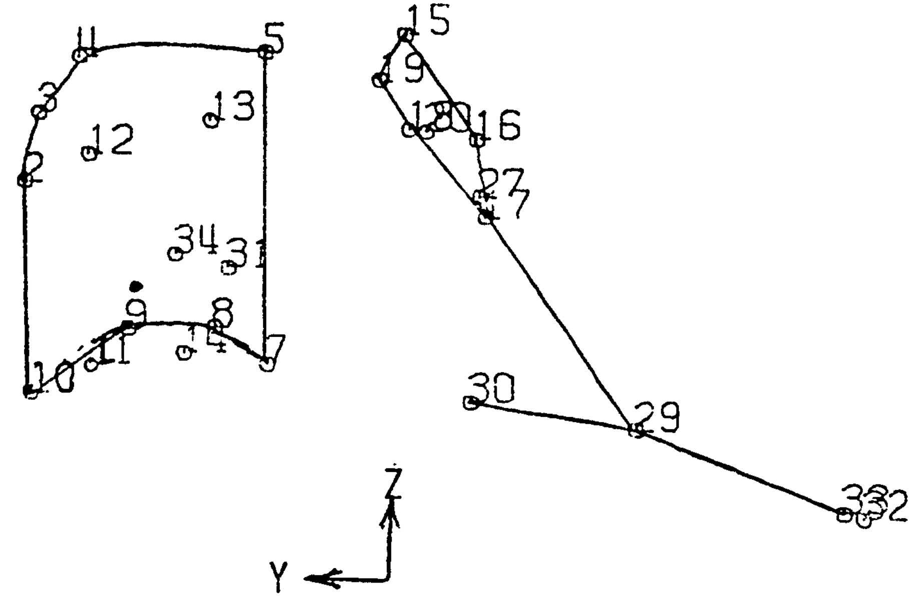


FIGURE C5: EJ 41 C3 VIEW 6

APPENDIX D

This appendix illustrates load and deflection at failure for all specimens tested. Several failure tests were attempted in the bending mode, but there were only three failures before the Plastic Padding® on the superior and inferior vertebra met. One test failed inadvertently in compression and is included in this data.

