RESEARCH REPORT

A Report on Behaviour of Brick Veneer/Steel Stud Tie Systems

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PART 4 OF THE McMASTER UNIVERSITY LABORATORY TEST PROGRAM ON BRICK VENEER/STEEL STUD WALL SYSTEMS

A

REPORT ON

BEHAVIOUR OF BRICK VENEER/STEEL STUD TIE SYSTEMS

Prepared for

PROJECT IMPLEMENTATION DIVISION
CANADA MORTGAGE AND HOUSING CORPORATION

by

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ABSTRACT

Brick Veneer/Steel Stud (BV/SS) wall ties were tested under various conditions of adjustability and with different types of exterior support including sheathing. Over 500 individual tension and compression tests on twelve different commonly used wall ties were reported. The results presented include both the ultimate load carrying capacity of the wall ties and the stiffness values over a serviceability performance range.

BV/SS wall ties evolved in part as a result of practical construction considerations which included the need for adjustability. Over the years, adjustability of wall ties has tended to be based on one of three features. Classification of these features can be made as follows, a slot cut in the anchor to accommodate various positions of the tie, or an extended leg of the wire tie allowing vertical movement within the anchor, or a groove at the fastening screw permitting vertical movement of the entire anchor. A fourth category of ties with other special features includes those supporting platforms, alternate wire tie locations, self-drilling and corrugated ties. In summary, the adjustable feature can be located in either the anchor, tie or screw.

The research results indicate that the lower bounds of both stiffness and capacity of some wall ties, resulting from different degrees of adjustment, attachment locations or installation practices are insufficient to satisfy present performance recommendations. Recommendations on limits to the amount of adjustability and on the development of appropriate tie standards are also included in this report.

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CHAPTER 1

INTRODUCTION

1.1 GENERAL

This report contains research information on the strength and stiffness characteristics of wall ties currently used to attach brick veneer to steel stud backup walls. The reported research is Part 4 of the five part McMaster University Laboratory Test Program on BV/SS Wall Systems sponsored by Canada Mortgage and Housing Corporation. The background to this CMHC sponsored research and the particular concerns relating to BV/SS tie systems are discussed in the following sections.

1.2 Background To Research On BV/SS Tie Systems

Use of steel stud wall systems as the backup wall for brick veneer followed the earlier development of brick veneer supported by concrete block backup for both low and high rise construction. It also had obvious similarities to low rise residential use of wood stud walls as backup for the brick veneer. Since widespread use of the BV/SS form of construction preceded research, development of accepted standards for construction, dissemination of educational information to the building profession, or even significant field performance experience, it is not surprising that much of the design and construction practices were borrowed from the previously mentioned wood stud or concrete masonry backup walls.

The above is particularly true in the area of design and construction practices related to BV/SS ties. For this reason, it was relatively common place to find 28 gauge corrugated strip ties (previously allowed for low rise residential housing) used on multi-storey construction without regard to loading conditions or corrosive atmosphere[9]. In addition, neither the design codes nor individual designers made any distinction between spacing requirements for ties regardless of the type of backup wall. In fact, it is only very recently that theoretical and experimental research has confirmed earlier calculations which showed that for BV/SS construction, top ties or ties near cracks in the veneer can be subjected to forces approaching half the lateral load on the wall.

Coincident with the introduction of BV/SS wall systems into the construction scene was a major growth of interest in the building science related issues for building envelopes. Deterioration of walls due to moisture resulting from rain penetration, water vapour transmission through materials, and air borne moisture from exfiltrating air was identified as a serious problem both from the point of view of safety as well as protection of investment. In addition, variable thermal performance, drafts and staining were identified as unacceptable. As a result of these considerations, design criteria, construction practices and introduction of new materials have all combined to alter the requirements for BV/SS ties.

Briefly, it was determined that the adequacy of ties for BV/SS construction should be judged in terms of the following:

- Adequate strength and stiffness for structural requirements.
- Sufficient robustness and durability to tolerate job site conditions with damage.

- Either tolerance for or designed-in limitations on adjustability, variations in installation locations, or misalignment so that specified properties can be relied upon.

- Adequate corrosion protection, including attachment mechanisms, to maintain structural integrity for the life of the structure.

- Compatibility of construction requirements with the design and installation of exterior sheathing, insulation, vapour barriers, and air barriers.

- Cost and convenience of use including level of inspection required.

1.3 SCOPE AND ORGANIZATION OF THE CMHC RESEARCH PROJECT

Although useful information on BV/SS construction has been recently published, limitations on scope and/or some controversy regarding interpretation of the results meant that the need for reasonably comprehensive research effort remained. In early 1986, Canada Mortgage and Housing Corporation sponsored a project to provide an independent investigation of the BV/SS wall system. The project was divided into the following three activities:

A. Production of an Advisory Document on design and construction aspects.

B. Organization of a Canada wide survey of BV/SS design and construction practices.

C. Laboratory testing of the BV/SS system and components.

SUTER KELLER INC. in collaboration with R.G. Drysdale of McMaster University were asked to undertake this research. The Advisory Document written by R.G. Drysdale and G.T. Suter has been prepared and H. Keller reported the findings of the Canada wide survey.

The Laboratory Test Progrm was conducted at McMaster University under the direction of R.G. Drysdale. It was composed of the following five parts:

Part 1: Fabrication and Testing of Components of Steel Stud Backup Walls.

Part 2: Fabrication and Testing of Brick Masonry Assemblages for Leakage.

Part 3: Fabrication of a Small Wall Test Facility and Tests of Small Walls for Air, Water Vapour and Heat Flow.

Part 4: Tests of Ties and Interactions of Ties with Other Wall Components.

In addition to a CMHC Advisory Committee which reviewed the original proposal and attended a mid term meeting at McMaster University to monitor progress, an open door policy was adopted which resulted in significant interaction with interested parties who arranged intermittent visits to the laboratory.

This report contains the results of the investigation of BV/SS tie systems identified as Part 4 of the McMaster BV/SS Laboratory Test Program.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The literature reviewed in this report was limited to material pertaining to behaviour, performance and design of BV/SS wall ties. Where other information such as for corrosion was relevant, it is included. Unfortunately, information is quite limited, perhaps because of the relatively recent increase in awareness of the importance of BV/SS wall ties. However, much more information exists on cavity wall ties where corrosion problems in the United Kingdom prompted several research programs. [11,12,25].

The literature most used by designers is provided by the manufacturers of BV/SS wall ties. The documents may contain test information and/or some empirical guidance for choosing ties or tie spacing. Unfortunately in some cases the usefullness of this information may be limited by one of the following observed situations:

- Capacities determined experimentally are subject to interpretations based on the test procedure and test set-up. Sometimes these are not documented. In some cases, where the test set-up was described, it is apparent that the results do not include the influences of the stud or even

the method of connection.

- Most data supplied does not relate capacity to displacement.

- Theoretical buckling capacities of wire ties rely on some effective tie area and moment of inertia. The Euler buckling load approach must be used with caution owing to the sensitivity of this calculation to end conditions and the influence of bent parts of the tie.

The remainder of this chapter contains brief summaries of the following contributions to the body of knowledge concerning BV/SS wall ties: Brick Institute of America, University of Alberta, Building Research Establishment, R. Heidersbach, Clemson University, University of Texas, Alderney Manor Investigation, Australian Standard (Wall Ties For Masonry Construction AS 2699-1984), and National Standards of Canada (Connectors for Masonry CAN3-A370-M84).

2.2 THE BRICK INSTITUTE OF AMERICA

The Brick Institute of America publishes a series of technical notes reflecting the present construction and design practices in North America. In this series, Technical Notes 28 and 44 were reviewed to show not only the final recommendations made, but also to serve as a record of the development of these recommendations.

2.2.1 Technical Note 28 Revised (1986)[2]

This article deals with buildings limited to three stories in height with a maximum cavity width of 25 mm. At this stage of the technical notes, the recommendations pertaining to ties for steel stud backup systems were limited to:

- use corrosion-resistant wire, minimum gauge 9
- minimum diameter of 4.8 mm
- maximum spacing of 600 mm
- tributary area of 0.25 m^2
- imbedment depth of 50 mm into the mortar joint.

2.2.2 Technical Note 28A Revised (1987)[3]

This article pertains to two-family dwellings and commercial buildings with a 25 mm cavity space. Recommendations in this note go a little farther by suggesting the following:

- corrosion resistance should conform to ASTM standards, ASTM A 153, A 116, B 227, and A 167. Also, it is suggested that the wire ties comply with ASTM A 82 or A 185.
- tie fasteners should be corrosion-resistant, self tapping screws and penetrate at least 13 mm through the metal.

2.2.3 Technical Note 28B Revised II (1987)[4]

This note addresses the use of brick veneer supported by steel studs in buildings over three storeys in height. In addition, the cavity width was increased to a minimum of 50 mm. The recommendations made pertaining to BV/SS ties are numerous and have been summarized as follows:

- 0.18 m^2 tributary wall area for each tie
- 600 mm maximum horizontal spacing
- 450 mm maximum vertical spacing
- minimum wire diameter of 3/16 in. (4.76 mm)
- two piece adjustable ties should be used
- corrugated ties should not be used

- provide ties 200 mm from edges of walls
- 50 mm embedment length in mortar joint
- ties should be hot-dipped galvanized (ASTM C (153)
- limited mechanical play of 1.2 mm
- maximum tie deformation of 1.2 mm under 444 N load
- screws shall be either hot-dipped galvanized, cadmium-plated, polymer-coated or composite zinc
- stainless steel screws and copper-coated screws should not be used owing to galvanic reactions.

2.2.4 Technical Note 44B (1987)[5]

The wall tie was discussed with the intention of defining its function, selection, specification, and installation. Here the tie was defined as having three primary functions:

1) provide a connection
2) transfer lateral loads
3) permit in-plane movement to accommodate differential movements, and sometimes restrain these movements.

The article further suggests that in order to fulfill these primary functions, the tie should possess the following qualities:

1) be securely attached and embedded
2) have sufficient stiffness to transfer loads with minimal deformations
3) have a minimum amount of mechanical play
4) be corrosion resistant

5) be easily installed to reduce damage to the tie itself and the tie system.

The note also provides a good comparison of the advantages and disadvantages of adjustable ties. The information presented is summarized as follows:

Advantages

1) It permits construction on interior wythes prior to exterior.
2) Being of two piece construction, there is a reducted chance of damage to the tie occurring before the exterior wythe is constructed.
3) It accommodates construction tolerences in multi-material construction.
4) It can accommodate larger differential movements than other standard ties.

Disadvantages

1) Mislocation of ties prior to construction of the facing wythe may render the tie useless.
2) Use may encourage less than perfect layout since adjustability is present.
3) Large variations in construction tolerance may not allow full engagement of ties placed prior to the construction of the facing wythe.
4) Use may result in large eccentricities.

5) Structural performance of some adjustable ties is lower than for standard ties.

This article makes direct recommendations on tie selection, which are for the most part identical to those made in Note 28B. However the differences presented were as follows:

- Do not specify ties with drips.
- Adjustable ties should satisfy stiffness limits at eccentricities expected in the field.
- Adjustable ties should provide positive vertical movement limitations to eliminate possible disengagement.
- The maximum tributary wall area per tie is $0.267m^2$ and $0.2m^2$ for less than 25 mm cavities and between 25 - 50 mm cavities, respectively.

2.2.5 General Comment

One confusing point in all the technical notes seems to be the notion of mechanical play when considering limiting stiffness. All recommendations suggest that the tie deform not more than 1.2 mm under 445 N of load and also not possess mechanical play in excess of 1.2 mm. It is not clear if these two limits are mutually exclusive.

2.3 UNIVERSITY OF ALBERTA

2.3.1 Masonry Veneer and Steel Stud Curtain Walls [24]

An experimental program investigating the interaction of the brick veneer, stud backing and ties in the BV/SS wall system was presented. The interaction of the ties, the behaviour of the stud/tie connection and the influence of location of attachment were identified as areas for testing.

In the test program three repetitions were completed for each test series and six different wall ties made up the sample population. Of these six ties, three were corrugated wall ties of varying gauge and the others were identified as similar to the wire loop, ladder and wire 'V' tie. The recommendations and conclusions found in this report can be summarized as follows:

- Locating the wall tie on the flange of the steel stud at great distances from the web reduced the tie/stud system stiffness.
- The magnitude of the bearing stress on the gypsum board sheathing was important and should be minimized by providing a metal backing plate for the tie.
- Ties should be modelled with an effective axial stiffness that accounts for the action of the tie and stud connection.

2.3.2 Brick Veneer Tie Support[20]

This report described a support device for brick veneer ties along with design information and tested capacities. The BVTS (Brick Veneer Tie Support), as described, was intended to puncture the exterior sheathing and directly transfer the load to the studs. Contained within the report was a discussion on the advantages and disadvantages of this system along with failure modes and load

levels. The support was tested in both tension and compression a total of 26 times with 22 and 16 gauge corrugated strip ties fastened to 18 gauge steel stud.

Compression test results indicated that the 22 gauge tie buckled at an average load level of 558 N (COV 31%), whereas the 16 gauge strip tie exhibited both tie buckling and device failure at an average load of 1364 N (COV 24%). Tension tests failed with screw pull-out at an average load of 1747 N (COV 15%).

2.3.3 The Behaviour of Styrofoam SM Insulation as Exterior Sheathing in Brick Veneer and Metal Stud Wall Systems[18]

The effectiveness of the brick veneer tie support (BVTS) and the influence of the tie on wall behaviour were investigated. Descriptions of test procedures and test set-ups were provided in the report. The study resulted in the following conclusions:

- Stiffer ties reduce top veneer movement.
- Wall behaviour is independent of tie stiffness prior to wall cracking.
- Use of the BVTS enchances tie performance.
- Veneer deflection can be delayed by mortar droppings on ties and extruded mortar fins across the cavity.
- Tie patterns affect wall behaviour.

2.4 BUILDING RESEARCH ESTABLISHMENT

2.4.1 The Performance of Cavity Wall Ties[25]

In this paper, attention was drawn to the absence of performance specifications for cavity wall ties. It was documented that the British Standard BS

1243:1978[6] only provides geometrical and material specifications for wall ties. Structurally, it was recommended that both strength and stiffness requirements should be imposed.

A major portion of the paper was concerned however with the corrosion aspects. Field surveys were conducted to determine the rate at which the galvanized wall ties loose their galvanizing. It was concluded that for wall ties coated with 460 g/m^2 and exposed to air and moisture, they could be expected to loose this coating in 23-46 years. Similarly it was documented that with 260 g/m^2 the loss would occur in 13-26 years (Note: Under CAN3-A370-M84[8], coatings of 458 and 610 g/m^2 are specified for wire and plate in ties).

2.4.2 Corrosion of Steel Wall Ties: Recognition, Assessment and Appropriate Action[11]

This paper contains information on how to recognize the presence of corrosion problems in cavity walls. Case studies were presented to illustrate the discussed corrosion problems. Recommendations were also provided as to the action which should be taken once the problem is identified.

2.4.3 Performance Specifications for Wall Ties[12]

In this paper, a framework for a performance based standard for wall ties was presented. The recommendations pertain specifically to the British Standard BS 1243:1978 and involve ultimate load considerations, safety factors and standarized test methods to achieve characteristic load and resistance levels.

2.5 CORROSION OF METAL COMPONENTS IN MASONRY BUILDING[21]

This paper specificially dealt with corrosion problems associated with steel studs and ties. It was recognized that provision of metallic coatings is only a delaying tactic and not a preventative measure. Other preventative measures such as proper draining of water from wall cavities were recommended.

2.6 THE ALDERNEY MANOR INCIDENT

In Nova Scotia the Alderney Manor apartment building, owned by Canada Mortgage Housing Corporation, experienced severe performance difficulties. The problems associated with the BV/SS wall system were widely discussed and the generated concern and controversy over the apparent reasons for the structural degradation in the system helped focus attention on the BV/SS situation in Canada.

One result of the investigations was preparation of several documents on the building faults and design shortcomings. It was apparent that there were many contributing factors to the wall system's poor performance. These factors are reported originally by J.W. Cowie Engineering 1976[9], Haseltine in 1984[17], Hodgkinson in 1985[22] and again by J.W. Cowie Engineering in 1985[10].

2.7 PERFORMANCE EVALUATION OF BRICK VENEER WITH STEEL STUD BACKUP[1]

This report was one of the first complete studies on the BV/SS wall system. Included in the experimental test program was an investigation comparing two different wall ties. These wall ties were identified as the corrugated strip tie

(22,20,18, and 14 gauge) and the adjustable DW-10 tie (14 and 12 gauge). The tests conducted present cyclic behaviour at load levels of 50, 100 and 150 lbs. The ties were tested to determine their properties independent of other interactions.

The report contains a parametric study in which the influence of effective tie stiffness was considered. The results of the study indicated that stiffer ties transfer more load to the veneer.

2.8 UNIVERSITY OF TEXAS

2.8.1 Metal Ties and Anchors for Brick Walls[15]

This paper was a review of metal ties used at the time. As documented in the paper, at the time the writer was unaware of any structural tests of adjustable wall ties.

Among the findings and conclusions still relevant today, Grimm pointed out that a 100% increase in the wall tie costs only amounted to a 1% increase in the total wall cost. In the conclusions the need for a rational design method was identified as well as the requirement for industry standards.

2.8.2 Distressed Exterior Masonry Walls[16]

A review of an investigation of the BV/SS wall problems in the Alderney Manor was presented. It was concluded that an inadequate tie had been selected and that an insufficient number of ties were employed. The tie under scrutiny, a corrugated dovetail anchor, was used in conjunction with a slotted, vertically mounted channel attached to the sheathing. It was also concluded that corrosion contributed to the damage.

2.9 CANADA MORTGAGE AND HOUSING CORPORATION

2.9.1 Exterior Wall Construction in High-Rise Buildings[26]

In this research document, BV/SS wall ties were not covered in detail. This was likely due to the lack of information available at the time. In fact, at that time, there was no CSA standard for masonry connectors. Attention was drawn to corrosion resistance requirements, limited unsupported length of corrugated ties, degradation of sheathing stiffness and the need for appropriate fasteners.

2.9.2. Masonry Veneer in High-Rise Buildings[29]

This document prepared for Canada Mortgage and Housing Corporation contains the results of a theoretical parametric study on the wall system. Along with the analytical work, discussions on related issues in the BV/SS wall system were provided. These issues included structural deformations, expansion joints, corrosion and common construction errors.

This report relied on the results of other research programs to provide representative stiffness and strength values. These values were required for determination of effective axial stiffness values for subsequent computer modelling.

From the results of the parametric study some interesting recommendations were made regarding ties in order to optimize a cracked wall design:

- Tie stiffness should be as low as possible.
- Ultimate resistance should exceed 1000 N.
- Ties should be attached to the stud web.
- The effect of dynamic windloads is negligible.

2.10 AUSTRALIAN STANDARD AS 2699-1984[27]

The Australian Standard, Wall Ties For Masonry Construction, replaced a standard written in 1953 (SAA Int. 324, Metal Wall Ties for Brickwork). In this standard, masonry veneer ties were specifically dealt with. These ties were classified into one of three groups depending on how they are attached to the load bearing member:

(i) Face-fixed type - fixing to the outer face

(ii) Flange-fixed type - fixing to the flange

(iii) Side-fixed type - fixing to the side

The standard requires that the wall ties meet certain performance requirements. These requirements include characteristic strength, characteristic stiffness, resistance to water transfer and anchorage. These requirements can be met by the process of standardized testing described in the document.

Also included in the standard is a requirement for the manufacturing industry to properly mark their product in a standardized manner. Another requirement is that manufacturers must either supply or specify the fastener to be used with their wall tie.

2.11 CANADIAN STANDARD CAN3-A370-M84[8]

This standard was the first of its kind in Canada, thus it is still in the developing stages. It provides guidance on material specifications, corrosion resistance requirements and possible working loads.

Related to BV/SS wall ties, the only tie given specific treatment by the standard is that identified as a standard wall tie. Unfortunately this standard tie is the corrugated strip tie which is limited by the same standard to use in cavities of 25 mm or less. Thus, virtually all the other BV/SS wall ties are classified as non-standard. Also included in the standard is a test method for determining the ultimate compressive and tensile strengths of ties used between two wythes of masonry.

CHAPTER 3

DESCRIPTION OF THE TIE TEST PROGRAM

3.1 INTRODUCTION

The tie test program was designed to include a wide range of tie types and to incorporate different loading conditions expected to affect performance. In total, twelve separate test series amounting to over 530 individual tie tests were conducted. For each of the twelve tests series, certain standard tests were performed whereas, depending on the type of tie, various other test conditions were added for several of the series. Table 3.1 contains a listing of the tie type corresponding to each series and the type of tests included in each case. To ensure a high level of confidence for the results, five repetitions for each type of test were chosen as the statistical sample.

3.2 TIE SYSTEMS SELECTED FOR TESTING

One of the most continuously changing and ever developing components of the BV/SS system is the system used to attach the brick veneer to the backup wall. In the past, the main design requirement was that these tie systems must transfer the lateral wind induced loads from the brick veneer to the steel stud backup wall. However the need to accommodate inevitable construction tolerances, the increased awareness of substantially greater structural requirements for individual ties, and impinging building science concerns have had the combined

effect of leading to development of ties designed specifically to satisfy some or all of a new set of requirements. While performance standards for BV/SS tie systems do not yet exist, some general requirements which have gradually become accepted include limited mechanical movement or "play", minimum stiffness and capacity, and non-destructive interference with air and vapour barriers.

The tie systems selected for this test program are described and illustrated on the following pages. It should be noted that for this research program, full co-operation was received from the tie manufacturers and that all of the ties were donated by the following companies: Bailey Metals Products Limited, Blok-Lok Limited, Dur-O-Wal Inc., Fero Holdings Limited, Hohmann and Barnard Inc. and Thermosteel Building Systems Inc. Catalog or serial numbers are not used to identify the different ties, instead an easily identified trade or generic name is used.

3.2.1. Tie No. 1: The Double Leg Adjustable Anchor (DLA)

The double leg adjustable veneer anchor shown in Figure 3.1 consists of a double legged wire pintle formed from 4.76 mm diameter wire and a reinforced 14 gauge steel anchor plate. The slotted legs of the plate can be specified with varying lengths to accommodate different cavity widths and/or thicknesses of exterior insulation. Two screws through predrilled holes in the plate provide the method of attachment to the steel studs. This unit has been fastened either directly to the steel stud or on the exterior sheathing.

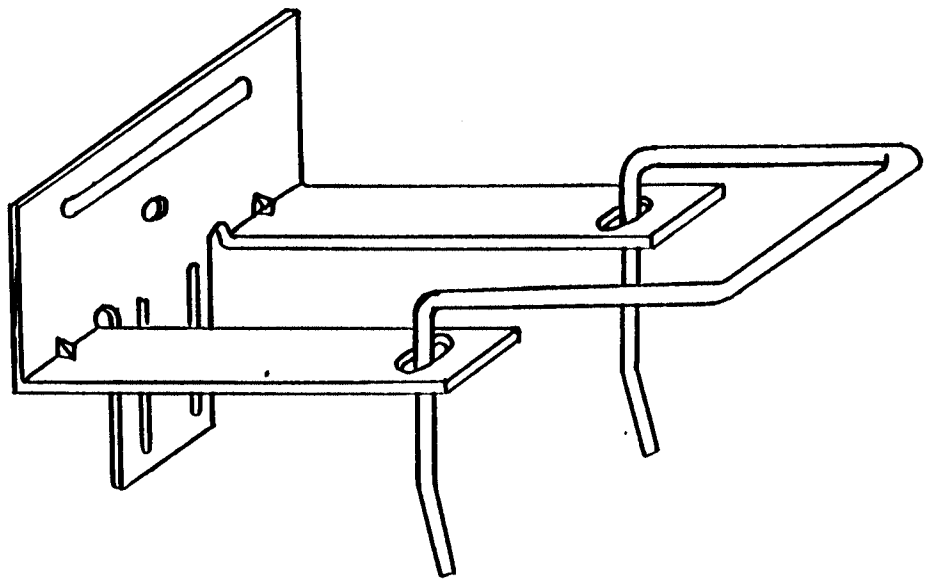


FIGURE 3.1 DOUBLE LEG ADJUSTABLE ANCHOR

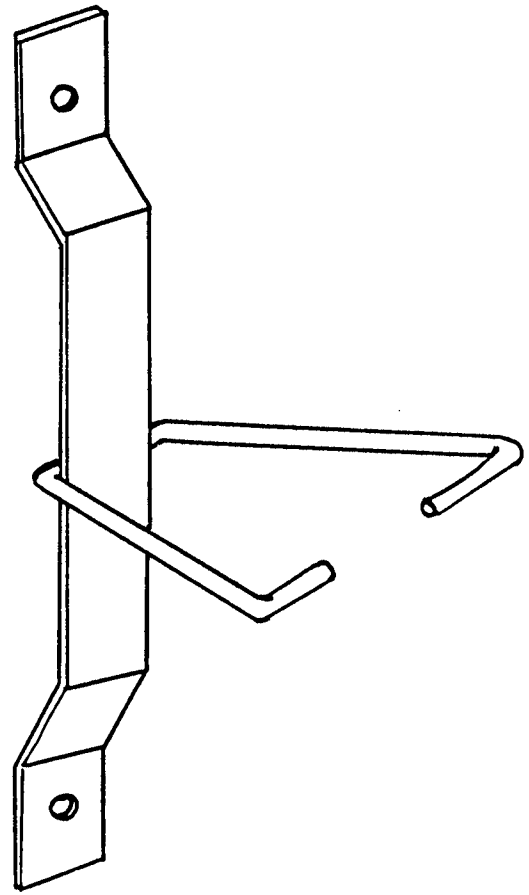


FIGURE 3.2 C TYPE ANCHOR

3.2.2 Tie No. 2: The 'C' type Anchor (CTA)

As shown in Figure 3.2, the 'C' type of veneer anchor is very simple in construction and consists of a single narrow strip of 3.2 mm steel plate bent in a fashion to provide approximately 160 mm of vertical adjustability. Along with the 'C' type anchor, different sizes of triangular wire ties can be used to accommodate different cavity widths. Owing to the inherent difficulty in puncturing the exterior sheathing with this unit, it must be located on any exterior sheathing.

3.2.3 Tie No. 3: The Speed Set Anchor (SSA)

The speed set anchor shown in Figure 3.3 can be specified in two different lengths. The anchor is manufactured from standard 2 mm plate, bent into a channel shape, and the tie is formed from 4.76 mm diameter wire. In order to adjust this unit once it is attached, the entire anchor must be slid vertically under the fastening screw which is installed through the vertical slot in the plate. Attachment of the anchor must be on the exterior sheathing.

3.2.4 Tie No. 4: The Single Leg Adjustable Anchor (SLA)

The single leg adjustable anchor, as the name implies, only supports a single legged wire tie. As shown in Figure 3.4, vertical adjustability of up to 35 mm can be achieved in the unit by movement of the vertical pintle of the wire tie through the extended leg of the anchor. In the past this anchor has been fastened either directly on the steel stud or the exterior drywall. The thickness of the plate material was 1.55 mm with the predrilled hole located 18 mm from the bend.

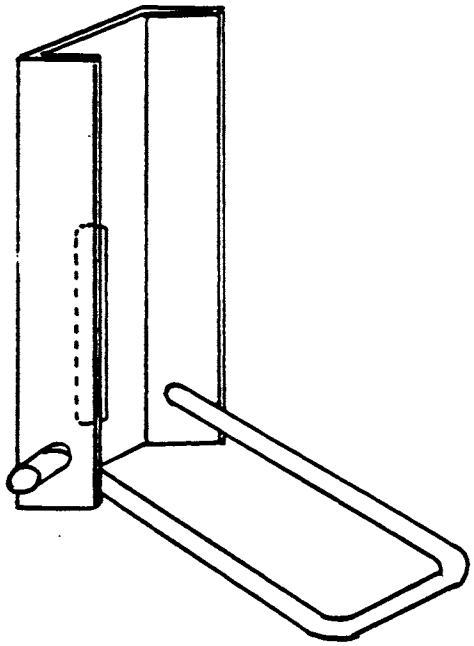


FIGURE 3.3 SPEED SET ANCHOR

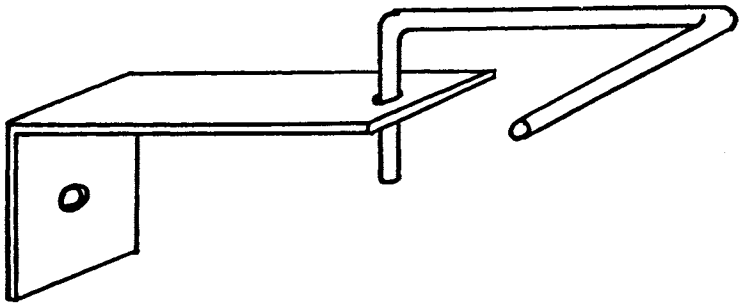


FIGURE 3.4 SINGLE LEG ADJUSTABLE ANCHOR

3.2.5 Tie No. 5: The Wire Loop Adjustable Tie (WLA)

As is illustrated in Figure 3.5, this tie is made from a single length of wire. Being of one piece construction, the wire loop tie can be attached with one screw and a washer on the exterior drywall. As was the case for the speed set anchor, the wire loop tie can be adjusted by sliding the unit vertically under the fastening screw.

3.2.6 Tie No. 6: The Flange Locking Anchor (FLA)

As is illustrated in Figure 3.6, the flange locking anchor is not mechanically fastened to the stud but rather is fabricated with a slot sized to fit around the flange. Because it must bear directly against the steel stud, it punctures the exterior sheathing to engage the wire tie. Like the single leg anchor, the adjustability of this tie lies in the movement of the wire pintle through the anchor. Unique in its construction, the flange locking tie requires no mechanical fasteners and is normally positioned through the joints between horizontally placed lengths of exterior sheathing.

3.2.7 Tie No. 7: The Wrap Around Tie (WAT)

Owing to the design of the wrap around tie shown in Figure 3.7, it fastens directly to the steel stud and must interrupt the exterior sheathing to engage the wire tie portion of the system. Vertical adjustability can be achieved by sliding a triangular wire tie through the slot provided in the extended leg of the anchor. Unlike many of the other anchors this unit fastens to the web of the stud as opposed to the flange. For the configuration shown, the screws through the web are essentially positioning screws with tension and compression loads being transferred by the wrap-around flanges of the tie. The extended leg of the tie is

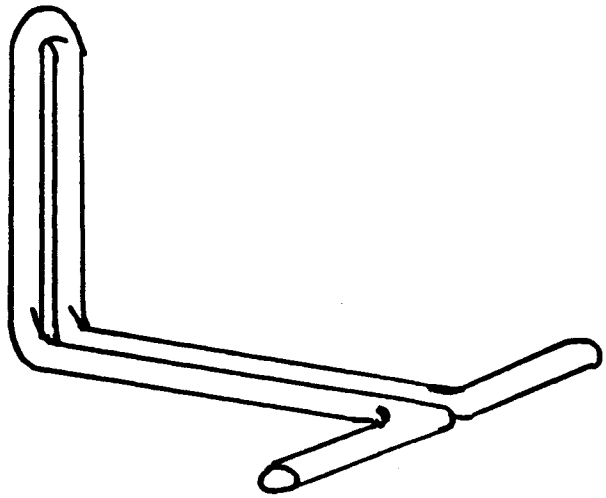


FIGURE 3.5 WIRE LOOP ADJUSTABLE TIE

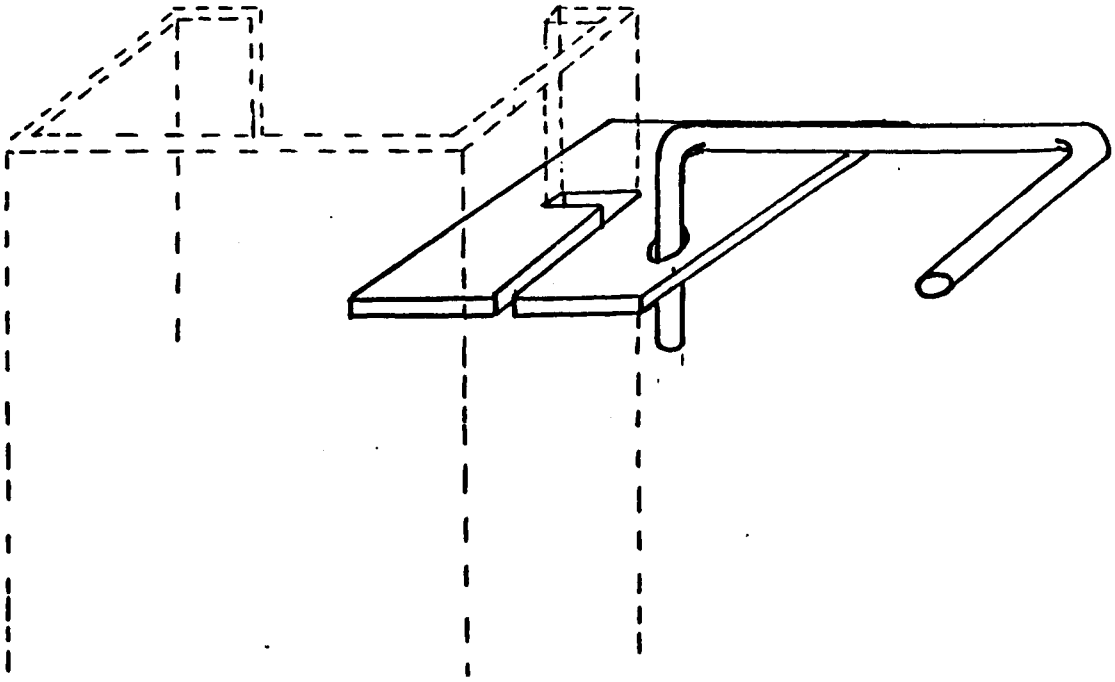


FIGURE 3.6 FLANGE LOCKING ANCHOR

available in various widths so that the slot is positioned outside of the exterior sheathing.

3.2.8 Tie No 8: Self Drilling Tie (SDT)

Screw like in appearance this self-drilling tie, shown in Figure 3.8, fastens through the exterior sheathing and bears directly on the steel stud. The shank or wider part of the tie comes in various lengths to match the thickness of the sheathing material. For compressive loading, the shank of the tie bears directly on the flange of the stud. For tension, the load can be transferred by the threads of the tie or a supplied nut and washer can be placed on the portion of the tie on the inside face of the flange. Where triangular wire ties are used, a short slot in the head of the tie and slight angling of the wire part of the tie can provide a small amount of adjustability. Otherwise, to achieve greater adjustability, a single leg wire tie has been used with the pintle extending through the slot in the head of the self-drilling part.

3.2.9 Tie No. 9: The DW-10X Anchor (DW10)

As can be seen in Figure 3.9, this tie has some of the same characteristics as the simple 'C' type anchor. While the vertical slot for adjustability dictates that it must be positioned on the sheathing, the DW-10X tie provides positive connection to the steel stud using legs extending through the exterior sheathing to bear on the stud. Thus this tie attaches on the exterior of the sheathing and also bears directly on the steel stud. Triangular wire ties with different lengths can be used to accommodate different cavity widths.

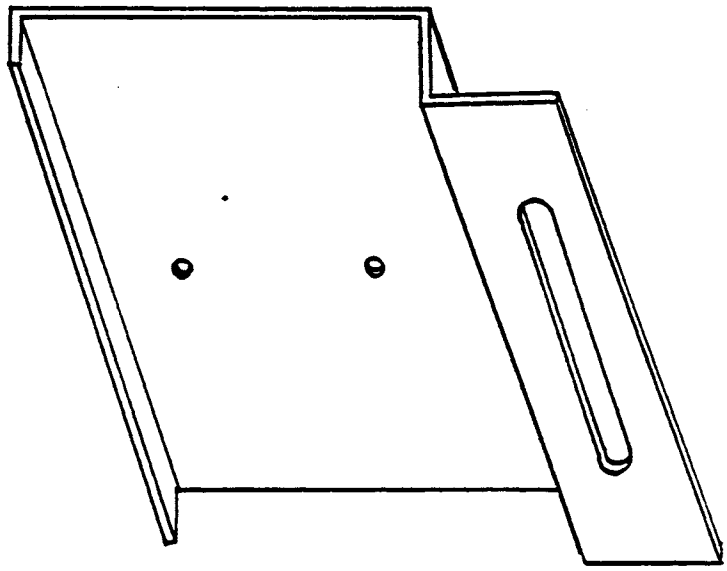


FIGURE 3.7 WRAP AROUND TIE

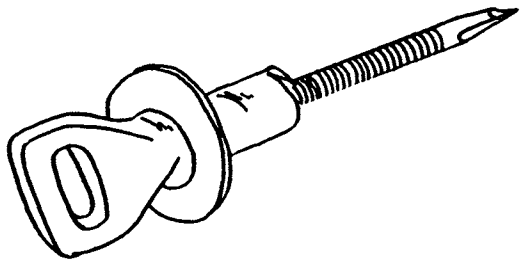


FIGURE 3.8 SELF-DRILLING TIE

3.2.10 Tie No. 10: The Corrugated Strip Tie (CST)

Twenty-two gauge standard corrugated strip ties, of the type shown in Figure 3.10, have been used in BV/SS construction. However its use is restricted, by CAN3-A370-M84[8], to cavities of 25 mm or less in width. Attachment must be made on the exterior sheathing. After fastening in place, further adjustment by altering the location of the bend or by sloping the extended leg are not acceptable practice.

3.2.11 Tie No. 11: The Brick Veneer Tie Support (BVTS)

The legs of this device provide positive contact with the steel stud while the flat part serves as a platform for tie systems which must attach on the exterior of the sheathing. The unit can be obtained in a number of leg lengths to accommodate different thicknesses and kinds of exterior sheathing. The tie support is attached to the flange of the steel stud by two screws. The tie itself may either be attached to the tie support or sufficiently long screws can be used to fasten the tie back to the stud.

3.2.12 Tie No. 12: The Thermosteel Anchor (TA)

The Thermosteel Anchor is a propietry anchor intended for open web types of studs and therefore cannot be attached to standard steel studs. The Thermosteel Stud, which utilizes a truss like web, must be used to accommodate the fastening features of the anchor which is positioned between the panel points of the truss like web. While no mechanical fasteners are used, the anchor can be locked in place by simply twisting a slotted leg over the flange which acts as a chord in the truss arrangement. In addition, predrilled holes are included to facilitate screw connection if required. Holes in the leg which extend into the cavity provide for

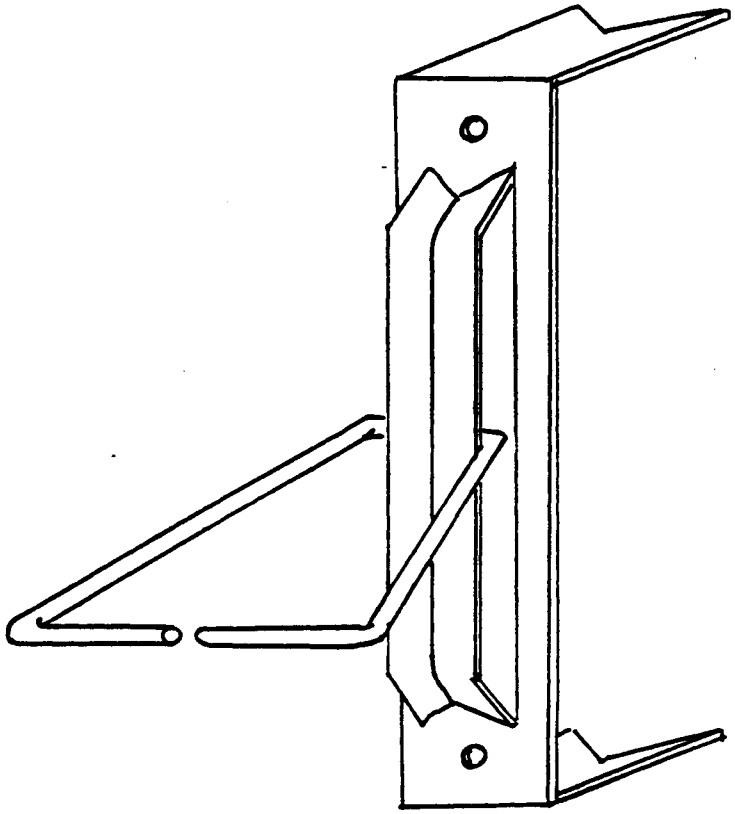


FIGURE 3.9 DW-10X ANCHOR

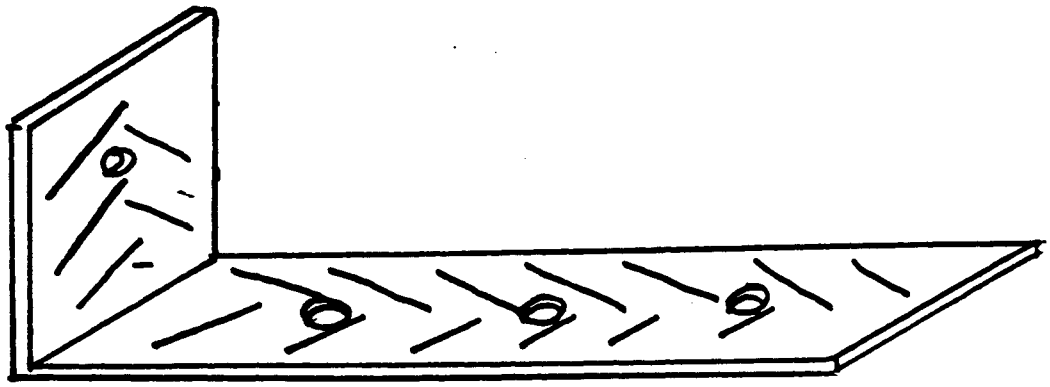


FIGURE 3.10 CORRUGATED STRIP TIE

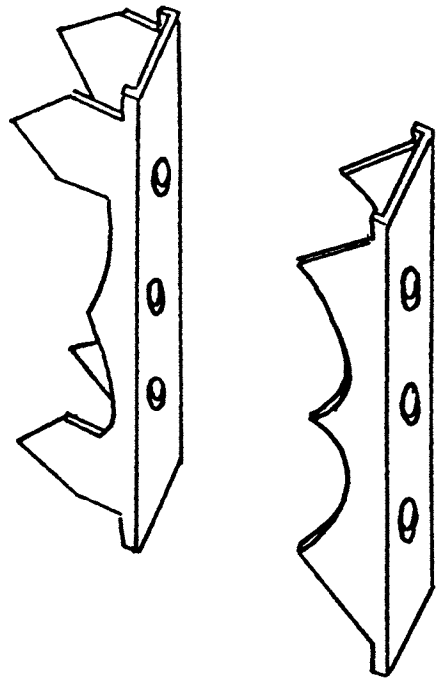


FIGURE 3.11 BRICK VENEER TIE SUPPORT

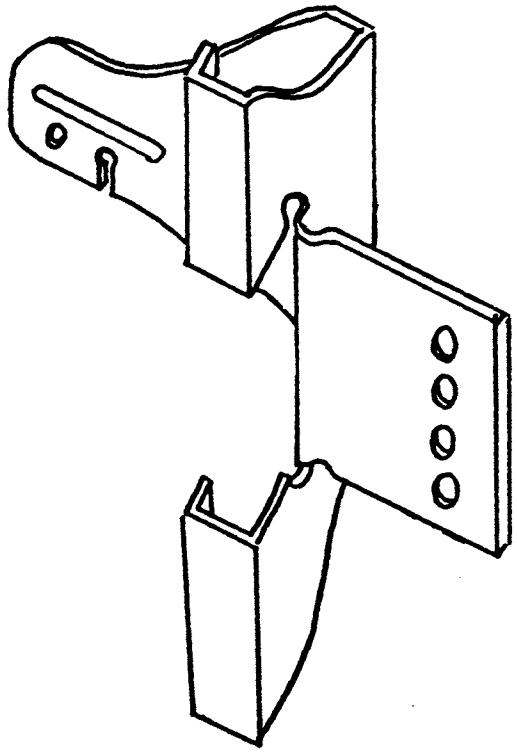


FIGURE 3.12 THERMOSTEEL ANCHOR

vertical adjustment of triangular wire ties.

3.3 DEFINITION OF TERMS

Throughout this report certain words or phrases are used which should be clearly defined. The following terms and definitions are provided.

Cavity Displacement: This term has been used to define the relative movement between the centre line of the stud and the brick veneer which in the tests is replaced by a clamping device. This displacement is illustrated in Figure 3.13.

Performance Range: The performance range of the tie has been defined as no greater than 4 mm of cavity displacement. It is argued that this amount of relative movement is beyond the range where the long term serviceability of the wall would be assured. Thus for comparison purposes many of the graphs in this report are limited to a domain of 4 mm cavity displacement.

Non-Yielding Support: Some of the tests conducted in this program were completed with ties attached to a non-yielding support. This means that the support, being a large steel section, did not contribute to the cavity displacement. Thus ties tested on the non- yielding supports provide results which isolate the tie's individual behaviour independent of the stud's influence.

3.4 DESCRIPTION OF THE TEST APPARATUS

The test apparatus used in the program was developed primarily to provide a standardized test that can be used to study the behaviour of the many different tie specimens prepared for testing. The test apparatus is illustrated in Figure 3.14. A requirement was to be able to define the strength and stiffness characteristics of the BV/SS tie systems outlined in the program under various conditions of attachment and adjustability. Thus an important feature of the apparatus was to have flexibility in setup without jeopardizing any consistency in the test procedure.

In Figure 3.14, two clamping devices are shown. The wire clamping devices served the function of the mortar joint in the veneer while the other secured the 450 mm long stud specimen to the loading table. Linear variable differential transducers (LVDT) and a load cell were employed to measure the displacements and applied loading during the tests.

The recorded data included the applied load, global displacement and relative displacement between the stud centreline and the loading table. The latter displacement was then subtracted from the global recording to determine the cavity displacement, which is independent of any beam deflection and represents tie movement, local stud deformation, fastener slippage and flange rotation. The test frame was a MTS Testing Machine operated under controlled displacements and constant speed. Each of the components of the test apparatus are described in greater detail below.

Cavity Width: This term is used to describe the unsupported length of the wall tie. Where the tie is directly supported on the steel stud, the sheathing is assumed not

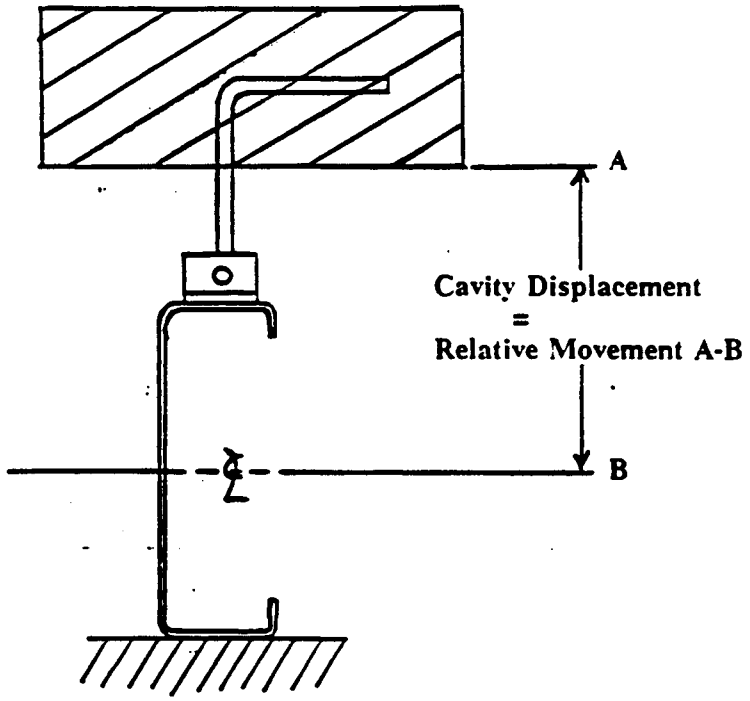


FIGURE 3.13 ILLUSTRATION OF CAVITY DISPLACEMENT

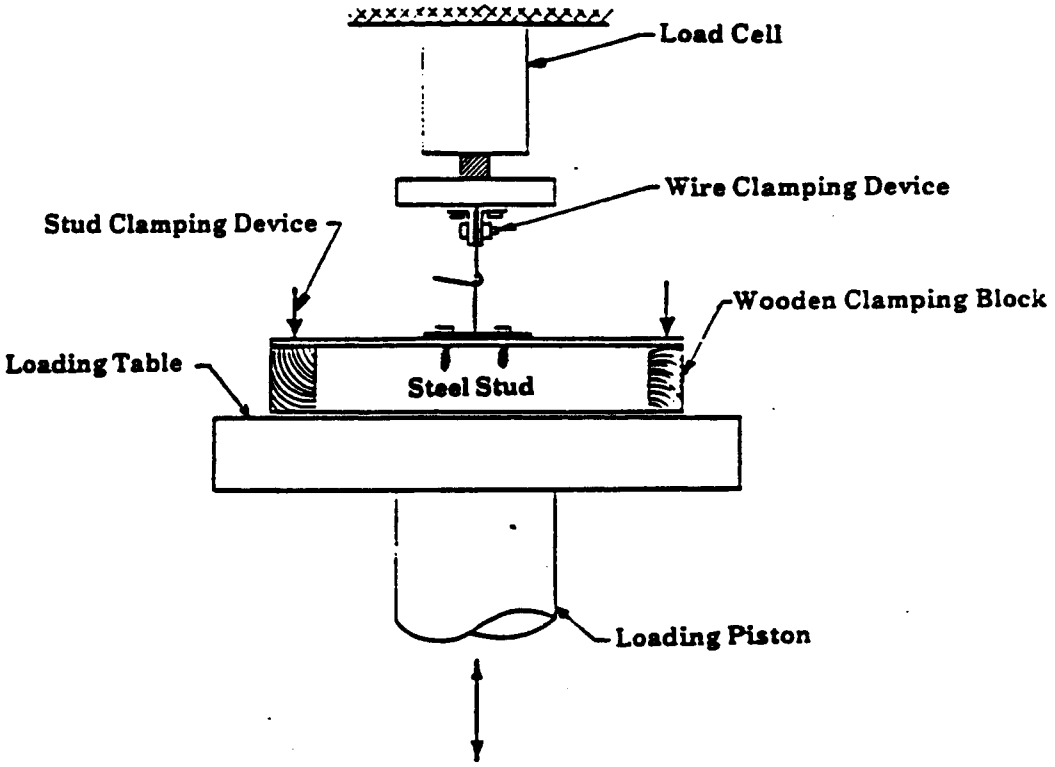


FIGURE 3.14 TEST APPARATUS

to offer any significant support to the tie. For ties mounted on exterior sheathing, the cavity width is the clear distance between the sheathing and the veneer.

Position A, B & C: These terms refer to the position of the tie on the flange of the stud with respect to the web. As shown in Figure 3.15, position A is 15 mm from the web (approximately the middle), position B is 10 mm and C is 20 mm. These three locations on the stud flange were used to represent the range of tie attachment positions.

Mechanical Play: The movement in the tie system before it is able to resist loading is defined as the mechanical play. For example the difference between the size of a hole and the diameter of the wire pintle is the mechanical play.

Tie Clamping Device: Owing in part to the large number of test repetitions planned for this test program, it was necessary to forgo the construction of brick assemblages as part of the test specimen. Instead, a clamping device was designed to replace the role of the mortar joint between bricks where the wire tie would be located. Since many of the wire ties are bent or formed in some pattern to support the ties, it was necessary to supply a template to fit snugly within the tie. The thickness of the template was made less than the wire diameter to allow the clamping angles shown in Figure 3.16 to bear directly against the wire and thus provide restraint to any movement within the clamping devices during the test. The template, as illustrated in Figure 3.16, was intended to act in a similar manner to an actual mortar joint and prevent the tie from straightening out during a tension test.

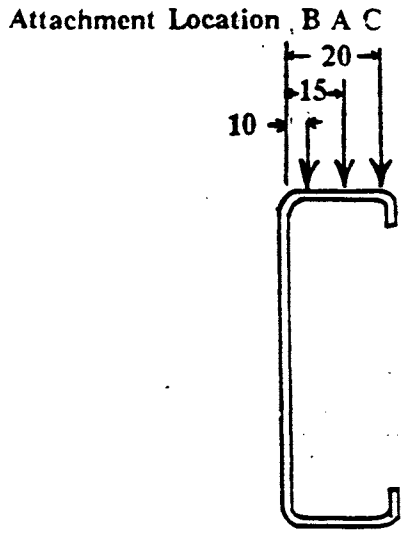


FIGURE 3.15 ILLUSTRATION OF THE ATTACHMENT POSITIONS ACROSS THE FLANGE OF A STEEL STUD

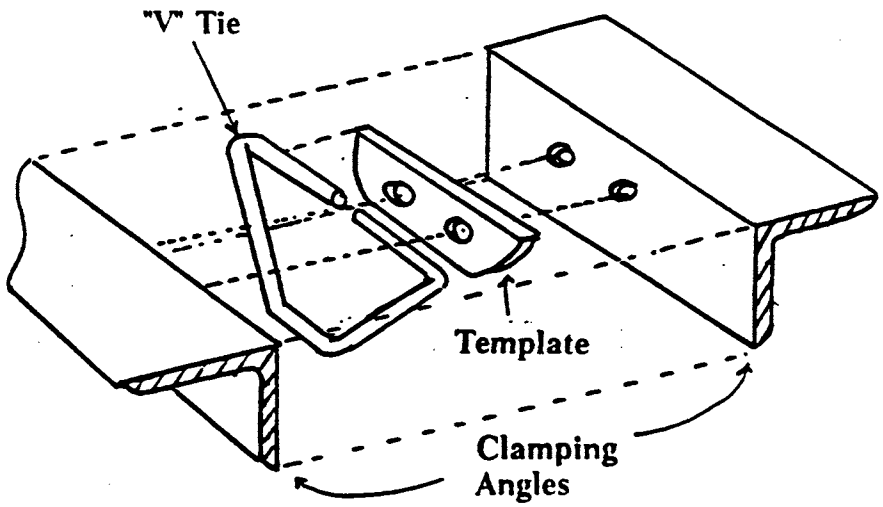


FIGURE 3.16 TIE CLAMPING DEVICE

The clamping device itself consisted of two steel angles placed back to back. One angle was permanently fastened to the load cell plate to ensure that all the specimens were placed into the apparatus concentric with the load cell. The other angle was fitted with a slotted hole to allow fastening and unfastening of the test specimens. Load-displacement tests conducted on wire ties in the clamping device confirmed that any slippage under the expected loading range was so small that it was not detectable. Therefore cavity displacement measurements did not include any component of pull out of the tie from the (modelled) mortar joint.

Stud Specimen Clamping Device: The tie clamping device secured the tie portion of the BV/SS tie system in a place where it could be fastened to the anchor portion already attached to the stud specimen. Once the entire unit was placed in the test apparatus and secured to the overhead load cell, it could be attached to the loading table.

The stud specimen was clamped at its ends where wood inserts were used to prevent the stud from being deformed by the firmly placed clamps. Since the stud rested against the loading table along its bottom flange, no beam deflection would occur under compression load on the tie. Thus for tie compression tests, the recorded displacement included tie induced flange rotation, local dimpling of the stud and any axial deformation in the tie unit (including compression of sheathing if present).

For the tie tension tests, which produced upward deflection of the stud, the beam deflection component of displacement had to be measured so that it could be subtracted from the overall displacement to give the cavity displacement. This simply involved subtracting the measured movement between the loading table

and the stud's centre line from the global displacement. Although the stud deflection was found to be rather small, for completeness it was subtracted to give the cavity displacement.

Displacement Measurement Devices: Linear variable differential transducers (LVDT) were employed to measure the displacements. The measurements were recorded as voltages by a Hewlett Packard scanner and converted to units of length using the appropriate calibration curve. These calibration curves were established in the laboratory and continuously monitored for accuracy.

Load Monitoring Method: The load cell was located between the head and the table of the MTS loading machine and functioned in both compression and tension. The load cell sent a voltage signal to the scanner which was then converted to units of force using the appropriate calibration constant.

Test Machine: The test frame used in the program was a MTS (Material Testing Machine). The machine operated under controlled displacements with manually controlled speed. The speed was kept constant for the duration of the test. Since the load cell was constantly monitored by the scanner, pauses in the tests could be introduced at relatively constant load increments so that all the transducers' signals could be permanently recorded by the data scanner.

3.5 DESCRIPTION OF TEST SERIES

For each type of tie, several different types of tests were performed in order to determine the influence of various factors on tension and compression strength and stiffness characteristics. Depending on the nature of the tie, different

combinations of tests were performed for each type of tie. To avoid having to repeat the descriptions of the individual types of tests, a complete listing of all the types of tests is provided below where identification numbers were assigned to each series. In the identification number, T stands for tie and the actual tie number (1 to 12) is used in place of the question mark. The final number is used to indicate the type of test as described below:

T-?-1 Compression test conducted on a tie system mounted at position A (middle of the flange) on a 20 gauge steel stud.

T-?-2 Tension test conducted on a tie system mounted at position A on a 20 gauge steel stud.

T-?-3 Tension test conducted on a tie system mounted at position A, B and C on a 20 gauge steel stud. (This series of tests was used to investigate the influence of attachment location on tie performance).

T-?-4 Tension test conducted on a tie system mounted at position A on a 20 gauge steel stud. (This series of tests was used to investigate the influence of adjustability of ties on performance).

T-?-5 Compression test conducted on a tie unit mounted on a non-yielding support. (This series of tests was used to investigate the influence of cavity width without the influence of the steel stud).

T-?-6 Tension test conducted on a tie system mounted at position A on an 18 gauge steel stud. (This series of tests was used to investigate the influence of steel gauge on tie performance).

T-?-7 Compression test conducted on a tie unit mounted on a non-yielding support. (This series of tests was used to investigate the influence of the steel stud on the tie's compressive behaviour).

T-?-8 Tension test conducted on a tie unit mounted on a non-yielding support. (This series of tests was used to investigate the influence of the steel stud on the tie's tensile behaviour).

T-?-9 Compression test conducted on a tie system mounted at position A on a 20 gauge steel stud. (These tests provided information on the influence of using different cavity widths).

T-?-10 Tension test conducted on a tie system mounted on a non-yeilding support. (This series of tests provided information on the influence of adjustability of the tie but without the influence of the steel stud).

T-?-11 Compression test conducted on a tie system mounted at position A on a 20 gauge steel stud. (These tests were used to investigate the behaviour of the ties when the anchor and the wire tie are misaligned).

T-?-12 Repeated loading test including compression and tension load reversals conducted on a tie system mounted at position A on a 20 gauge steel stud.

(These tests were used to investigate the behaviour of the ties under repeated and reversing loads).

3.6 TEST PROCEDURE

For all the tests a standard procedure was followed to reduce any experimental scatter in the data. The procedure was very simple and was adopted following extensive preliminary testing to ensure reliable results. The procedure was executed as follows:

1. Clamp the wire tie into the upper clamping device.
2. Connect the tie to the anchor which had previously been attached to the stud or rigid support.
3. Raise the MTS table up to the specimen.
4.. Clamp the ends of the stud or rigid support to the table.
5. Fasten LVDT to the centre of the stud web below the load transfer point.
6. Properly align tie and adjust to eliminate any inherent mechanical play.
7. Take initial readings and then apply load in uniform load increments.
8. Continue to collect data until the tie system yields or until sufficient high level of load or displacement has been reached.

3.7 TESTS ON FASTENER SCREWS

Since it was anticipated that the screw connection would likely limit the tensile capacity of some wall ties, tests to determine screw pull-out load levels were

required. After discussions with fastener suppliers and tie manufacturers regarding commonly used self-tapping screws, it was concluded that a standard screw does not exist. However, a reasonable selection of currently used fastening screws were identified and tested. From the results, a screw with average performance characteristics was selected for general use in the test program. It was necessary to choose one screw type to eliminate yet another variable in the test program. This factor was of course only significant for the tension tests.

3.7.1 Screws Selected For Testing

The following screws were identified as having being used for BV/SS wall ties connections and as such were included in this test program.

S-A	Stainless Steel Screw 5.5x2.8
S-B	Accessary Mounting Screw (No. 1)
S-C	Accessary Mounting Screw (No. 2)
S-D	Heavy Structural Steel Screw 12-24$_x$1 1/4" HWH/5
S-E	Teks/3 No. 10-16 x 3/4" HWH/2
S-F	Drywall High-Low Screw

3.7.2 Screw Pull-Out Test Apparatus

In Figure 3.17, the test set-up used to determine the axial pull-out capacity of the selected screws is illustrated. Briefly the main part of the set- up amounts to a universal screw extraction device which ensures, through orthogonally controlled lateral freedoms, pure axial force on the screw. Peak loads are recorded in a manner similar to the previously discussed tie tests.

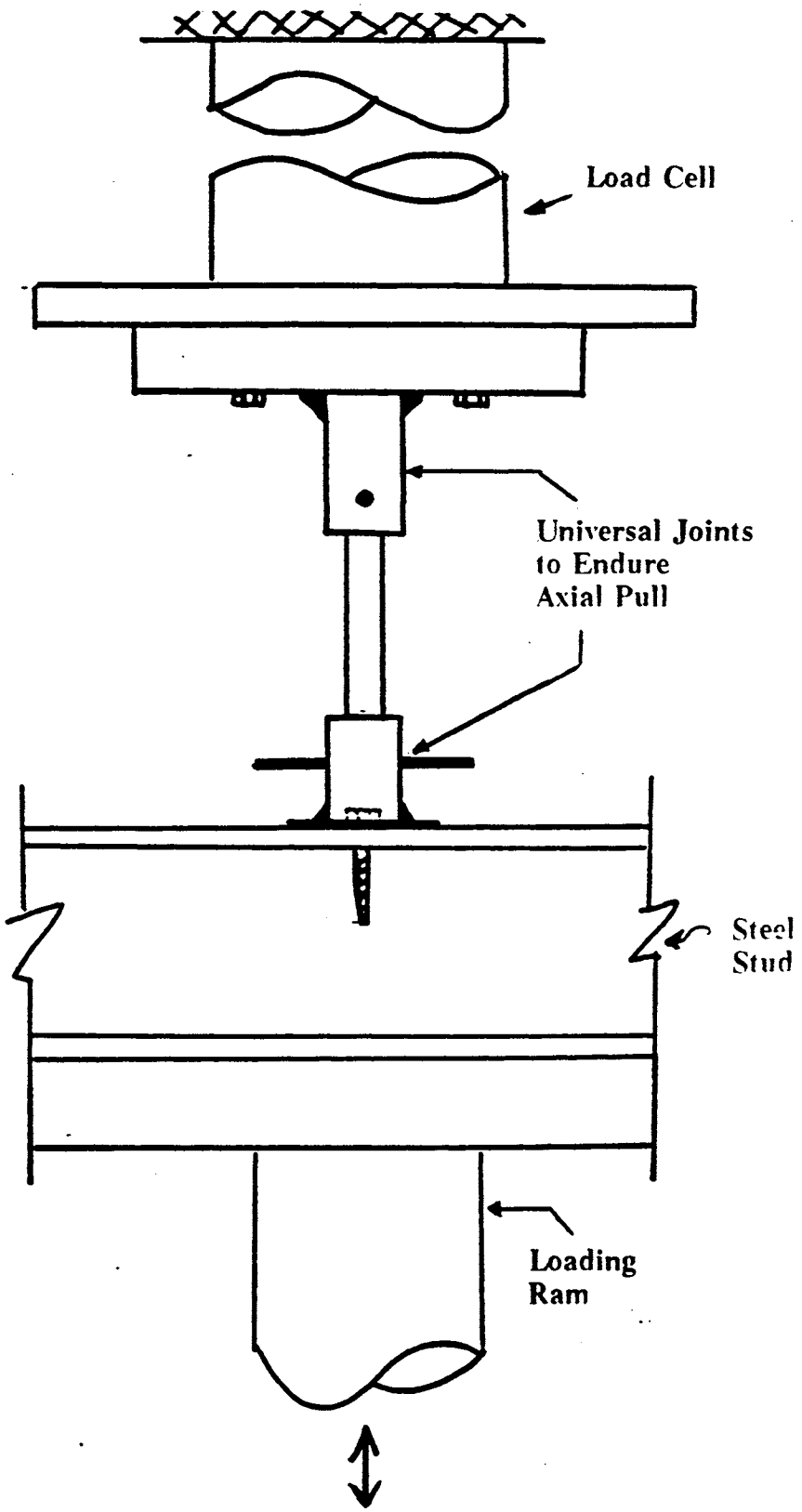


FIGURE 3.17 SCREW PULL-OUT TEST APPARATUS

CHAPTER 4

TEST PROGRAM RESULTS

4.1 GENERAL ORGANIZATION OF THE TEST PROGRAM

The experimental program includes testing of the complete tie system including interaction with the steel stud and sheathing materials. Also the characteristics of the tie itself were determined by testing the tie alone mounted on a rigid steel section. For the latter tests, bolts with comparable diameter and head size to the self drilling screw are employed. These tests correspond to the Test Series T-?-1,2,7 and 8.

In this section of the report, the data from tests of each of the ties is presented separately to illustrate its characteristic load-displacement behaviours as established in the laboratory. The graphs represent the performance domain of the mean compression and tension curves for ties attached to the steel stud and separately attached to the rigid supports. More complete reproduction of the test data are provided in Appendix A. For comparison between the various ties tested, figures have been provided to illustate different observed behaviour characteristics.

For the standard tests, 20 gauge 90 mm deep steel studs were used exclusively. To serve as a comparison, a later section contains the experimental findings for tests completed on 18 gauge studs. For standard tests, the ties were fastened to the flange of the stud at a distance of 15 mm away from the web. This was considered to represent the average location of attachment. The influence that the location of attachment had on tie performance is also presented in a later section of this chapter.

For convenience during discussions, an attempt was made to classify the adjustable wall ties. Four distinct classes based on adjustable features can be described as follows:

Class 1 - A slot in the anchor accommodates various positions of the wire tie extending from the veneer.

Class 2 - An extended vertical portion of the brick wire tie allows adjustment.

Class 3 - Movement of the anchor portion, attached to the steel stud permits vertical adjustment relative to the fastener.

Class 4 - Either non-adjustable or having a feature permitting alternate locations of parts of the tie.

The twelve types of ties included in this test program were classified based on the above criteria and they are listed in Table 4.1 according to these classifications.

4.2 AUXILIARY TESTS AND MEASUREMENTS

4.2.1 Properties of the BV/SS Ties

For future interpretation of the results of the tie tests and as a quality control measure, tests were done to determine the yield stresses of the tie materials and measurements were taken to document geometric characteristics. While some of the measurements were included in the tie descriptions provided in Chapter 3, those dealing with adjustable range and mechanical play are listed in Table 4.1. The yield strengths are the mean of three tests of test coupons cut from the same batch of ties as was used in the Test Program. Table A.1 in Appendix A contains the complete listing for individual tests

including tests on the wire components of the ties.

4.2.2 Screw Pull Out Test Results

The results of the screw pull out test are provided below. It should be noted that each screw was tested five times and the results were averaged. Coefficients of variation were provided as a measure of the test consistency. The results of the test were listed in Table 4.2 and indicate that some were tested on both 18 and 20 gauge stud specimens. The results were graphically presented by means of a bar chart in Figure 4.1.

4.3 DISCUSSION OF THE GENERAL PERFORMANCE OF INDIVIDUAL TIES

Table 4.2 contains a summary of the mean results for the different series of tests completed to indicate the general characteristics for each type of tie. The full listing of data has been included in Appendix A. In the following sub-sections, specific comments related to the general performance of each tie are provided in turn. These results were for Test Series T-?-1, 2, 7 and 8. Comparisons between ties and information on the influences of common factors are introduced in later sections.

4.3.1 T-1: The Double Leg Adjustable Tie (DLA)

From the curves in Figure 4.2, it can be observed that, although attachment to the steel stud does not greatly alter the general behaviour characteristics, it does have a pronounced effect on the stiffness of the system. From the tests on the steel stud, the tension behaviour is reasonably linear compared to the non-linear behaviour for the compression tests. This behaviour

is repeated in the tests on the tie unit itself. The difference in stiffness between the two compression tests can be attributed to the flange rotation experienced by the specimen mounted on the steel stud. In tension, as shown in the photograph in Figure 4.3, the stud mounted specimen exhibited flange rotation and eventually experienced screw pull out. In compression the failure was characterized by sideways deflection of the anchor legs followed by buckling of the wire tie. Since the two legs do not share the load equally (because of flange rotation), failure was initiated in the most heavily loaded leg; being closest to the stud web.

The compression and tension tests of the tie unit itself produced similar results with a few exceptions. Since the tie unit is supported on a rigid support, both legs of the anchor were able to participate equally to resist the applied load. This provided a more random failure mode, with either or both legs initiating failure. When tested in tension, the ties double legged pintel was forced to bend and work its way free from the rigidly held anchor legs.

4.3.2 T-2: "C" Type Anchor (CTA)

The compression and tension test curves shown in Figure 4.4 graphically demonstrate the recorded large differences between the stiffnesses under compressive and tensile loading. In tension the tie was very flexible owing to the fact that it was loaded in the middle of its adjustable range. This configuration proved to be the most flexible for this particular tie. (In another section of the report the behaviour of the tie under tension loading will be examined for the entire adjustable range.) The bending pattern for the tie and both pull-out and shear of the screw are illustrated in the photograph in Figure 4.5.

TABLE 4.1 SUMMARY OF WALL TIE PROPERTIES

	Adjustable Range (mm)	Mechanical Play (mm)	Anchor Yield (MPa)	Cov. (%)	Wire Yield (MPa)	Cov. (%)
CLASS 1						
Wrap Around Tie (WAT)	76	0.75	353	0.3	615	0.8
'C' Type Anchor (CTA)	90	1.24	287	0.3	615	0.8
D-W 10X Wall Tie (DW10)	90	0.3	346	1.7	615	0.8
CLASS 2						
Double Leg Adjustable (DLA)	35	1.24	283	0.3	696	8.1
Flange Locking Anchor (FLA)	35	0.3	357	1.5	490	1.7
Single Leg Adjustable (SLA)	35	0.2	292	4.1	490	1.7
CLASS 3						
Speed Set Anchor (SSA)	35	-	429	4.4	-	-
Wire Loop Adjustable (WLA)	35		-	-	613	0.6
CLASS 4						
Self-Drilling Tie (SDT)	4.8	0.9	-	-	615	0.8
Corrugated Strip Tie (CST)	-	-	-	-	-	-
Brick Veneer Tie Support (BVTS)	-	-	-	-	-	-
Thermosteel Anchor (TA)	33	1.6	418	1.0	615	0.8

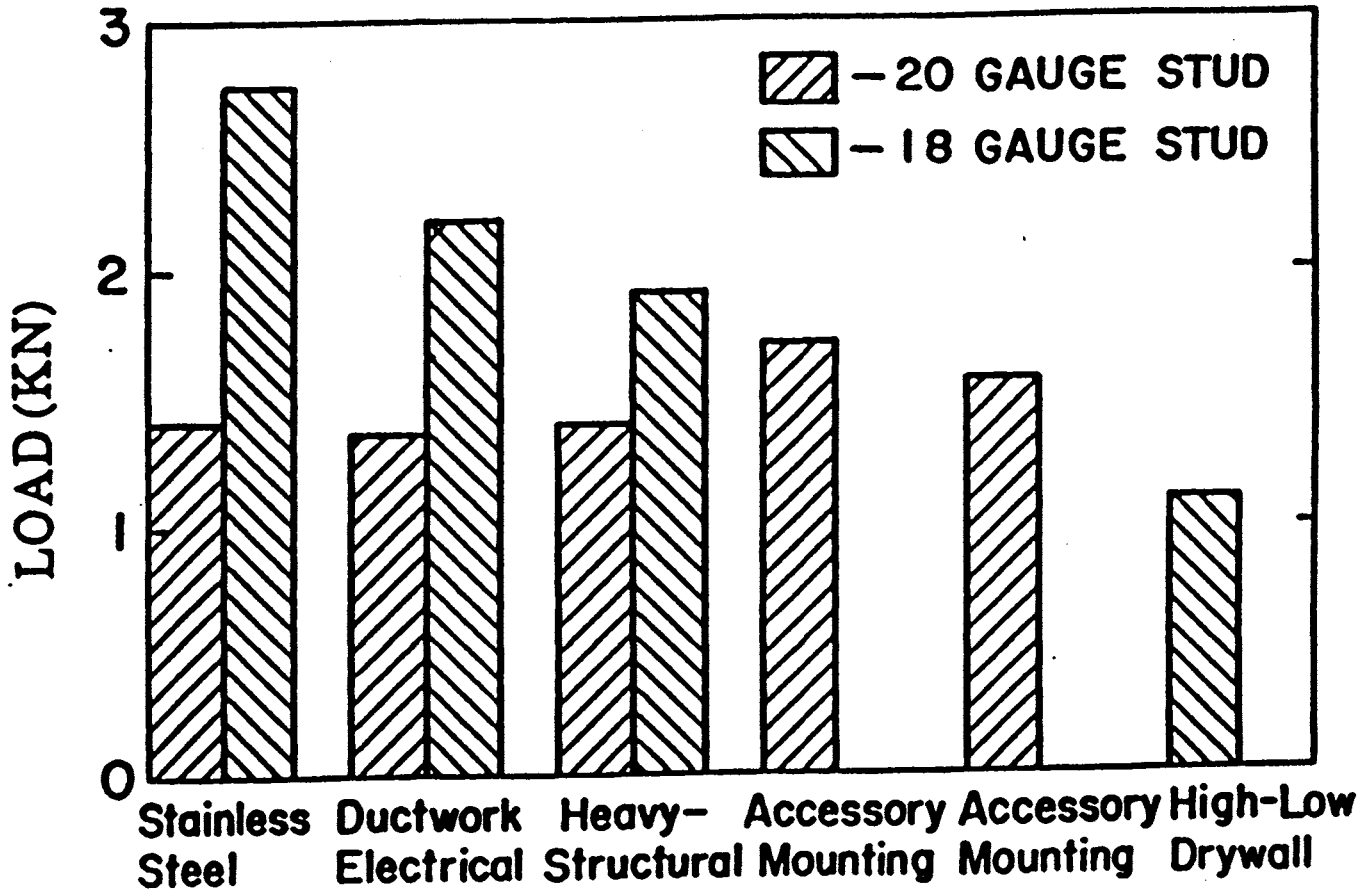


FIGURE 4.1 SCREW PULL-OUT TEST RESULTS

TABLE 4.2 SCREW PULL-OUT TEST RESULTS

Screw Type	Capacity		COV(%)
20 Gauge Stud			
S-A	1390 N	(312 lbs)	2.3
S-B	1700 N	(380 lbs)	2.4
S-C	1550 N	(350 lbs)	3.1
S-D	1380 N	(310 lbs)	1.9
S-E	1350 N	(303 lbs)	3.5
S-F	1080 N	(240 lbs)	5.9
18 Gauge Stud			
S-A	2700 N	(600 lbs)	3.2
S-D	1890 N	(425 lbs)	5.0
S-E	2170 N	(490 lbs)	3.6

+See Section 3.7.1 for description

TABLE 4.3 SUMMARY OF TEST RESULTS ON GENERAL BEHAVIOUR OF TIES MOUNTED ON STEEL STUDS AND ON RIGID SUPPORTS.

TIE	TEST[2]	ULT. LOAD (N)	COV. (%)	REGRESSION COEFFICIENTS[1] a	b	c	d	e	LOAD @ 1.2 mm (N)
DLA	T-1-1	1678.0	8.1	577.0	55.7	-24.4			730
	T-1-2	1708.9	10.9	382.0	-15.5				436
	T-1-7[xx]			402.8	1654.9	-0.2705	0.6811		1732
	T-1-8			588.0	63.1	-13.2			774
CTA	T-2-1	2278.3	1.9	799.0	-96.5	3.83			826
	T-2-2	2190.6	1.8	86.8	0.31	-0.03			104
	T-2-8			283.0	-9.31				326
SSA	T-3-1			870.0	-114.0	4.75			888
	T-3-2	1167.5	3.6	570.0	-70.6				582
	T-3-7			2657.0	-474.0				2506
	T-3-8			2151.0	-347.0				2082
SLA	T-4-1	1087.5	6.5	602.0	-34.2	-17.0			644
	T-4-2	1004.5	7.0	220.0	-13.0				245
	T-4-7			505.0	853.0	-429.0			1093
	T-4-8			793.8	-199.13	1.85	7.42	-0.86	682
WLA	T-5-1	2457.6	1.4	694.9	-79.9				718
	T-5-2	1287.5	4.6	508.82	-96.19	7.16			484
	T-5-7			2427.0	24.0	-273.0			2475
	T-5-8			2077.0	-791.0	83.60			1498
FLA	T-6-1	1760.7	3.9	523.0	-39.9				570
	T-6-2	1128.7	6.1	477.0	-46.3				505
	T-6-7			1017.0	-143.0				1014
	T-6-8			787.0	338.0	-180.0			1120
WAT	T-7-1	4500.4	2.0	61.00	801.0	-185	11.50		930
	T-7-2	2641.8	4.6	770.0	-65.70				829
SDT	T-8-1			707.73	-179.22	22.50	-1.29		626
	T-8-2	1417.9	3.1	670.0	-127.0	9.68			635
DW10	T-9-1[xx]			15448265	68511637	229741.9	27506.74		372
	T-9-2	2007.3	3.4	296.0	-19.7	0.59			328
	T-9-8			726.75	-195.67	31.15	-2.23	0.06	640
CST	T-10-1	699.0	6.3	659.00	-182.00	12.90			551
	T-10-2	1481.0	3.0	127.35	-36.21	4.46	-0.18		108
TA	T-12-1[xx]	3514.9	13.7	1423.26	70.42	0.105	0.0475		1515
	T-12-2[xx]	4107.6	10.8	891.18	-7216	-0.075	0.00419		1055

1. Regression coefficients refer to the equation: $Y = ax + bx^2 + cx^3 + dx^4 + ex^5$ except for tests marked with [xx] where $Y = (ax + bx^2)/(1 + cx + dx^2)$

   Y = load (N) x = displacement (mm)

2. T-?-1 = compression test of system
   T-?-2 = tension test of system
   T-?-7 = compression test of tie alone
   T-?-8 = tension test of tie alone

3. 25 mm cavity space used.

The testing of the tie in compression on a rigid support was omitted since it only involved the compression of the wire tie itself bearing directly on the support.

4.3.3 T-3: Speed Set Anchor (SSA)

This tie was mounted on 12mm exterior grade gypsum board sheathing and the self-drilling screw was fastened such that 15 mm separated the wire tie from the screw position on the anchor. Because of the eccentricity of loading on the wire part of the tie, it was observed that as the tie was either pushed into the gypsum board in compression or pulled away in tension, a prying action existed on the screw. Additional tests presented later in the report provide a more detailed investigation of the influence of this prying action.

The tie unit itself was found to be a very compact and rigid device, which acted as a unit. Therefore, as shown in Figure 4.6, the characteristics of the tie were quite different for the rigidly supported cases versus stud supported tests.

4.3.4 T-4: The Single Leg Adjustable Tie (SLA)

From the compression and tension test curves shown in Figure 4.7, it can be observed that, although the influence of the steel stud did not affect the general behaviour characteristics of this tie, it had a pronounced effect on the stiffness of the system. This can be attributed to the flange rotation experienced by the specimen mounted on the steel stud and, for tension, by the pull-out of the screw shown in Figure 4.8.

When the tie was tested in compression on the steel stud there was bending observed in both the anchor leg and the wire pintle. The bending was

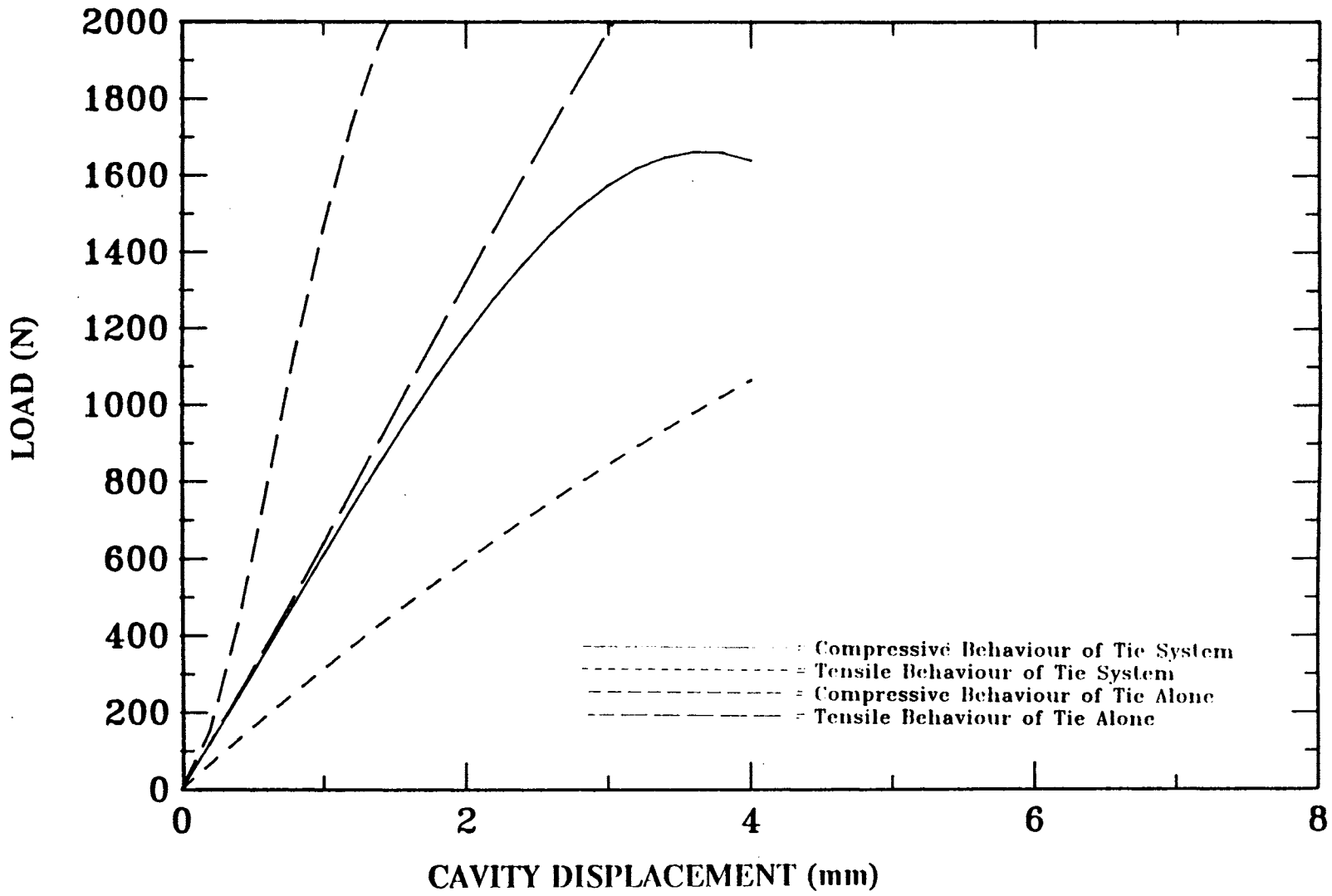
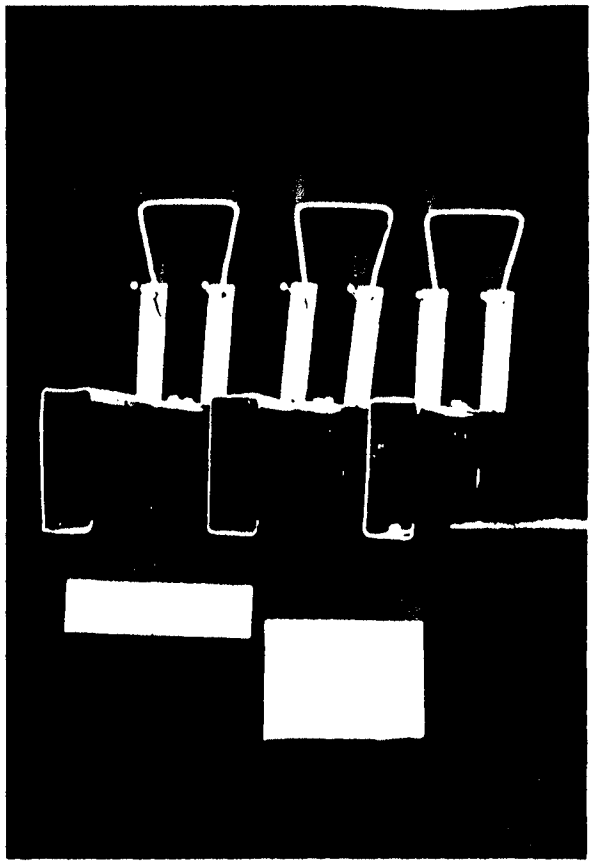


FIGURE 4.2 GENERAL BEHAVIOUR OF DOUBLE LEG ADJUSTABLE TIE

a)



b)

FIGURE 4.3 TENSION TEST OF DLA TIE

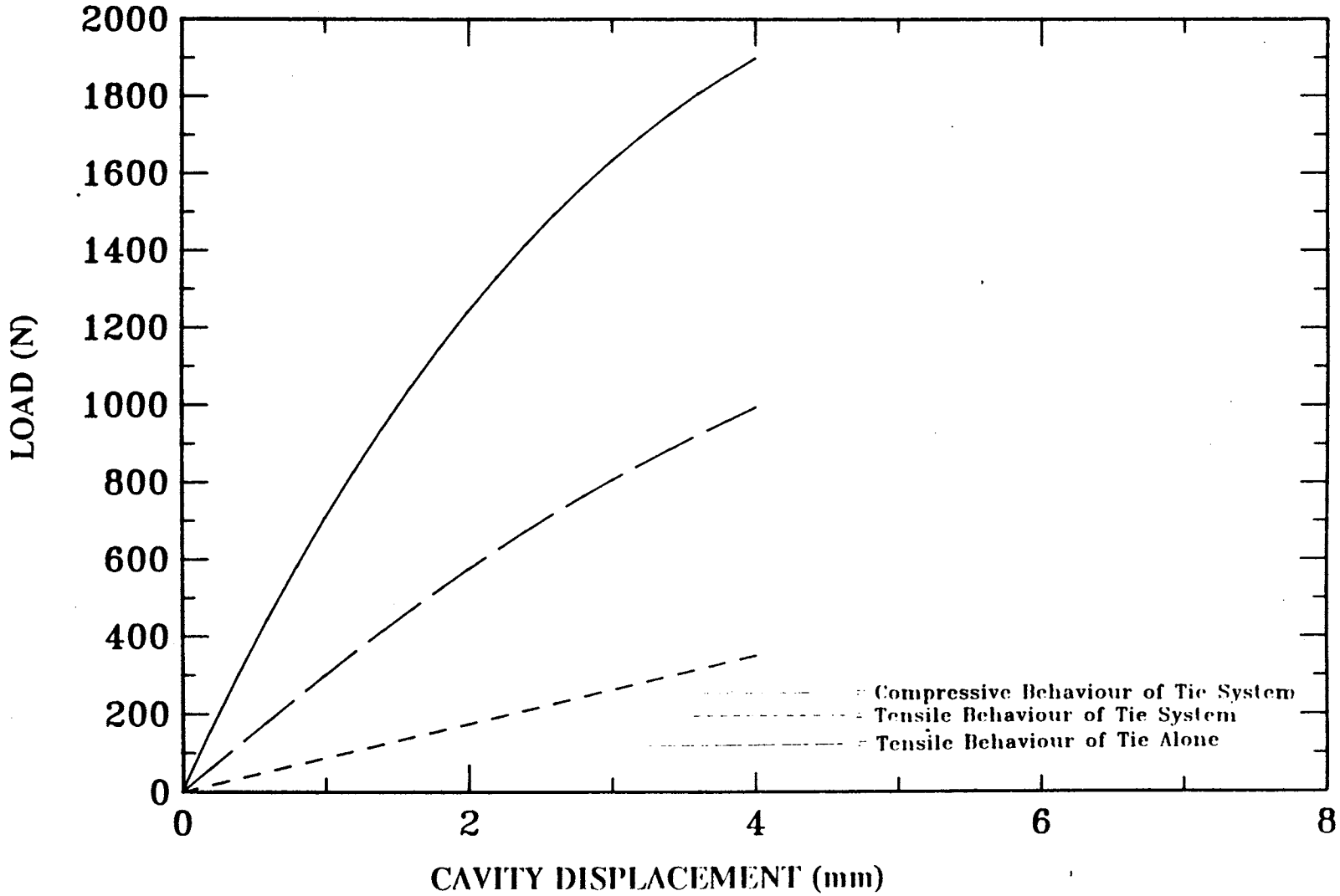


FIGURE 4.4 GENERAL BEHAVIOUR OF C TYPE ANCHOR

most prominent at the 90 degree bend in the anchor and at the clamped edge in the wire.

In the tension tests, the tie anchor and wire tended to straighten, but before the wire could slip through the hole in the anchor, the screw pulled loose. In all the tension tests screw failure prevailed. The loading on the screw was not strictly axial since the anchor tended to pry on the screw and cause a shearing force.

4.3.5 T-5: Wire Loop Adjustable Tie (WLA)

In Figure 4.9, the difference between the compression and tension tests with the tie attached to the stud (and mounted on gypsum board sheathing) and those with the tie attached to the rigid support indicated that the steel stud and sheathing strongly influenced both the failure and stiffness characteristics of the wire loop tie. This can be attributed to its one piece construction. Other ties that consist of two parts usually possess a weak link which is more flexible than the stud flange. In essence this tie merely acts as a load point on the flange of the stud. Thus it is not surprising that the two tests produced quite distinct behaviour characteristics.

4.3.6 T-6: Flange Locking Anchor Tie (FLA)

When tested in compression on both the steel stud and the rigid support, the anchor first twisted sideways and then continued to buckle at both the flange connection and along the unsupported length of the wire pintle.

In tension, the tests consistently revealed that the anchor itself yielded prior to the wire pintle. Failure was observed as a continuous opening up of the anchor at the slot accommodating attachment to the flange of the stud. For the tests

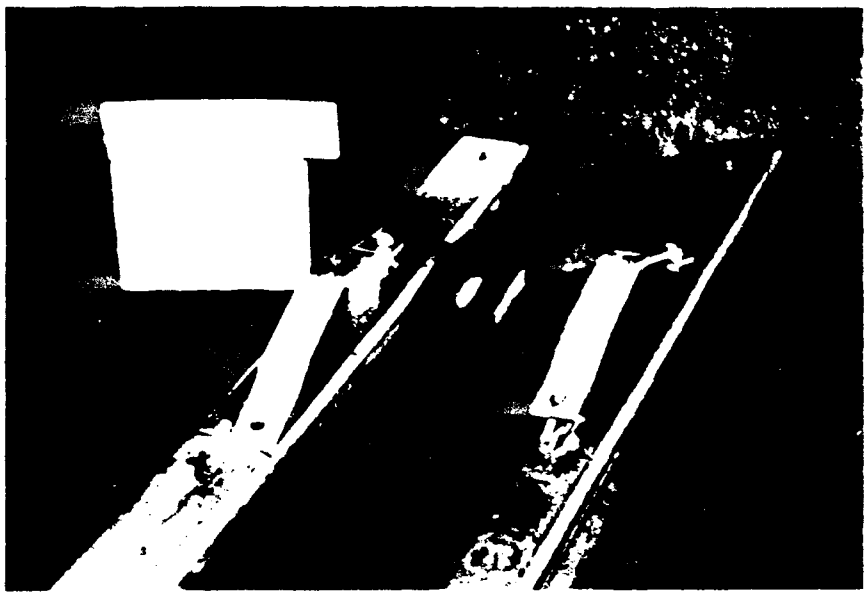


FIGURE 4.5 TENSION TEST OF CTA TIE

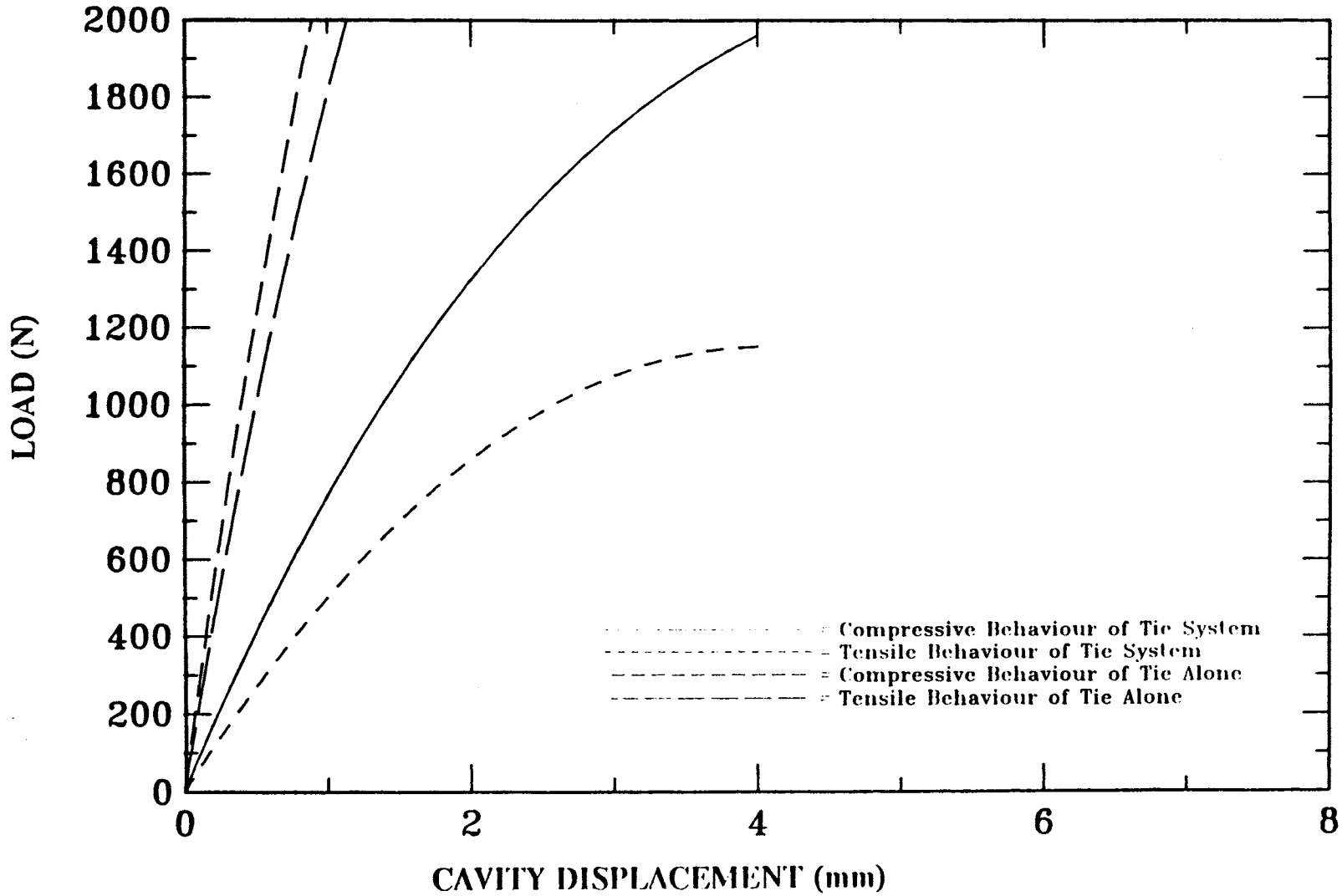


FIGURE 4.6 GENERAL BEHAVIOUR OF A SPEED SET ANCHOR

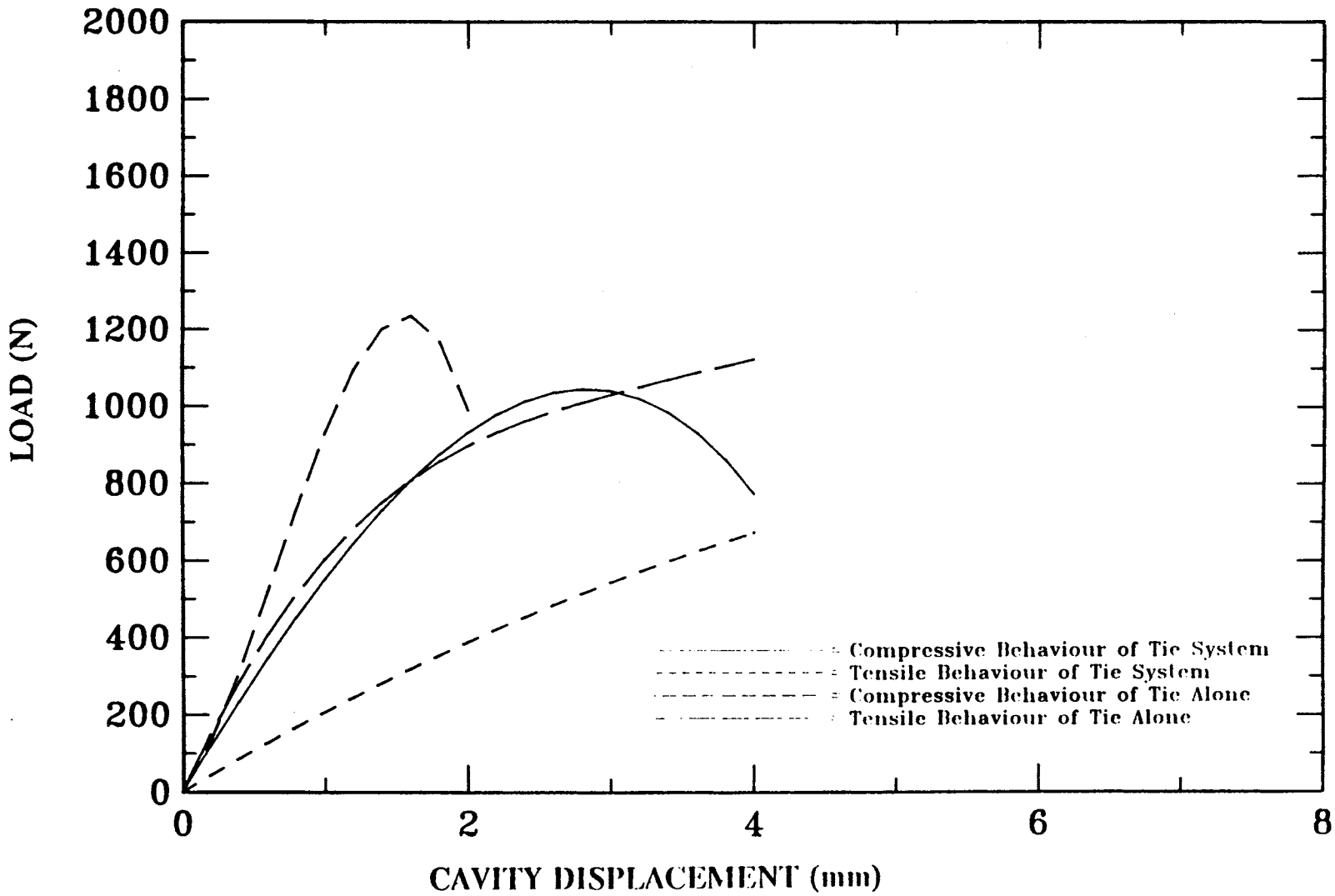


FIGURE 4.7 GENERAL BEHAVIOUR OF A SINGLE LEG ADJUSTABLE TIE

conducted on steel stud, this was accompanied by local bending and rotation of the stud's flange since the load was ultimately transferred at the outer edge of the flange itself. As can be seen in Figure 4.10, the transfer of both compressive or tensile load to the stud resulted in significant loss of strength and stiffness.

4.3.7. T-7: Wrap Around Tie (WAT)

Although the compression behaviour of this tie eventually became stiffer than for tension, initially its stiffness was greatest under tension loading. This flexibility in compression can be attributed to some initial bending in the flange of the tie itself. The flange did not perfectly fit the profile of the steel stud and when first loaded there was movement until the tie and stud flanges were in more complete contact. Ultimately, however, it was the wire tie that yielded first as shown in Figure 4.11(a).

The tension tests were carried out in the middle or neutral position of the adjustable range. Later in the report it will be shown that this location actually provides the least stiffness. As shown in Figure 4.11(b), ultimately the metal strip along the outside of the adjustable slot twisted and bent, causing a loss of stiffness in the tie system. As shown in Figure 4.12, no tests were done using rigid supports since this type of tie does wrap around the steel stud.

4.3.8 T-8: Self-Drilling Tie (SDT)

For this self-drilling tie, the compression test was terminated after significant deformation in both the steel stud and the wire tie. No noticeable deformation was observed in the tie itself.