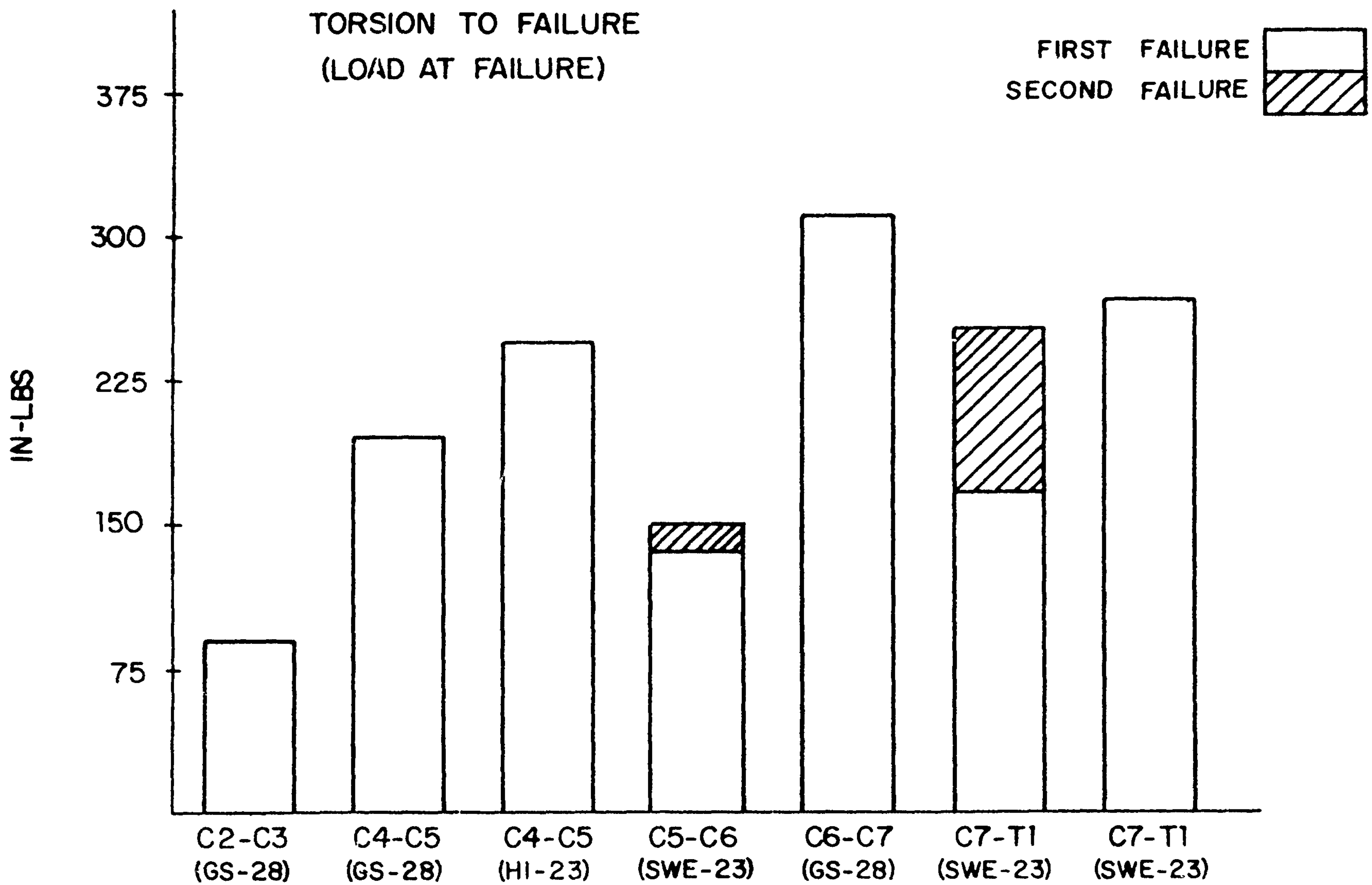


Figure D1: Failure Load

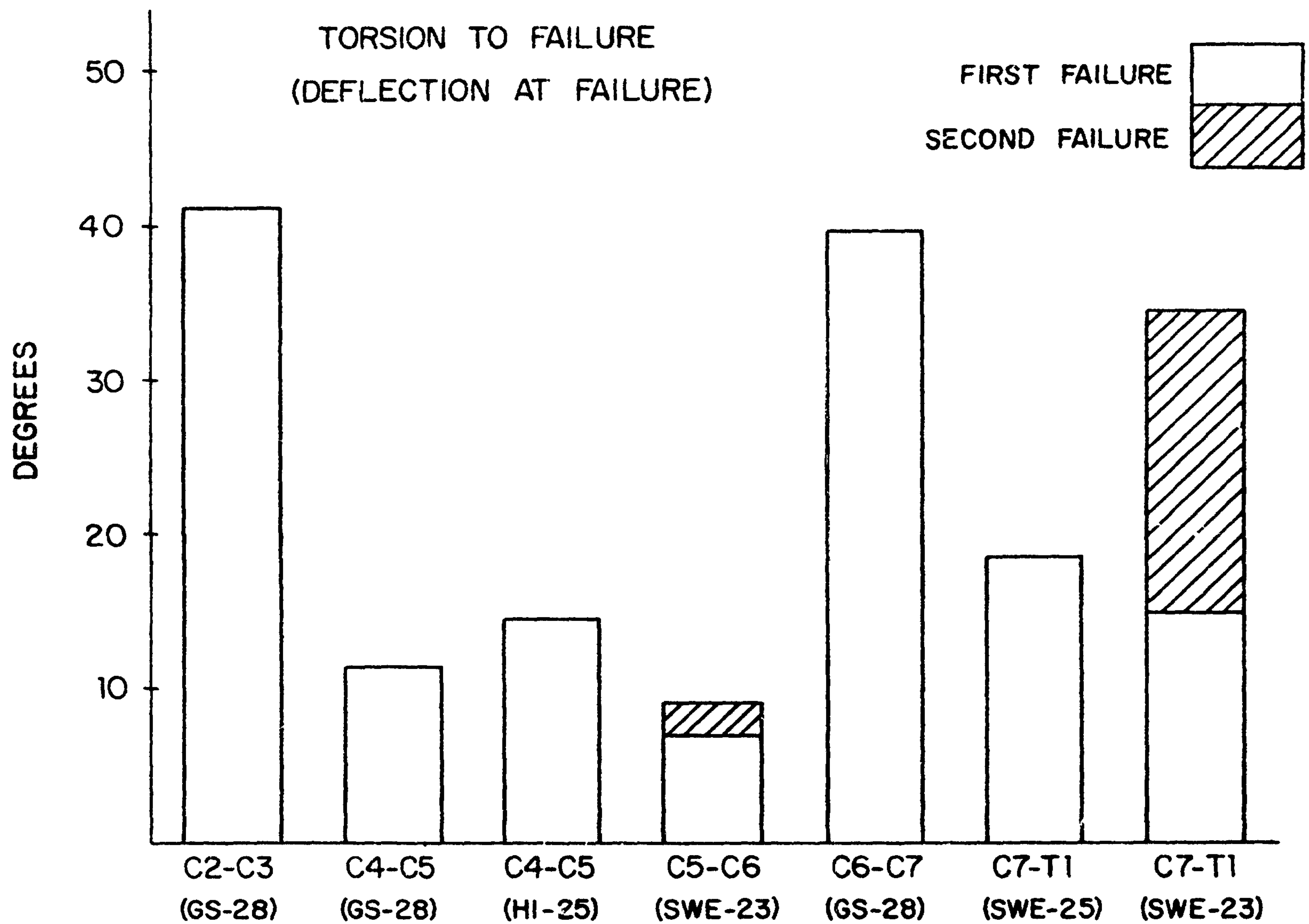


Figure D2: Deflection at Failure