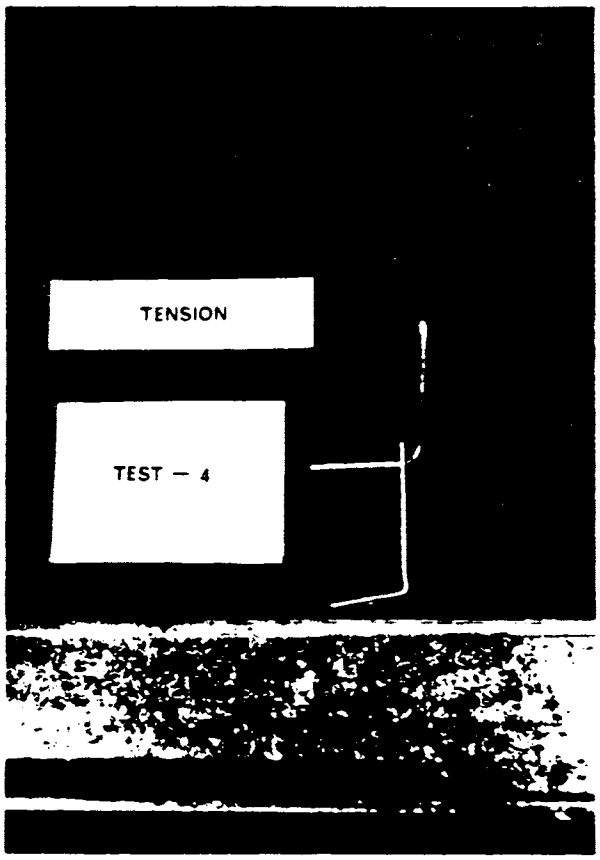


FIGURE 4.8 TENSION TEST OF SLA TIE

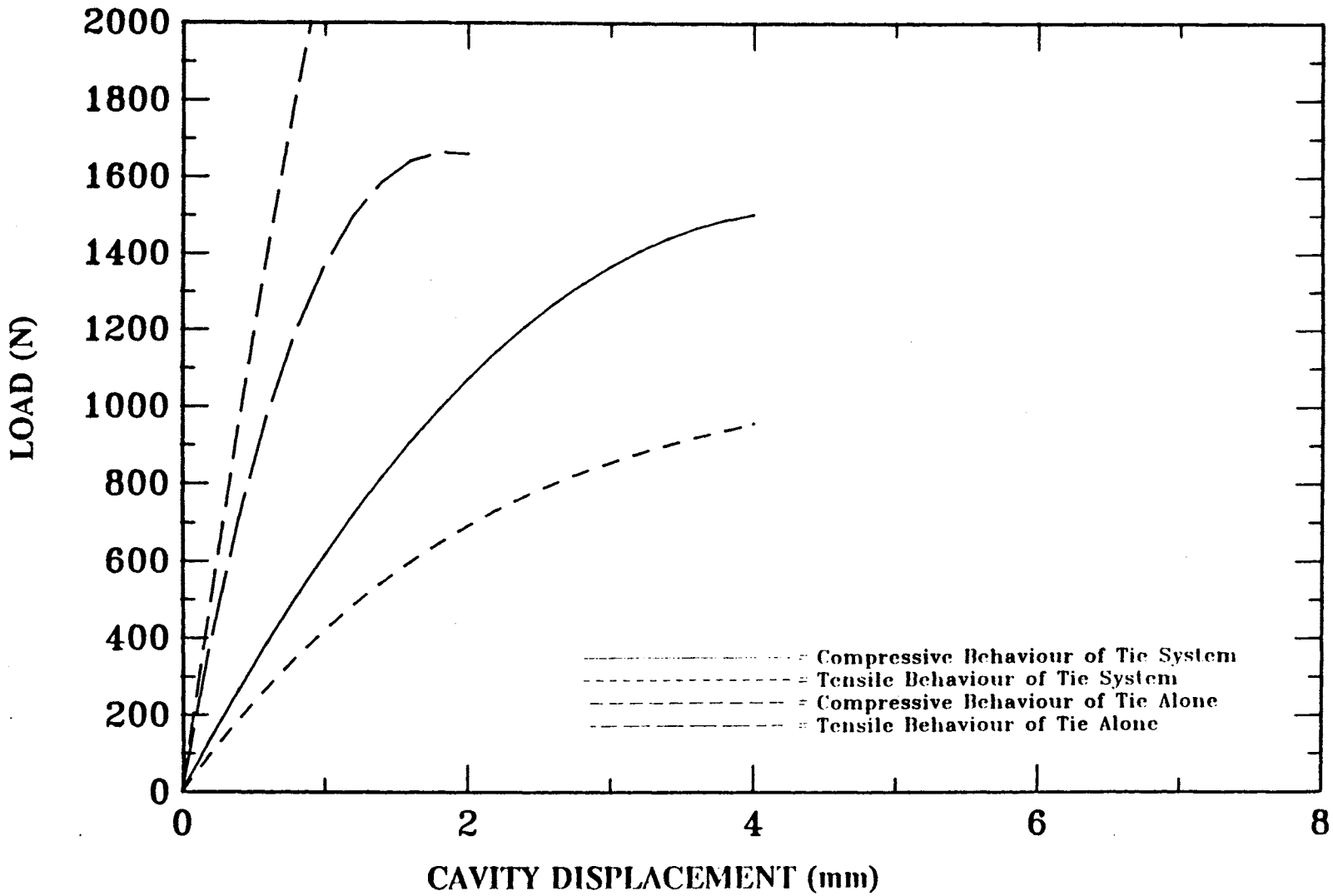


FIGURE 4.9 GENERAL BEHAVIOUR OF WIRE LOOP ADJUSTABLE TIE

When tested in tension the screw was pulled from the steel stud. In a later section of this report, the influence of securing the screw tie with a nut on the inside of the flange will be reported. As is indicated in Figure 4.13, no tests were done using rigid supports.

4.3.9 T-9: The DW-10X Tie

The DW-10X tie was mounted on 38 mm (1.5 in.) Styrofoam SM board. The compression test of the tie system revealed that the anchor yielded and deformed into the SM board. When tested in tension, again it was the tie anchor that yielded as shown in Figure 4.14. It should be noted that the tie was set in the middle of the adjustable range. Later in the report it will be shown that this tie position was neither the stiffest configuration for the tie nor the most flexible.

As shown in Figure 4.15, the tension test conducted on a non-yielding support exhibited an increased stiffness but provided very similar modes of deformations. The difference was that the effect of flange rotation was eliminated in the rigidly mounted specimens.

4.3.10 T-10: The Corrugated Strip Tie (CST)

When the corrugated strip tie was tested in tension, it pulled up straight and eventually the screw was pulled from the stud. In compression the tie buckled. These tests were completed on an unsupported tie length of 1 inch and represent a lower bound for the performance of this tie since larger cavity widths are not allowed[8]. In a later section of this report, the results from other tests incorporating some of the many variables that are consistent with use of this type of tie in the field will be presented. The load-deflection data was plotted in Figure 4.16.

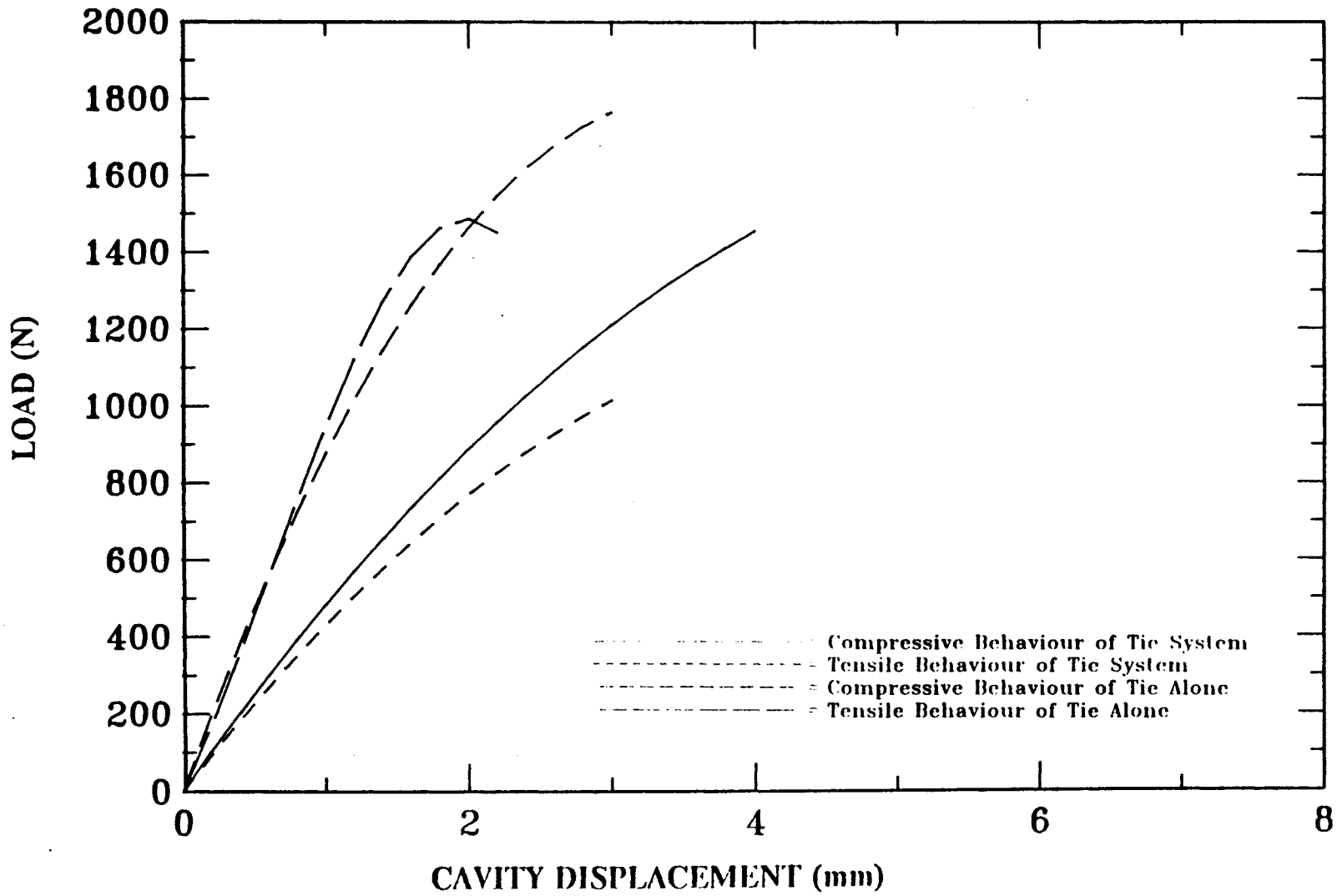
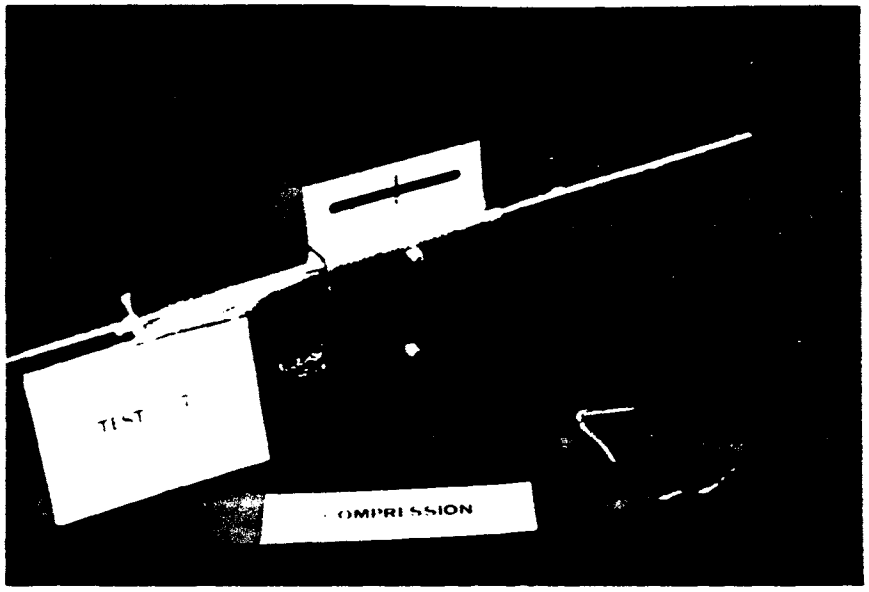
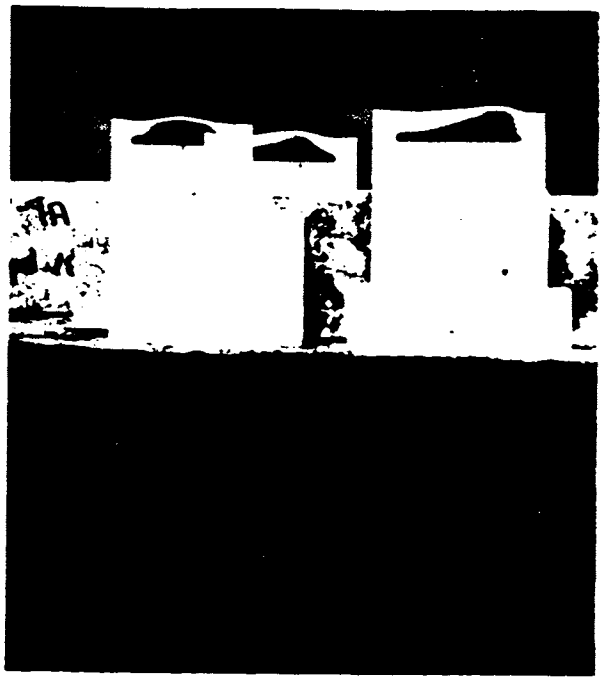


FIGURE 4.10 GENERAL BEHAVIOUR OF FLANGE LOCKING TIE



a) Compression Failure of Wire Tie



b) Tension Failure at Slot

FIGURE 4.11 FAILURE OF WAT TIES

4.3.11 T-11: The Brick Veneer Tie Support (BVTS)

Since the characteristics of the Brick Veneer Tie Support are very much influenced by the type of tie attached to it, results were not presented in this general section.

4.3.12 T-12: Thermosteel Tie (TA)

This tie was unique in that it requires a special type of steel stud for its application. This caused some difficulty when comparing this tie's performance with others.

From the graphs in Figure 4.17, it can be observed that the compression-tension behaviours are unique. The tie was stiffest when loaded in compression. When the tie was tested in compression the wire tie ultimately bent at the tie anchor connection and in tension the tie became disengaged from the thermosteel stud. It was observed that the clip, which was bent around the flange/chord of the stud to secure the tie on the stud, gradually came free from the stud under tension loading.

4.4 INFLUENCE OF LOCATION OF ATTACHMENT OF TIES

4.4.1 General

Brick veneer/steel stud wall ties installed in the field are vulnerable to variable attachment locations on the steel studs. Ideally, from an inspection point of view, it is most advantageous to have the tie mounted directly on the stud where its location can be inspected. Unfortunately this is impractical for some tie types owing to the extent of puncturing of the sheathing and inherent damage to the air

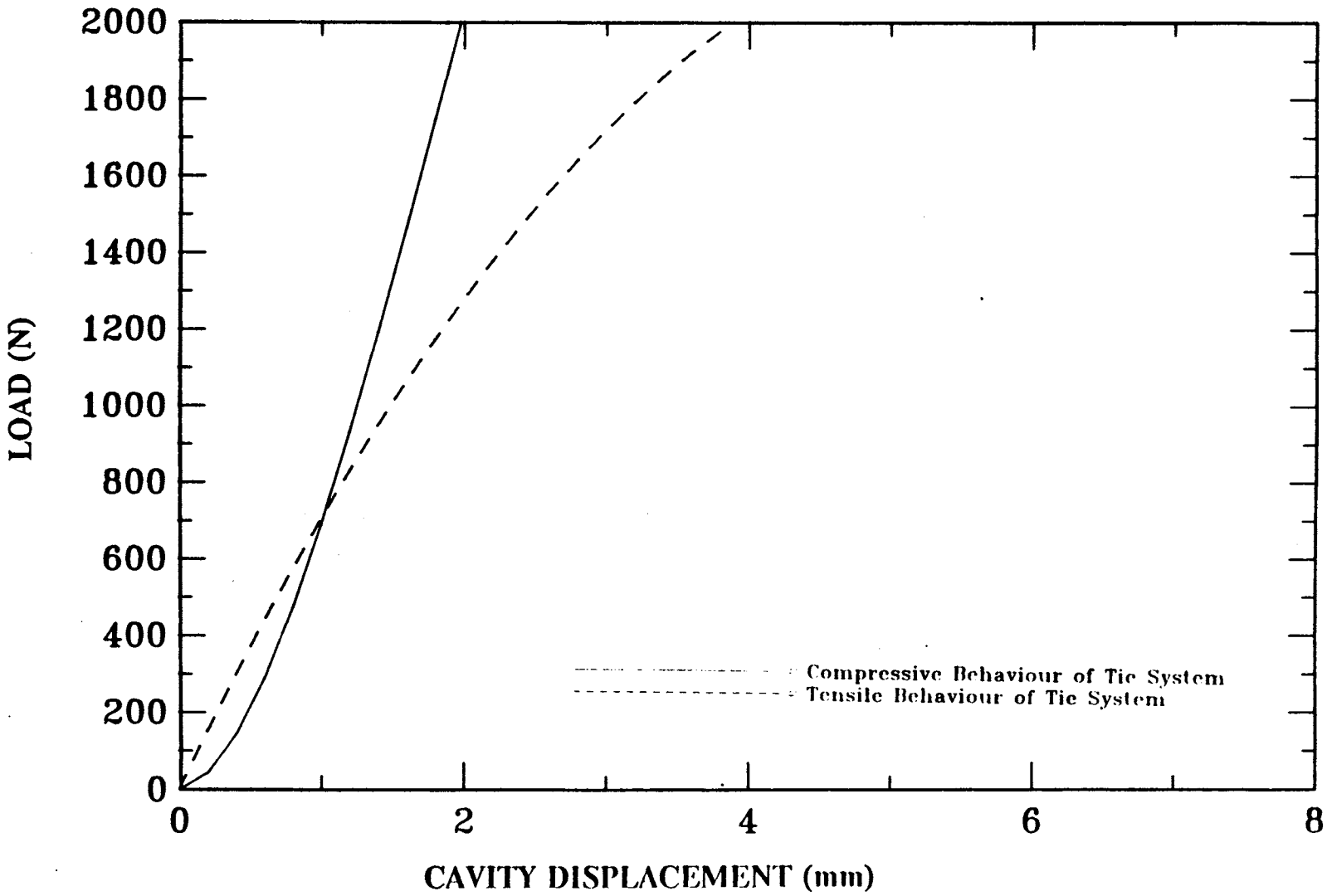


FIGURE 4.12 GENERAL BEHAVIOUR OF WRAP AROUND ANCHOR

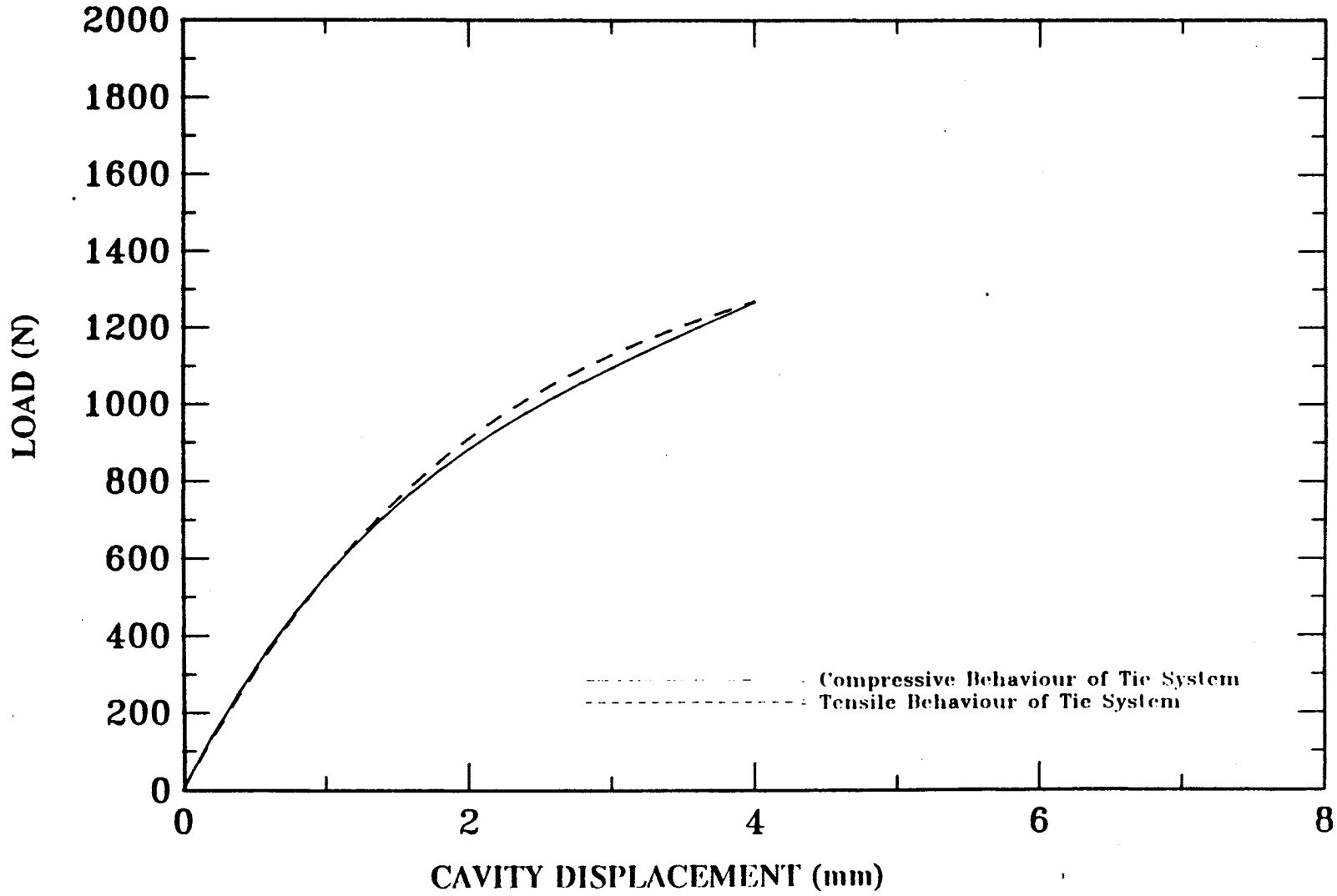


FIGURE 4.13 GENERAL BEHAVIOUR OF SELF-DRILLING TIE

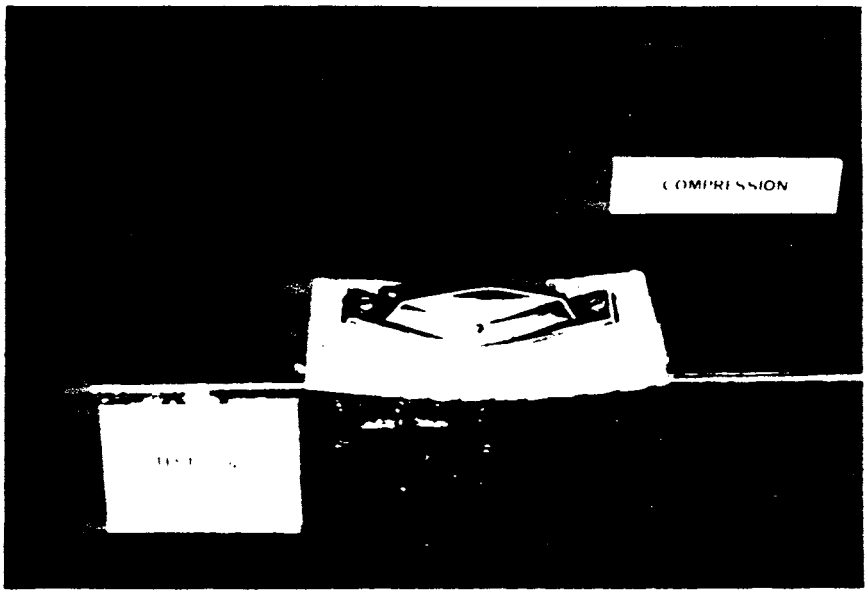


FIGURE 4.14 COMPRESSION TEST OF DW-10 TIE

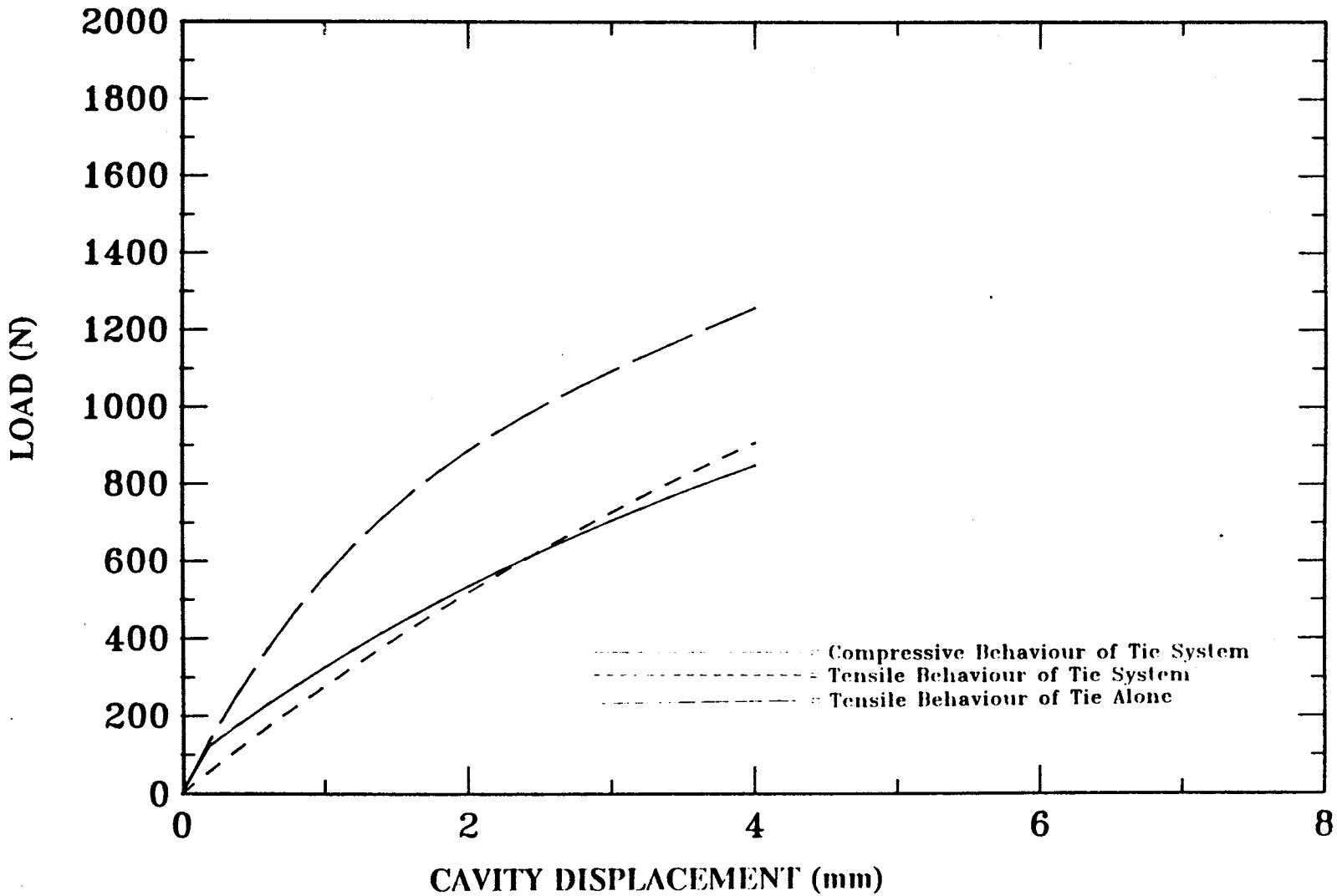


FIGURE 4.15 GENERAL BEHAVIOUR OF DW-10X ANCHOR

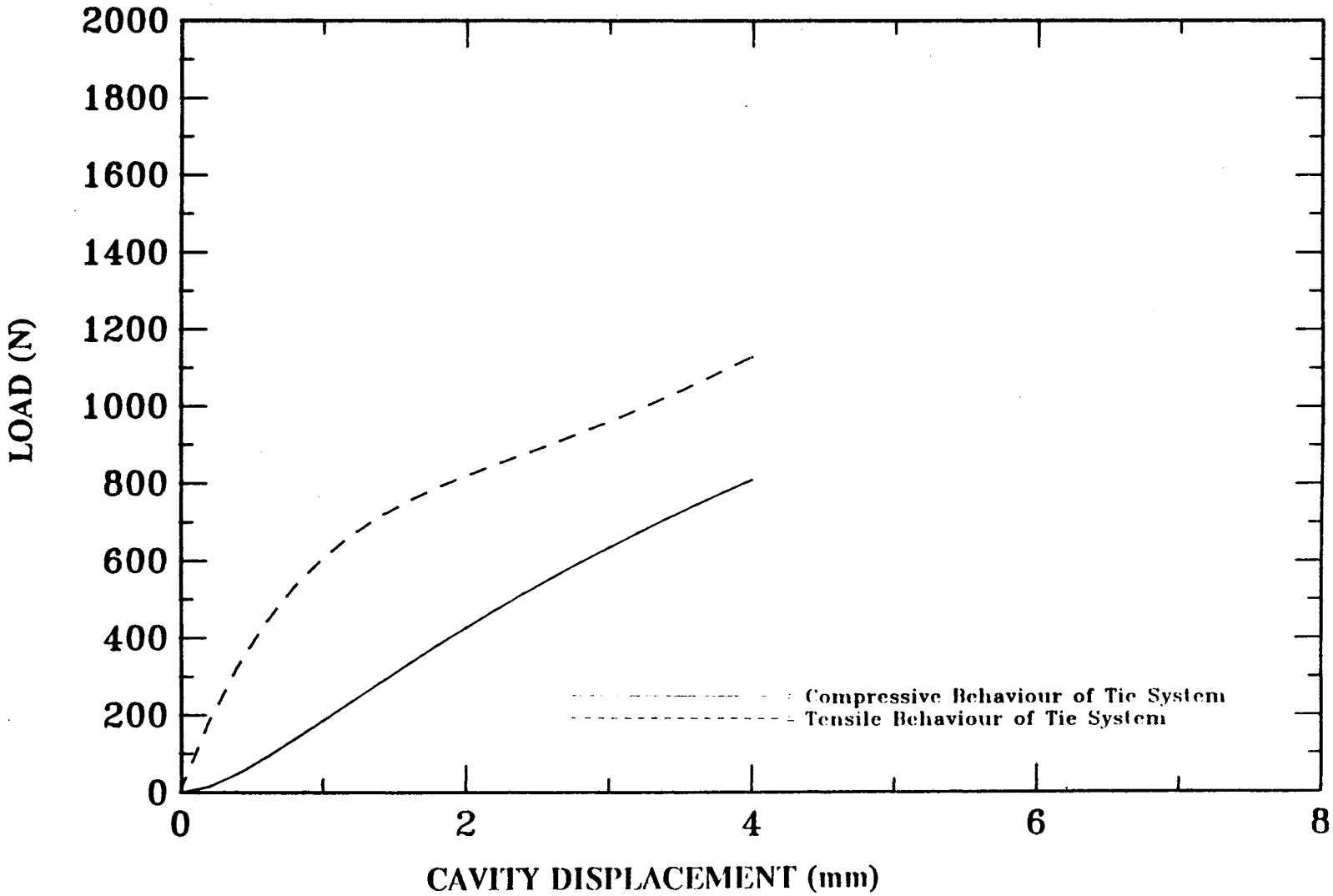


FIGURE 4.16 GENERAL BEHAVIOUR OF CORRUGATED STRIP TIE

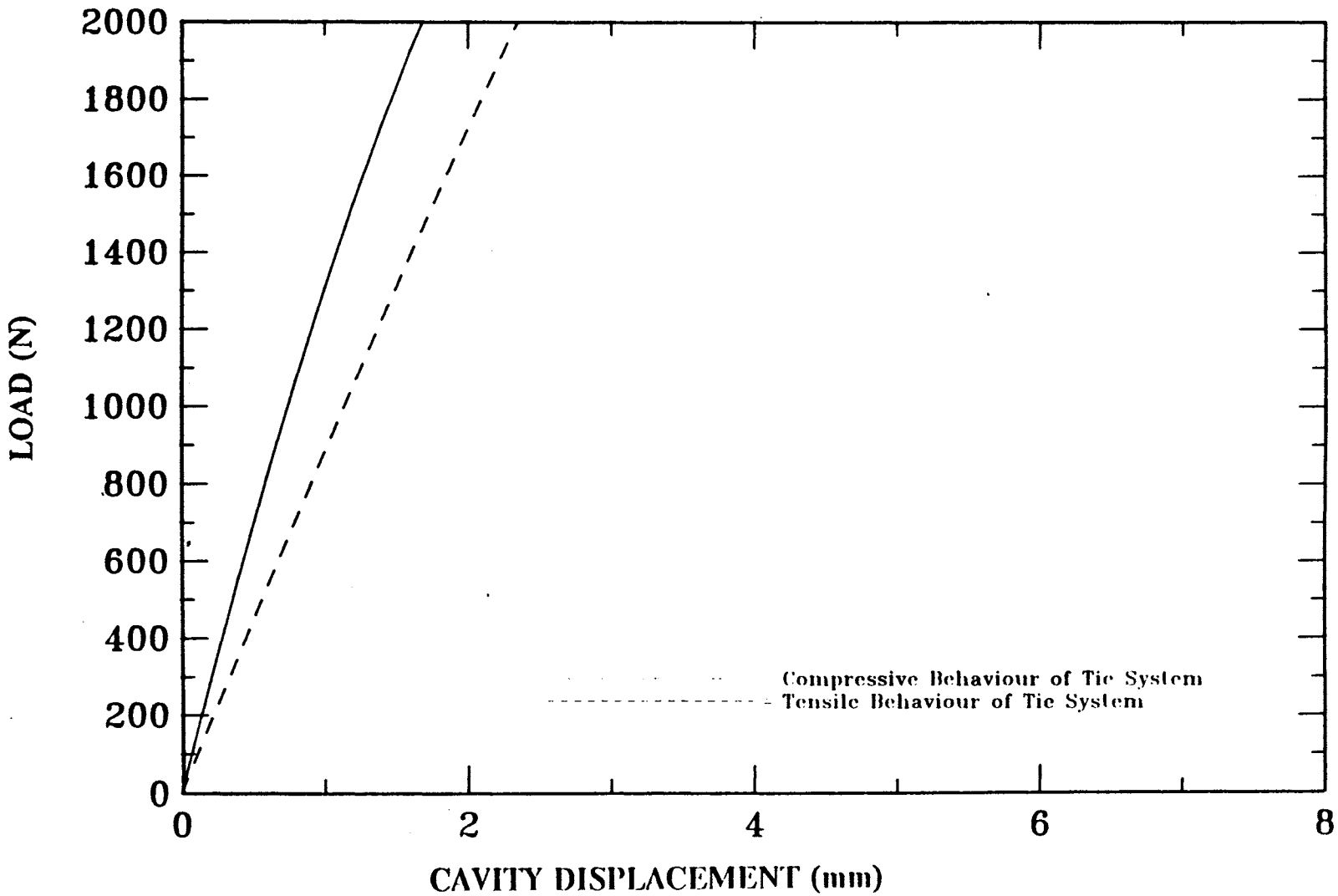


FIGURE 4.17 GENERAL BEHAVIOUR OF THERMOSTEEL TIE

and vapour barrier designs which would be necessary. Thus many ties are fastened directly on the sheathing. Such ties make it very difficult to either determine or control just where on the flange of the stud they are fastened. For this reason, the test program included an investigation on the influence of attachment location on tie performance. A summary of the results for this influence were listed in Table 4.4. These test series were limited to tension tests and basically provided stiffness information for ties tested on 20 gauge steel studs fastened at three locations on the flange. The additional tests for this comparison correspond to test series T-?-3 of the test program.

The following sub-sections include figures illustrating the mean test results over the performance range of the recorded behaviours.

4.4.2 Discussion of Findings

The three ties used to investigate the influence of attachment location included: T-1, the double leg adjustable tie (DLA), T-2, the 'C' type tie (CTA), and T-8, the self-drilling tie (SDT). The figures provided for comparison purposes were limited to the standard performance domain of 4 mm to avoid confusion or misinterpretations which could result from observing the full range of deformations provided in Appendix A.

When the DLA and SDT were tested at the three locations of 10, 15 and 20 mm from the web, considerable differences in stiffness were observed. However when the CTA was tested it was not initially obvious why very little influence was observed. These effects can be seen in Figure 4.18, 4.19 and 4.20.

An explanation is that the SDT and the DLA were comparatively stiff and thus the rotation of the flange of the stud significantly contributed to the

displacement. This can be seen for the DLA in the photograph in Figure 4.3. Thus flange rotation displacement and correspondingly the cavity displacement increased with increased attachment distance from the web. Conversely with the CTA, the tie itself was more flexible than the flange and in fact, it tended to brace the flange of the stud. Hence, the greatest portion of the cavity displacement was from tie deformation which was relatively independent of attachment location.

4.5 INFLUENCE OF RANGE OF ADJUSTMENT ON TIE PERFORMANCE

To accommodate field installation tolerances, most brick veneer steel stud wall ties provide for some degree of adjustment. In this report, the adjustable ranges over which the ties were intended to function in a satisfactory fashion were measured and reported in Table 4.1. A separate test series summarized in Table 4.5 was dedicated to studying the influence of the adjustable ranges on the performance of various ties. Figure 4.21 was drawn to illustrate the adjustable range for each of the included ties.

This portion of the test program investigated the changes in tie strength and changes in stiffness within the performance domain at different degrees of adjustment. All ties were tested at the lower, upper and intermediate levels of their adjustable ranges. The tests were carried out in tension on 20 gauge steel studs with the tie fastened to the flange of the stud 15 mm from the web. Once again the load-displacement curves were limited to the performance domain of 4 mm of cavity displacement. These tests correspond to test series T-?-4 of the test program.

TABLE 4.4 SUMMARY OF TEST RESULTS FOR INFLUENCE OF LOCATION OF THE TIE ATTACHMENT ON STEEL STUDS.

TIE	TEST[2]	ULT. LOAD (N)	COV. (%)	REGRESSION COEFFICIENTS[1] a	b	c	d	e	LOAD @ 1.2 mm (N)
DLA	T-1-3A	1723.1	9.6	476.0	33.7				523
	T-1-2	1708.9	10.9	382.0	-15.5				436
	T-1-3B	1620.5	2.4	201.6	-3.4	-0.2			236
CTA	T-2-3A	2125.5	4.7	91.3	-2.12	0.01			107
	T-2-2	2190.6	1.8	86.8	0.31	-0.03			104
	T-2-3B	2155.3	2.6	92.4	-0.69				110
SDT	T-8-3A	1559.7	2.8	1442.0	-552.0	83.20			1055
	T-8-2	1417.9	3.1	670.0	-127.0	9.68			635
	T-8-3B	1373.8	3.9	382.0	-42.3	1.75			400

1. Regression coefficients refer to the equation: $Y = ax + bx^2 + cx^3 + dx^4 + ex^5$ except for tests marked with * where $Y = (ax + bx^2)/(1 + cx + dx^2)$

Y = load (N) x = displacement (mm)

2. Distance of attachment from outside face of web of stud.

3A - 10 mm
2 - 15 mm
3B - 20 mm

4.5.1 T-1: Double Leg Adjustable Tie (DLA)

This tie can be adjusted in the field by sliding the double leg pintle up and down through slotted holes in the anchor legs. The upper bound on the adjustable range was set at 35 mm. For this tie, the lower bound occurred when the bent part of the wire pintle and the legs of tie anchor were positioned tight together.

Larger adjustments translated into increased moment arm on the wire pintle, as illustrated in Figure 4.21. This increased bending caused the wire pintle to yield earlier and as shown in Figure 4.22, test results showed that as the adjustment was increased the system became more flexible and the capacity at 4 mm displacement and at failure decreased.

4.5.2 T-2: C Type Tie (CTA)

The adjustment of the 'C' tie lies in the ability of the triangular wire tie to move between the anchor and the stud or sheathing. For this tie, tests were performed at the middle, quarter and end points of the adjustable range. The response shown in Figure 4.23 for these loading positions provided some interesting observations. When the tie was tested in the middle position, the anchor yielded and bent upwards and, after considerable displacement, pulled the screw free in a shearing manner. This was shown in Figure 4.4. When the test was conducted at the quarter point the displacements decreased and the screw was pulled out in more of a direct tension fashion. However, when the tie was tested at the end point, the combination of localized axial pull and shear force on the screw provided the system with a greater stiffness and increased the overall capacity of the tie system.

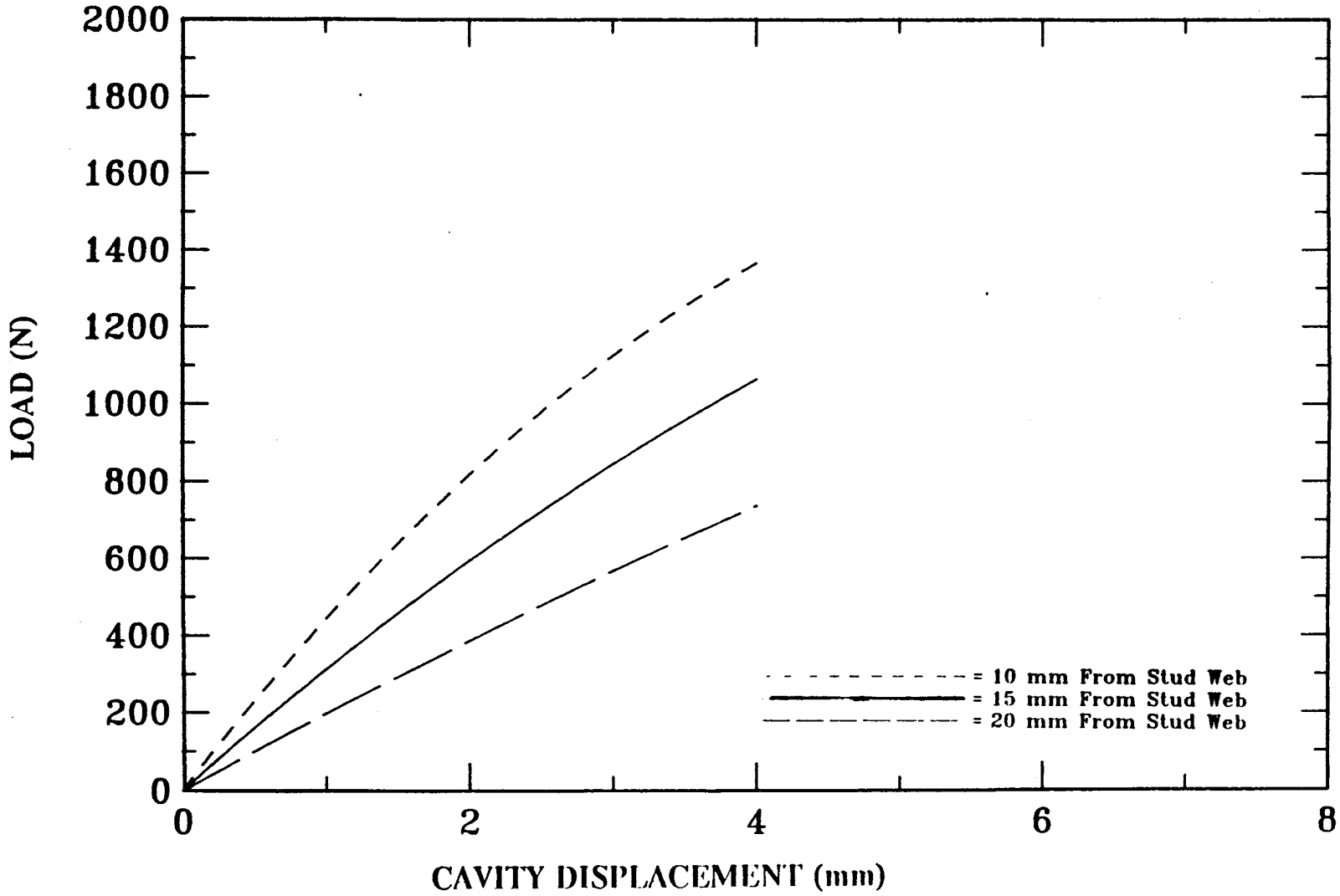


FIGURE 4.18 INFLUENCE OF ATTACHMENT LOCATION OF DLA ON STEEL STUD

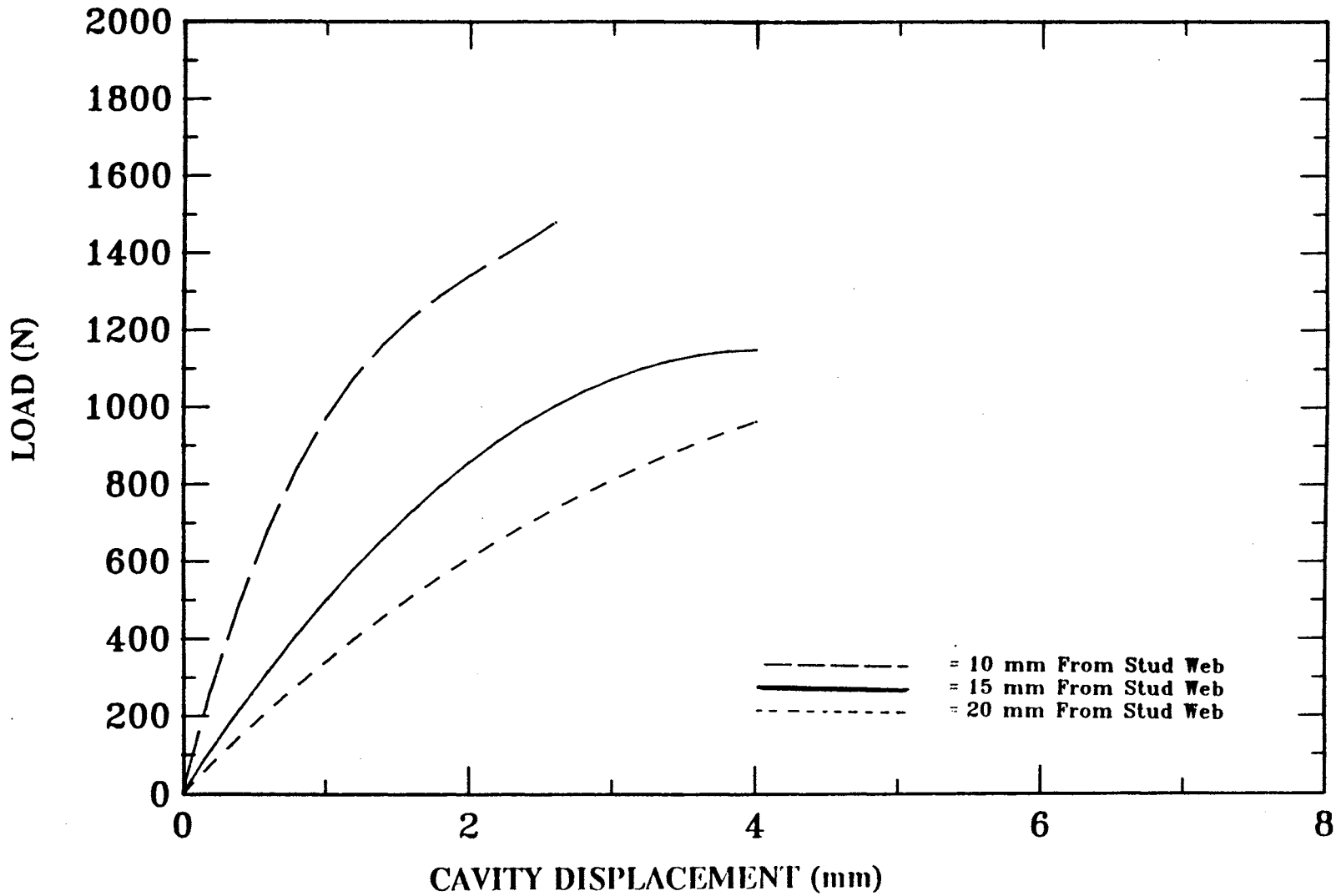


FIGURE 4.19 INFLUENCE OF ATTACHMENT LOCATION OF SDT ON STEEL STUD

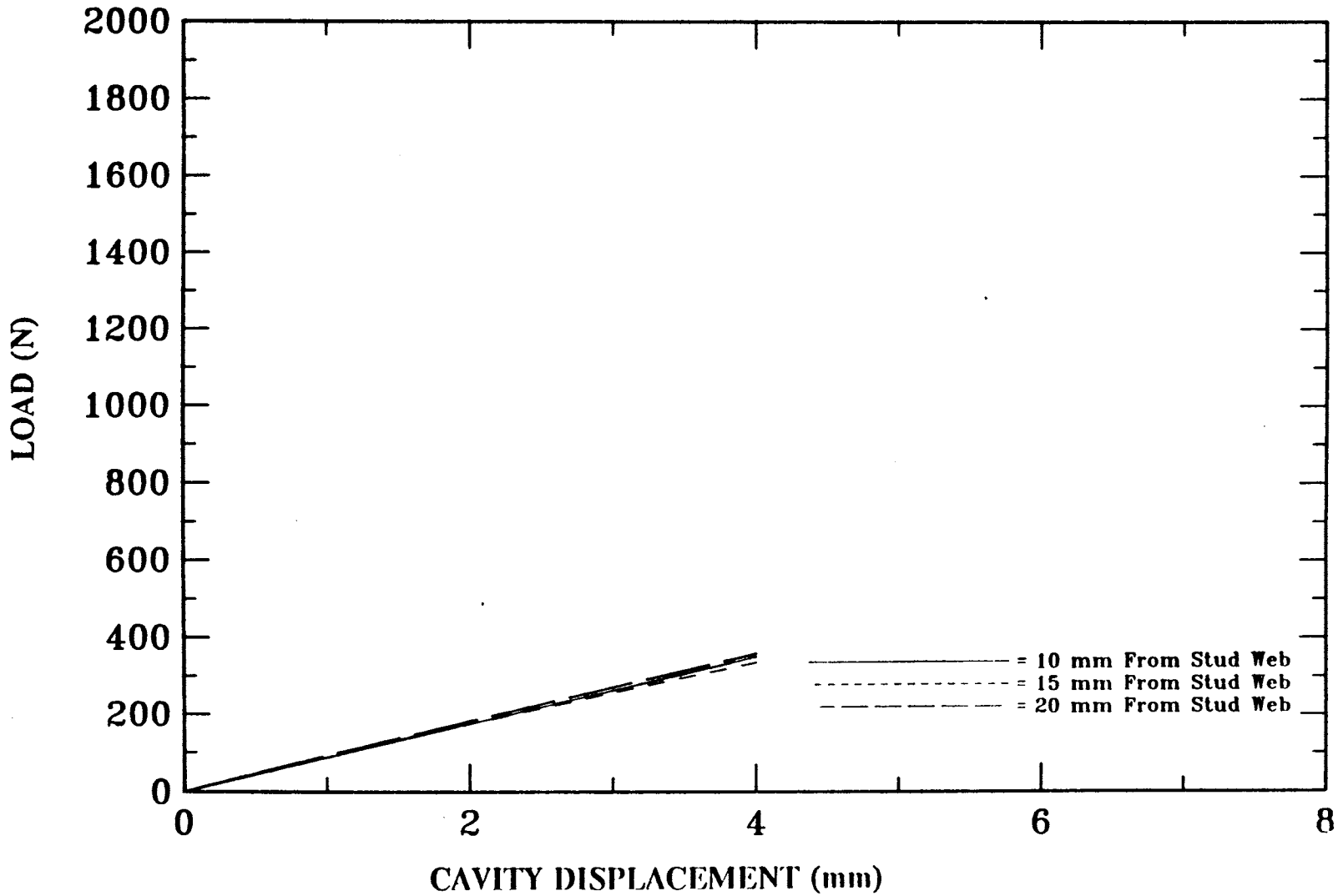


FIGURE 4.20 INFLUENCE OF ATTACHMENT LOCATION OF CTA ON STEEL STUD

4.5.3 T-3: Speed Set Anchor (SSA)

The adjustment of the speed set anchor relied on the anchor itself moving under the fastening screw already attached to the stud and sheathing. For these tests, 12 mm gypsum board was employed as the sheathing. The lower bound of the adjustment range was identified when the fastening screw was 10 mm from the wire tie. The upper bound was at 25 mm.

The test results, shown in Figure 4.24, indicated that the lower bound provided the most flexibility. It was observed that this position most nearly induced direct axial load on the screw which in turn resulted in large displacements. The greatest stiffness was achieved when the screw was located in the middle of the adjustment range. Similar to the CTA, the interaction of axial and shearing load produced the stiffest tie system. For the upper bound of the adjustment range, it was observed that the anchor first pried then pulled the screw free. This action was illustrated in the photograph in Figure 4.25.

4.5.4 T-5: The Wire Loop Adjustable Tie (WLA)

In a similar fashion to the SSA, adjustment of the WLA relied on the movement of the anchor after it was initially fastened to the stud and sheathing. The wire tie was mounted on 12 mm gypsum board for these tests. The lower bound adjustment was set at 10 mm from the wire leg to the centre of the fastening screw head. The upper bound of the adjustment range, at the farthest possible location from the wire leg, was found to be 30 mm.

From Figure 4.26 it can be seen that the behaviour at the lower bound was considerably stiffer than at the upper bound of the adjustment range. In the test at the upper bound, the eccentric loading caused bending of the wire as shown

TABLE 4.5 SUMMARY OF TEST RESULTS FOR INFLUENCE OF RANGE OF ADJUSTABILITY OF TIES ON STEEL STUDS.

TIE	TEST*	ULT. LOAD (N)	COV. (%)	REGRESSION COEFFICIENTS+ a	b	c	d	LOAD @ 1.2 mm (N)
WAT	T-7-2[1]	2641.8	4.6	770.00	-65.70			829
	T-7-4[2]	2713.4	3.4	1016.00	-110.00			1061
	T-7-4[3]	3450.6	2.4	1207.00	-121.00	1.83		1277
CTA	T-2-2[1]	2139.2	1.8	86.80	0.31	-0.03		105
	T-2-4[2]	1353.4	3.7	202.00	-12.80	0.29		225
	T-2-4[3]	1742.1	5.2	399.50	45.00	0.95	0.0038	254
DW10	T-9-2[1]	2007.9	3.4	296.00	-19.70	0.59		328
	T-9-4[2]	1966.1	5.3	234.00	-11.50	0.21		265
	T-9-4[3]**	2366.0	7.8	987.00	115.60	0.82	0.0177	672
DLA	T-1-2[4]	1708.9	10.9	382.00	-15.50			436
	T-1-4[5]	1139.8	10.4	208.00	-9.20			236
	T-1-4[6]	572.0	2.5	67.80	-2.08			78
FLA	T-6-2[4]	1128.7	6.1	477.00	-46.30			506
	T-6-4[5]			193.00	-18.40	0.58		206
	T-6-4[6]			40.11	5.90	-2.22	0.16	53
SSA	T-3-2[5]	1167.5	3.6	570.01	-70.60			582
	T-3-4[7]	1115.4	5.2	455.00	-50.10			474
	T-3-4[8]	1000.4	4.1	303.00	-22.60			331
WLA	T-5-2[5]	1287.5	4.6	508.82	-96.19	7.16		484
	T-5-4[7]	1204.5	4.5	530.00	-104.00	7.69		500
	T-5-4[9]	1101.2	6.4	324.68	-90.04	14.64	-1.15	283

Regression coefficients refer to the equation: $Y = ax + bx^2 + cx^3 + dx^4$

except for tests marked with ** where $Y = (ax + bx^2)/(1 + cx + dx^2)$

Y = load (N) x = displacement (mm)

* Footnotes refer to adjustment location where: 1 = middle, 2 = quarter point, 3 = end location, 4 = minimum, 5 = 15 mm, 6 = 35 mm, 7 = 25 mm, 8 = 10 mm, 9 = 30 mm, and 10 = 20 mm.

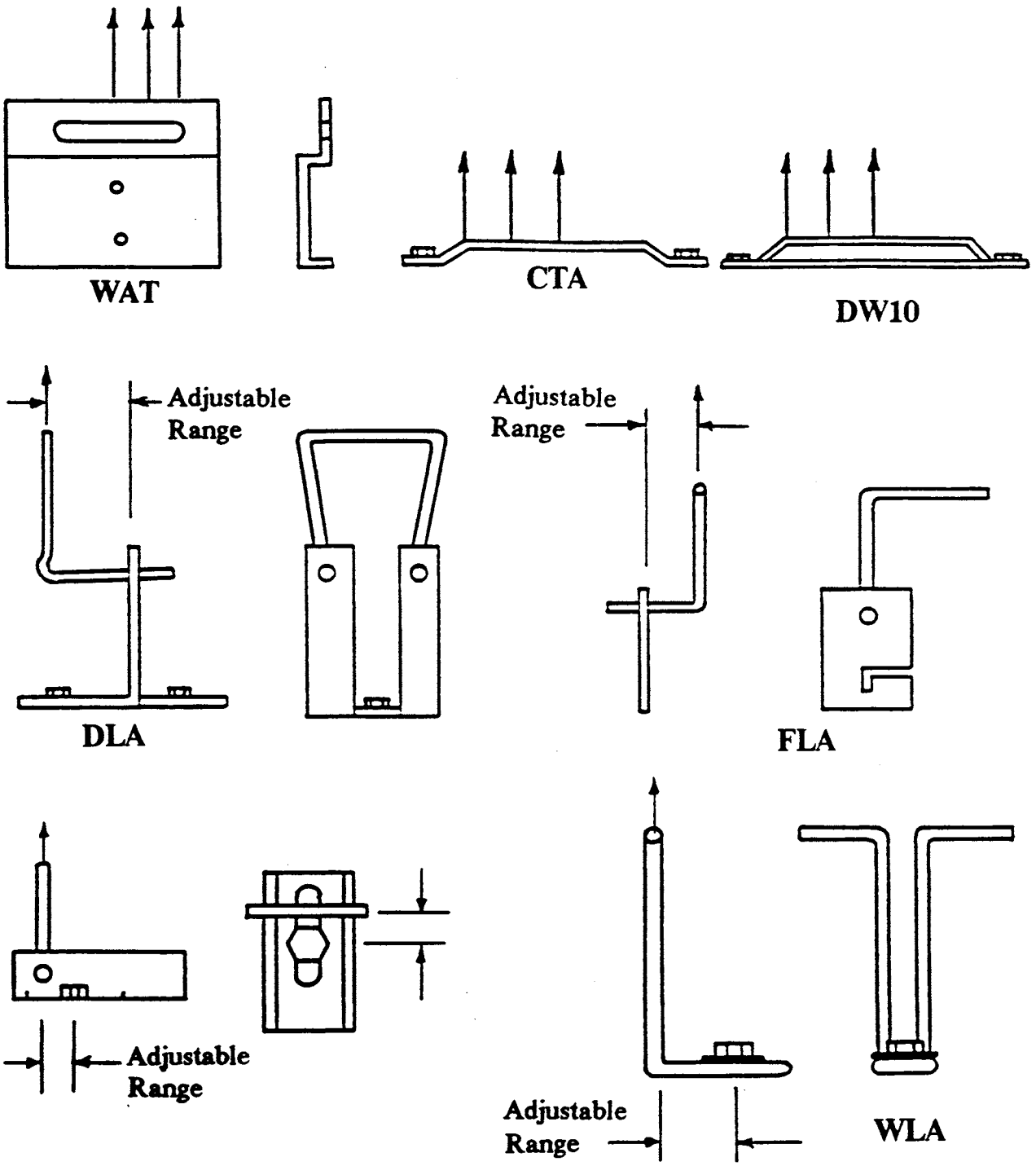


FIGURE 4.21 TEST CONFIGURATIONS FOR ADJUSTABLE RANGE

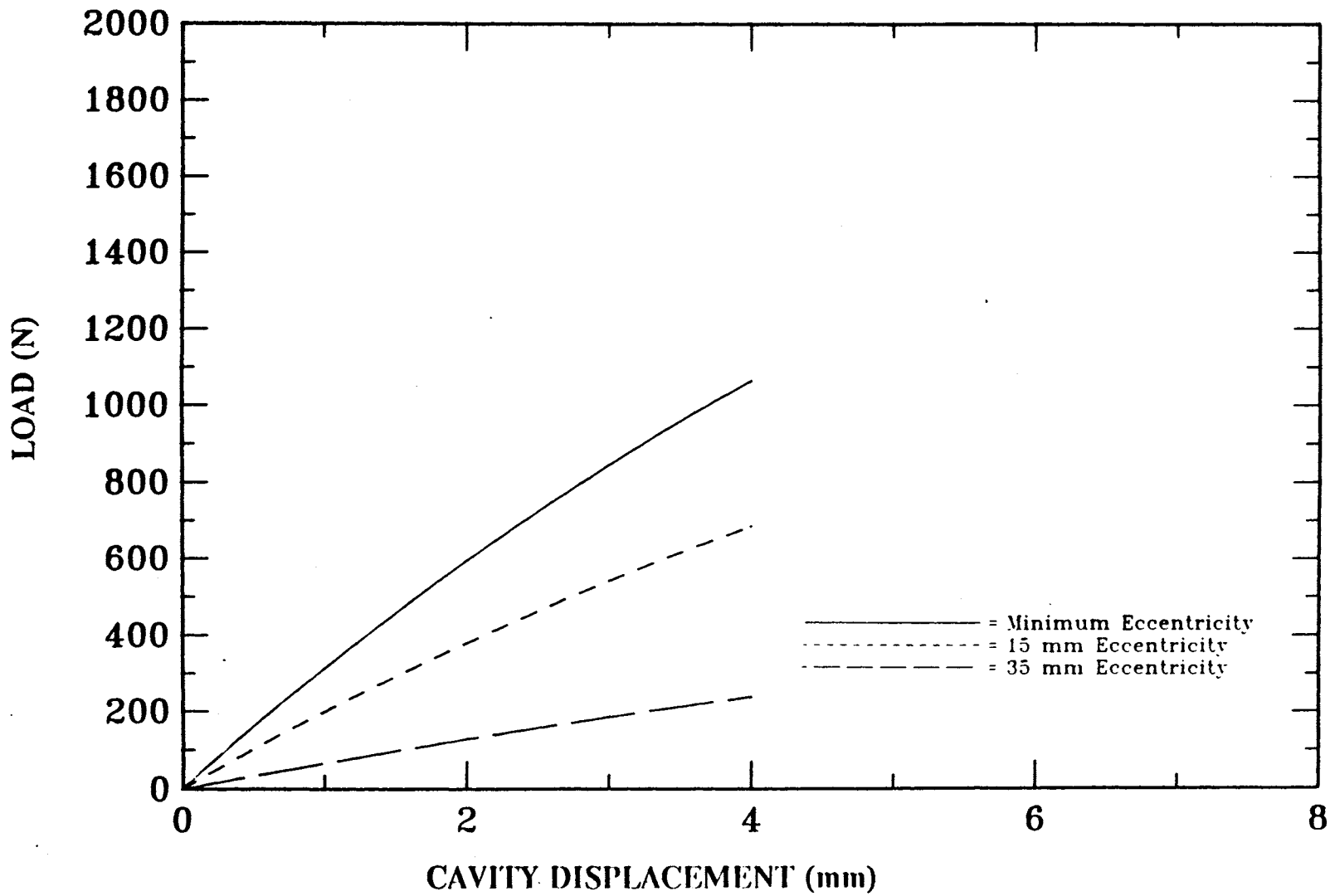


FIGURE 4.22 INFLUENCE OF ADJUSTABLE RANGE ON PERFORMANCE OF DLA TIE

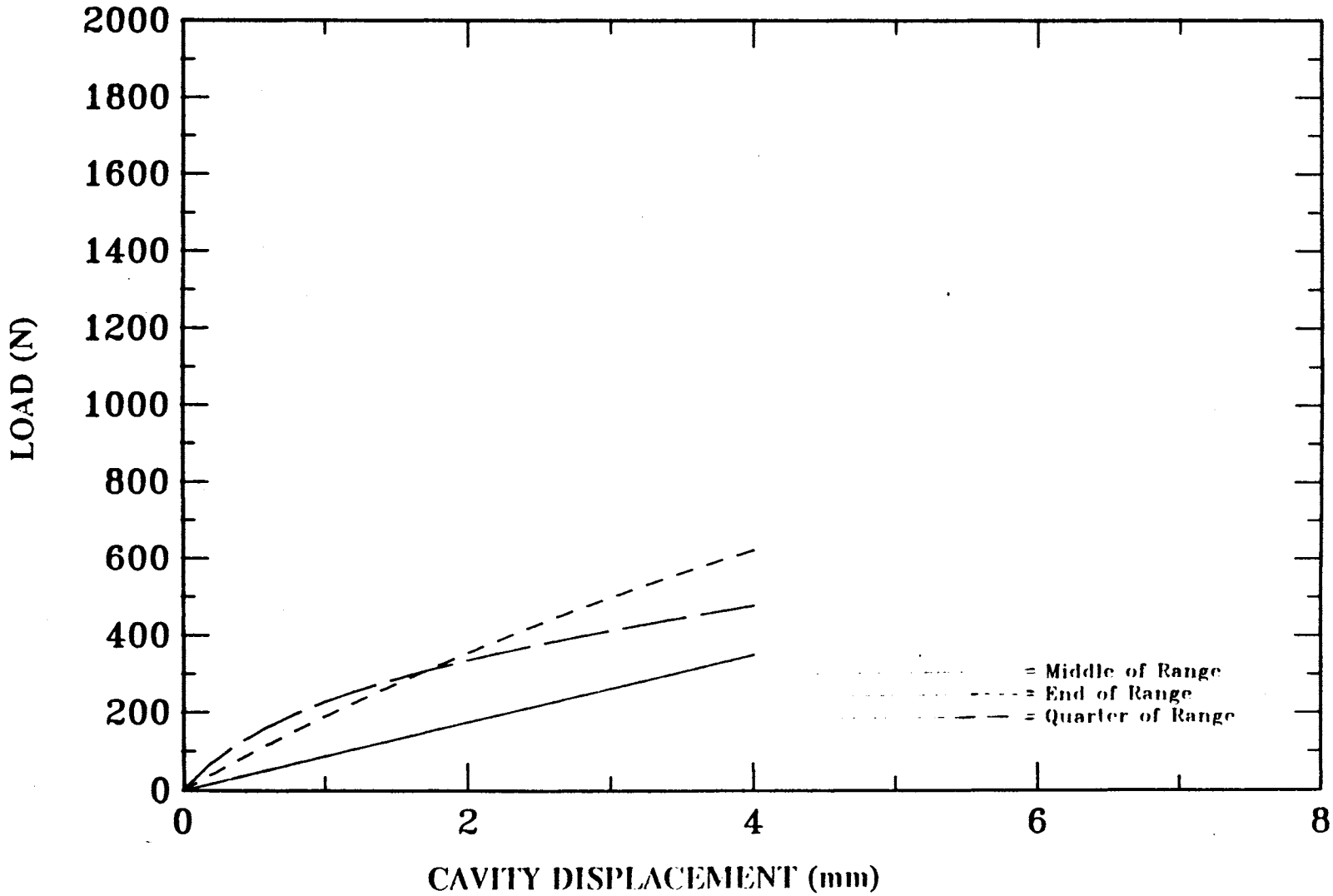


FIGURE 4.23 INFLUENCE OF ADJUSTABLE RANGE ON PERFORMANCE OF CTA TIE

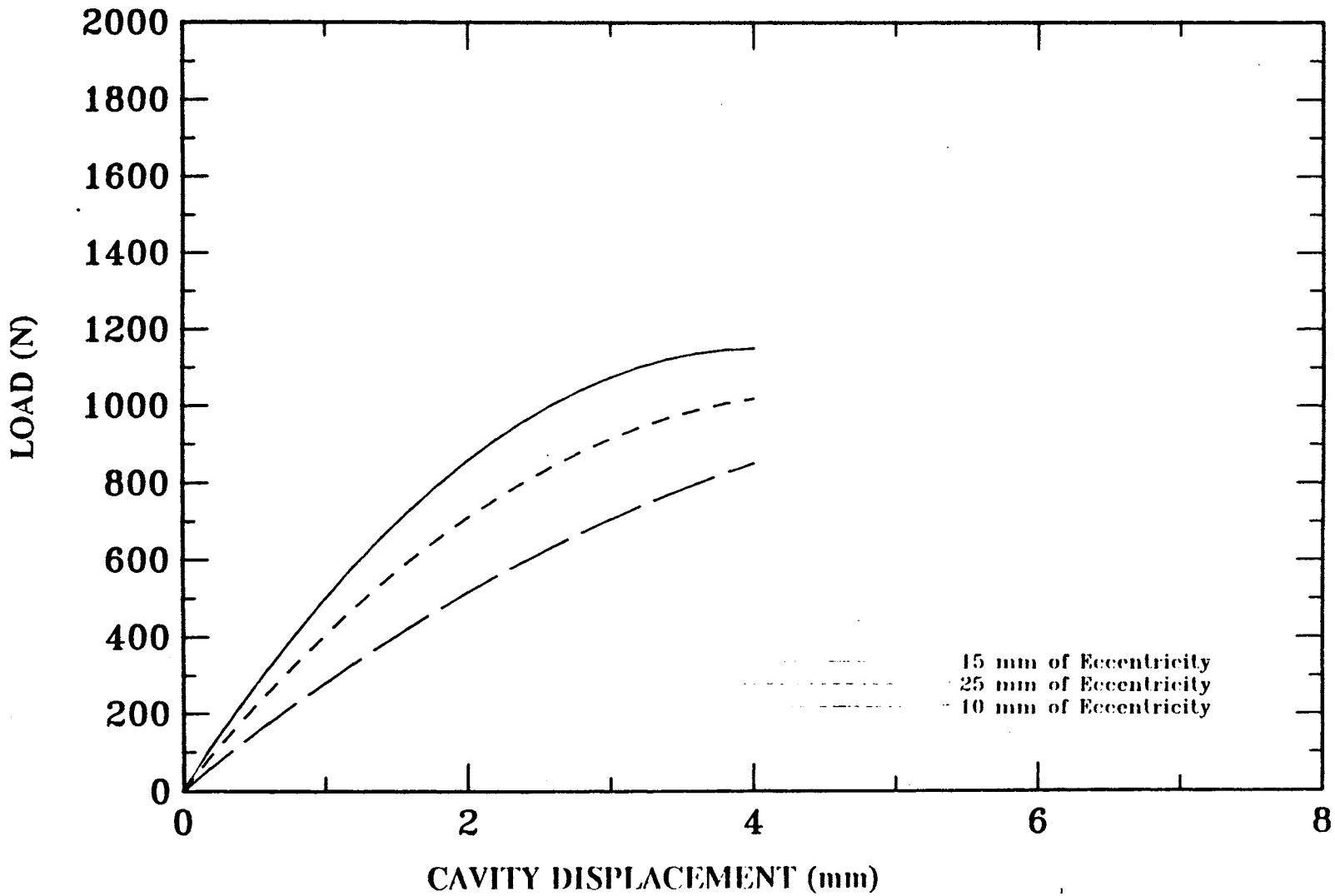


FIGURE 4.24 INFLUENCE OF ADJUSTABLE RANGE ON PERFORMANCE OF SSA TIE

in the photograph in Figure 4.27 and enough prying action on the screw to induce a loss of system stiffness and reduce the tie's ultimate capacity. To further investigate this behaviour, an intermediate position in the range was investigated without applying the gypsum board. The results of the test were practically identical to the test at the lower range of adjustment with gypsum board, indicating that the gypsum board reduced the system stiffness.

4.5.5 T-6: Flange Locking Tie (FLA)

The adjustment in the FLA was very similar to that provided in the DLA where the wire pintle was free to slide through the anchor and accommodate differences between the anchor line and the brick coursing. The resulting eccentric loading caused bending of the wire pintle which, as was shown in Figure 4.28, resulted in decreased strength and stiffness with increased adjustment (eccentricity). The lower bound of the adjustment range with close contact between the anchor and the bend in the wire pintle corresponded to a minimum eccentricity of 5 mm. At the upper bound of the range, the anchor contacted the vertical pintle at a distance of 35 mm from the horizontal leg of the wire tie.

4.5.6 T-7: Wrap Around Tie (WAT)

The WAT allowed the triangular wire tie to move through a vertical slot that extended into the cavity. The adjustable range of this tie was tested at the middle, quarter and end points of this slot, as shown in Figure 4.21.

The test results illustrated in Figure 4.29 showed that when positioned at the end of the slot, the tie possessed the greatest stiffness. It was most flexible when positioned at the middle of the slot. As was shown in Figure 4.11(b), at this

position, the steel strip along the slot twisted and buckled sideways.

4.5.7 T-9: The DW-10X Tie (DW10)

The adjustment and behaviour of this tie was very similar to the CTA except that this tie did not fail with screw pull-out. The adjustment range was tested at the middle, quarter and end points.

When tested it was observed that the anchor itself yielded and deformed. This behaviour was most pronounced when the tie was at the quarter point of the anchor. The tie system was found to be stiffest when loaded at the end of the adjustment slot and nearest to a fastening screw. The results were shown in Figure 4.30.

4.5.8 T-12: Thermosteel Tie (TA)

This tie required a special type of steel stud to accommodate fastening. It provided four alternate holes to locate a triangular wire tie. These holes were located on a vertical strip that extended into the cavity space as was illustrated in Figure 3.12.

Because of the different form of adjustability, these results were not included in Table 4.5. The test results shown in Figure 4.31 indicated that the specimens tested using the inside hole had greater stiffness than those tests using the outside hole. In both cases the ultimate failure resulted in the tie becoming disengaged from the thermosteel stud.

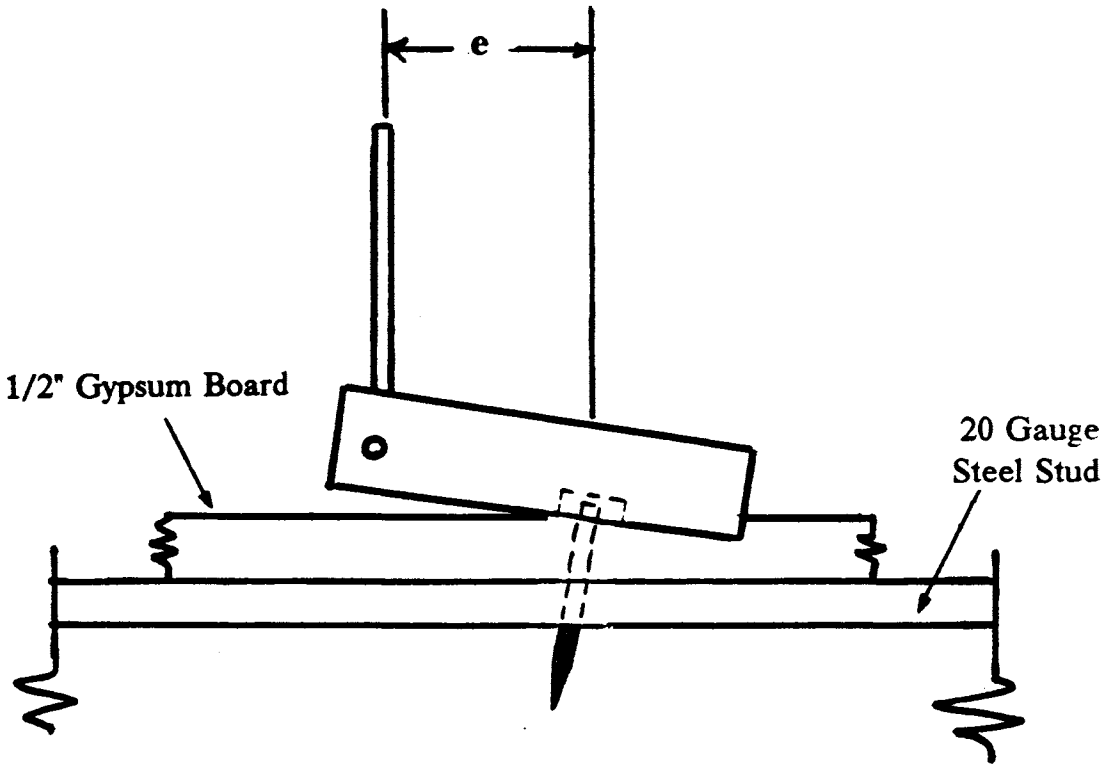


FIGURE 4.25 PRYING ACTION OF SSA TIE

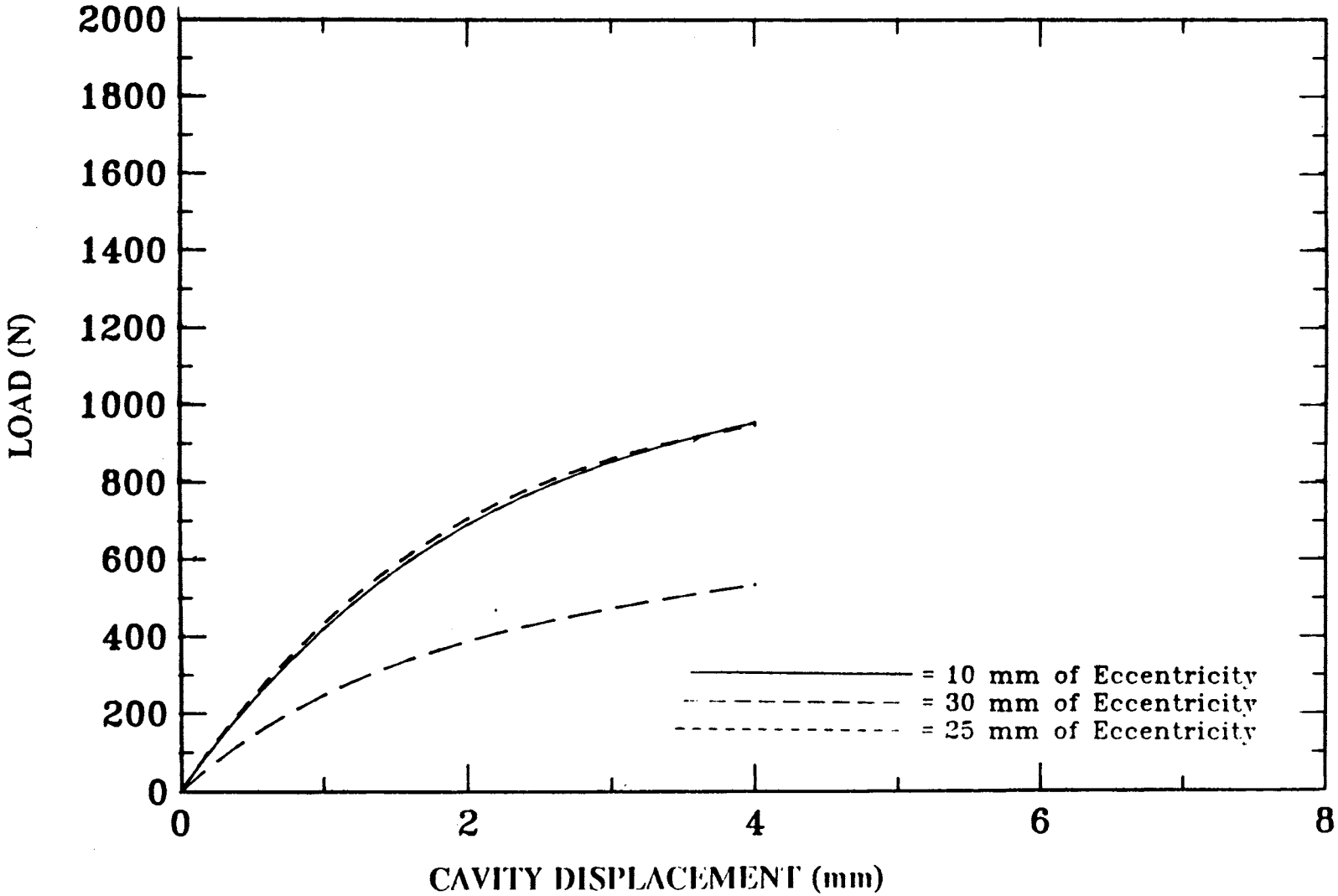


FIGURE 4.26 INFLUENCE OF ADJUSTABLE RANGE ON PERFORMANCE OF WLA TIE

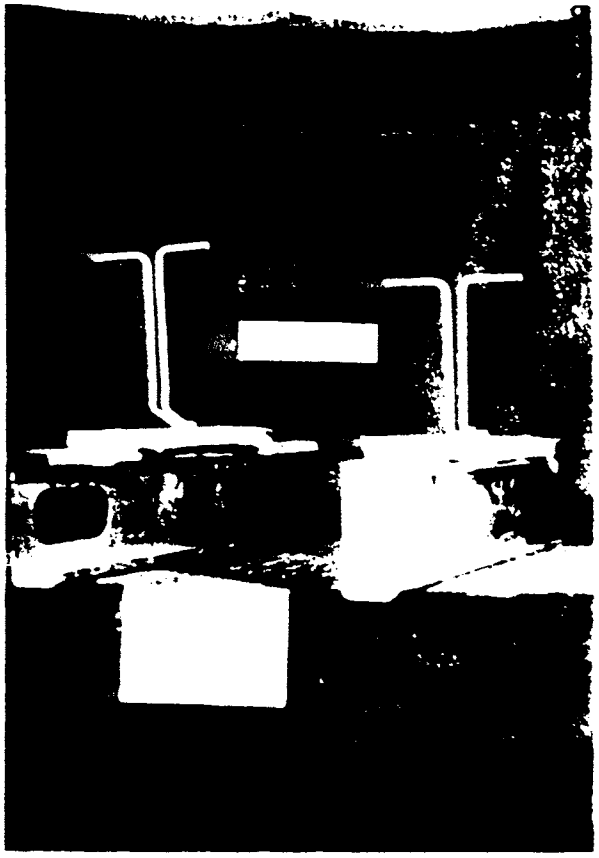


FIGURE 4.27 PHOTOGRAPH SHOWING FAILURE OF WLA ON GYPSUM BOARD

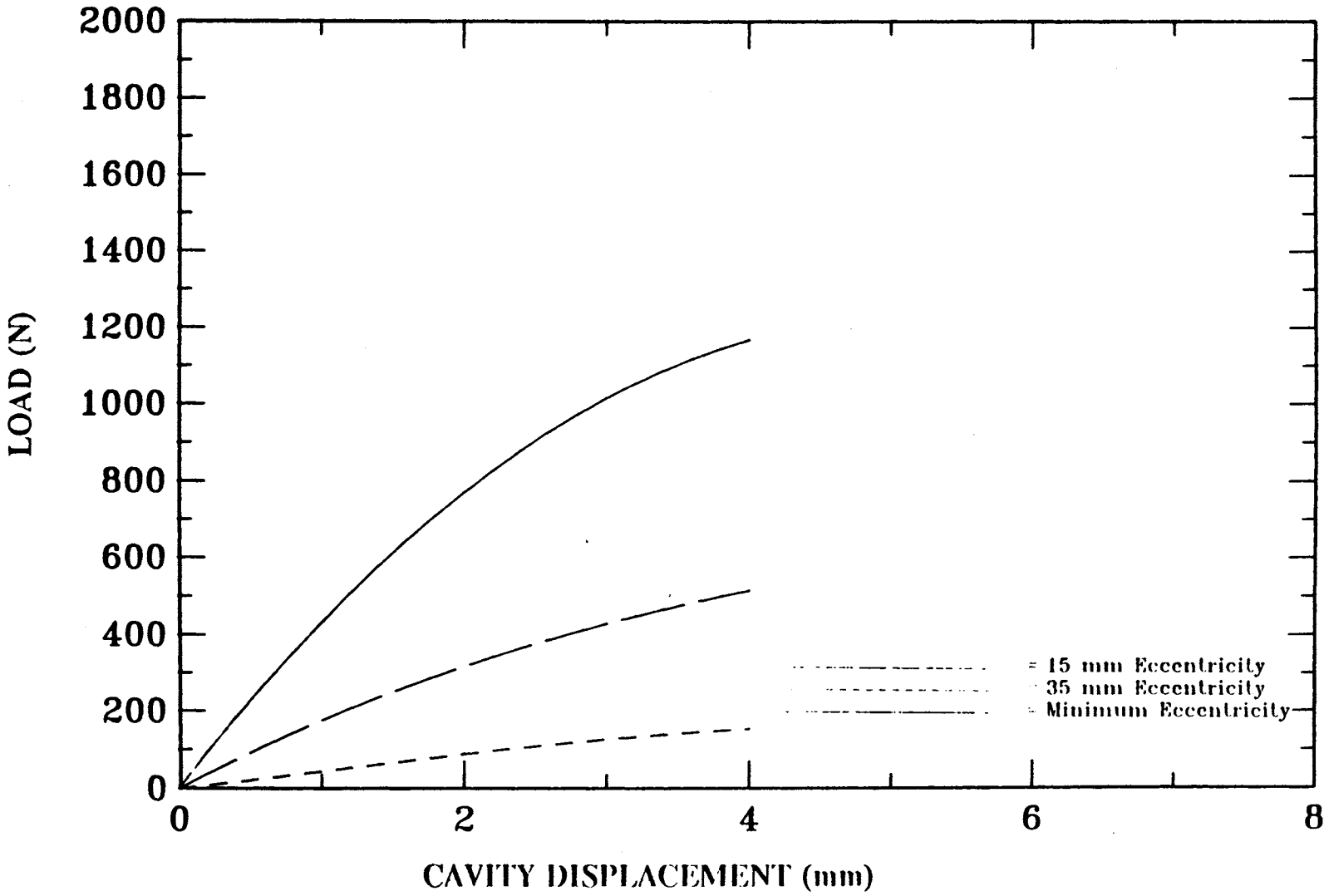


FIGURE 4.28 INFLUENCE OF ADJUSTABLE RANGE ON PERFORMANCE OF FLA TIE

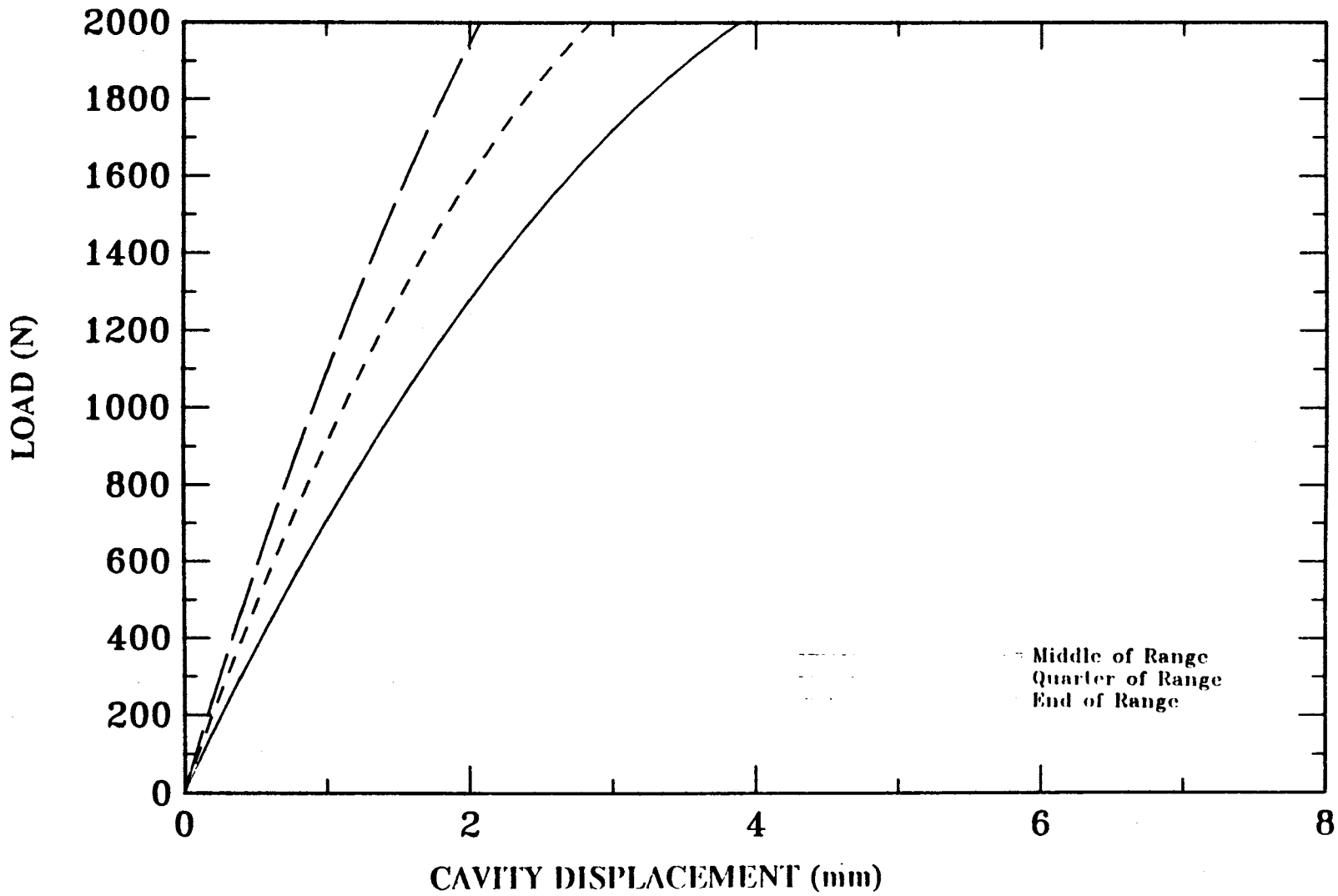


FIGURE 4.29 INFLUENCE OF ADJUSTABLE RANGE ON PERFORMANCE OF WAT TIE

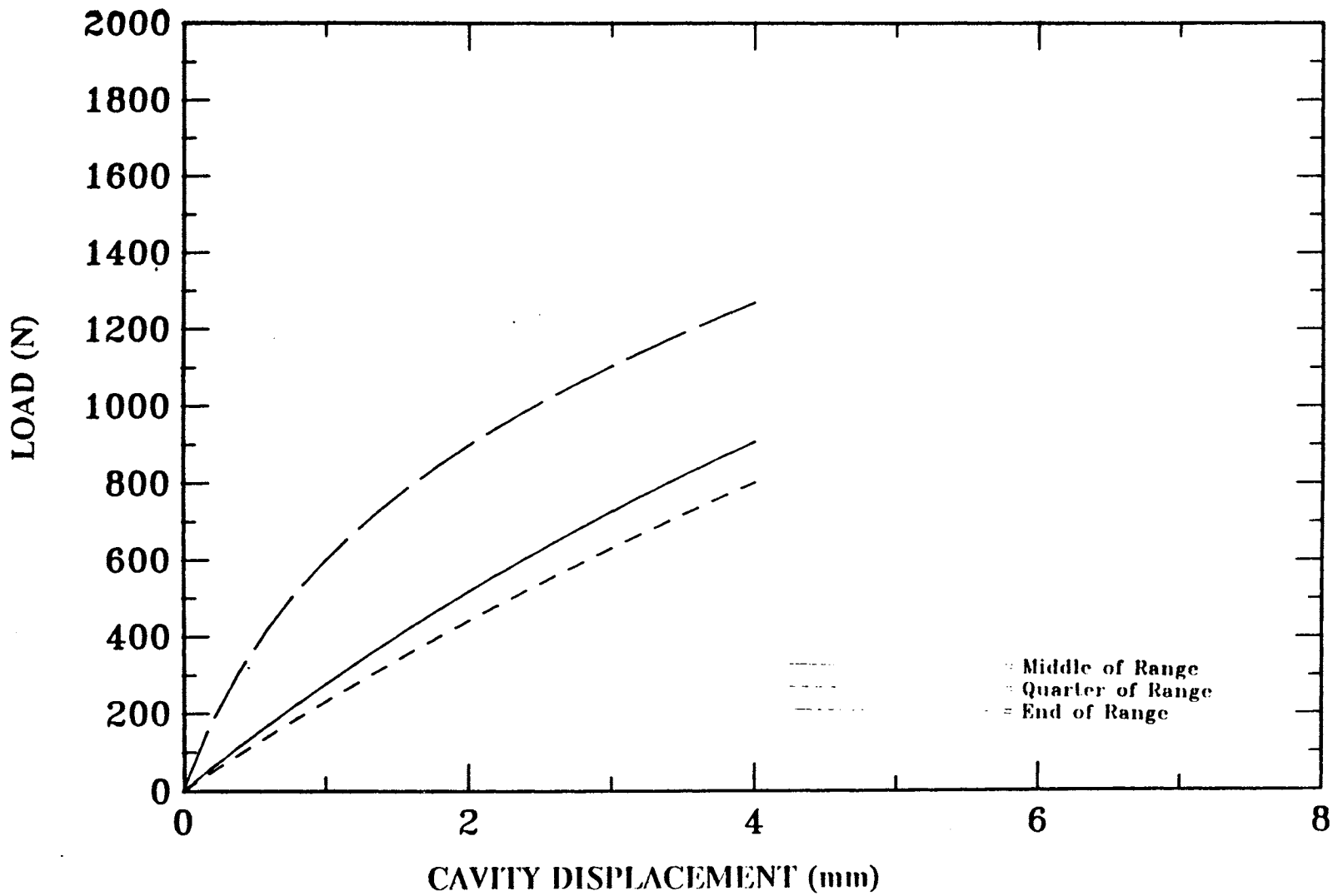


FIGURE 4.30 INFLUENCE OF ADJUSTALBE RANGE ON PERFORMANCE OF DW10 TIE

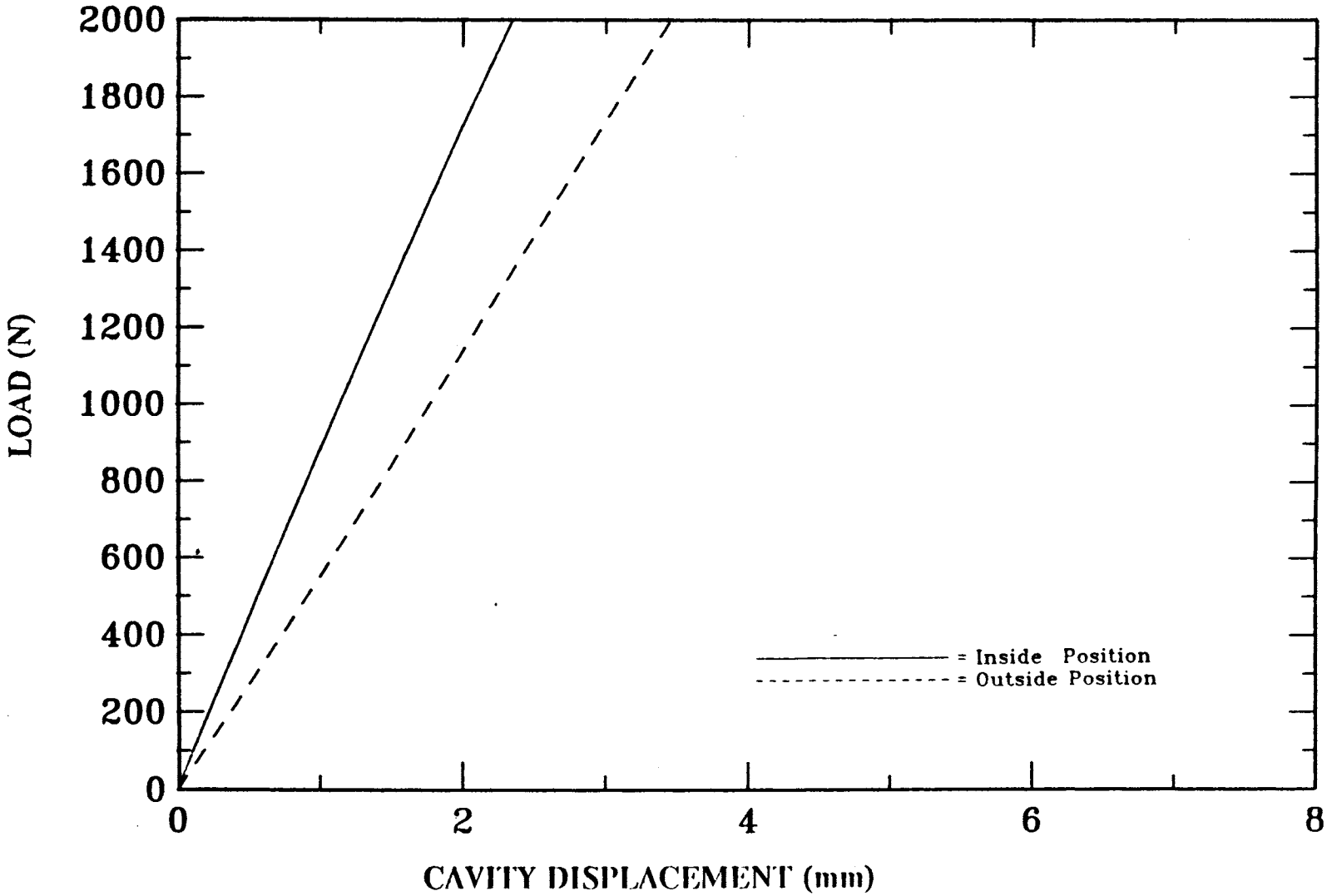


FIGURE 4.31 INFLUENCE OF ADJUSTABLE RANGE ON PERFORMANCE OF TA TIE

4.6 EFFECT OF ADJUSTMENT ON PERFORMANCE OF THE TIE UNIT ALONE

In Section 4.5, the influence of adjustment on the performance of the tie system was investigated. As an extension of that study, another test series was designed to study the response of the tie unit itself to vertical adjustment, free from the influences of fasteners and steel stud. The tests were completed on the four different ties listed in Table 4.6.

The test results for the DLA shown in Figure 4.32 had basically the same trends as those found for the stud supported specimens. The only difference between the two sets of results lay in the stiffness and the ultimate capacity. In these tests, the anchor was rigidly supported, thus eliminating the flange rotation present in the stud supported tests. Without this rotation the two wire pintles are loaded more equally which resulted in an increased capacity and stiffness.

The CTA results shown in Figure 4.33, when compared to the results in Figure 4.23, show that elimination of screw pull-out and flange rotation had a great effect on increased strength and stiffness.

The SLA produced very similar trends to those observed for the DLA but as shown in Figure 4.34 the strength and stiffness were less owing to the single leg. For attachment to a steel stud the stiffness would be less due to bending of the flange and pull-out of the screw.

For the FLA, comparison of the results for a rigid support (Figure 4.35) with those with attachment on a stud indicated that, particularly for minimum eccentricity, the stiffness was much greater when the effects of flange rotation were eliminated.

TABLE 4.6 SUMMARY OF TEST RESULTS FOR INFLUENCE OF RANGE OF ADJUSTABILITY OF TIES ON RIGID SUPPORTS.