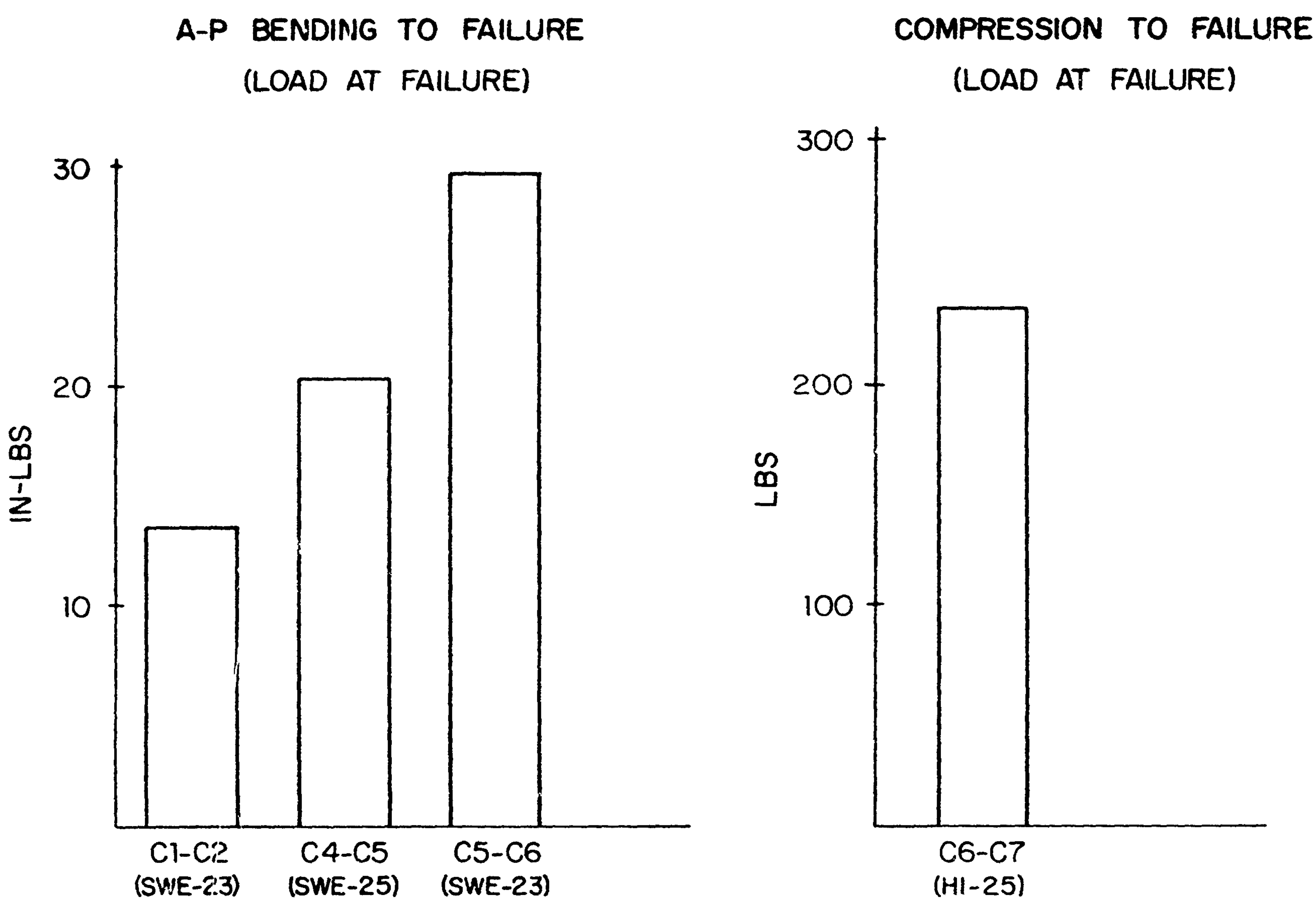


Figure D3: Failure Load

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