TIE	TEST*	REGRESSION COEFFICIENTS+ a	b	c	d	e	LOAD @ 1.2mm (N)
DLA	T-1-8[4]	588.0	63.10	-13.2			773
	T-1-10A[5]	488.0	43.50	-13.60			625
	T-1-10B[6]	102.0	13.60	-1.85			139
CTA	T-2-8[1]	283.0	-9.31				326
	T-2-10A[2]	0.0	305.07	-82.17	5.92	0.06	310
	T-2-10B[3]=	425.91	238.31	-0.05102	0.01565		889
SLA	T-4-8[4]	793.8	-199.13	1.85	7.42	-0.86	682
	T-4-10A[10]	207.0	-23.60				214
	T-4-10B[6]	80.4	-1.83	-0.27			93
FLA	T-6-8[4]	787.0	338.0	-180.0			1120.08
	T-6-10A[5]	249.0	-44.4	2.86			239.81
	T-6-10B[6]	76.60	1.74	-1.22			92.32

+ Regression coefficients refer to the equation: $Y = ax + bx^2 + cx^3 + dx^4 + ex^5$ except for tests marked with = where $Y = (ax + bx^2)/(1 + cx + dx^2)$

Y = load (N) x = displacement (mm)

* Footnotes refer to adjustment locations (see Table 4.5)

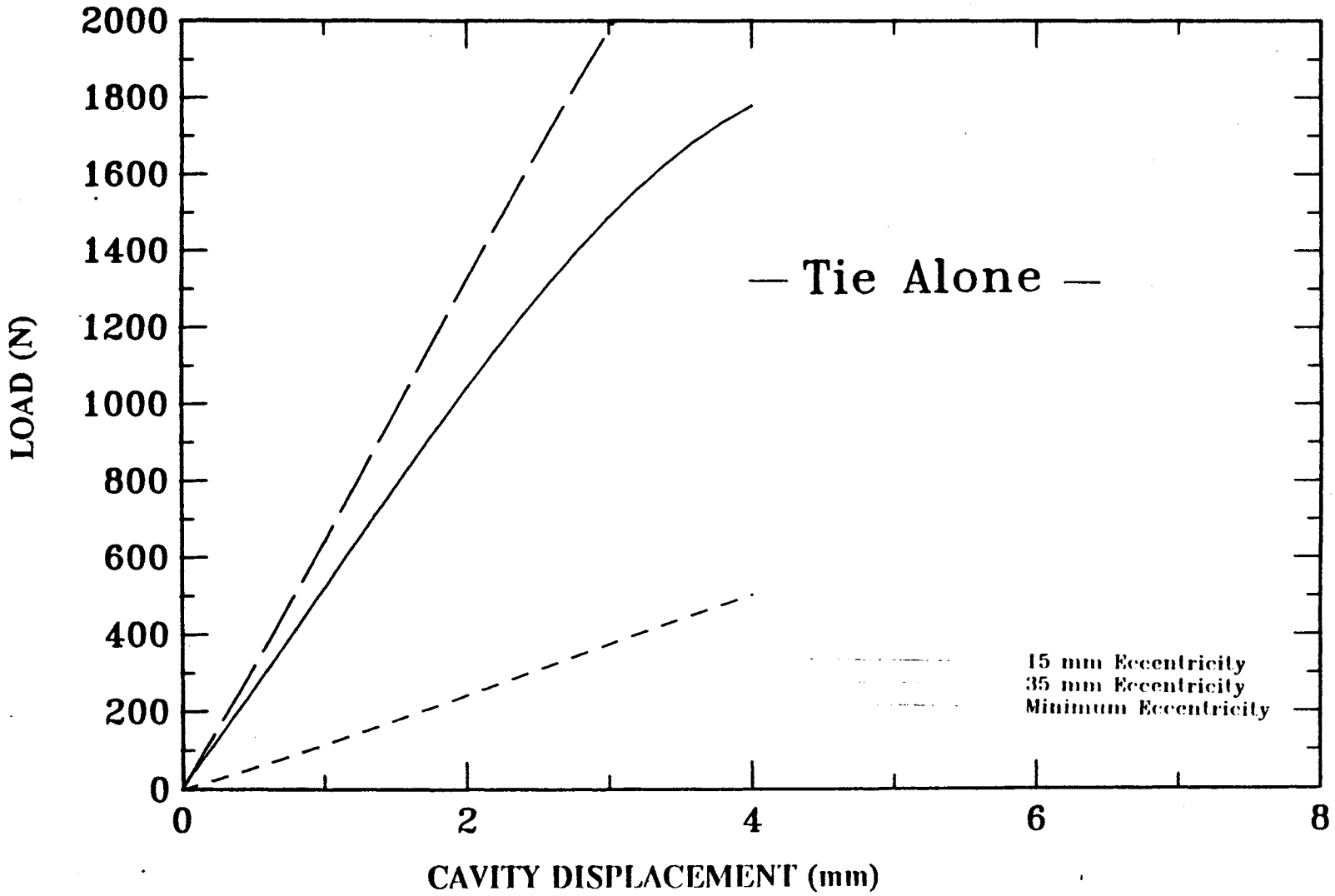


FIGURE 4.32 INFLUENCE OF ADJUSTMENT RANGE OF PERFORMANCE OF DLA TIE ALONE

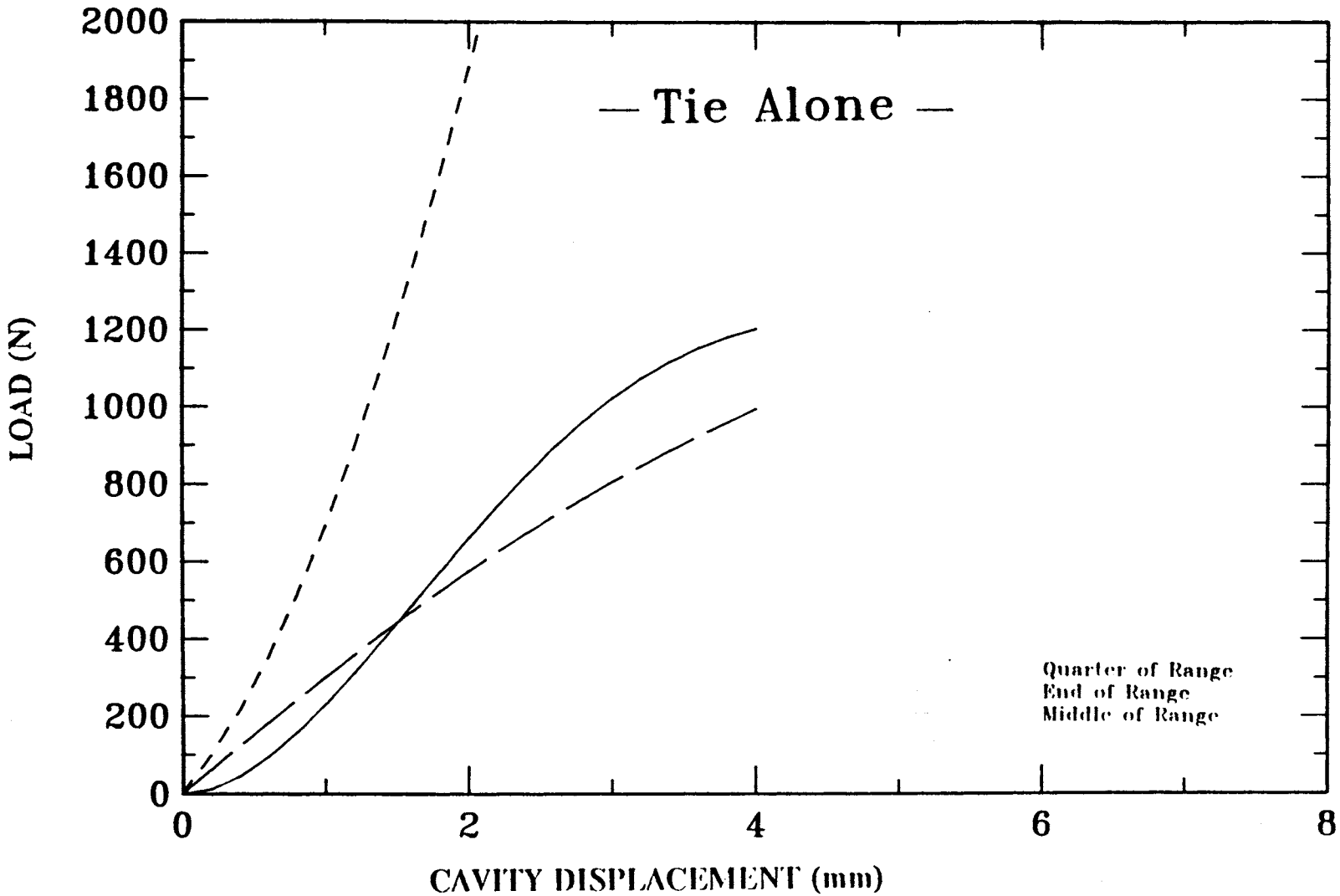


FIGURE 4.33 INFLUENCE OF ADJUSTMENT RANGE OF PERFORMANCE OF CTA TIE ALONE

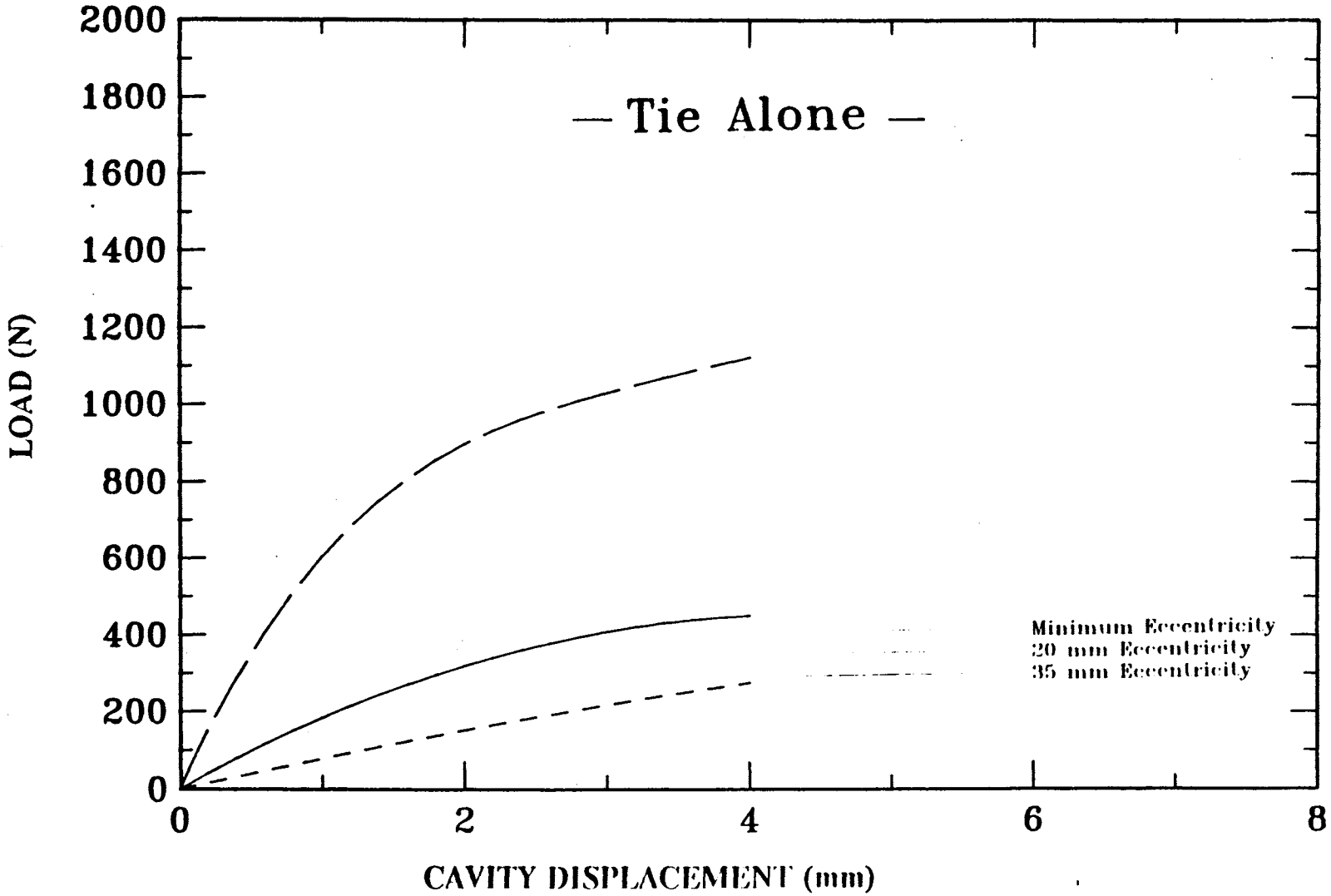


FIGURE 4.34 INFLUENCE OF ADJUSTMENT RANGE OF PERFORMANCE OF SLA TIE ALONE

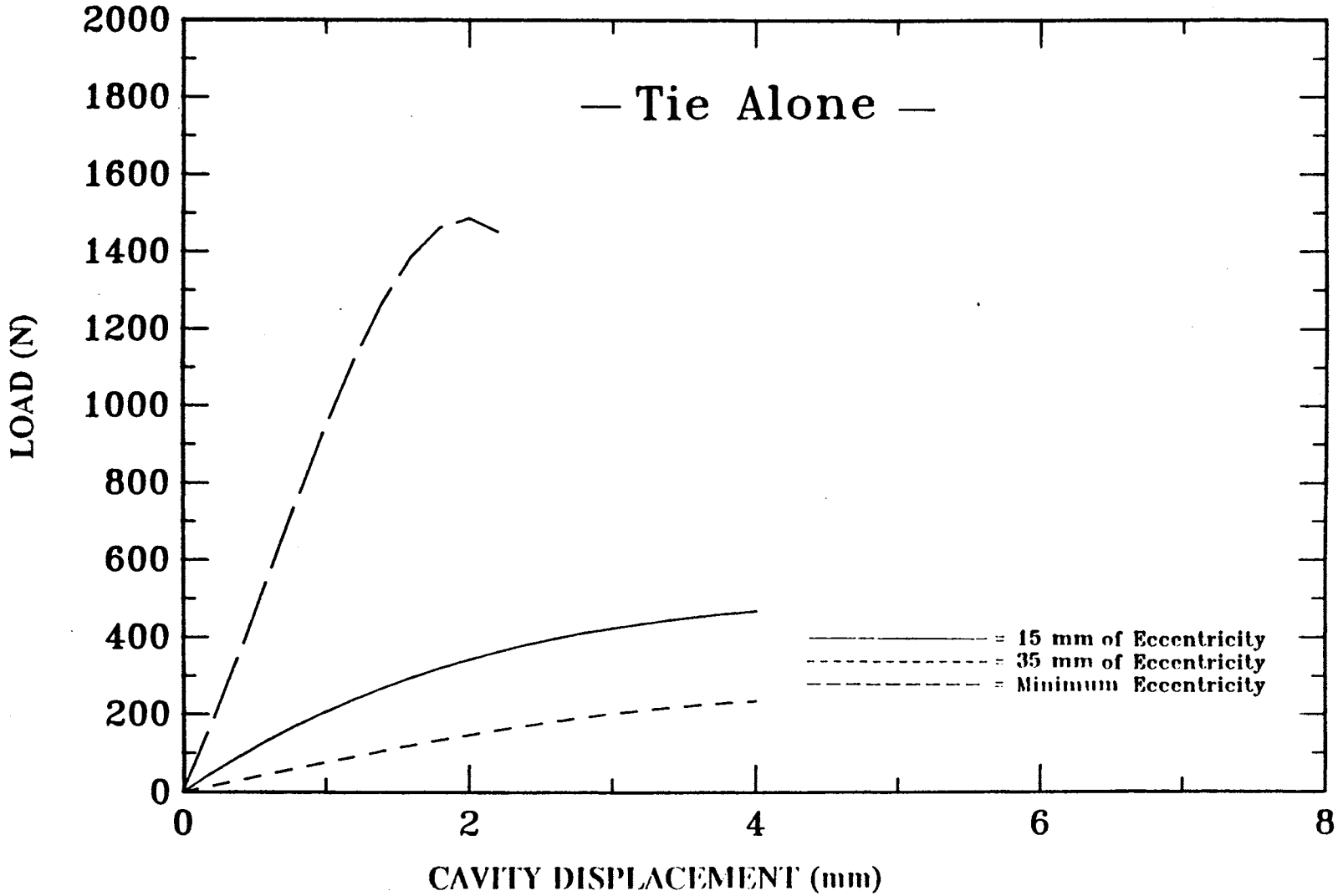


FIGURE 4.35 INFLUENCE OF ADJUSTMENT RANGE OF PERFORMANCE OF FLA TIE ALONE

4.7 INFLUENCE OF CAVITY WIDTH ON TIE PERFORMANCE

4.7.1 General

Many of the ties investigated in this test program accommodated various cavity widths. In this test series the influence of the cavity width on tie performance was investigated using compression tests on 20 gauge steel stud specimens corresponding to Test Series T-?-9 but also included results from the standard series T-?-1.

While many of the longer anchors are designed to work with various combinations of sheathing and insulation placed in the cavity, any lateral support for the tie that the sheathing can be relied upon to provide was thought to be minimal and was omitted in this test series. However, for shorter ties that are fastened directly to the sheathing, the 12mm layer of gypsum board was included in the test specimens.

Table 4.7 contains the results for the ties selected to document the influence of cavity width. In the following section, figures representing performance domain of the mean test curves are presented and discussed along with observations during these tests.

4.7.2 Discussion of Findings

The load-displacement results for the four types of ties investigated in this test series were presented in Figures 4.36 to 4.39.

The DLA tie results shown in Figure 4.36 were very similar for the 20 and 100 mm legs up to about a third of the ultimate load after which the longer legs began to deflect at a greater rate.

The test results for the SLA tie were unique in that the anchor with the larger unsupported length provided the stiffer unit. However it did buckle and produced a lower capacity as expected. The flexibility of the smaller single leg tie can be attributed to the softening of the gypsum board it was mounted on. For the larger cavity width, the tie was mounted on the stud as might be the case with insulation in the cavity.

For the WLA results shown in Figure 4.38, very little difference was noticed in the two larger cavity widths of 100 and 125 mm, but the smaller 75 mm wire tie did prove to be both stiffer and ultimately stronger.

Similar to the WLA, the FLA experienced its stiffest and highest capacity with the smallest cavity width. Interestingly however, as shown in Figure 4.39, FLA with a double legged wire tie did not perform very well. The problem was that the two legs on the tie were positioned on the anchor at a large distance from the stud web and the corresponding shear centre. During the test the tie buckled and bent around the flange at a very low load compared to the single leg pintle used with the FLA.

4.8 INFLUENCE OF GAUGE OF STEEL STUD ON TIE PERFORMANCE

In BV/SS construction, there often arises the situation where 18 gauge steel stud is used. Whereas the majority of tie tests performed using 20 gauge steel studs provided a lower bound, a small study was conducted to assess the influence of the gauge of steel on wall tie performance.

The additional tests were identical to the tension test on 20 gauge steel stud (Test Series T-?-2) and corresponded to Test Series T-?-6 of the test program.

TABLE 4.7 SUMMARY OF TEST RESULTS FOR INFLUENCE OF CAVITY WIDTHS FOR TIES ON STEEL STUDS

TIE	TEST*	ULT. LOAD (N)	COV. (%)	REGRESSION COEFFICIENTS++ a	b	c	d	e	LOAD @ 1.2 mm (N)
DLA	T-1-1[1]	1678.0	8.1	577.0	55.7	-24.4			730
	T-1-9[2]	1866.5	2.3	789.4	-196.9	25.5	-1.52	0.03	704
SLA	T-4-1[4]	1087.5	6.5	602.0	-34.2	-17.0			644
	T-4-9[2]	1970.1	10.9	224.0	-8.84	0.11			256
WLA	T-5-1[4]	2457.6	1.4	694.9	-79.9				718
	T-5-9A[5]	2829.9	9.0	622.1	-65.75	3.42	0.08	0.0007	657
	T-5-9B[2]	3035.0	1.1	741.9	-76.81	3.26	-0.05		785
FLA	T-6-1[2]	1760.7	3.9	523.0	-39.9				570
	T-6-9A[2+]	1120.6	14.1	167.0	-7.30	0.09			190
	T-6-9B[3]	1365.4	6.3	273.0	-17.5	0.33			303

++ Regression coefficients refer to the equation: $Y = ax + bx^2 + cx^3 + dx^4 + ex^5$ except for tests marked with ⁼ where $Y = (ax + bx^2)/(1 + cx + dx^2)$

Y = load (N) x = displacement (mm)

* Footnotes identify cavity widths as follows: 1 = 125 mm, 2 = 50 mm, 3 = 75 mm, 4 = 100 mm.

+Flange locking anchor with a double pintel wire tie was used.

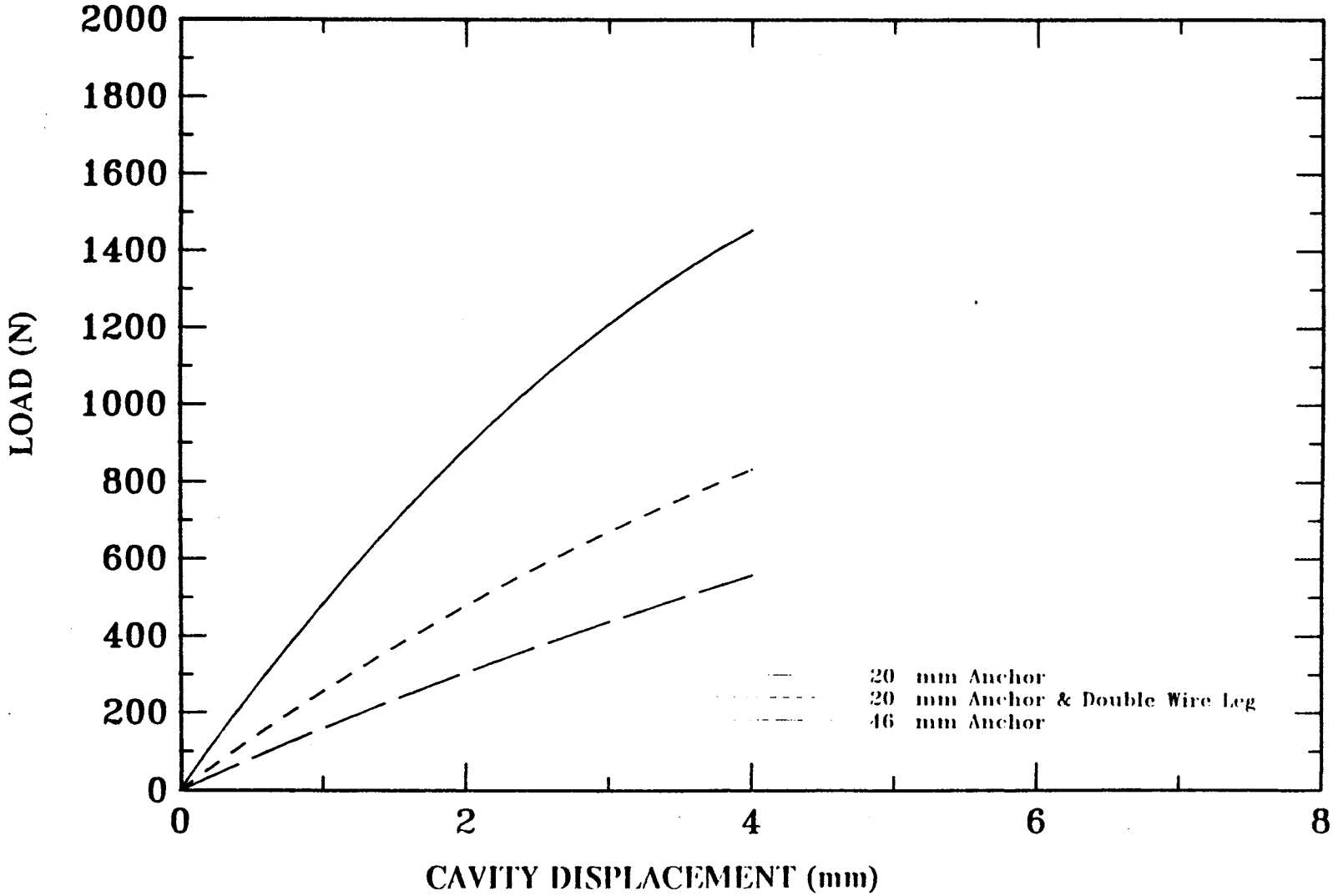


FIGURE 4.39 INFLUENCE OF CAVITY WIDTH ON PERFORMANCE OF FLA TIE

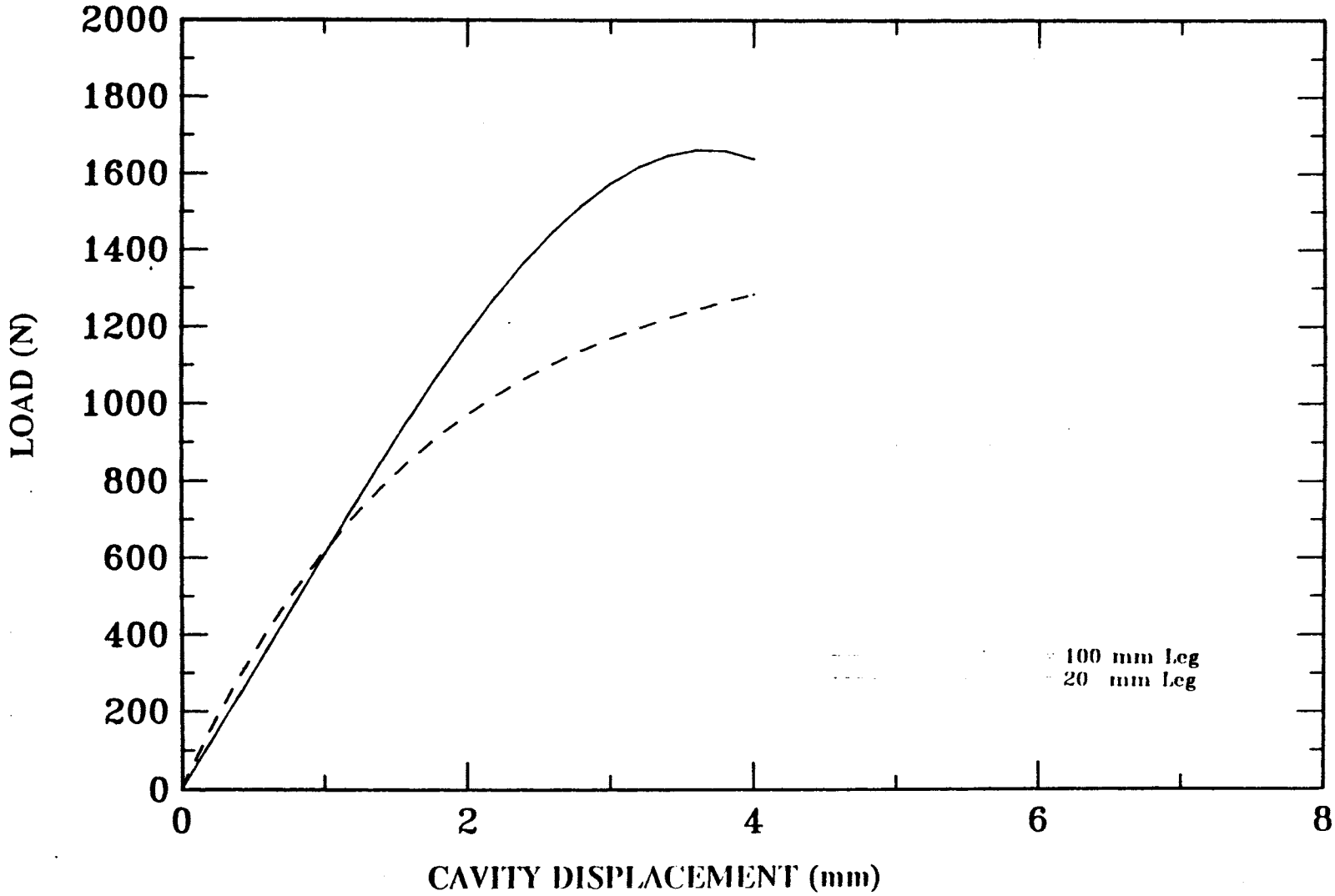


FIGURE 4.36 INFLUENCE OF CAVITY WIDTH ON PERFORMANCE OF DLA TIE

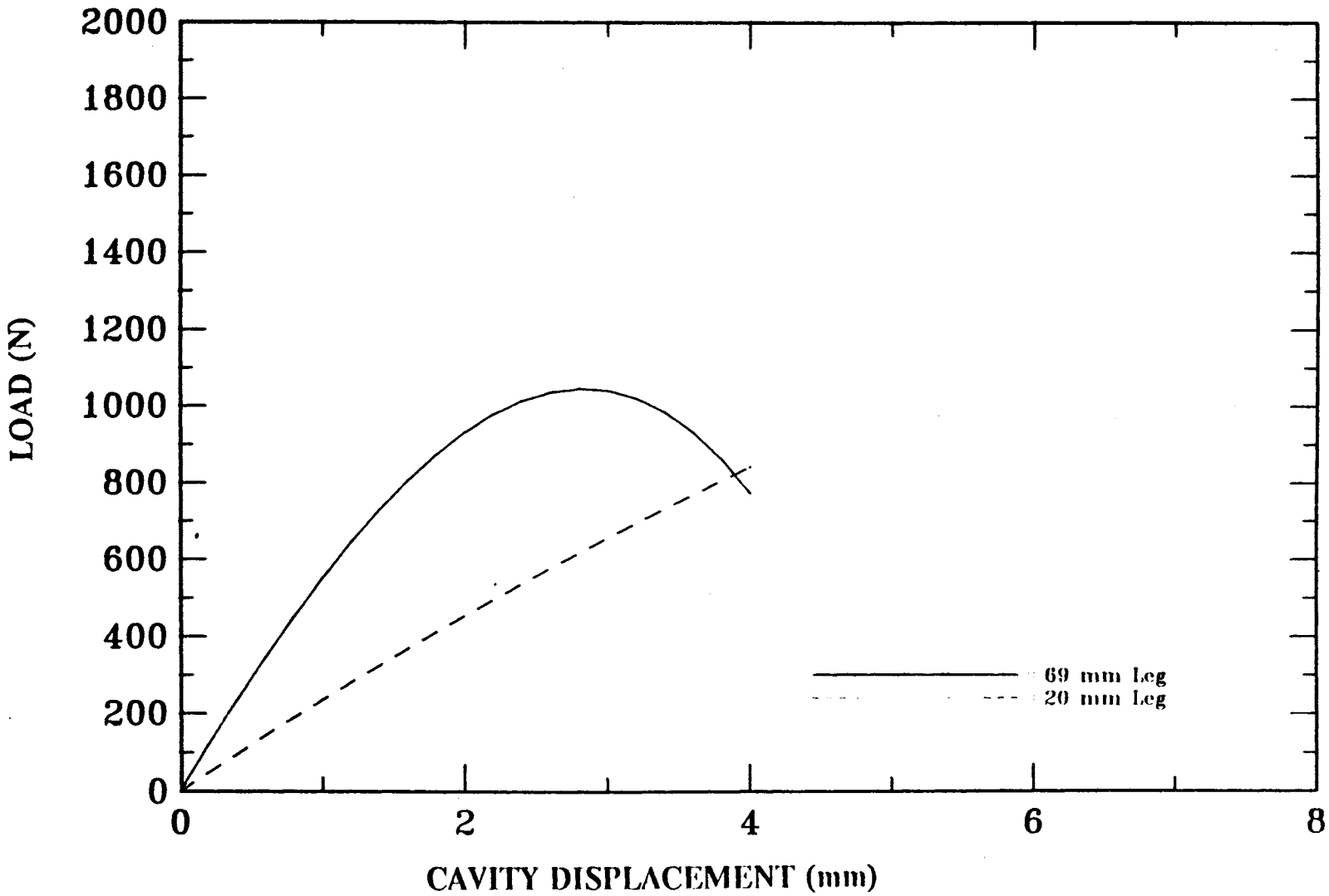


FIGURE 4.37 INFLUENCE OF CAVITY WIDTH ON PERFORMANCE OF SLA TIE

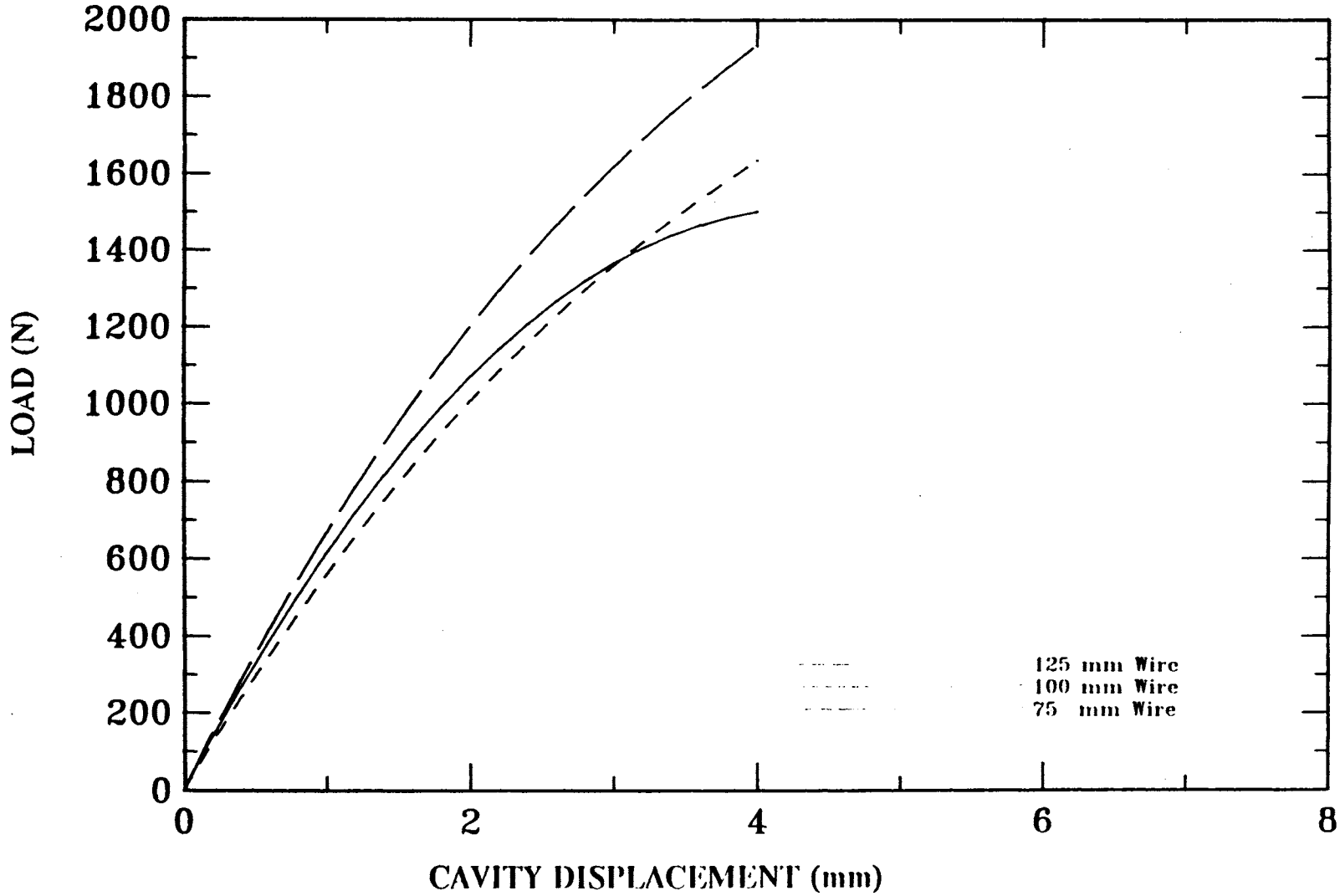


FIGURE 4.38 INFLUENCE OF CAVITY WIDTH ON PERFORMANCE OF WLA TIE

Table 4.8 contains the results of both series for the ties used. They were selected to represent a fair range of ties from compact stiff units to screw fastened and mechanically fastened ties.

For the CTA (Tie 2) and FLA (Tie 6) ties in which cases stiffness was limited mainly by the tie itself, there was only a small influence within the 4 mm displacement performance domain. However, beyond this domain the ultimate capacity of the CTA which was limited by screw failure, did increase as a result of using the 18 gauge stud. In fact, during the 20 gauge tests the screw simply pulled from the stud whereas for the 18 gauge tests it actually ripped through the stud material and in two cases the screw sheared off.

On the other hand, the SSA (Tie 3) showed a marked increase in stiffness when tested on the 18 gauge stud. In the SSA tests with 20 gauge studs, flange rotation contributed more significantly to the cavity displacement than was the case for the CTA or FLA tie tests. Taking this into consideration, it is reasonable to assume that the 18 gauge support reduced the flange rotation and served to stiffen the tie system. The mean load-deflection curves for these tests were plotted in Figure 4.40. Thus it can be observed that the influence of the gauge of the steel stud was very much dependent on the characteristics of the tie.

4.9 INFLUENCE OF MISALIGNMENT OF ANCHOR AND TIE ON PERFORMANCE

4.9.1 General

The installation of wall ties requires that the anchor, which is pre-fastened to the stud, lines up properly to accommodate the wire tie once it is embedded in the mortar joint of the brick veneer. It has been observed that, in the field, this

requirement of proper alignment is difficult to control. Thus this test program include a small series of tests to investigate the influence of misalignment on tie performance.

In the tests summarized in Table 4.9, it was determined that the maximum amount of misalignment likely would be about 12 degrees to the horizontal, as illustrated in Figure 4.41. Although many ties provide adjustment to minimize misalignment, when considering field and installation conditions, there is still a likelihood of occurrence.

The four different types of ties chosen for this test series included ties with wire pintles (DLA, SLA and FLA) and the corrugated wall tie (CST). The tests were conducted in compression on 20 gauge steel studs (Test Series T-?-11).

4.9.2 Discussion of Findings

As shown in Figures 4.42 and 4.43 the test results from both the DLA and SLA ties showed that the misalignment of the tie initially had little influence on the ties' performance. However, as the test progressed, the misaligned ties began to loose stiffness. In both cases this loss of stiffness initiated at a lower load level and buckling of the ties occurred at a reduced capacity compared to properly positioned ties.

The FLA actually showed no influence of misalignment in the performance domain shown in Figure 4.44. This can be attributed to the fact that, even in the properly aligned compression test, the tie anchor rotates vertically and actually acts as a misaligned tie.

The greatest influence of misalignment was observed for the CST where the problem of misalignment is most probable. As shown in Figure 4.45, even in

TABLE 4.8 SUMMARY OF TEST RESULTS FOR INFLUENCE OF GAUGE OF STEEL STUDS.

TIE	TEST*	ULT. LOAD (N)	COV. (%)	REGRESSION COEFFICIENTS++ a	b	c	d	e	(N)	LOAD @ 1.2 mm
CTA	T-2-2[1]	1708.9	10.9	86.8	0.31	-0.03				104
	T-2-6[2]	2614.9	1.7	121.0	-2.04	0.10				142
SSA	T-3-2[1]	1167.5	3.6	570.0	-70.6					582
	T-3-6[2]	1883.1	2.5	805.0	-85.1					843
FLA	T-6-2[1]	1128.7	6.1	477.0	-46.3					506
	T-6-6[2]	1493.4	5.9	496.0	-386	-0.11				539

++ Regression coefficients refer to the equation: except for tests marked with * where

$$Y = ax + bx^2 + cx^3 + dx^4 + ex^5 \qquad Y = (ax + bx^2)/(1 + cx + dx^2)$$

Y = load (N) x = displacement (mm)

1. 20 gauge steel stud.

2. 18 gauge steel stud.

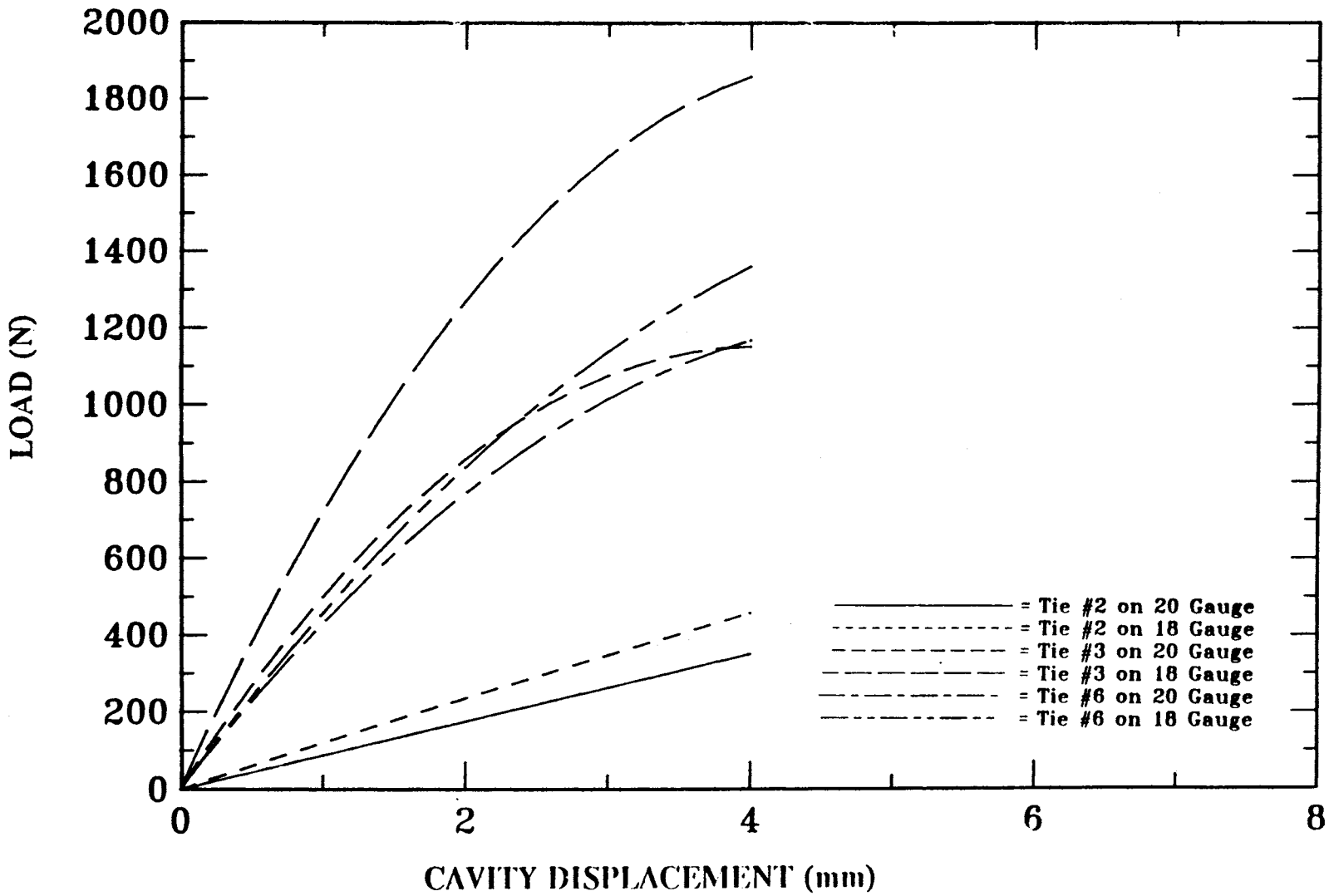


FIGURE 4.40 INFLUENCE OF GAUGE OF STEEL STUD ON TIE PERFORMANCE

the initial stages of the test the misaligned tie performed far below the level achieved by its properly positioned counterpart.

Another form of misalignment or perhaps even adjustability for the CST has to do with the position of the bend in the tie. As illustrated in Figure 4.46, for tension testing, whether the tie was bent close to the head of the fastening screw used to attach the tie, or whether it was bent close to a washer made very little difference on strength and stiffness within the performance domain. (The ultimate strength was of course lower when no washer was used). However, even with a washer in place, bending the tie 25 mm from the screw resulted in a marked decrease in stiffness. However, after the initial bend had straightened out and a new bend was formed at the washer, the strength was roughly the same. Unfortunately due to the large displacement, the strength would not be usable.

4.10 INFLUENCE OF WALL SHEATHING ON TIE PERFORMANCE

4.10.1 General

Many of the ties selected for this test program can be installed after the backup wall is enclosed by exterior sheathing. In some cases, direct attachment of the tie to the steel stud is not practical and despite drawings which show otherwise, they have been placed on the sheathing in the field. In this series of tests, the influence of the sheathing on the performance of two different types of ties was investigated. It should be noted that the DW10 tie which is placed over sheathing was previously mentioned. The two ties chosen for these tests were the WLA (Tie 5) and the CTS (Tie 10). The corrugated strip tie was tested with an unsupported length of 13 mm.

TABLE 4.9 SUMMARY OF TEST RESULTS FOR INFLUENCE OF MISALIGNMENT OF TIES ON STEEL STUD SUPPORTS.

TIE	TEST*	ULT. LOAD (N)	COV. (%)	REGRESSION COEFFICIENTS++ a	b	c	d	LOAD @ 1.2 mm (N)
DLA	T-1-1	1678.0	8.1	577.0	55.7	-24.4		730
	T-1-11 **	1407.9	1.0	525.17	385.67	-0.01083	0.322	817
SLA	T-4-1	1087.5	6.5	602.0	-34.2	-17.0		644
	T-4-11 **	826.3	10.5	405.52	71.81	-.006	0.1536	486
FLA	T-6-1	1760.7	3.9	523.0	-39.9			570
	T-6-11 **	1695.8	11.0	386.81	284.83	0.1512	0.1738	611
CST	T-10-1B	699	6.3	659.0	-182.0	12.90		551
	T-10-11 **	844.0	5.2	603.42	47.63	0.72	0.02104	418

++ Regression coefficients refer to the equation: $Y = ax + bx^2 + cx^3 + dx^4 + ex^5$

except for tests marked with ** where $Y = (ax + bx^2)/(1 + cx + dx^2)$

Y = load (N) x = displacement (mm)

* In the third field of the test identification, 1 indicates aligned and 11 indicates misaligned as described in the text.

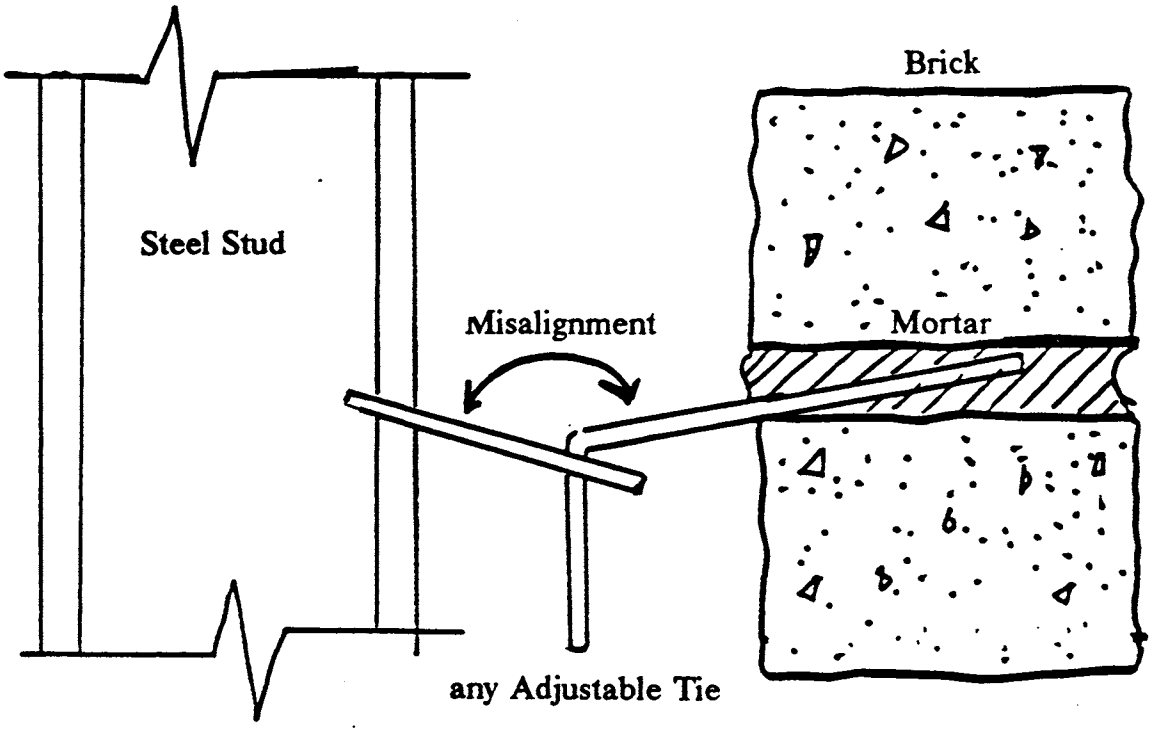


FIGURE 4.41 MISALIGNMENT OF TIES BY AN ANGLE OF 12 DEGREES

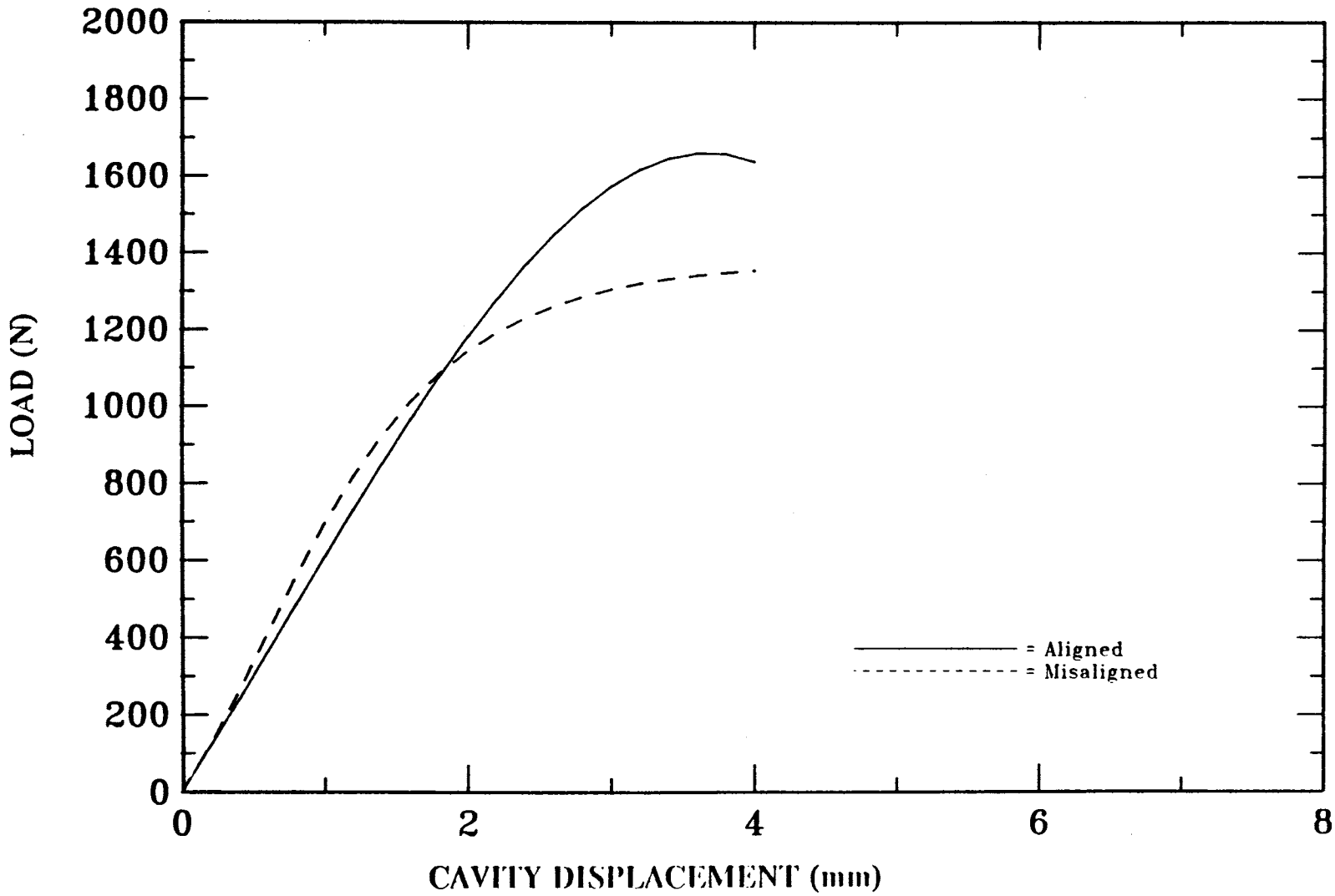


FIGURE 4.42 INFLUENCE OF MISALIGNMENT ON PERFORMANCE OF DLA TIE

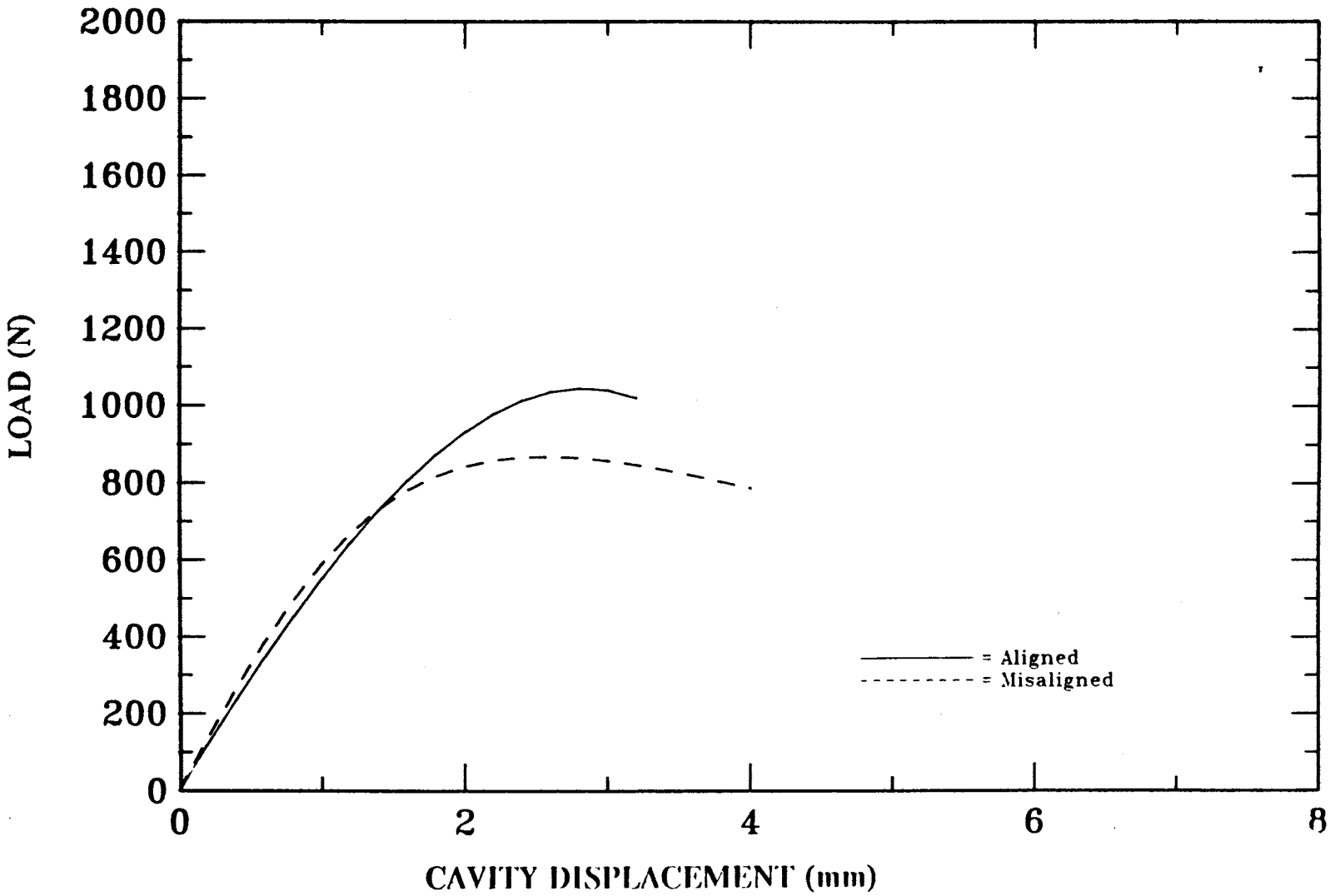


FIGURE 4.43 INFLUENCE OF MISALIGNMENT ON PERFORMANCE OF SLA TIE

For this investigation, compression tests were chosen because it seemed that the sheathing would have the most significance for this situation. The tests consisted of tests on gypsum board, Styrofoam SM board and on both a Styrofoam and gypsum board mounting devices identified as Tie 11. These mounting platforms provided smooth surfaces to attach the tie anchors and served to transfer the tie load to the wall stud. The concept was that the mount would reduce the problem of bearing directly on soft sheathing. The summary of results from these test series were listed in Table 4.10.

4.10.2 Discussion of Findings

For the corrugated strip tie, it was observed that the stiffest system was achieved with the tie mounted directly on the gypsum board. This result was surprising considering the design rationale for the tie mount. However, before loading it was observed that the pointed legs of the tie mount came into contact with the steel stud leaving a small gap between the mounting platform and the sheathing. When tested, the tie platform simply bent at the fastening location of the tie until better contact was made with the sheathing, These results were shown in Figure 4.47.

Tests of the WLA tie with gypsum board sheathingg produced test results very similar to those for the CST where the bending of the mount (Tie ll) was observed. However, quite different results were found when the WLA was attached on the Styrofoam SM mounting platform. The mounting platform intended for use with rigid insulation appeared to be more fully supported along its flat area by the polystyrene and, therefore, it was strong enough to transfer the tie load to the stud with minimal bending. As indicated in Figure 4.48, the WLA bearing directly on

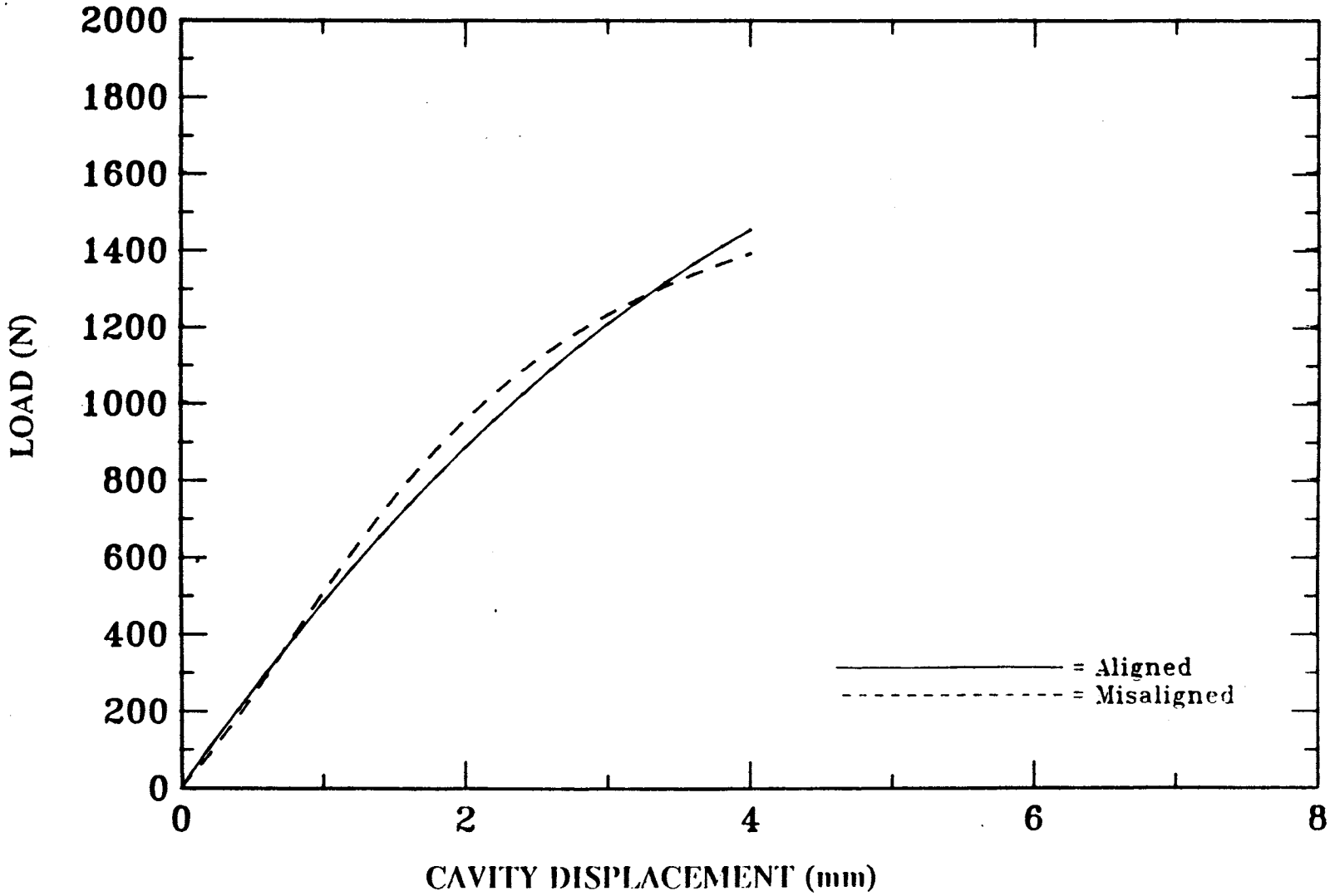


FIGURE 4.44 INFLUENCE OF MISALIGNMENT ON PERFORMANCE OF FLA TH

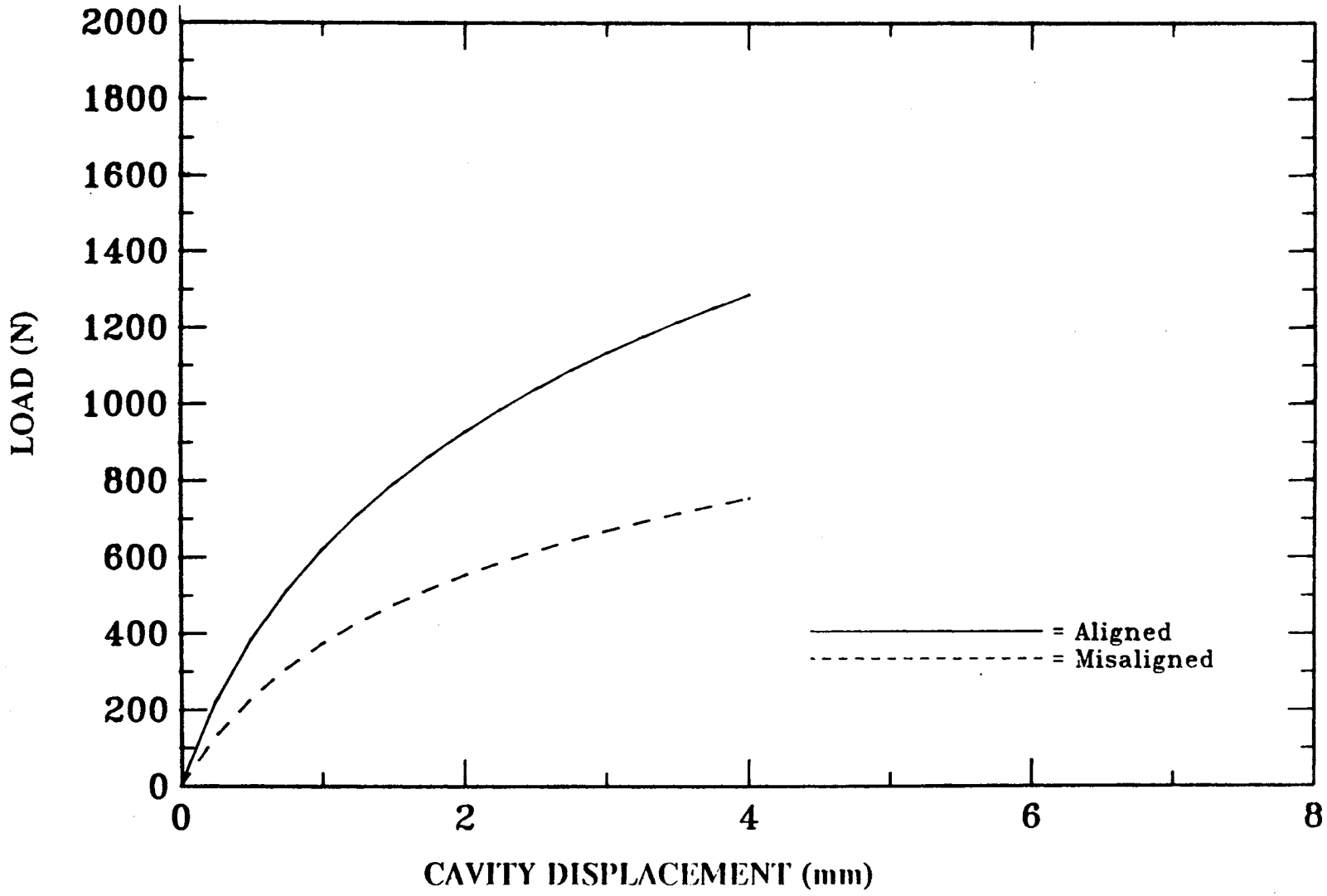


FIGURE 4.45 INFLUENCE OF MISALIGNMENT ON PERFORMANCE OF CST TIE

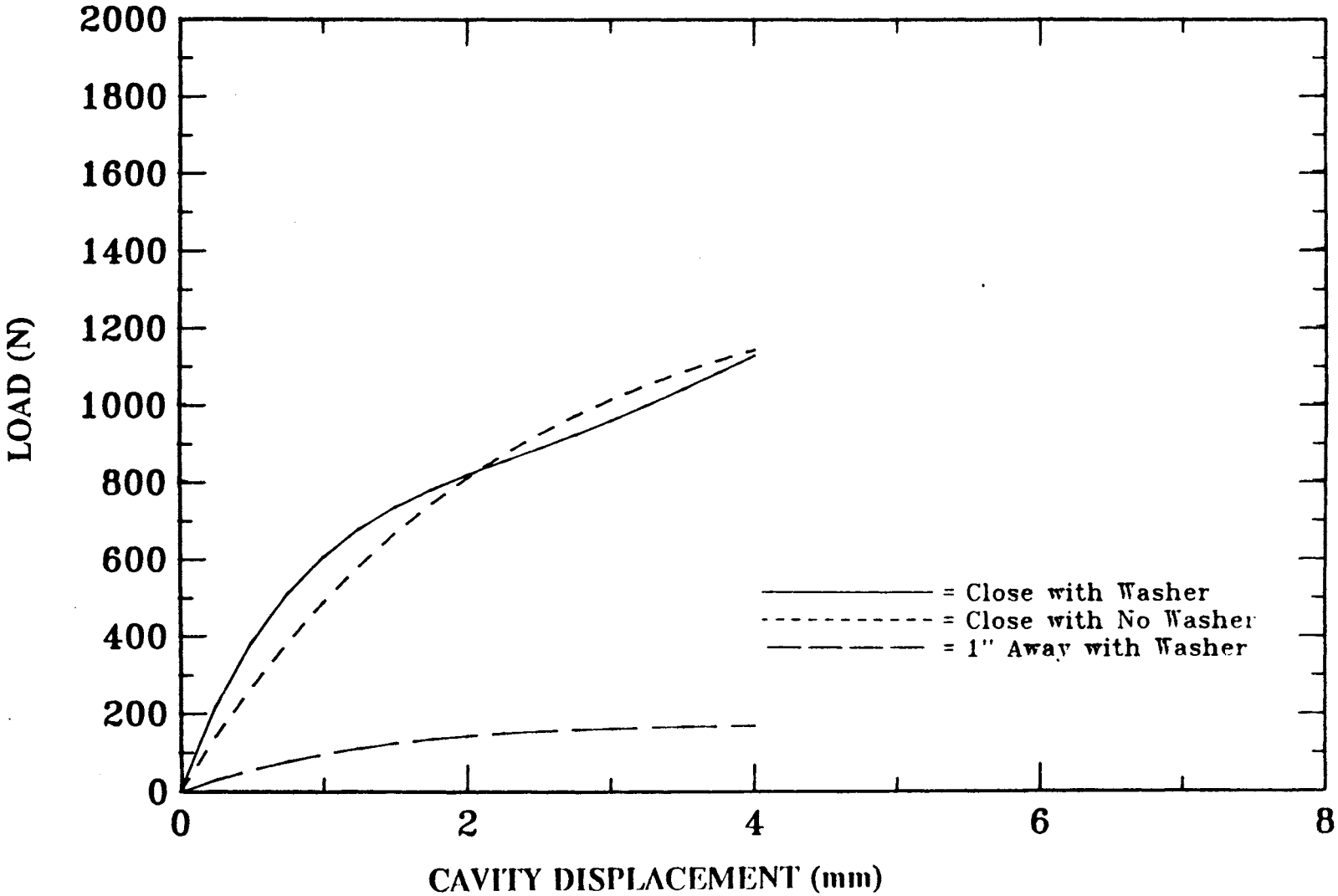


FIGURE 4.46 a) INFLUENCE OF MISALIGNMENT / ADJUSTMENT ON PERFORMANCE OF CST

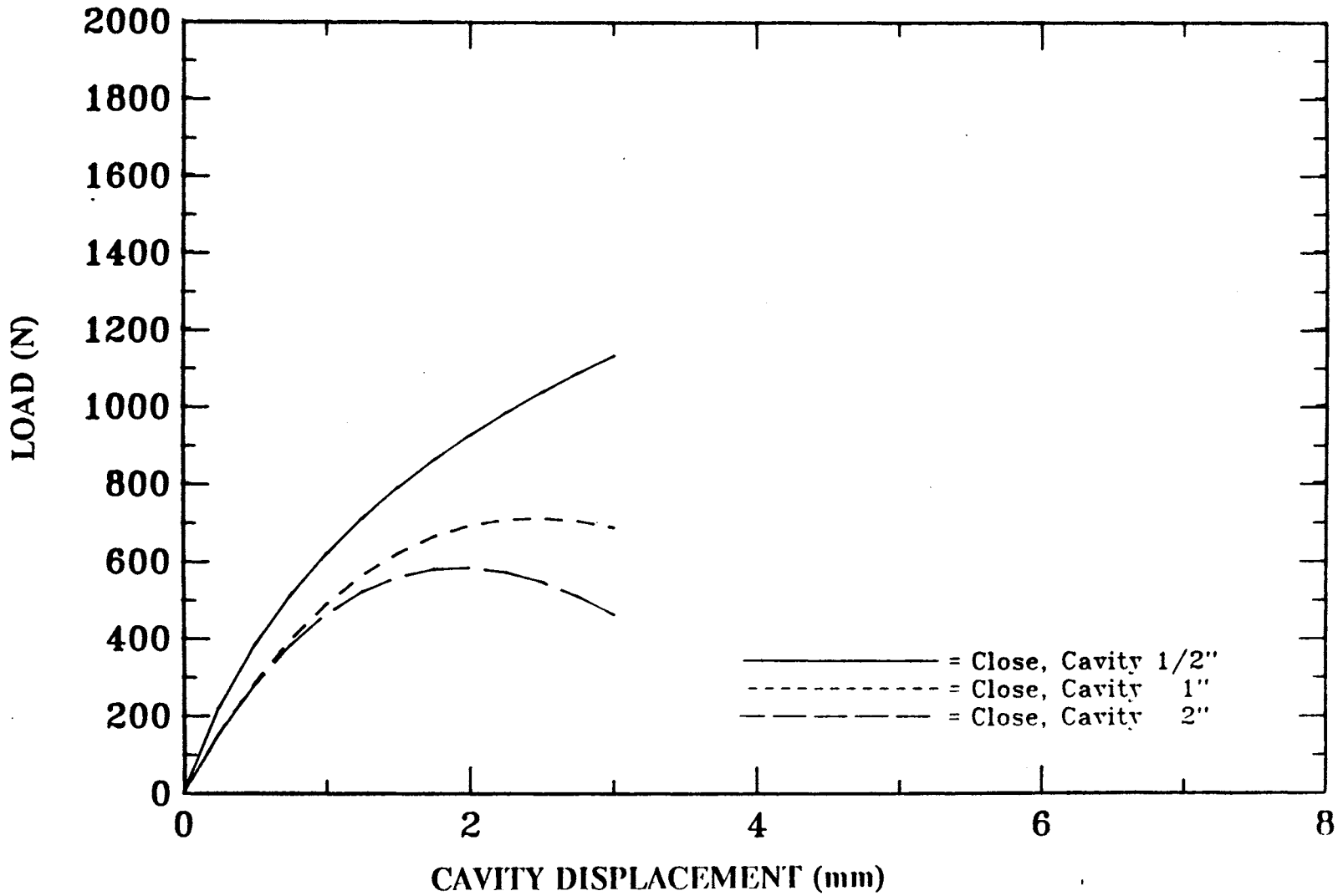


FIGURE 4.46 (b) INFLUENCE OF MISALIGNMENT/CAVITY WIDTH OF PERFORMANCE ON CST

the insulation resulted in much lower stiffness. The excessive penetration of the insulation was shown in the photograph in Figure 4.49. Tests done where the gypsum board was damaged (paper torn) during attachment of the WLA deviated from the tests on undamaged gypsum board at quite low loads.

4.11 FATIQUE TESTING OF TIES

4.11.1 General

Since the BV/SS wall tie will be subjected to countless repetitions and reversals in loading, the behaviour of the wall tie system under these conditions is of interest. In order to assess the adequacy of the various wall ties under repetitive and reversing load, the behaviours of four BV/SS ties were investigated.

The ties tested were the DLA (Tie 1), SLA (Tie 4), WLA (Tie 5) and the FLA (Tie 6). The test procedure was identical for all tests. Each fatique test followed the tie loading stages shown:

Stage 1 - Load levels:	Tension	- 400 N
	Compression	- 400 N
	Repetitions	- 1000 cycles
Stage 2 - Load levels:	Tension	- 700 N
	Compression	- 700 N
	Repetitions	- 1000 cycles
Stage 3 - Load levels:	Tension	- 1000 N
	Compression	- 1000 N
	Repetitions	- until failure

The results of these tests were summarized in Table 4.11 and graphically presented in the figures discussed in Section 4.11.2.

TABLE 4.10 SUMMARY OF TEST RESULTS FOR INFLUENCE OF WALL SHEATHING.

TIE	TEST*	ULT. LOAD (N)	COV. (%)	REGRESSION COEFFICIENTS++ a	b	c	d	LOAD @ 1.2 mm (N)
BVTS/ CST								
	T-11-A	508.2	15.0	503.0	-120.0			430
	T-11-B	527.8	7.9	613.0	-171			489
	T-10-1B	699.0	6.3	659.0	-182.0	12.9		551
BVTS/ WLA								
	T-11-A	1503.1	7.5	472.0	-36.6			513
	T-11-B	2491.3	8.9	744.0	-101.00	5.0		756
	T-5-1	2457.6	1.4	694.9	-79.9			718
	T-5-1D			229.0	-8.34	0.11		263
	T-5-1B[m]			2842.31	3165.77	19.79	2.5902	325

++ Regression coefficients refer to the equation: $Y = ax + bx^2 + cx^3 + dx^4 + ex^5$

except for tests marked with [m] where $Y = (ax + bx^2)/(1 + cx + dx^2)$

Y = load (N) x = displacement (mm)

* In the third field in the test identification the letter has the following meaning:

A = gypsum board mounting device,
B = mounted on 38 mm of polystyrene,
D = damaged gypsum board.

4.11.2 Summary of Fatigue Test Results

The mean compression and tension cavity displacement results were listed in Table 4.11 for each tie at the end of each stage of repeated loading. These mean values where based on the three test repetitions for each tie as illustrated in Figures 4.50 to 4.53. As can be seen, all ties reached a reasonably stable condition after 1000 cycles at 700 N tension and compression loading. Oddly, all failed at roughly the same average number of cycles of reversing 1000 N loads. The typical failure modes were as follows:

DLA - fracture of the anchor plate near extended legs of the tie.

SLA - pull out of screw

WLA - pull out of screw

FLA - fracture of the flange locking part of the anchor at the slot cut into the plate.

4.12 SUMMARY

The test results for the tie tests were presented in condensed form in this chapter based on average values. Full documentation of the test data was reproduced in Appendix A. Review of that data is useful in terms of gaining an appreciation for the inherent scatter of test results for each series. Also the full behaviour beyond the arbitrarily set 4 mm displacement performance domain was included.

The influence of various factors affecting tie performance were discussed in this chapter. Further discussion, conclusion, and recommendations are provided in Chapter 5.

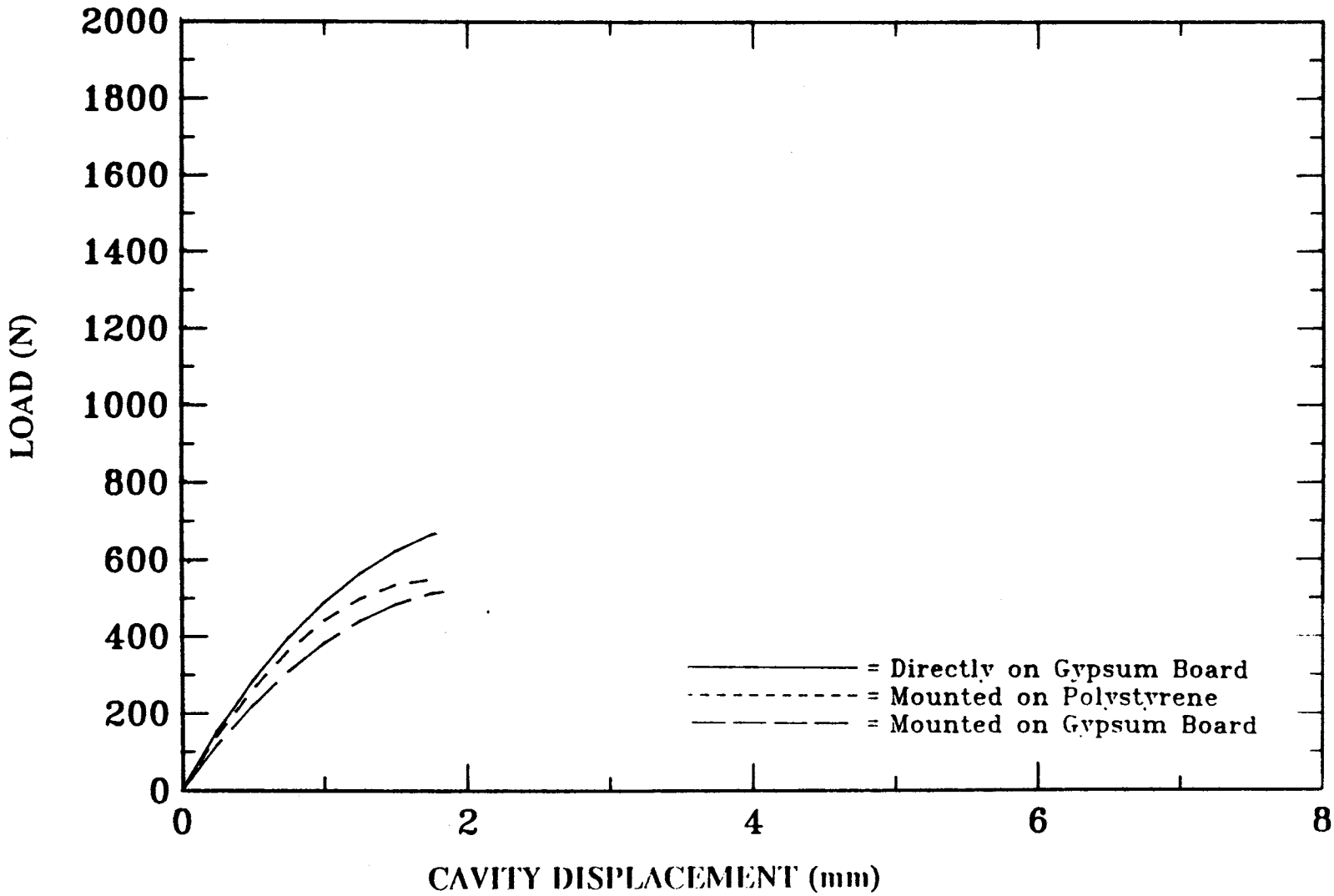


FIGURE 4.47 INFLUENCE OF WALL SHEATHING ON PERFORMANCE OF CST TIES

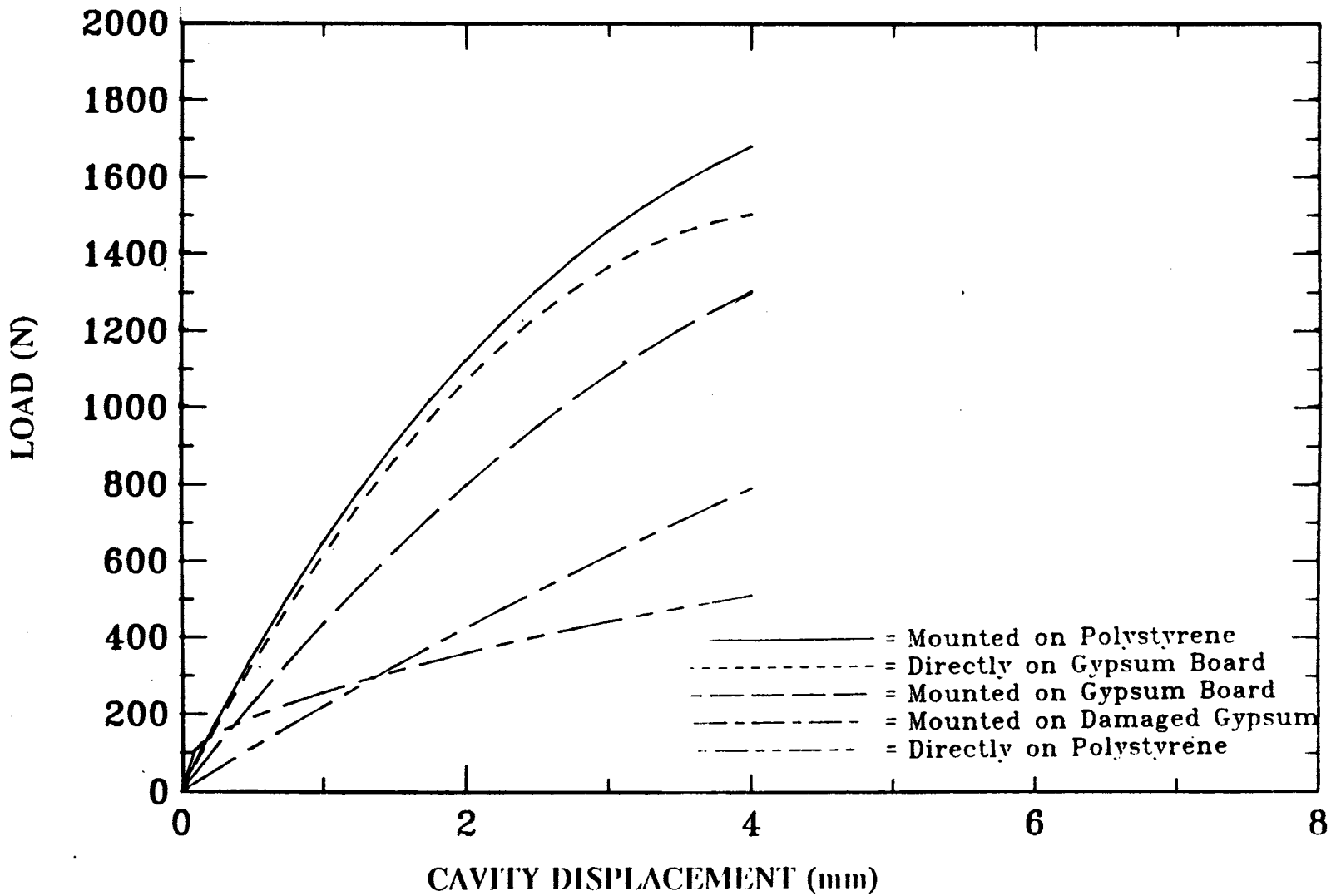


FIGURE 4.48 INFLUENCE OF WALL SHEATHING ON PERFORMANCE OF WLA TIES

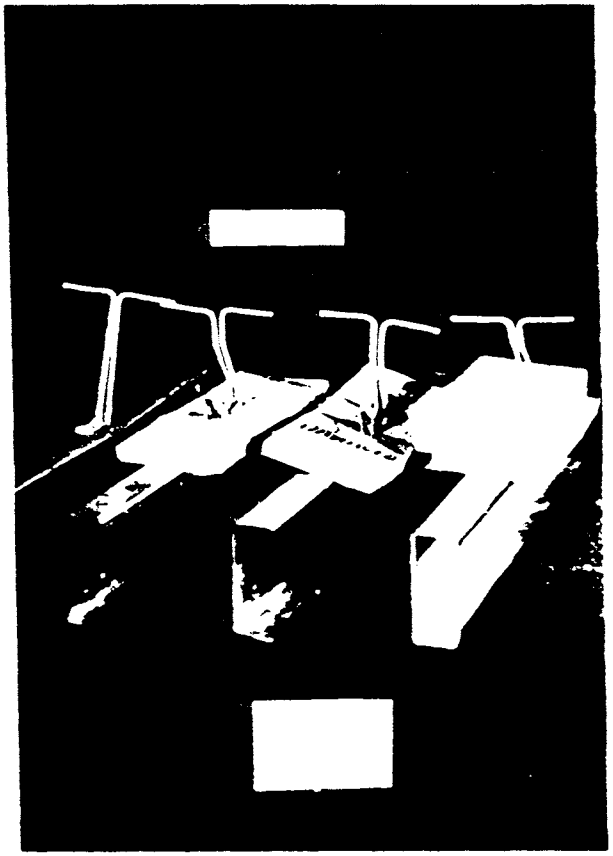


FIGURE 4.49 PHOTOGRAPH ILLUSTRATING THE INFLUENCE OF WALL SHEATHING ON BEHAVIOUR OF WLA TIE

TABLE 4.11

SUMMARY OF FATIGUE RESULTS: MEAN DISPLACEMENTS

AND

AVERAGE FAILURE CYCLES

STAGE	TIE	CAVITY DISPLACEMENTS (mm) COMPRESSION	TENSION	CYCLES TO FAILURE
1	DLA	0.3	1.3	
(+/- 400 N)	SLA	0.5	0.8	
	WLA	0.5	0.8	
	FLA	0.8	1.5	
2.	DLA	0.5	4.5	
(+/- 700 N)	SLA	1.0	2.5	
	WLA	0.9	1.4	
	FLA	0.9	3.0	
3.	DLA	1.0	6+	3525
(+/- 1000 N)	SLA	2.0	4+	2038
	WLA	1.3	4+	2500
	FLA	1.5	3+	2000

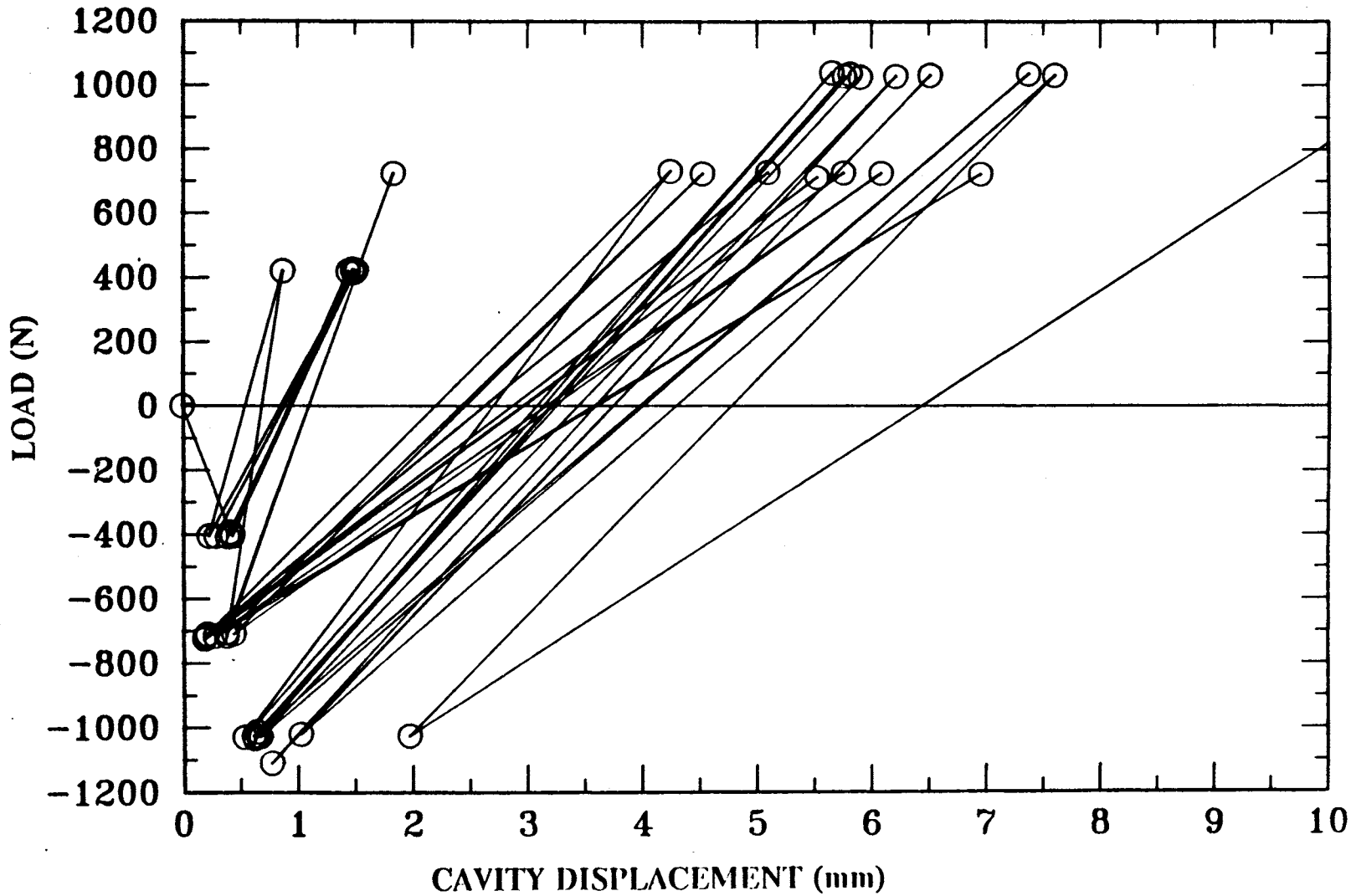


FIGURE 4.50 a) DISPLACEMENTS FOR DLA TIE UNDER FATIGUE LOADING TEST SPECIMEN 1

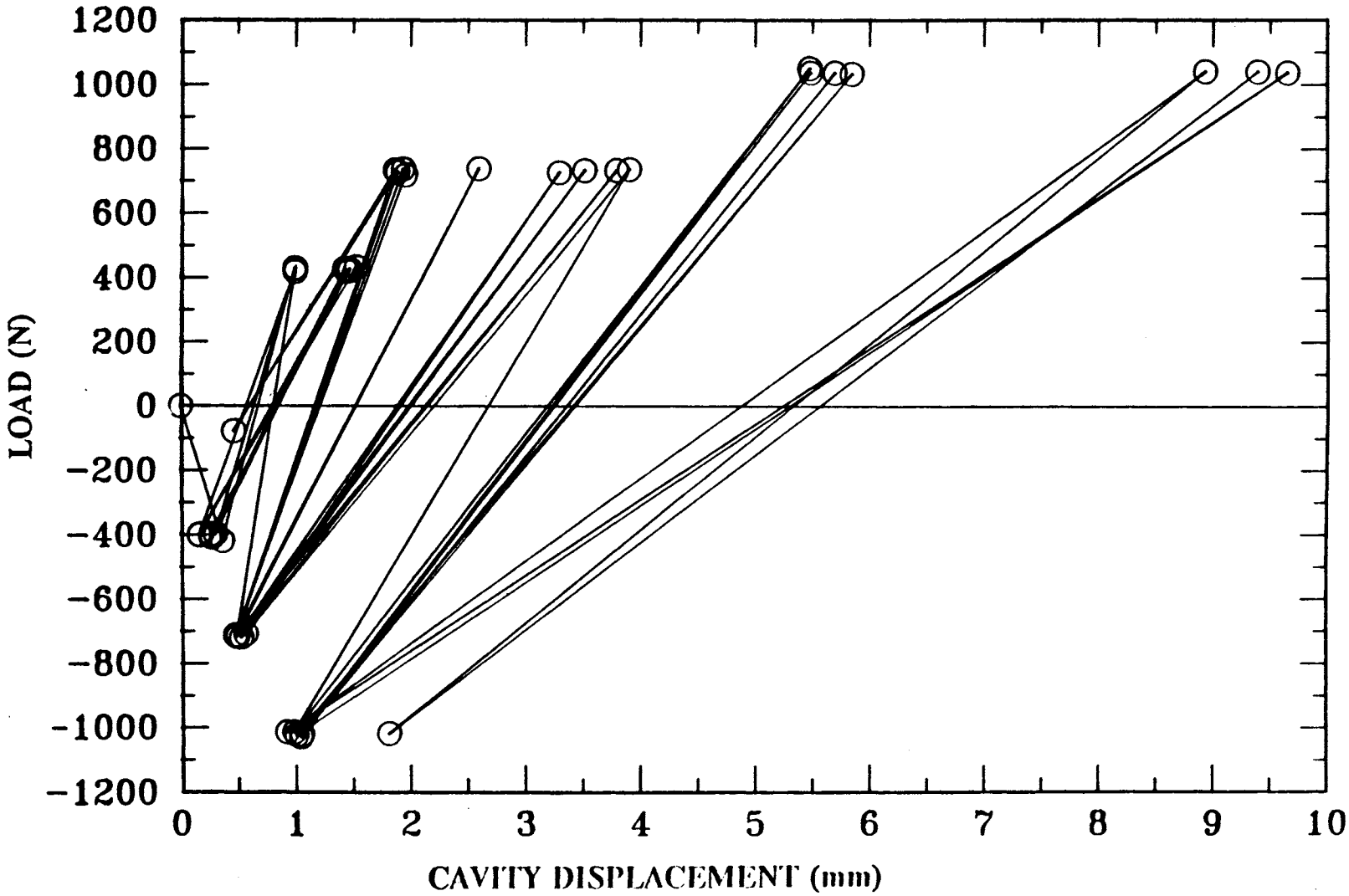


FIGURE 4.50 b) DISPLACEMENTS FOR DLA TIE UNDER FATIGUE LOADING TEST SPECIMEN 2

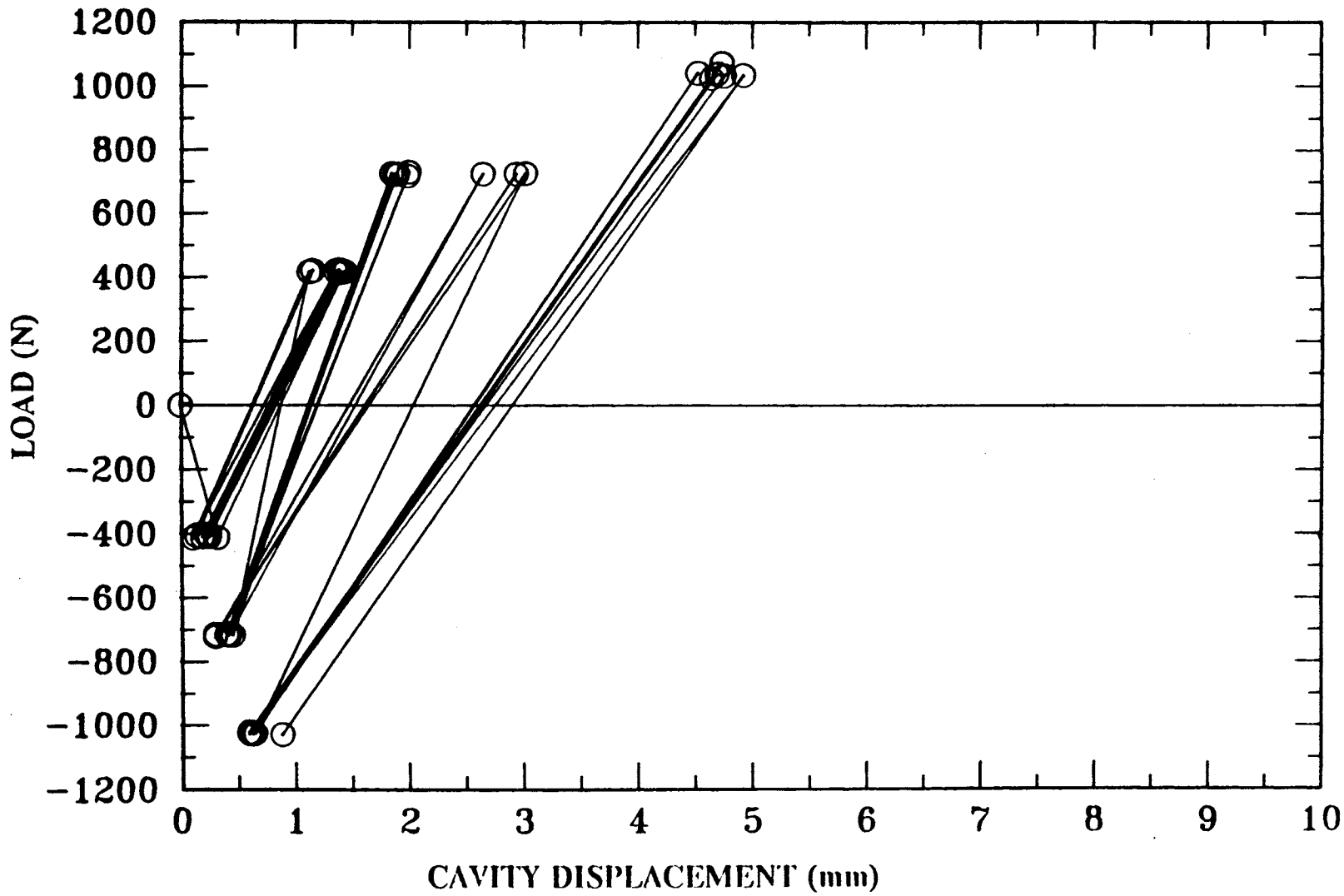


FIGURE 4.50 c) DISPLACEMENTS FOR DLA TIE UNDER FATIGUE LOADING TEST SPECIMEN 3

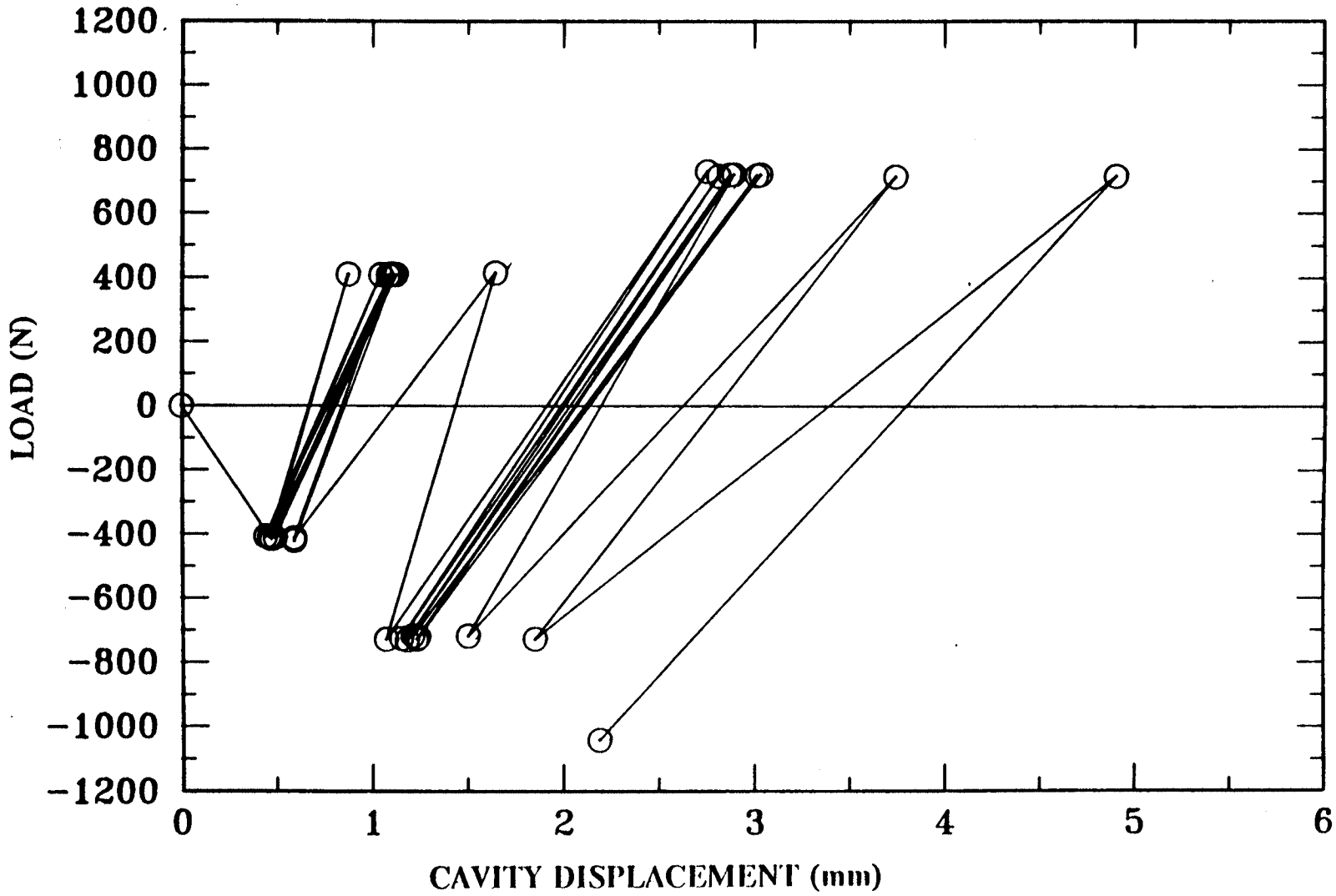


FIGURE 4.51 a) DISPLACEMENTS FOR SLA TIE UNDER FATIGUE LOADING TEST SPECIMEN 1

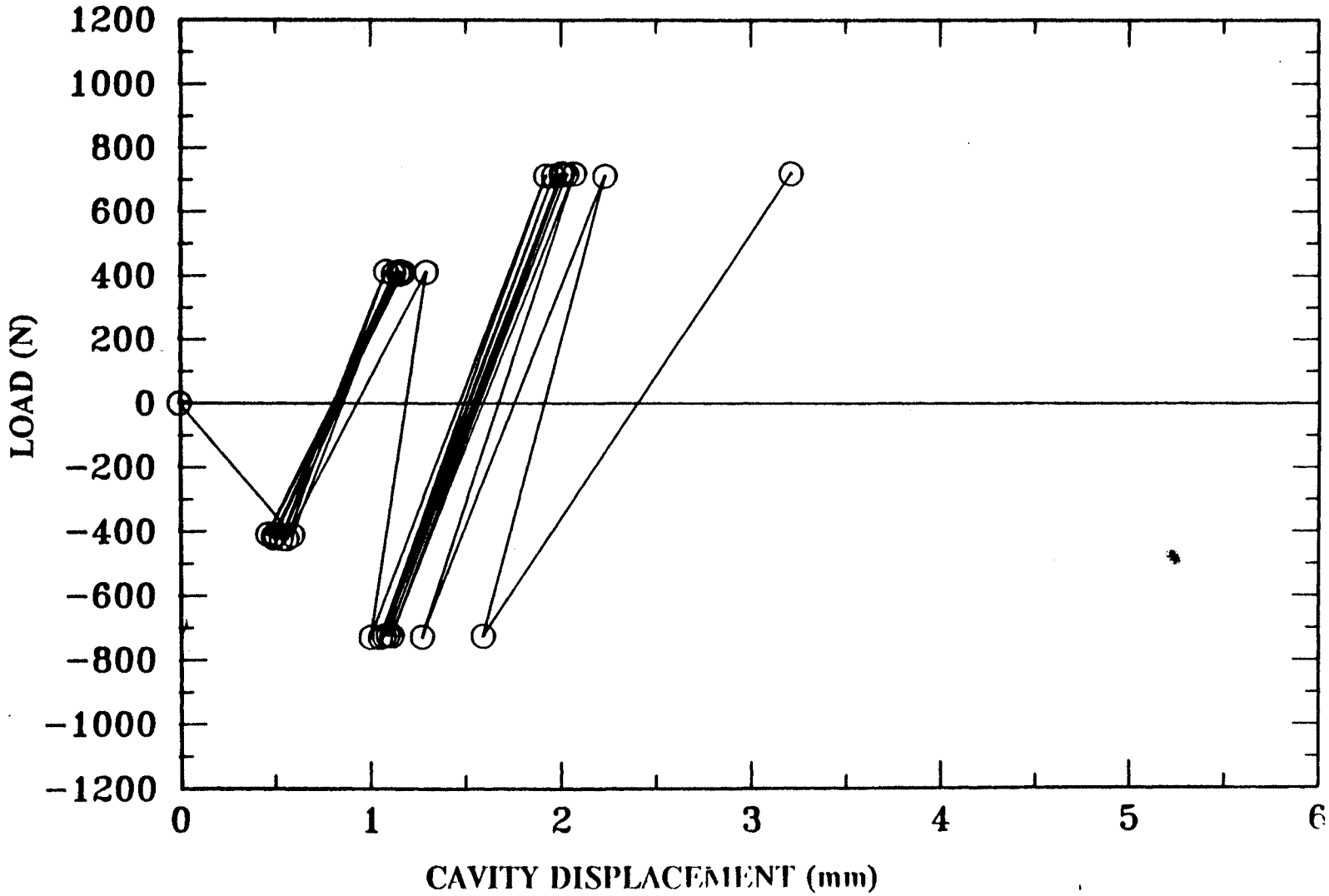


FIGURE 4.51 b) DISPLACEMENTS FOR SLA TIE UNDER FATIGUE LOADING TEST SPECIMEN 2

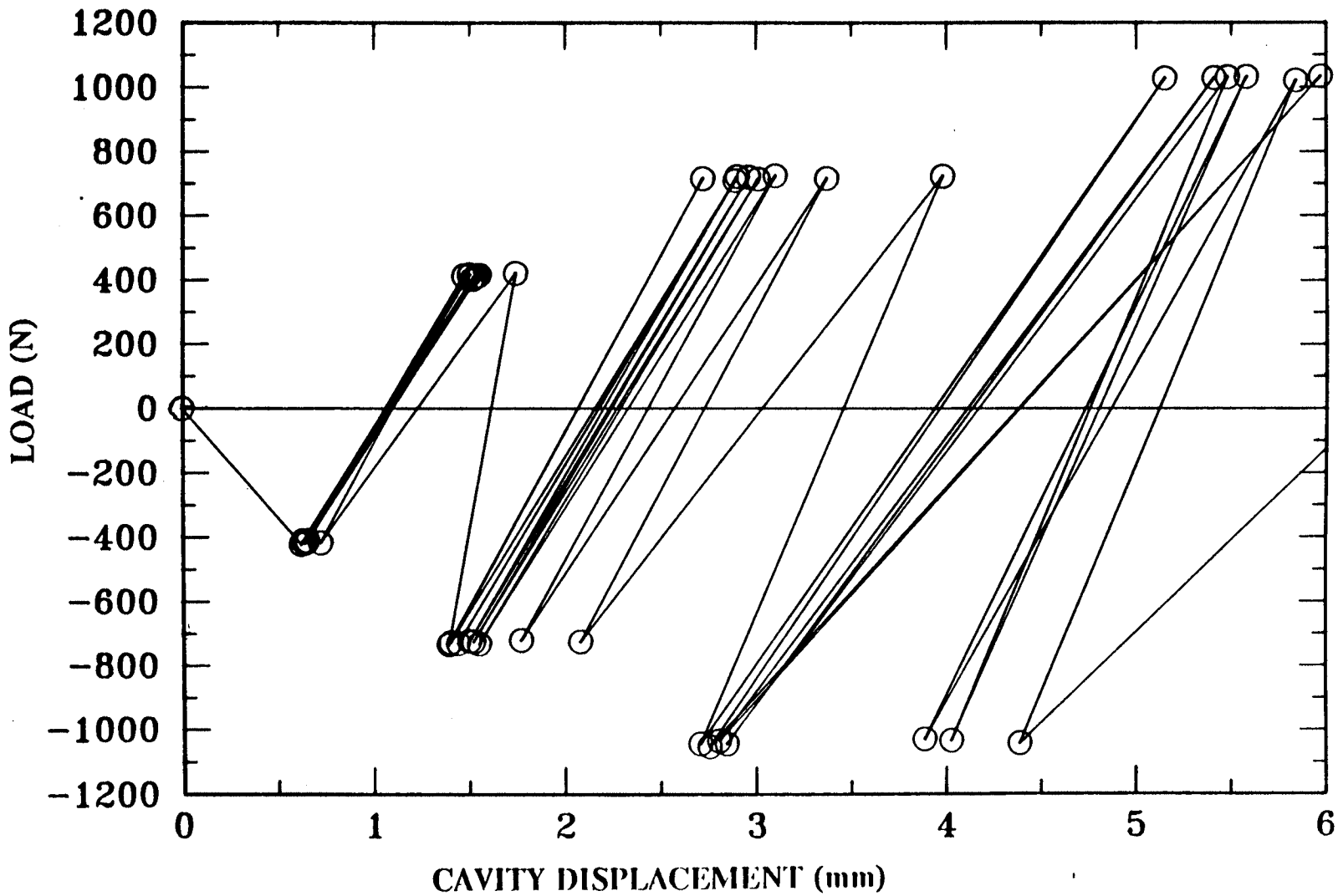


FIGURE 4.51 c) DISPLACEMENTS FOR SLA TIE UNDER FATIGUE LOADING TEST SPECIMEN 3

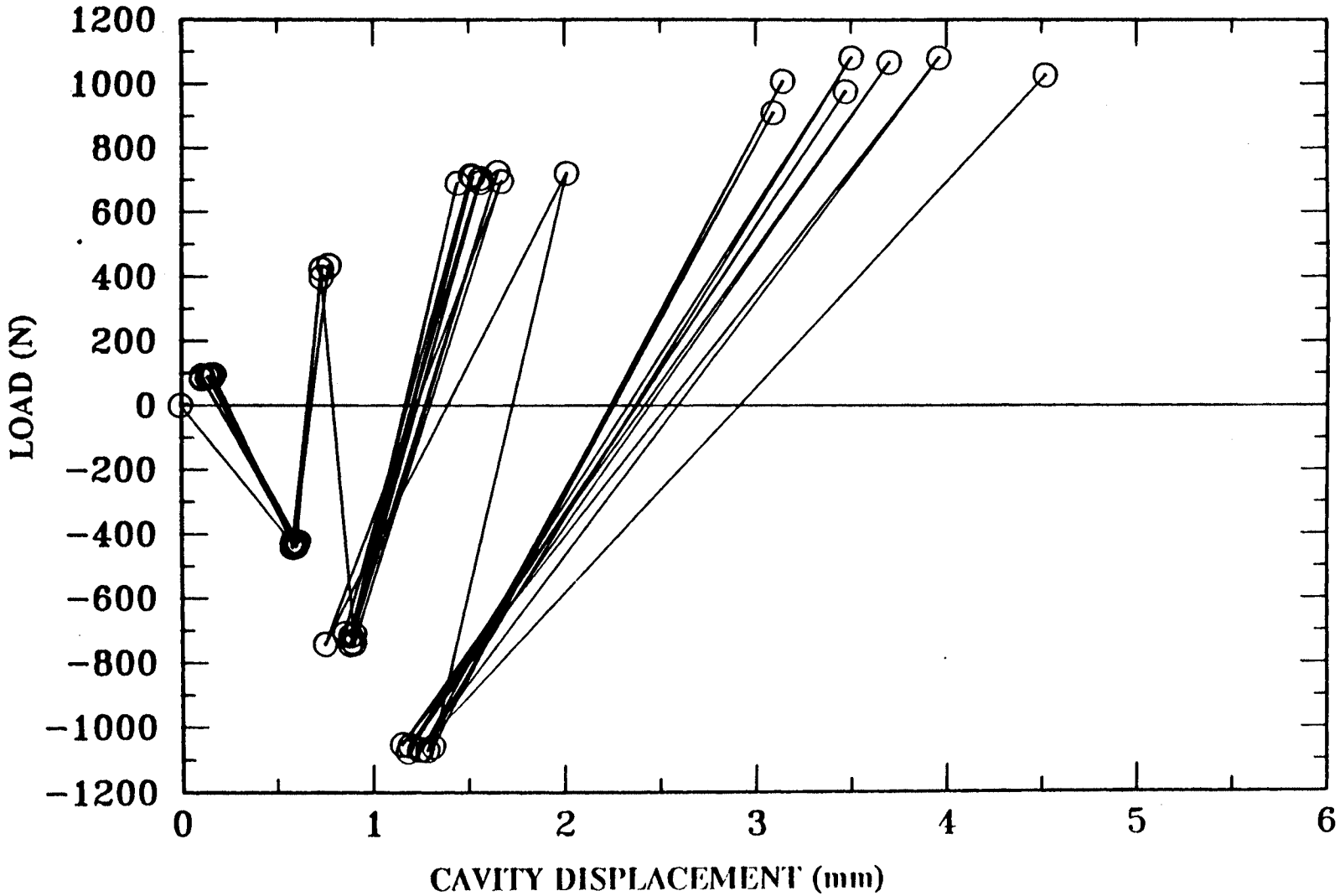


FIGURE 4.52 a) DISPLACEMENTS FOR WLA TIE UNDER FATIGUE LOADING TEST SPECIMEN 1

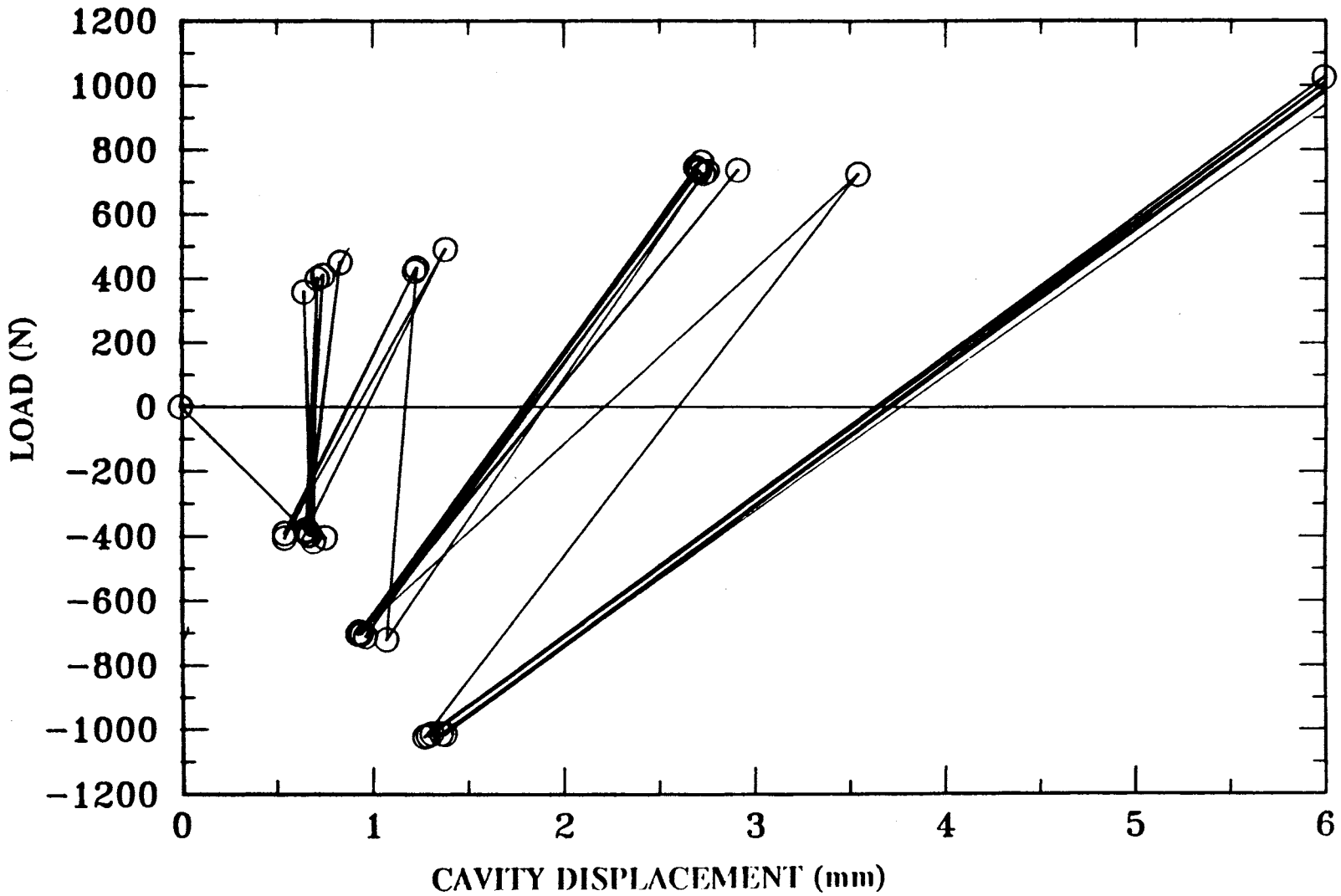


FIGURE 4.52 b) DISPLACEMENTS FOR WLA TIE UNDER FATIGUE LOADING
TEST SPECIMEN 2

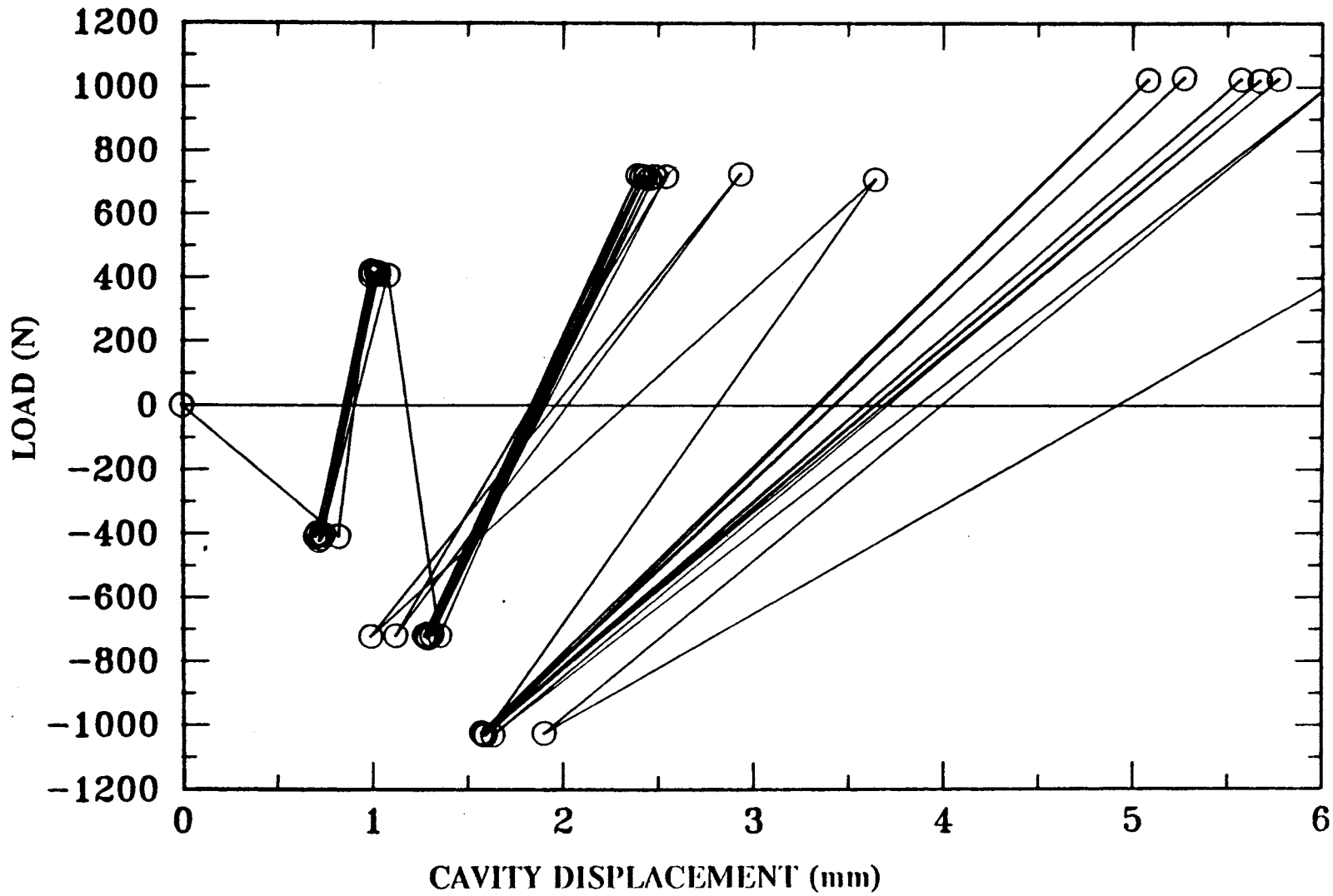


FIGURE 4.52 c) DISPLACEMENTS FOR WLA TIE UNDER FATIGUE LOADING TEST SPECIMEN 3

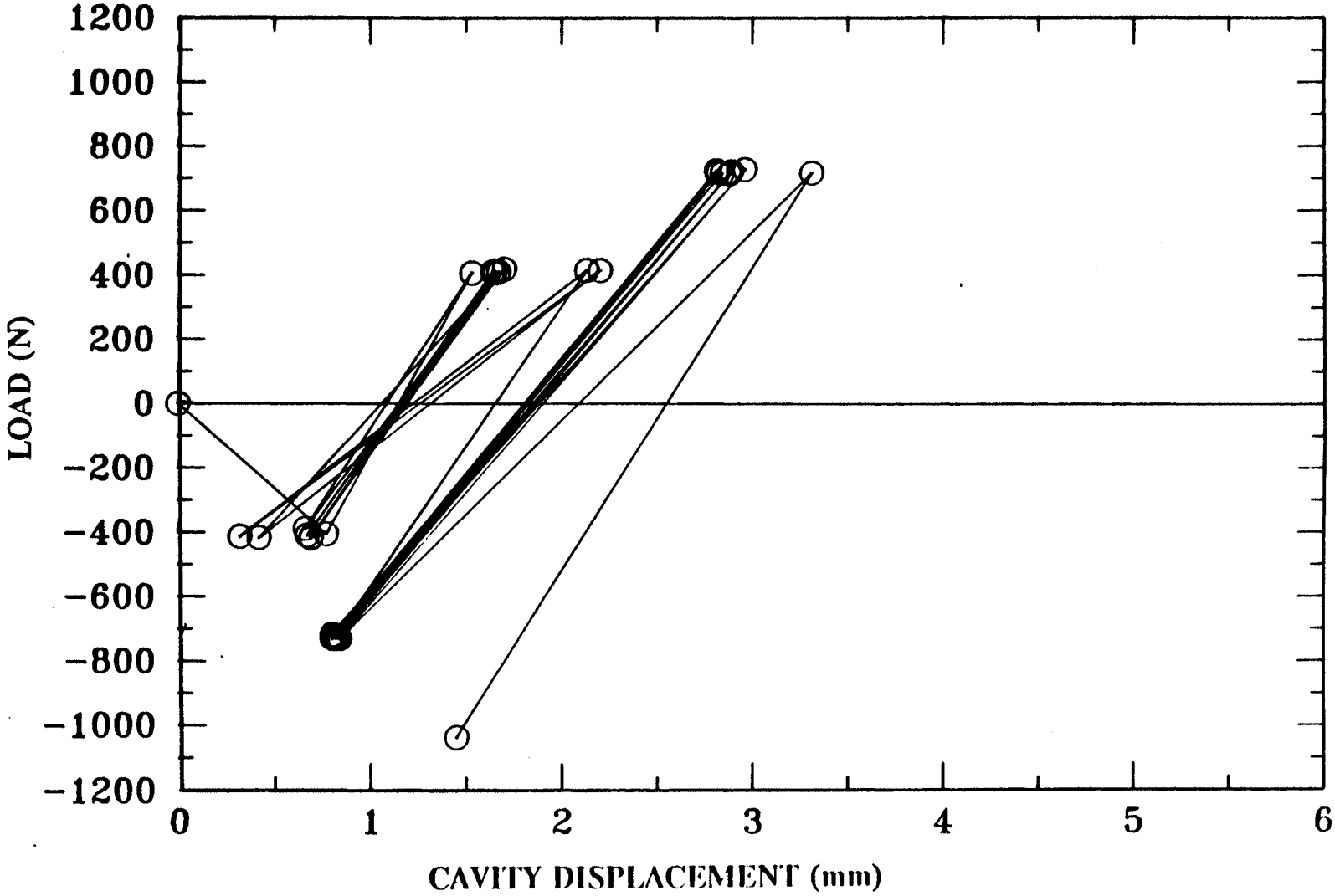


FIGURE 4.53 a) DISPLACEMENTS FOR FLA TIE UNDER FATIGUE LOADING TEST SPECIMEN 1

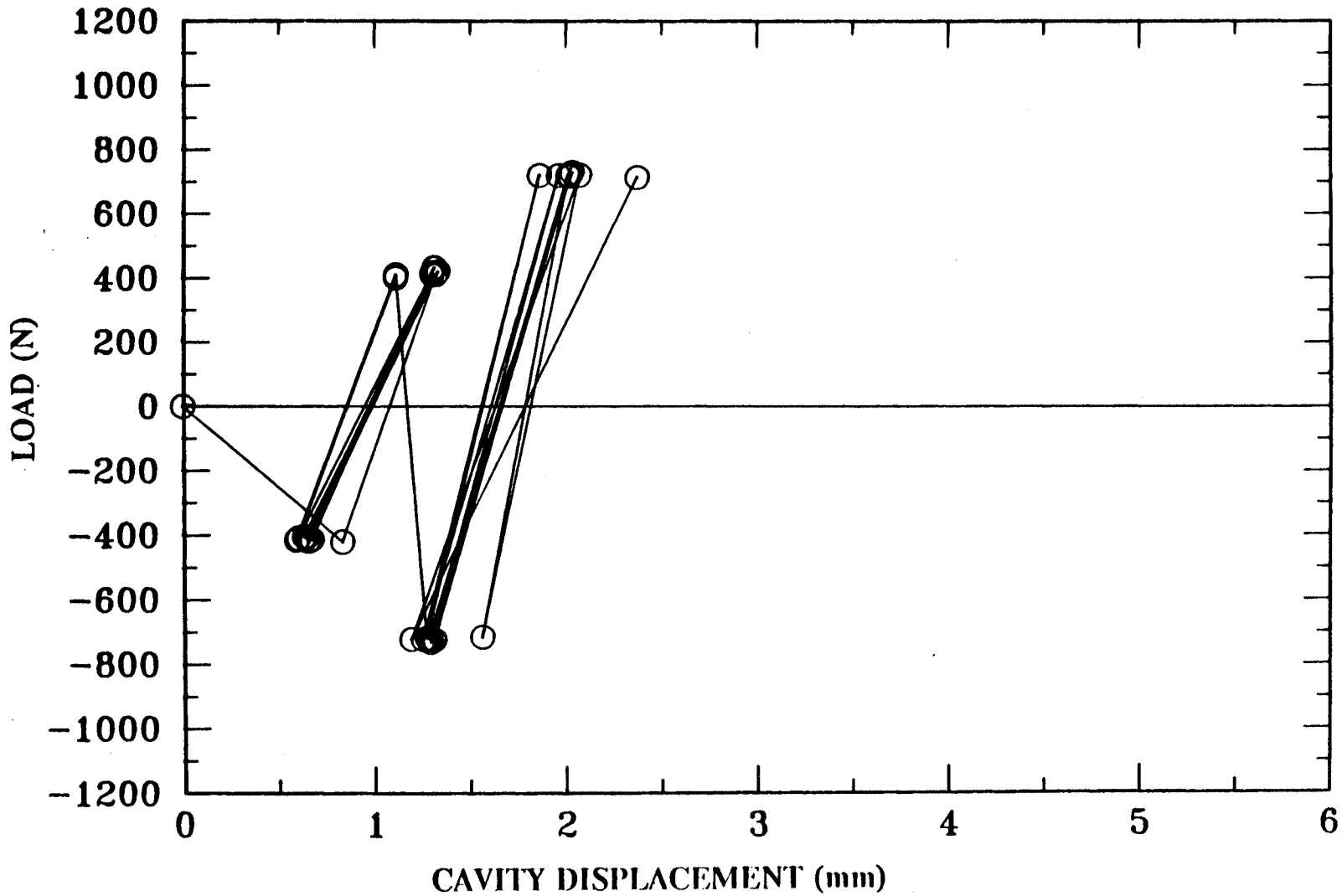


FIGURE 4.53 b) DISPLACEMENTS FOR FLA TIE UNDER FATIGUE LOADING TEST SPECIMEN 2

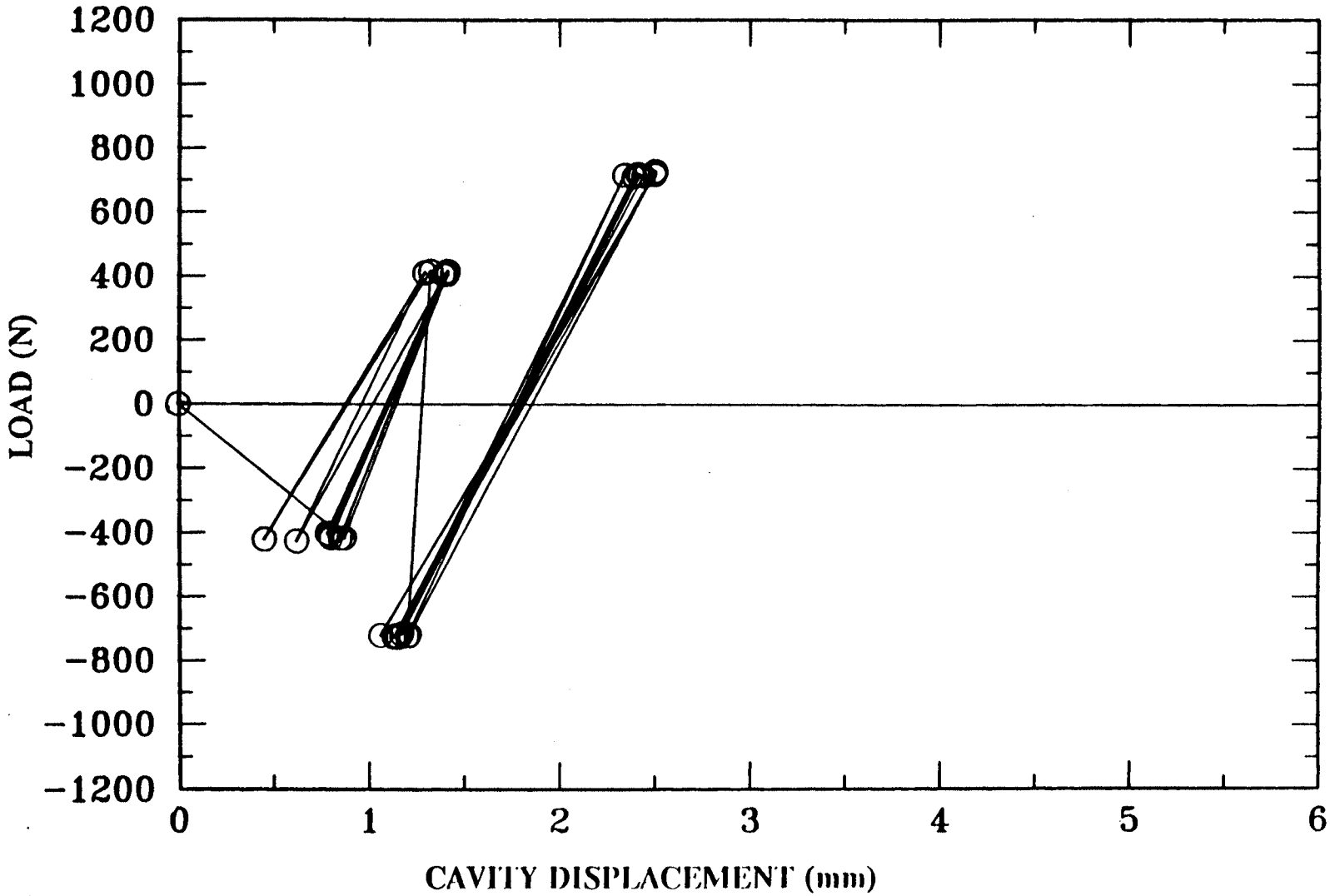


FIGURE 4.53 c) DISPLACEMENTS FOR FLA TIE UNDER FATIGUE LOADING TEST SPECIMEN 3

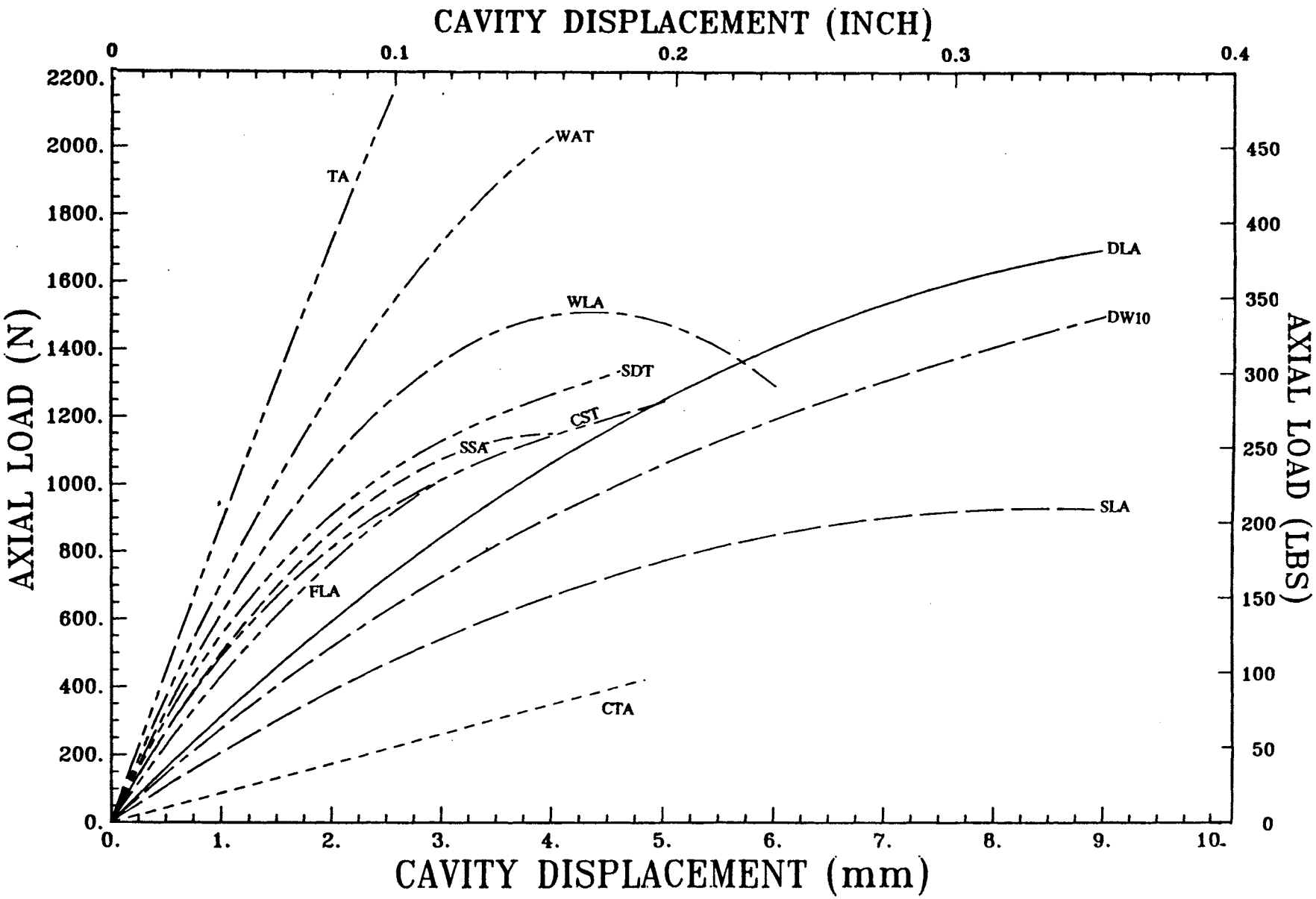


FIGURE 5.1 TENSILE BEHAVIOUR OF BV/SS WALL TIES

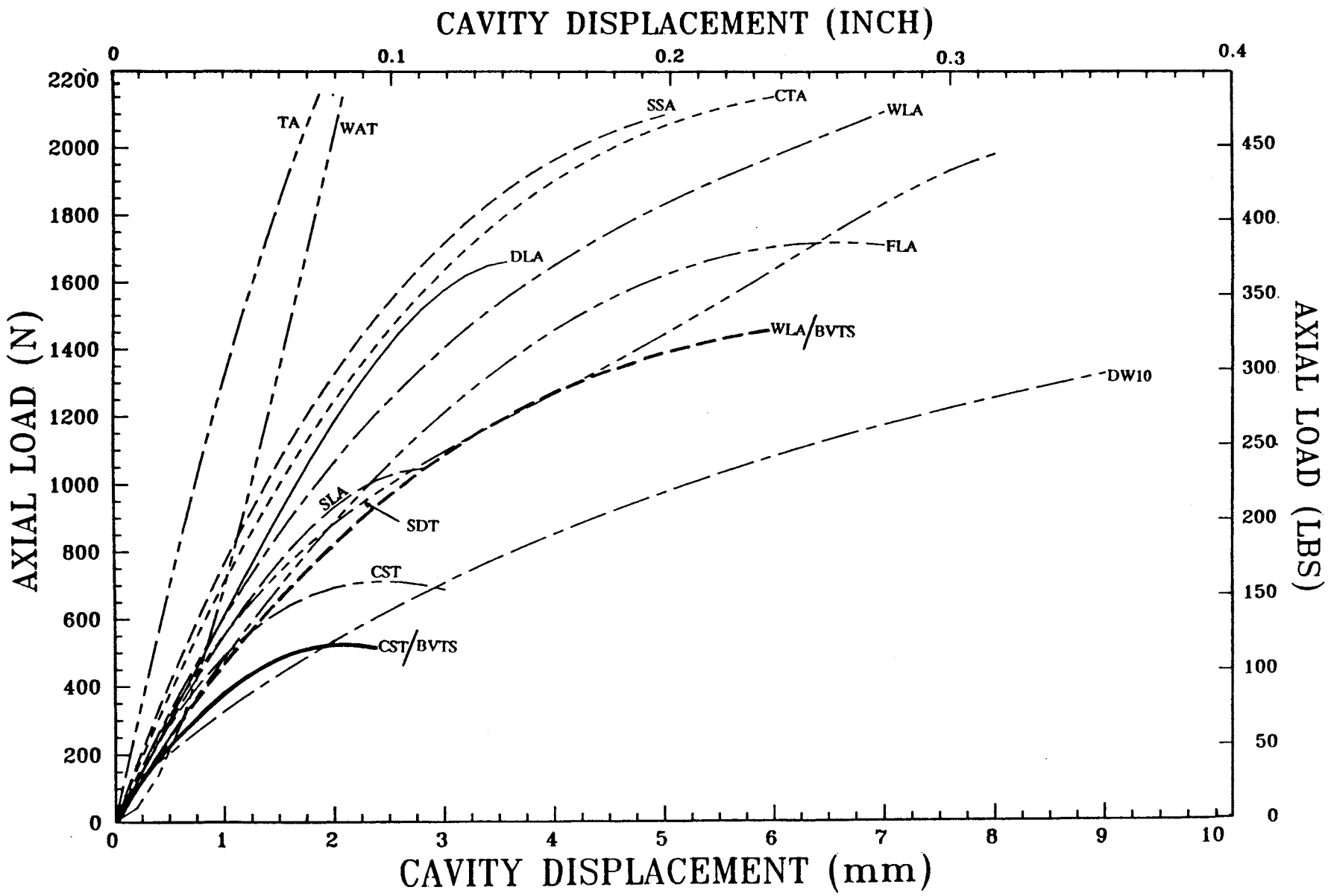


FIGURE 5.2 COMPRESSIVE BEHAVIOUR OF BV/SS WALL TIES

backup walls such as steel stud construction, the non-uniform distribution of tie loads is much more pronounced and creates a much more critical situation because the stiffer brick veneer resists the largest part of the lateral load regardless of whether the wind pressure is on the veneer or the backup wall[13]. If the brick veneer is cracked, then the very high top tie load is reduced but the tie nearest the crack becomes similarly highly loaded.

As a result of the above, it should be apparent that BV/SS ties must be designed to transfer loads which are much larger than those associated with the tributary area around individual ties. The magnitude of the load to be transferred will depend on the wind pressure related to the geographic location, exposure conditions and location on the face of the building, as well as to the span of the veneer and the relative stiffness between the brick veneer and the steel stud backup. This means that, unless it is considered to be satisfactory to have relatively conservative designs for most cases in order to satisfy extreme loading situations, no simple capacity requirement can be stated. This topic will be discussed further in Section 5.3.

5.1.3 Requirements for Stiffness

Large differences in strength were noted, not just between different ties but also for different sizes, cavity widths, locations of adjustment, attachment locations and sheathing materials for individual ties. Similarly large differences in stiffness were documented and study of the graphical presentations of this data clearly shows that some strengths are relatively meaningless where they correspond to very large displacements. Therefore it seems sensible to try to define a "Performance Domain" within which to judge the characteristics of ties. In this

research, a performance domain of 4 mm displacement was arbitrarily selected but was considered to be a sensible limit.

Computer analyses[7,13] of wall systems have shown that, within reason, less stiff ties result in slightly lower tie loads and bending stresses in the veneer. An explanation is that the softer ties act "somewhat like shock absorbers" and result in a slightly more uniform distribution of the tie loads. However a certain minimum stiffness is required to ensure that movement of the veneer does not result in other problems such as fatiguing of components including non structural items such as caulking. In this regard, the performance recommendation of BIA[4] that ties develop 100lb. resistance at a displacement of less than 0.05 in. (444 N @ 1.2 mm) seems a reasonable compromise and a good starting point.

An added consideration for limiting the deformation of the tie under load is related to control of crack size. When veneer deflection is significantly more than the steel stud deflection as a result of tie deformation, the width of the crack in the veneer will be proportionally larger.

5.1.4 Construction Requirements

In the past, probably the single most dominant factor in choice of ties for construction has been economy both in terms of cost of the tie and in terms of time and convenience of installation which also has a cost value. The development of two component ties addresses convenience of use where interference of the ties with construction of the veneer is eliminated. Where adjustability is also incorporated, there is less dependence on careful positioning of the portion attached to the backup. Therefore these factors have been important in the development of BV/SS tie systems.

As a result of increased interest and discussion by the design professions, building officials and standards committees, other factors have begun to be recognized as equally important. Besides possessing some yet undefined minimum level of strength and stiffness, interactions of the ties with the building envelope have been identified. Where exterior sheathing is used, the provisions for placing the sheathing after the ties are fastened to the steel studs must be practical. Alternately, ties which are attached after the sheathing is in place must be designed to account for the mounting mechanism. In both cases the interactions of these ties with air and vapour barriers must be considered.

5.1.5 Other Considerations

Galvanizing of ties to provide corrosion protection is a standard requirement. However, it must be recognized that galvanizing is a sacrificial form of protection and, in corrosive environments, the protection will eventually be used up. Therefore, particularly for buildings which are expected to remain in use for long periods of time, use of stainless steel or other materials or methods of protection have become more common.

A consideration for tie design not previously dealt with in the subject of vulnurability. This can be assessed from many different aspects:

- robustness of the tie to stand up to field handling
- sensitivity to installation practices (i.e. overturning of screws, location of attachment and misalignment)
- potential for and consequences of failure (i.e. corrosion of screw hole, disingagement of tie)
- redundancy or otherwise ability to retain load carrying properties under damaged or overloaded conditions.

In view of the above, it can be appreciated that the increased awareness of the importance of ties to the long term performance of BV/SS walls has been and is leading to a more thorough consideration of design requirements.

5.2 DISCUSSION OF THE TEST RESULTS

5.2.1 General

In this section the discussion is focussed on general trends and on comparisons with performance recommendations for wall ties. Although no specific Canadian building code provisions exist to cover load capacity or minimum stiffness requirements for BV/SS ties, there have been some proposals [5.28]. Performance recommendations from the Brick Institute of America[5] specify that the tie be able to resist a load of 444 N (100 pounds) at a displacement of 1.2 mm. Whether the 1.2 mm of displacement should include the mechanical play inherent in most adjustable tie systems is questionable. However, such a restriction is not practical at this time since typical values for mechanical play for many of the currently available ties are 0.8 to 1.2 mm.

The tests were conducted so that the displacements did not include mechanical play. In part, this procedure was followed because anticipated future stiffness requirements may result in much reduced magnitudes of mechanical play.

5.2.2 Ultimate Load and Performance Stiffness

Where applicable, the mean ultimate capacity of each tie was listed in the tables in Chapter 4. However the use of this single parameter to compare ties

would be a mistake. For instance, although the CTA tie is one of the stronger ties, a closer examination reveals that its performance is well below BIA's definition of adequate stiffness. The regression equation coeffiecients were provided to facilitate further comparison at various limits of allowable displacement. In addition, the stiffness values obtained by dividing the loads at 1.2 mm displacement by 1.2 mm is a meaningful basis for comparison of tie properties in the service range of loading. In this way, some absolute requirement for stiffness may be evaluated.

From review of the test data, it is clear that no tie has a unique load-displacement relationship. In fact many factors can cause dramatic changes in behaviour. Probably the most significant of these factors is the influence of adjustability of the tie. From Figure 5.3, which contains results for the ties specifically designed to incorporate adjustability, the range of behaviour is apparent. This observation applies both to the range of adjustability for a tie and to the differences between ties.

As an aid to comparing the performance of the previously defined classes of adjustable ties, a performance index (PI) has been defined. This index is an indicator of sensitivity of tie stiffness to use within its adjustable range. In interpreting the index, a value of 1.0 represents a tie for which stiffness is independent of adjustment, whereas lower values indicate increased sensitivity to adjustment. The index is calculated as :

$$PI = 1 - \frac{\text{(maximum stiffness - minimum stiffness)}}{\text{maximum stiffness}}$$

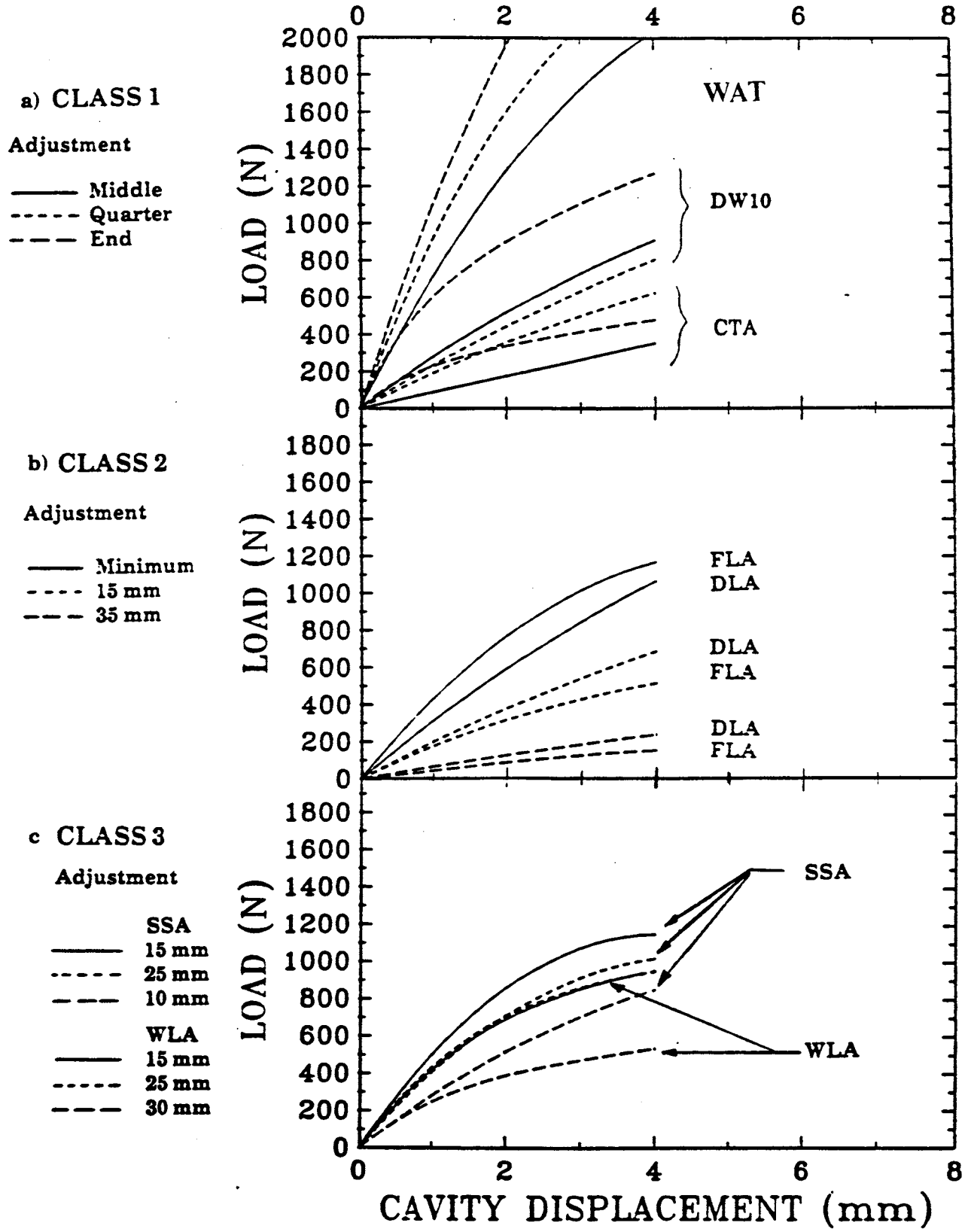


FIGURE 5.3 TENSILE TEST RESULTS FOR TIES WITH ADJUSTABLE RANGE

As an arbitrary but reasonable basis for comparison, mean PI values were calculated over the 0 to 4 mm displacement range.

The PI bar chart shown in Figure 5.4 permits comparisons between these 7 ties and between the classes of ties classified in terms of mechanism for adjustability. It can be observed that the CLASS 2 ties (relying on a wire pintle) performed very poorly compared to the others.

It is important to note that adjustability alone is not the only means of measuring a tie's performance. For instance, a comprehensive method of indexing BV/SS wall ties should also address the method and location of attachment. In this case, an attachment index (AI), rating of the CLASS 3 ties, (attached over the exterior sheathing) would likely be lowest as a result of increased probability of poor attachment and difficulty with accurate positioning on the stud flange.

Other factors such as misalignment, potential for improper installation (ie. incorrect bend point in a corrugated strip tie) and site damage could be included in a workmanship index (WI) rating.

Whether or not some formal rating system can be developed to aid in setting standards for design of ties, it is apparent that standards are needed. The next section deals with recommendations derived from the observations and conclusions of this BV/SS tie test program.

CHAPTER 5

DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

5.1 DISCUSSION OF REQUIREMENTS FOR THE BV/SS TIES

5.1.1 General Observations

One of the most obvious findings from this research is that all types of ties are not equal. This finding is very graphically shown in Figures 5.1 and 5.2 where mean tension and compression results were plotted using the mid range of adjustment for adjustable ties. In large part, this wide range of strength and stiffness can be attributed to the lack of established standards for design of ties. As a result, manufacturers have used criteria for design of BV/SS tie systems which differ markedly in the factors which seem dominant.

5.1.2 Requirements for Strength

Historically, the concept of a tie transferring load from a tributary area on the veneer (defined by horizontal and vertical tie spacings) to the backup wall has led to building code requirements specifying uniform maximum tie spacings for a few defined cases. Such a concept does lead to the conclusion that high tie loads are not encountered and that there is little difficulty in satisfying the strength requirements. However, even for a rigid backup wall such as reinforced concrete or concrete block, tie loads are far from uniform with the top tie resisting around half of the portion of lateral load carried by the veneer in bending. For flexible

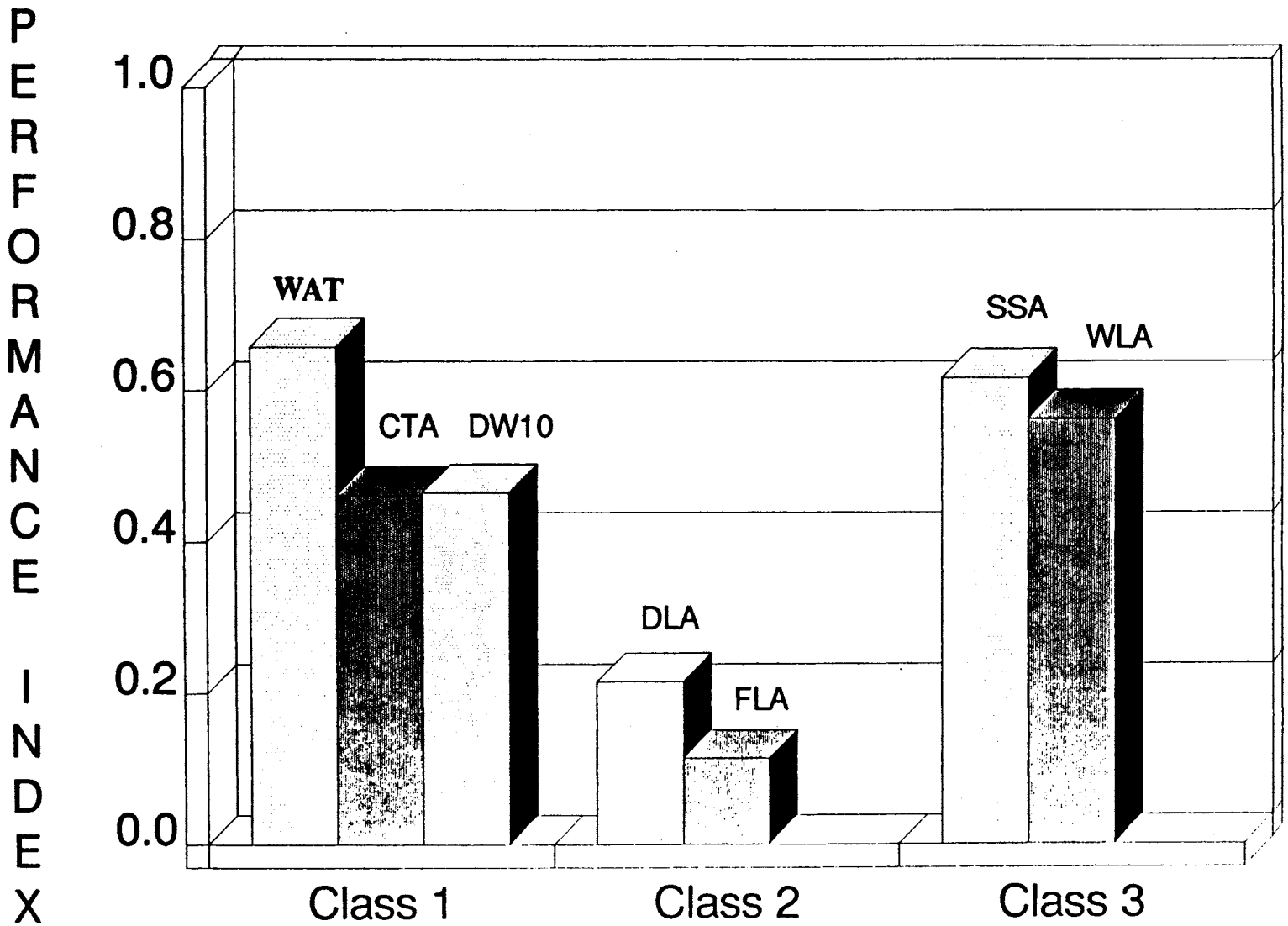


FIGURE 5.4 PERFORMANCE INDEX FOR ADJUSTABLE TIES

5.3 CONCLUSIONS AND RECOMMENDATIONS

5.3.1 Conclusions

Tie strengths and stiffnesses can be significantly affected by:

- positioning within the adjustable range,
- location of attachment on the steel studs,
- type of sheathing where ties are not directly attached to the studs,
- cavity width,
- gauge of the steel stud,
- misalignment or improper installation,
- and, although not included as part of this study, long term deterioration.

At the extremes of their adjustability, several of the tested ties have very low capacities and would not be adequate to resist the wind forces generated at top ties or at ties near veneer crack locations. Also many of the configurations tested did not satisfy the suggested maximum 1.2 mm displacement at a load of 450 N. As a result, it is recommended that prior to specifying a wall tie, test data be reviewed to ensure that it can perform its intended function at all possible degrees of adjustment and attachment locations. This requirement in itself would serve to place controls on the amount of adjustment possible for some ties.

At present CAN3-A370-M84[8] does not provide sufficient guidance for either tie manufacturers or designers to evaluate ties in a consistent manner. Therefore there is an identified need for this connector standard to be updated to include BV/SS type ties. However, consideration of tie requirements must be co-ordinated with other building code work to define overall strength and stiffness

requirements for the BV/SS wall system. In addition, due consideration must also be given to developing appropriate construction standards.

5.3.2 Recommendations

The general overall recommendation arising from this research is that BV/SS ties must be designed for the loads and conditions under which they are intended to be used. This requires that designers have access to reliable information on strength and stiffness. Where recommendations for arbitrary spacings and tie stiffnesses and strengths are provided as a design aid, these must be based on a comprehensive analysis of the influences of all the previously mentioned variables for the range of application of these aids.

In order that reliable and consistent information can be made available to code writing bodies and designers, it is necessary that standard test and reporting procedures be followed. It is suggested that the procedures shown in this report can serve as a guide to development of such a standard. In this respect it is very important that ties be evaluated as part of a system including steel stud, sheathing material, and screws or other attachment mechanisms. The characteristics of the tie should then be provided for the full range of adjustment, attachment location and misalignment.

5.4 CLOSURE

This research was carried out with the complete co-operation and openness of the tie manufacturers mentioned in the acknowledgements. Information provided here which reveals large differences in behaviour characteristics for various types of ties is indicative of the general problem that has become associated with BV/SS construction. Construction simply preceeded adequate research and the development of accepted standards for design and construction. It is anticipated that the test results and comments provided in this report will help interested parties reach a consensus on how to correct the current unsatisfactory situation.

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APPENDIX A

TABLE A.1 TESTS ON TIE MATERIALS

Tensile Tests on Coupons from Steel Plate Part of Tie

Specimen	Thickness in	Width in	Area in^s	Yield Load lbs	Yield Stress ksi	Mpa
T1-1	0.074	0.379	0.028	1157.4	41.3	294.1
-2	0.074	0.380	0.028	1157.4	41.2	293.5
-3	0.074	0.378	0.028	1135.4	40.8	290.1
mean =	41.110	st. dev.=	0.295	cov =	0.7%	
T2-1	0.122	0.370	0.045	1896.0	41.8	297.6
-2	0.123	0.373	0.046	1918.0	41.9	297.8
-3	0.123	0.370	0.045	1873.9	41.3	293.8
mean =	41.650	st. dev.=	0.330	cov =	0.8%	
T3-1	0.073	0.208	0.015	1047.2	68.8	489.5
-3	0.073	0.200	0.015	1036.2	70.7	503.4
-2	0.075	0.209	0.016	970.0	62.3	443.4
mean =	62.270	st. dev.=	4.417	cov =	6.6%	
T4-1	0.061	0.303	0.019	793.7	42.7	303.6
-2	0.061	0.303	0.019	749.6	40.4	287.4
-3	0.061	0.303	0.018	804.7	43.8	311.9
mean =	42.280	st. dev.=	1.750	cov =	4.1%	
T6-1	0.078	0.377	0.029	1477.1	50.2	357.6
-2	0.079	0.377	0.030	1532.2	51.6	367.1
-3	0.080	0.376	0.030	1598.3	53.3	379.0
mean =	51.712	st. dev.=	1.520	cov =	2.9%	
T7-1	0.078	0.374	0.029	1477.1	50.6	360.3
-2	0.077	0.374	0.029	1477.1	51.0	363.2
-3	0.078	0.374	0.029	1499.1	51.5	366.9
mean =	51.198	st. dev.=	0.318	cov =	0.6%	
T9-1	0.069	0.124	0.009	418.9	48.7	346.7
-2	0.070	0.125	0.009	451.9	52.0	369.8
-3	0.070	0.124	0.009	429.9	49.7	353.6
mean =	50.120	st. dev.=	1.668	cov =	3.3%	
T12-1	0.076	0.372	0.028	1741.6	61.3	436.6
-2	0.076	0.372	0.028	1708.6	60.6	431.1
-3	0.077	0.371	0.029	1719.6	60.2	428.4
mean =	60.700	st. dev.=	0.586	cov =	1.0%	

Tensile Tests on Wire Part of Tie

Specimen *	Diameter in	Width in	Area in^s	Yield Load lbs	Yield Stress ksi	Mpa
TD-1	0.185		0.027	2568.4	95.2	677.8
-2	0.185		0.027	2866.0	106.6	758.8
-3						
mean =	100.900	st. dev.=	8.050	cov =	8.0%	
TL-1	0.186		0.027	2392.0	88.4	629.2
-2	0.181		0.026	2303.8	89.2	635.1
-3						
mean =	88.860	st. dev.=	0.552	cov =	0.6%	
TS-2	0.185		0.027	1873.9	69.9	497.2
-3	0.189		0.028	2017.2	72.2	513.9
-1						
mean =	71.030	st. dev.=	1.659	cov =	2.3%	
TT-1	0.188		0.028	2458.1	88.6	630.9
-2	0.187		0.027	2469.2	90.1	641.2
-3	0.190		0.028	2524.3	88.8	632.3
mean =	89.190	st. dev.=	0.792	cov =	8.9%	

* TD = double leg wire pintle
TL = wire loop anchor (WLA)
TS = single leg wire pintle
TT = triangular wire tie

Test T-1-1

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.41	149.22	0.31	113.41	0.33	176.08	0.17	155.19	0.30	182.05
0.85	334.25	0.59	310.38	0.61	346.19	0.46	295.46	0.54	280.53
1.05	447.66	0.78	459.60	0.72	402.89	0.82	465.57	0.96	537.19
1.25	564.05	0.87	578.97	1.08	698.35	1.23	695.37	1.23	677.46
1.58	716.26	0.97	689.40	1.31	829.66	1.32	787.88	1.45	772.96
1.83	856.52	1.04	796.83	1.65	1056.48	1.57	1023.65	1.79	892.34
2.00	946.05	1.23	972.91	2.07	1292.25	1.75	1131.09	2.17	1038.57
2.29	1157.95	1.42	1092.29	3.45	1456.39	2.03	1369.84	2.89	1172.87
2.68	1351.93	1.63	1262.40			2.41	1525.03	4.72	1435.50
3.08	1563.83	1.85	1429.53			2.58	1605.61		
3.79	1754.83	2.18	1545.92			2.91	1701.11		
		2.56	1662.31						

Test T-1-2

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.08	158.17	0.81	158.17	1.24	116.39	0.40	205.92	0.26	182.05
1.59	379.02	1.08	283.52	1.48	274.56	1.28	295.46	0.49	310.38
1.96	599.86	1.75	537.19	1.82	450.64	1.79	495.41	0.76	483.47
2.35	784.90	2.82	722.22	2.31	593.90	2.26	578.97	1.22	608.82
2.95	928.15	3.44	883.38	2.78	746.10	2.65	692.38	1.91	737.15
3.61	1059.46	4.30	1038.57	3.32	883.38	3.06	817.73	2.60	907.26
4.60	1160.93	5.18	1199.73	4.05	1011.71	3.50	955.01	3.07	1050.51
4.91	1232.56	6.00	1328.06	5.39	1178.84	4.45	1140.04	3.80	1226.59
5.62	1360.89	7.12	1492.20	6.99	1292.25	4.86	1244.49	4.71	1357.90
				8.00	1417.59	5.47	1337.01	5.55	1477.28
				9.74	1548.90	6.35	1483.25	6.03	1525.03
								6.88	1641.42
								8.24	1841.37
								9.49	1939.86

Test T-1-3A

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.44	143.25	0.31	143.25	0.67	113.41	0.81	188.02	1.51	313.36
1.07	292.47	0.91	319.33	1.01	262.63	0.94	325.30	1.88	477.50
1.73	510.33	1.81	641.65	1.18	573.00	1.12	432.74	2.10	611.80
1.95	626.72	1.98	752.07	1.45	764.01	1.45	719.24	2.33	695.37
2.75	755.05	2.20	919.20	1.65	892.34	1.53	758.04	2.58	859.51
2.94	868.46	2.68	1119.15	2.03	1098.26	1.74	862.49	2.82	943.07
3.32	1047.52	2.91	1220.62	3.85	1268.37	1.97	1050.51	4.30	1113.18
3.87	1184.81	3.12	1369.84	4.41	1486.23	2.37	1301.20	4.86	1322.09
5.54	1337.01	3.46	1507.12	4.84	1644.40	4.22	1516.08	8.84	1438.48
6.36	1492.20	3.93	1653.36	5.55	1796.61	5.05	1626.50	9.48	1480.26
		4.51	1793.62						
		4.94	1880.17						
		5.94	1907.03						

Test T-1-3B

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.66	104.45	0.96	146.24	0.68	143.25	1.12	131.31	0.83	182.05
2.67	390.96	1.54	295.46	1.77	382.00	1.52	286.50	1.26	301.42
3.06	444.68	1.93	414.83	2.21	447.66	2.68	441.69	2.38	420.80
3.67	561.07	2.38	564.05	2.78	537.19	3.34	593.90	2.49	435.72
4.46	707.30	3.42	734.16	3.06	635.68	3.95	704.32	2.60	471.54
5.21	847.57	4.06	862.49	3.64	755.05	4.74	790.87	3.06	567.04
5.83	910.24	5.06	1014.70	4.32	871.44	5.30	880.40	3.54	686.41
6.75	1068.42	5.94	1146.01	5.31	1023.65	6.16	1011.71	4.35	829.66
7.78	1208.68	7.34	1295.23	6.45	1175.85	7.21	1128.10	5.20	984.85
8.74	1298.21	8.57	1423.56	7.89	1325.07	8.13	1235.54	6.16	1101.24
10.23	1471.31	11.50	1480.26	9.17	1456.39	9.01	1337.01	7.65	1235.54
10.81	1519.06	12.47	1551.89	10.05	1557.86	9.55	1369.84	8.46	1328.06
11.53	1578.75	14.11	1608.59			10.29	1477.28	9.06	1399.68
12.20	1629.48					11.70	1569.79	9.58	1459.37

Test T-1-4A

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.88	137.28	1.71	220.85	0.68	107.44	0.76	89.53	0.66	167.13
1.51	289.49	2.33	319.33	1.46	274.56	1.93	196.97	1.24	304.41
1.97	441.69	3.31	492.43	2.00	384.99	2.75	355.14	1.79	438.71
2.72	614.79	4.39	578.97	2.67	516.30	3.44	501.38	2.20	507.35
3.85	758.04	4.96	683.43	3.71	698.35	4.35	662.54	3.30	737.15
5.56	853.54	5.30	749.08	4.72	835.63	5.09	772.96	4.15	862.49
7.36	1029.62	6.64	829.66	6.04	1005.74	6.87	969.93	4.87	946.05
9.85	1154.96		919.20	9.13	1125.12	7.98	1035.59	5.80	1053.49
10.67	1211.67			10.45	1181.82	10.01	1107.21	6.77	1119.15
	1232.56				1226.59		1175.85		1154.96

Test T-1-4B

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.76	68.64	2.20	107.44	1.42	44.77	0.86	50.73	1.18	62.67
2.13	110.42	3.75	185.03	2.54	110.42	2.50	122.36	2.22	125.34
2.84	193.99	4.94	265.61	3.75	173.10	3.40	185.03	3.46	173.10
3.62	271.58	5.31	274.56	5.81	304.41	5.10	265.61	4.91	253.67
4.19	328.28	6.44	349.17	7.34	373.05	6.15	334.25	6.69	331.27
4.81	384.99	8.24	432.74	9.87	465.57	8.08	411.85	8.32	384.99
5.83	426.77	9.54	465.57	12.19	498.39	10.00	471.54	10.64	426.77
7.13	474.52	12.12	519.29	15.93	543.16	12.04	513.32	14.26	507.35
9.71	543.16	14.12	522.27		552.11	13.59	543.16	16.40	537.19
12.85	567.04		561.07			18.50	570.02		573.00
	590.91						584.94		

Test T-1-6

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.64	158.17	0.19	53.72	0.25	92.52	0.63	95.50	0.72	92.52
1.21	244.72	2.60	244.72	0.89	325.30	1.04	226.81	2.20	355.14
2.61	379.02	4.34	399.91	5.99	584.94	2.72	382.00	3.73	504.36
6.04	543.16	6.57	584.94	7.52	731.18	4.35	638.66	4.96	602.85
9.30	704.32	7.32	677.46	9.66	916.21	5.77	808.77	6.74	743.12
11.94	910.24	8.78	856.52	11.70	1199.73	6.91	981.87	8.91	901.29
13.94	1310.15	10.41	1065.43	13.89	1569.79	8.04	1146.01	11.46	1104.23
15.49	1572.78	11.90	1268.37	15.83	1886.14	9.28	1268.37	13.55	1384.76
17.38	1901.06	13.12	1525.03	16.97	2080.13	11.30	1632.47	14.60	1614.56
19.38	2199.50	14.86	1835.41	18.38	2300.97	12.77	1847.34	16.01	1880.17
21.57	2438.25	17.10	2038.35	19.96	2500.93	*	*	*	*
*	*	*	*	21.32	2587.47	*	*	*	*

Test T-1-7

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.18	202.94	0.23	158.17	0.30	235.77	0.26	202.94	0.13	191.00
0.35	340.22	0.44	307.39	0.52	474.52	0.53	474.52	0.25	355.14
0.58	575.99	0.91	549.13	0.63	769.98	0.62	689.40	0.31	483.47
0.81	787.88	1.27	901.29	0.81	1116.17	0.65	847.57	0.42	608.82
0.94	904.27	1.45	1143.03	0.94	1334.03	0.78	1253.45	0.53	844.59
1.12	1095.27	1.72	1396.70	1.06	1548.90	0.88	1566.81	0.70	1286.28
1.33	1375.81	2.09	1892.11	1.26	1883.16	1.01	1978.66	0.92	1775.72
1.51	1611.58	2.33	2247.25	1.41	2208.46	1.17	2342.75	1.27	2491.97
1.74	2008.50	2.53	2417.36	1.54	2345.74	1.26	2733.71		
2.10	2545.69	2.88	2674.02	1.64	2524.80	1.42	2879.95		
2.40	2775.49			2.00	2721.77				

Test T-1-8

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.98	199.95	0.97	205.92	0.99	152.20	1.02	125.34	0.64	107.44
1.38	387.97	1.27	343.21	1.16	310.38	1.38	358.13	1.41	247.71
1.65	603.45	1.77	534.21	1.43	480.49	1.75	537.19	1.96	486.46
2.10	710.29	2.44	683.43	1.74	590.91	1.85	623.74	2.30	617.77
2.64	847.57	3.44	943.07	2.18	731.18	2.19	734.16	2.56	662.54
3.13	928.15	5.82	1134.07	3.12	868.46	3.22	859.51	2.96	781.91
4.13	1065.43	5.92	1211.67	4.08	1101.24	4.43	987.84	4.71	892.34
5.40	1202.71	7.45	1495.18	5.34	1220.62	6.14	1265.39	7.14	1098.26
7.40	1498.17	9.20	1823.47	6.70	1480.26	7.21	1480.26	8.63	1250.46
8.37	1874.20	9.47	1889.13	7.80	1653.36	8.16	1733.94	9.97	1405.65
8.79	2008.50	10.54	2178.61	9.35	1856.30	9.06	1951.80	11.18	1674.25
9.28	2259.19	*	*	10.28	1975.67	9.63	2235.32	12.02	1829.44
*	*	*	*	10.74	2232.33	*	*	12.21	2214.42

Test T-1-9

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.11	86.38	0.11	74.47	0.07	74.47	0.10	104.25	0.09	98.30
0.21	178.72	0.27	193.62	0.22	184.68	0.21	178.72	0.22	187.66
0.32	247.23	0.37	262.13	0.32	244.25	0.34	256.17	0.33	256.17
0.43	309.78	0.49	318.72	0.51	348.51	0.44	327.66	0.45	312.76
0.54	378.29	0.60	366.38	0.64	387.23	0.56	396.17	0.56	354.47
0.65	434.89	0.72	411.06	0.80	452.76	0.68	437.87	0.68	399.15
0.77	470.63	0.87	485.53	0.94	521.27	0.79	476.59	0.80	437.87
0.87	521.27	1.02	568.93	1.07	634.46	0.93	530.21	0.95	530.21
0.99	560.00	1.17	664.25	1.20	726.80	1.11	667.23	1.11	637.44
1.08	583.83	1.30	753.61	1.31	792.33	1.27	697.02	1.22	726.80
1.20	649.36	1.43	839.99	1.42	875.74	1.53	822.12	1.36	801.27
1.32	723.82	1.56	911.48	1.53	860.84	1.72	914.46	1.49	890.63
1.42	786.38	1.69	968.08	1.70	893.61	1.84	965.10	1.65	965.10
1.58	881.70	1.80	1048.50	1.84	956.16	2.25	1042.54	1.77	1027.65
1.43	783.40	2.12	1030.63	2.04	1024.67	2.54	1122.97	1.90	1102.12
1.55	845.95	2.27	1087.23	2.58	1087.23	2.87	1182.54	2.03	1134.88
1.91	845.95	2.49	1140.84	3.04	1176.59	3.85	1259.99	2.20	1117.01
2.02	878.72	3.02	1197.44	4.10	1239.14	4.92	1346.37	2.72	991.91
2.13	926.38	2.86	1262.97	5.13	1319.56	5.66	1408.93	3.15	1117.01
2.27	962.12	3.98	1343.39	6.12	1388.07	6.44	1489.35	3.56	1185.52
2.38	971.06	4.48	1408.93	7.34	1465.52	7.00	1560.84	4.05	1268.93
2.50	1006.80	5.36	1486.37	7.81	1578.71	7.77	1641.26	4.11	1343.39
2.69	1054.46	5.61	1486.37	8.05	1617.43	8.24	1706.80	5.84	1414.88
2.98	1122.97	6.89	1548.92	8.35	1688.92	9.56	1781.26	7.24	1501.26
3.94	1185.52	7.89	1629.35	8.69	1757.43	10.72	1796.16	7.56	1572.75
5.20	1271.90	8.38	1706.80	9.67	1819.99	11.82	1808.07	7.89	1647.22
6.02	1328.50	9.03	1784.24	11.00	1811.05	13.23	1825.94	8.47	1709.77
6.82	1402.97	9.52	1864.67	12.84	1811.05	15.18	1843.82	9.22	1784.24
7.54	1519.14	10.76	1918.28	15.06	1778.28	16.09	1805.09	10.25	1799.13
7.76	1560.84	13.18	1912.33	15.83	1694.88	16.32	1659.14	11.53	1825.94
8.11	1674.03	14.44	1834.88			16.68	1608.50	12.41	1831.90
8.29	1727.65	15.52	1700.84					13.15	1793.18
8.53	1784.24							13.47	1763.39
8.98	1846.79							14.42	1706.80
10.25	1855.73								
12.62	1918.28								
14.18	1811.05								
15.69	1748.50								
16.74	1632.33								

Test T-1-10A

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.38	8.06	0.20	256.66	0.48	358.13	0.19	158.17	0.99	188.02
0.64	322.32	0.43	414.83	1.21	617.77	0.43	253.67	1.25	384.99
0.99	483.47	0.67	587.93	1.49	719.24	0.97	465.57	1.64	701.33
1.18	552.11	0.97	746.10	1.94	934.12	1.57	677.46	2.22	1062.45
1.56	865.48	1.27	871.44	2.18	1098.26	2.00	874.43	2.50	1229.57
1.89	1044.54	1.80	1163.92	2.42	1238.53	2.82	1196.74	2.72	1325.07
2.28	1295.23	2.20	1366.86	2.98	1507.12	3.10	1292.25	3.12	1489.22
2.84	1596.65	2.62	1584.72	3.36	1635.45	3.55	1432.51	3.71	1656.34
4.22	1829.44	3.45	1913.00	4.00	1847.34			4.19	1730.95
		3.85	1969.70					4.57	1796.61

Test T-1-10B

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.26	104.45	1.65	155.19	1.11	128.33	1.80	167.13	2.14	155.19
2.30	271.58	2.15	256.66	1.81	268.60	2.44	280.53	3.07	301.42
3.05	379.02	2.72	382.00	2.74	438.71	3.17	426.77	3.71	414.83
3.66	444.68	3.54	522.27	3.79	564.05	4.43	590.91	4.44	510.33
4.51	546.15	4.25	629.71	4.86	680.44	5.37	659.55	5.42	608.82
6.16	641.65	5.50	743.12	6.04	719.24	6.12	713.27	6.77	668.51
7.93	689.40	6.38	775.94	8.35	731.18	7.26	752.07	8.07	689.40
						8.46	775.94	9.18	698.35

Test T-1-11

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00				
0.12	80.42	0.10	41.70	0.07	176.08				
0.29	217.45	0.27	163.83	0.22	346.19				
0.42	315.74	0.39	226.38	0.32	402.89				
0.54	417.02	0.50	327.66	0.51	698.35				
0.69	542.12	0.64	411.06	0.64	829.66				
0.85	646.38	0.77	500.42	0.80	1056.48				
1.03	759.57	0.90	595.74	0.94	1292.25				
1.18	825.10	1.06	670.21	1.07	1456.39				
1.36	929.35	1.23	780.42	1.20					
1.51	1021.69	1.37	842.97	1.31					
1.73	1117.01	1.51	920.42	1.42					
1.99	1200.42	1.65	979.99	1.53					
2.50	1304.67	1.92	1090.20	1.70					
2.87	1328.50	2.17	1185.52	1.84					
3.22	1328.50	2.40	1262.97	2.04					
3.85	1295.73	2.86	1352.33	2.58					
4.57	1286.80	3.45	1402.97	3.04					
7.12	1274.88	3.89	1367.22	4.10					
8.26	1292.76	4.90	1295.73	5.13					
9.40	1295.73	6.07	1245.10	6.12					
10.73	1337.44	8.38	1245.10	7.34					
11.42	1337.44	10.09	1289.78	7.81					
12.03	1367.22	12.42	1331.48	8.05					
13.20	1394.03	13.87	1271.90	8.35					
14.54	1417.86	15.60	1179.57	8.69					
15.50	1379.14			9.67					
16.36	1313.61			11.00					
17.83	1248.08			12.84					
				15.06					
				15.83					

Test T-2-1

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.21	173.10	0.47	373.05	0.35	414.83	0.42	232.78	0.28	259.6
0.46	322.32	0.80	543.16	0.63	516.30	0.71	390.96	0.45	507.3
0.89	581.96	1.10	737.15	0.74	695.37	0.93	531.22	0.79	707.3
1.17	755.05	1.55	913.23	0.96	937.10	1.24	683.43	0.93	847.5
1.63	949.04	1.94	1077.37	1.18	1059.46	1.65	832.65	1.39	1137.0
2.01	1101.24	2.40	1250.46	1.53	1235.54	2.16	990.82	1.84	1360.8
2.49	1295.23	2.78	1396.70	1.89	1357.90	*	*	2.60	1823.4
3.50	1674.25	3.27	1572.78	2.53	1563.83	*	*	3.51	2071.1
4.18	1823.47	4.63	1847.34	3.06	1719.01	*	*	4.66	2196.5
4.78	1993.58	5.86	2041.33	3.66	1865.25	*	*	7.73	2247.2
5.92	2169.66	9.52	2101.02	4.48	1981.64	*	*	*	*
7.08	2333.80	*	*	6.59	2101.02	*	*	*	*

Test T-2-2

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
1.47	62.67	0.68	41.78	0.33	71.63	1.34	53.72	0.42	56.7
2.58	179.06	2.86	179.06	1.79	134.30	2.08	211.89	2.71	193.9
3.61	268.60	5.70	358.13	4.05	241.74	2.73	364.10	4.08	307.3
5.04	379.02	10.15	635.68	5.16	361.11	3.79	528.24	5.38	456.6
6.98	507.35	11.58	865.48	6.86	486.46	5.02	647.61	6.44	590.9
9.14	659.55	12.45	1017.68	11.90	1104.23	6.19	766.99	8.09	752.0
10.25	811.76	15.27	1181.82	13.22	1262.40	8.53	880.40	9.50	880.4
14.43	1041.56	17.44	1399.68	17.26	1480.26	10.22	1059.46	11.01	1035.5
16.76	1250.46	20.11	1626.50	18.91	1635.45	11.97	1268.37	12.87	1184.8
21.26	1510.11	24.78	1850.33	25.15	1880.17	16.82	1480.26	15.66	1328.0
23.95	1757.81	27.83	2121.91	*	*	19.18	1656.34	18.75	1507.1
27.87	1907.03	*	*	*	*	24.03	1829.44	22.29	1817.5
32.60	2047.30	*	*	*	*	29.11	2029.39	24.74	1901.0
*	*	*	*	*	*	33.61	2095.05	*	*

Test T-2-3A

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
1.39	128.33	1.97	143.25	2.23	110.42	3.63	202.94	2.20	220.8
3.70	310.38	2.85	313.36	3.56	250.69	4.28	304.41	2.77	289.4
6.43	396.93	3.66	444.68	5.85	468.55	6.08	393.94	3.62	423.7
12.47	495.41	6.74	647.61	6.95	561.07	12.30	495.41	6.39	590.9
13.78	650.60	8.96	787.88	7.79	734.16	13.70	638.66	8.75	734.1
15.64	969.93	11.09	889.35	9.23	931.13	15.45	889.35	10.44	886.3
17.63	1232.56	12.89	996.79	10.32	1050.51	16.31	1032.60	12.79	1104.2
18.70	1328.06	14.10	1211.67	12.26	1172.87	20.18	1492.20	16.82	1429.5
20.51	1465.34	16.20	1387.75	17.15	1399.68	22.12	1662.31	20.07	1692.1
23.50	1692.15	18.18	1513.09	18.76	1536.97	23.20	1865.25	23.38	1948.8
25.38	1921.95	20.70	1727.97	20.23	1707.08	24.94	2032.38	*	*
26.96	2089.08	23.58	1880.17	22.10	1859.28	*	*	*	*
*	*	26.41	2232.33	24.99	1987.61	*	*	*	*

Test T-2-3B

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
3.33	265.61	3.00	202.94	2.07	214.88	2.39	250.69	3.25	256.6
4.81	358.13	3.83	340.22	2.94	346.19	2.81	343.21	4.45	426.7
8.99	513.32	4.46	417.82	4.05	474.52	4.13	573.00	5.80	584.9
11.01	644.63	7.21	581.96	6.53	581.96	6.08	749.08	9.50	725.2
13.13	859.51	8.51	698.35	8.93	737.15	8.68	931.13	11.67	901.2
14.83	1071.40	9.96	865.48	10.68	877.41	11.56	1077.37	13.15	1059.4
16.52	1223.60	11.69	1044.54	13.40	1178.84	14.53	1342.98	14.89	1256.4
17.91	1289.26	13.50	1166.90	14.72	1322.09	17.44	1471.31	17.93	1504.1
20.12	1516.08	15.98	1375.81	16.46	1477.28	20.77	1674.25	19.45	1650.3
25.55	1772.73	*	*	22.12	1611.58	23.53	1880.17	22.71	1692.1
27.08	1921.95	*	*	26.18	1868.23	26.41	2062.22	25.80	1918.9
28.21	1993.58	*	*	28.06	2044.31	28.23	2202.49	28.13	2026.4
30.29	2172.64	*	*	29.54	2154.74	*	*	*	*

Test T-2-4A

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	*	*	0.00	0.00	0.00	0.00	0.00	0.0
0.62	131.31	*	*	0.68	110.42	0.67	116.39	0.26	116.3
1.56	256.66	*	*	1.81	274.56	2.01	292.47	0.95	298.4
2.95	435.72	*	*	2.43	358.13	2.66	402.89	1.92	537.1
4.25	581.96	*	*	2.99	435.72	3.57	552.11	2.49	671.4
5.29	677.46	*	*	3.82	540.18	4.25	662.54	3.30	841.6
7.00	859.51	*	*	4.94	704.32	4.72	707.30	*	*
8.64	957.99	*	*	*	*	5.21	769.98	*	*
15.81	1014.70	*	*	*	*	*	*	*	*
17.79	1157.95	*	*	*	*	*	*	*	*
21.74	1289.26	*	*	*	*	*	*	*	*
22.12	1456.39	*	*	*	*	*	*	*	*
24.19	1560.84	*	*	*	*	*	*	*	*
27.05	1722.00	*	*	*	*	*	*	*	*

Test T-2-4B

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*	*
1.02	98.49	0.31	158.17	0.72	65.66	0.78	95.50	*	*
2.05	250.69	0.60	241.74	2.95	235.77	2.17	259.64	*	*
3.57	432.74	1.06	328.28	4.15	358.13	3.46	396.93	*	*
4.96	543.16	1.53	411.85	6.98	516.30	6.38	575.99	*	*
10.29	689.40	2.60	561.07	9.69	662.54	14.46	844.59	*	*
12.86	817.73	3.46	650.60	14.30	847.57	16.72	1026.63	*	*
16.71	1050.51	4.00	701.33	16.08	960.98	20.97	1199.73	*	*
20.87	1301.20	5.77	811.76	18.95	1119.15	24.01	1426.54	*	*
25.82	1575.76	7.96	886.37	21.25	1241.51	34.94	1486.23	*	*
30.11	1683.20	16.78	1056.48	24.38	1423.56	*	*	*	*
*	*	20.20	1292.25	28.43	1548.90	*	*	*	*
*	*	22.28	1435.50	31.02	1713.05	*	*	*	*
*	*	25.40	1510.11	33.71	1757.81	*	*	*	*
*	*	29.63	1593.67	*	*	*	*	*	*
*	*	32.30	1671.26	*	*	*	*	*	*

Test T-1-6

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.64	158.17	0.19	53.72	0.25	92.52	0.63	95.50	0.72	92.5
1.21	244.72	2.60	244.72	0.89	325.30	1.04	226.81	2.20	355.1
2.61	379.02	4.34	399.91	5.99	584.94	2.72	382.00	3.73	504.3
6.04	543.16	6.57	584.94	7.52	731.18	4.35	638.66	4.96	602.8
9.30	704.32	7.32	677.46	9.66	916.21	5.77	808.77	6.74	743.1
11.94	910.24	8.78	856.52	11.70	1199.73	6.91	981.87	8.91	901.2
13.94	1310.15	10.41	1065.43	13.89	1569.79	8.04	1146.01	11.46	1104.2
15.49	1572.78	11.90	1268.37	15.83	1886.14	9.28	1268.37	13.55	1384.7
17.38	1901.06	13.12	1525.03	16.97	2080.13	11.30	1632.47	14.60	1614.5
19.38	2199.50	14.86	1835.41	18.38	2300.97	12.77	1847.34	16.01	1880.1
21.57	2438.25	17.10	2038.35	19.96	2500.93	*	*	*	*
*	*	*	*	21.32	2587.47	*	*	*	*

Test T-1-8

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.98	199.95	0.97	205.92	0.99	152.20	1.02	125.34	0.64	107.4
1.38	387.97	1.27	343.21	1.16	310.38	1.38	358.13	1.41	247.7
1.65	603.45	1.77	534.21	1.43	480.49	1.75	537.19	1.96	486.4
2.10	710.29	2.44	683.43	1.74	590.91	1.85	623.74	2.30	617.7
2.64	847.57	3.44	943.07	2.18	731.18	2.19	734.16	2.56	662.5
3.13	928.15	5.82	1134.07	3.12	868.46	3.22	859.51	2.96	781.9
4.13	1065.43	5.92	1211.67	4.08	1101.24	4.43	987.84	4.71	892.3
5.40	1202.71	7.45	1495.18	5.34	1220.62	6.14	1265.39	7.14	1098.2
7.40	1498.17	9.20	1823.47	6.70	1480.26	7.21	1480.26	8.63	1250.4
8.37	1874.20	9.47	1889.13	7.80	1653.36	8.16	1733.94	9.97	1405.6
8.79	2008.50	10.54	2178.61	9.35	1856.30	9.06	1951.80	11.18	1674.2
9.28	2259.19	*	*	10.28	1975.67	9.63	2235.32	12.02	1829.4
*	*	*	*	10.74	2232.33	*	*	12.21	2214.4

Test T-2-10A

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
1.25	101.47	1.51	137.28	0.84	92.52	0.42	113.41	0.99	191.0
1.56	295.46	1.71	313.36	1.70	313.36	0.79	232.78	1.36	310.3
1.66	405.88	1.91	581.96	1.93	528.24	1.20	513.32	1.38	417.8
1.88	587.93	2.40	761.02	2.08	695.37	1.50	653.58	1.64	701.3
2.14	713.27	2.81	883.38	2.43	901.29	1.85	815.93	2.14	853.5
2.47	829.66	3.54	1032.60	2.87	1068.42	2.19	949.04	2.57	946.0
3.46	1002.76	5.32	1238.53	3.60	1169.88	2.68	1056.48	3.17	1020.6
5.14	1134.07	7.11	1348.95	4.49	1304.18	3.73	1169.88	4.62	1187.7
6.05	1265.39	9.01	1474.29	5.95	1459.37	5.41	1369.84	5.17	1322.0
7.46	1396.70	9.53	1665.30	6.85	1617.54	7.36	1572.78	5.71	1441.4
9.30	1629.48	10.11	1823.47	7.77	1808.55	8.91	1802.58	6.61	1605.6
9.94	1784.67	10.21	1936.88	10.64	2193.53	10.64	2196.52	7.84	1868.2
10.54	2041.33	10.55	2056.25	*	*	*	*	9.35	2244.2
10.86	2223.38	10.79	2184.58	*	*	*	*	*	*

Test T-2-10B

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.43	95.50	1.17	89.53	0.47	119.38	0.47	226.81	0.86	59.6
0.81	244.72	1.30	220.85	0.57	426.77	0.67	390.96	0.93	387.9
0.96	417.82	1.35	301.42	0.70	614.79	0.87	823.69	1.08	602.8
1.08	626.72	1.52	635.68	0.76	752.07	1.18	996.79	1.11	674.4
1.22	859.51	1.62	805.79	0.91	1038.57	1.46	1175.85	1.49	955.0
1.37	984.85	1.80	877.41	1.21	1181.82	1.93	1322.09	1.71	1125.1
1.54	1178.84	1.95	1056.48	1.54	1432.51	2.81	1513.09	2.44	1217.6
1.88	1340.00	2.33	1175.85	2.54	1575.76	4.00	1757.81	3.61	1459.3
2.44	1459.37	2.81	1307.17	3.36	1701.11	4.59	1880.17	4.61	1599.6
3.35	1572.78	4.12	1492.20	4.51	2002.53	5.37	2029.39	5.25	1778.7
5.30	1892.11	5.35	1689.17	5.42	2109.97	5.69	2175.63	5.78	2163.6
6.02	2175.63	6.56	1966.72	6.26	2250.24	*	*	6.16	2297.9
*	*	8.17	2166.67	*	*	*	*	*	*

Test T-3-1

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.35	202.94	0.22	220.85	0.36	283.52	0.69	271.58	0.33	301.4
0.52	399.91	0.44	468.55	0.56	504.36	0.88	438.71	0.62	489.4
0.61	495.41	0.54	602.85	0.77	755.05	1.17	692.38	1.02	713.2
0.76	677.46	0.65	761.02	1.17	1056.48	1.64	963.96	1.60	1071.4
0.97	841.60	0.86	931.13	1.68	1283.29	2.10	1166.90	2.08	1328.0
1.33	1014.70	1.13	1131.09	2.44	1611.58	2.66	1375.81	2.61	1498.1
1.70	1172.87	1.50	1304.18	6.43	1835.41	3.22	1566.81	3.15	1724.9
2.11	1301.20	1.91	1525.03	11.17	2106.99	4.33	1886.14	3.93	1975.6
2.86	1531.00	2.44	1763.78	12.44	2381.55	6.17	2187.57	4.70	2127.8
3.83	1671.26	3.35	2035.36	13.57	2590.46	8.07	2366.63	5.48	2303.9
5.08	1847.34	4.84	2336.79	*	*	*	*	*	*
6.82	2035.36	*	*	*	*	*	*	*	*

Test T-3-2

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.13	140.27	0.12	119.38	0.30	119.38	0.28	110.42	0.36	113.4
0.29	253.67	0.26	229.80	0.44	253.67	0.48	304.41	0.63	271.5
0.49	420.80	0.48	393.94	0.67	414.83	0.64	402.89	1.06	462.5
0.70	567.04	0.84	555.10	0.91	531.22	0.84	561.07	1.29	513.3
0.95	710.29	1.23	716.26	1.49	722.22	1.20	704.32	2.04	656.5
1.45	775.94	1.74	856.52	2.08	847.57	1.77	832.65	3.34	877.4
1.90	862.49	2.37	972.91	2.96	996.79	2.44	987.84	3.81	940.0
2.37	937.10	3.05	1035.59	3.85	1116.17	2.88	1071.40	4.46	1044.5
3.04	1035.59	*	*	4.49	1163.92	3.47	1146.01	5.11	1098.2
3.95	1125.12	*	*	*	*	*	*	5.38	1083.3
*	*	*	*	*	*	*	*	5.62	1160.9

Test T-3-4A

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.26	74.61	0.26	125.34	0.07	122.36	0.15	68.64	0.05	89.5
0.86	262.63	0.91	241.74	0.24	241.74	0.47	247.71	0.30	262.6
1.05	331.27	1.44	358.13	0.49	420.80	0.63	328.28	0.67	396.9
1.44	438.71	1.73	444.68	0.72	513.32	1.00	462.58	0.76	414.8
2.21	614.79	2.20	540.18	0.97	641.65	1.41	587.93	1.03	516.3
3.51	811.76	2.86	647.61	1.34	793.85	1.65	662.54	1.27	590.9
4.66	919.20	3.56	755.05	1.51	856.52	1.94	722.22	1.54	680.4
6.21	1032.60	4.18	841.60	1.83	946.05	2.31	796.83	2.09	793.8
*	*	4.98	922.18	2.31	1014.70	3.26	910.24	2.74	880.4
*	*	6.38	1056.48	2.77	1110.20	4.98	990.82	*	*

Test T-3-4B

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.36	188.02	0.13	89.53	0.14	50.73	0.15	89.53	0.05	68.6
0.65	274.56	0.47	214.88	0.37	125.34	0.49	256.66	0.30	196.9
1.06	399.91	0.91	358.13	0.72	220.85	0.80	367.08	0.66	259.6
1.54	516.30	1.39	489.44	1.21	319.33	1.06	438.71	0.75	343.2
2.11	605.83	1.83	573.00	1.86	426.77	1.37	534.21	1.03	390.9
2.89	683.43	2.32	638.66	2.81	531.22	1.70	605.83	1.25	462.5
4.17	796.83	3.09	743.12	3.78	614.79	1.98	686.41	*	952.0
5.03	844.59	3.65	808.77	4.96	710.29	2.55	772.96	*	*
5.79	886.37	4.92	868.46	7.22	871.44	3.01	814.74	*	*
6.33	916.21	5.40	931.13	8.26	943.07	3.67	889.35	*	*
*	*	6.11	1008.73	8.90	972.91	4.91	901.29	*	*
*	*	*	*	9.94	1008.73	5.41	969.93	*	*

Test T-3-6

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.16	229.80	0.16	92.52	0.27	268.60	0.24	277.55	0.36	262.6
0.46	379.02	0.42	241.74	0.50	567.04	0.41	373.05	0.56	414.8
0.67	525.25	0.68	444.68	0.63	656.57	0.59	578.97	0.78	632.6
0.95	725.21	0.82	534.21	0.79	817.73	0.82	692.38	1.18	949.0
1.13	874.43	1.11	683.43	1.18	1146.01	1.16	877.41	1.45	1116.1
1.24	993.81	1.70	940.09	1.49	1262.40	1.69	1059.46	1.83	1405.6
1.57	1241.51	2.70	1187.79	1.91	1447.43	2.37	1211.67	2.11	1519.0
2.10	1396.70	4.08	1459.37	2.28	1507.12	3.65	1444.45	2.51	1653.3
2.83	1519.06	5.18	1647.39	2.51	1602.62	4.77	1620.53	3.11	1757.8
3.81	1686.19	6.30	1802.58	*	*	*	*	3.53	1808.5
5.56	1781.69	6.72	1874.20	*	*	*	*	3.83	1838.3
6.42	1853.31	*	*	*	*	*	*	*	*

Test T-3-7

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.06	468.55	0.09	331.27	0.20	373.05	0.03	29.84	0.24	361.1
0.23	766.99	0.20	587.93	0.34	728.19	0.13	313.36	0.39	734.1
0.44	1157.95	0.30	835.63	0.52	1020.66	0.23	540.18	0.52	1011.7
0.60	1414.61	0.44	1217.64	0.55	1190.78	0.37	1011.71	0.65	1450.4
0.76	1733.94	0.67	1748.86	0.69	1787.66	0.64	1608.59	0.84	1835.4
0.99	2071.17	0.82	2130.86	0.81	2106.99	0.83	2068.19	1.03	2381.5
1.16	2378.57	1.06	2623.29	0.93	2193.53	1.12	2265.16	1.25	2554.6
1.31	2530.77	1.31	2888.90	1.26	2336.79	1.27	2566.58	1.37	2787.4
1.50	2954.56	1.51	3217.18	1.64	2820.26	1.69	3038.12	1.83	3315.6
1.74	3124.67	1.98	3664.84	1.88	3044.09	2.25	3411.17	2.24	3438.0
2.10	3357.45	*	*	*	*	*	*	*	*
3.47	3673.80	*	*	*	*	*	*	*	*

Test T-3-8

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.09	361.11	0.21	271.58	0.19	116.39	0.15	355.14	0.19	116.3
0.29	581.96	0.49	677.46	0.49	459.60	0.28	573.00	0.49	459.6
0.38	1071.40	0.58	1104.23	0.65	886.37	0.45	1119.15	0.65	886.3
0.59	1393.71	0.70	1393.71	0.91	1357.90	0.68	1441.47	0.91	1357.9
0.69	1686.19	0.78	1635.45	1.03	1760.80	1.01	1847.34	1.03	1760.8
0.83	1957.77	0.94	1957.77	1.25	2169.66	1.22	2023.42	1.25	2169.6
0.99	2172.64	1.08	2229.35	2.04	3232.11	1.51	2277.10	2.04	3067.9
2.15	2530.77	1.37	2518.83	2.61	3506.67	2.05	2730.73	2.61	3506.6
2.25	2736.69	1.60	2754.60	*	*	2.66	2984.40	*	*
2.47	3232.11	2.03	2996.34	*	*	3.16	3220.17	*	*
2.87	3500.70	2.63	3282.84	*	*	*	*	*	*

Test T-4-1

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.32	232.78	0.62	193.99	0.45	250.69	0.52	208.91	0.31	241.7
0.50	364.10	0.86	399.91	0.58	370.07	0.83	387.97	0.57	349.1
0.75	519.29	1.15	546.15	0.91	537.19	1.20	531.22	0.98	507.3
0.90	596.88	1.37	674.47	1.11	656.57	1.63	719.24	1.28	704.3
1.19	752.07	1.74	832.65	1.30	737.15	2.08	883.38	1.63	775.9
1.51	892.34	2.02	946.05	1.52	859.51	2.44	999.77	2.08	901.2
2.31	1017.68	2.20	1050.51	2.12	946.05			2.34	937.1
		2.52	1146.01	3.04	1011.71				

Test T-4-2

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.44	95.50	0.58	62.67	0.60	134.30	0.48	77.59	1.06	125.3
0.96	241.74	1.20	211.89	1.16	235.77	1.05	235.77	1.48	199.9
1.85	411.85	1.69	301.42	1.74	364.10	1.54	334.25	1.97	307.3
2.81	540.18	2.18	373.05	2.12	423.78	1.98	438.71	2.66	396.9
3.27	617.77	3.03	495.41	2.58	510.33	2.37	507.35	3.41	513.3
3.83	701.33	3.70	555.10	3.20	620.76	2.85	596.88	4.57	659.5
4.64	799.82	4.61	668.51	3.87	728.19	3.25	665.52	5.47	775.9
5.26	853.54	5.67	746.10	4.81	838.62	4.11	731.18	7.28	895.3
7.42	910.24	6.78	829.66	5.78	910.24	5.09	826.68		
9.90	957.99	7.69	889.35	6.82	940.09				
		8.74	916.21						

Test T-4-5

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.25	208.91	0.42	286.50	0.45	474.52	0.38	334.25	0.44	298.4
0.45	519.29	0.54	480.49	0.69	793.85	0.53	740.13	0.67	599.8
0.64	835.63	0.60	722.22	0.83	1181.82	0.76	1292.25	0.84	913.2
1.02	1199.73	0.78	1319.10	0.94	1507.12	0.88	1626.50	1.01	1286.2
1.08	1375.81	1.02	1677.23	1.11	1692.15	1.03	1895.09	1.18	1590.6
1.12	1674.25	1.16	2023.42	1.22	1913.00	1.28	2405.43	1.31	1817.5
1.21	2181.60	1.37	2172.64	1.46	2142.80			1.55	1930.9
		1.85	2384.54						

Test T-4-7

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.06	83.56	0.37	193.99	0.26	229.80	0.26	250.69	0.45	313.3
0.45	370.07	0.55	349.17	0.35	334.25	0.39	373.05	0.57	346.1
0.62	492.43	0.76	650.60	0.57	504.36	0.53	626.72	0.70	513.3
0.82	716.26	1.01	931.13	0.73	641.65	0.72	778.93	0.99	728.1
0.98	865.48	1.11	1089.31	0.97	862.49	0.81	904.27	1.22	871.4
1.20	1104.23	1.18	1235.54	1.15	996.79	1.06	1095.27	1.38	1020.6
1.35	1253.45	1.38	1465.34			1.45	1220.62	1.67	1137.0
1.51	1292.25								

Test T-4-8

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.01	32.83	0.13	80.58	0.19	104.45	0.33	182.05	0.18	128.3
0.24	205.92	0.26	235.77	0.78	313.36	0.50	343.21	0.31	229.8
0.48	393.94	0.48	477.50	1.11	441.69	0.83	498.39	0.76	435.7
0.74	525.25	0.72	596.88	1.71	647.61	1.06	549.13	0.99	540.1
1.11	710.29	1.03	758.04	2.59	874.43	1.55	749.08	1.28	659.5
1.57	853.54	1.50	993.81	3.40	934.12	2.09	847.57	1.99	916.2
1.86	972.91	2.08	1062.45	4.91	1068.42	2.97	934.12	2.74	996.7
2.59	1059.46	3.15	1181.82			5.44	1122.13	3.60	1074.3
4.85	1223.60	4.09	1241.51			6.67	1223.60	4.64	1151.9
						7.26	1295.23	5.55	1241.5
								6.91	1331.0

Test T-4-9

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.42	89.36	0.34	77.45	0.44	89.36	0.22	53.62	0.62	71.4
0.73	190.64	0.68	145.96	0.69	154.89	0.51	125.11	0.99	151.9
1.01	271.06	0.97	217.45	0.88	238.30	0.83	196.59	1.34	226.3
1.25	342.55	1.47	351.49	1.12	312.76	1.11	262.13	1.66	294.8
1.35	372.34	1.88	446.80	1.50	393.19	1.48	336.59	2.08	372.3
1.80	482.55	2.24	524.25	1.81	452.76	1.89	420.00	2.45	446.8
2.08	533.19	2.59	592.76	2.19	536.17	2.43	506.38	2.97	533.1
2.34	607.65	3.04	673.19	2.48	595.74	2.81	554.04	3.38	589.7
2.78	699.99	3.79	792.33	2.84	679.14	3.37	637.44	3.94	661.2
3.39	828.08	4.11	819.14	3.27	756.59	3.83	708.93	4.81	747.6
3.82	887.65	5.17	902.55	3.72	810.21	4.29	786.38	5.46	828.0
4.33	971.06	5.66	974.03	4.28	899.57	4.80	869.78	5.97	899.5
5.08	1024.67	6.21	1051.48	4.85	985.95	5.24	941.27	6.52	974.0
6.20	1161.69	6.66	1117.01	5.29	1057.44	5.82	1015.74	7.14	1045.5
7.68	1289.78	7.27	1188.50	5.79	1119.99	7.16	1164.67	8.08	1128.9
9.36	1346.37	9.13	1346.37	6.41	1194.46	8.01	1251.05	9.36	1191.4
11.53	1608.50	10.59	1569.77	7.09	1259.99	9.32	1310.63	12.27	1230.2
12.53	1724.67	11.01	1656.16	8.27	1334.46	10.86	1388.07	12.68	1280.8
13.69	1721.69	11.50	1718.71	13.06	1480.41	11.07	1465.52	12.88	1346.3
21.89	1465.52	12.25	1787.22	13.30	1584.67	11.39	1534.03	13.15	1420.8
		15.92	1867.64	13.79	1751.48	11.98	1611.48	13.75	1489.3
		21.84	1635.31	14.13	1864.67	12.89	1685.94	14.66	1563.8
				14.48	1951.05	14.03	1760.41	15.65	1635.3
				14.91	2046.37	15.20	1808.07	16.91	1715.7
				15.19	2091.05	18.74	1906.37	18.50	1787.2
				16.03	2174.45	22.98	1965.94	19.45	1688.9
				16.99	2260.83			21.86	1921.2
				19.19	2371.05				
				25.91	1814.03				

Test T-4-10A

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.34	35.81	0.23	41.78	0.06	26.86	0.34	56.70	0.29	23.8
0.70	95.50	0.79	143.25	0.74	122.36	0.97	143.25	0.64	116.3
1.49	241.74	1.18	205.92	1.33	232.78	1.67	253.67	1.20	193.9
2.08	328.28	1.86	319.33	1.84	313.36	2.30	313.36	1.79	313.3
2.68	399.91	2.49	384.99	2.39	420.80	3.02	370.07	2.20	361.1
3.30	429.75			2.98	447.66	3.50	399.91	2.74	402.8
						4.41	429.75	3.39	450.6

Test T-4-10B

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.58	41.78	0.83	59.69	0.38	23.88	0.94	56.70	0.69	41.7
1.25	104.45	1.61	113.41	1.21	98.49	1.83	131.31	1.42	104.4
2.13	161.16	2.74	205.92	2.22	161.16	2.67	202.94	2.11	167.1
2.84	217.86	3.30	250.69	3.81	241.74	4.41	280.53	3.42	271.5
3.75	265.61	4.00	292.47	4.93	274.56	7.10	328.28	4.49	313.3
4.43	289.49	4.97	337.24			9.06	376.03	5.87	373.0
4.90	298.44	5.92	358.13					7.17	453.6
7.26	343.21	7.34	405.88						

Test T-4-11

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.38	113.19	0.12	50.64	0.10	26.81	0.05	11.91	0.16	65.5
0.61	178.72	0.40	187.66	0.26	116.17	0.22	80.42	0.33	119.1
0.82	241.27	0.52	223.40	0.39	169.79	0.37	160.85	0.48	199.5
1.15	312.76	0.72	288.93	0.53	241.27	0.49	208.51	0.65	300.8
1.54	393.19	1.03	390.21	0.66	300.85	0.65	277.02	0.78	390.2
1.98	461.70	1.44	503.40	0.87	390.21	0.76	327.66	0.91	461.7
2.50	533.19	1.84	557.02	1.05	455.74	0.89	384.25	1.20	601.7
3.27	607.65	2.33	622.55	1.34	557.02	1.09	458.72	1.33	643.4
3.75	652.34	3.75	699.99	1.57	616.59	1.28	524.25	1.46	673.1
4.27	685.10	4.55	708.93	1.85	694.04	1.57	607.65	1.71	750.6
5.28	714.89	5.35	723.82	2.20	783.40	1.89	694.04	1.96	822.1
5.86	708.93	6.51	708.93	2.58	848.93	2.19	759.57	2.52	878.7
7.31	723.82	7.67	694.04	3.30	866.80	2.56	828.08	3.44	872.7
8.87	697.02	9.24	670.21	4.10	860.84	3.25	911.48	4.52	863.8
10.53	682.12	10.70	631.48	4.71	839.99	3.74	938.29	6.04	831.0
13.72	628.51	12.67	577.87	6.59	798.29	4.71	911.48	7.25	798.2
15.20	604.68			7.64	768.50	5.63	884.67	9.33	735.7
				10.35	691.06	7.45	831.06	10.99	702.9
				12.39	631.48	9.81	762.55		
						12.77	691.06		

Test T-5-1

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*	*
0.19	179.06	0.26	164.14	0.39	235.77	0.34	271.58	*	*
0.52	307.39	0.45	337.24	0.64	411.85	0.59	405.88	*	*
0.92	384.99	0.63	447.66	0.77	489.44	0.77	510.33	*	*
1.39	453.63	0.83	614.79	1.07	650.60	1.03	629.71	*	*
1.83	510.33	1.01	701.33	1.37	781.91	1.29	734.16	*	*
2.51	635.68	1.17	781.91	1.67	937.10	1.55	835.63	*	*
3.13	734.16	1.44	907.26	2.29	1116.17	1.97	981.87	*	*
4.90	811.76	1.69	1032.60	2.53	1199.73	2.29	1104.23	*	*
7.02	1005.74	2.26	1181.82	3.16	1372.82	2.82	1253.45	*	*
7.48	1148.99	2.99	1363.87	3.85	1489.22	3.17	1381.78	*	*
8.20	1334.03	3.87	1522.04	4.77	1602.62	3.60	1477.28	*	*
9.22	1516.08	5.27	1641.42	6.24	1742.89	4.19	1569.79	*	*
10.30	1632.47	6.69	1787.66	8.19	1895.09	5.37	1707.08	*	*
12.10	1793.62	8.94	1966.72	12.81	2005.52	7.26	1883.16	*	*
13.88	1915.98	11.86	2184.58	16.00	2244.27	8.59	1978.66	*	*
19.24	2104.00	15.35	2336.79	23.07	2390.50	11.95	2169.66	*	*
28.06	2250.24	*	*	*	*	14.91	2280.08	*	*
32.34	2441.24	*	*	*	*	17.57	2393.49	*	*
*	*	*	*	*	*	23.85	2459.15	*	*

Test T-5-1C

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	*	*	*	*	*	*
1.28	193.99	0.45	182.05	*	*	*	*	*	*
2.48	331.27	1.19	349.17	*	*	*	*	*	*
3.66	405.88	1.90	447.66	*	*	*	*	*	*
6.26	567.04	4.43	632.69	*	*	*	*	*	*
8.73	668.51	6.99	731.18	*	*	*	*	*	*
12.25	749.08	10.18	808.77	*	*	*	*	*	*
15.67	832.65	14.29	880.40	*	*	*	*	*	*
23.58	907.26	20.38	996.79	*	*	*	*	*	*
31.80	1077.37	23.23	960.98	*	*	*	*	*	*
36.17	1184.81	28.96	1229.57	*	*	*	*	*	*
40.95	1310.15	37.99	1510.11	*	*	*	*	*	*
46.68	1596.65	*	*	*	*	*	*	*	*
52.01	1760.80	*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*	*	*

Test T-5-2

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.17	116.39	0.17	110.42	0.29	128.33	0.19	86.55	0.11	134.3
0.34	191.00	0.35	232.78	0.60	226.81	0.66	277.55	0.19	211.8
0.99	352.16	0.67	373.05	1.11	390.96	1.07	384.99	0.33	340.2
1.48	447.66	1.22	555.10	1.73	561.07	1.85	534.21	0.80	587.9
2.06	570.02	1.46	599.86	2.56	728.19	2.46	677.46	1.09	704.3
2.70	680.44	1.73	653.58	3.36	856.52	3.50	868.46	1.51	862.4
3.46	805.79	2.22	758.04	4.19	987.84	4.35	984.85	*	*
4.14	904.27	2.81	886.37	5.33	1134.07	5.39	1137.06	*	*
4.86	1002.76	3.48	984.85	6.32	1241.51	6.27	1223.60	*	*
5.53	1110.20	4.77	1059.46	6.79	1244.49	*	*	*	*
6.39	1175.85	5.80	1128.10	7.16	1304.18	*	*	*	*
7.19	1274.34	6.49	1226.59	*	*	*	*	*	*

Test T-5-4A

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.06	23.88	0.10	89.53	0.26	116.39	0.13	74.61	0.20	107.4
0.34	202.94	0.52	295.46	0.81	304.41	0.38	220.85	0.52	232.7
0.81	334.25	0.82	417.82	1.34	447.66	0.56	319.33	0.77	313.3
1.42	465.57	1.16	540.18	1.61	537.19	0.88	471.54	1.11	405.8
2.17	584.94	1.28	584.94	2.21	668.51	1.13	552.11	1.38	468.5
2.87	692.38	1.46	656.57	2.97	787.88	1.34	620.76	1.75	561.0
3.94	823.69	1.92	772.96	3.74	889.35	1.44	641.65	2.00	611.8
5.23	946.05	2.33	859.51	4.39	969.93	1.86	784.90	2.48	716.2
*	*	2.75	910.24	*	*	2.34	880.40	3.36	853.5
*	*	3.28	996.79	*	*	3.14	1008.73	3.87	910.2
*	*	4.20	1068.42	*	*	3.71	1056.48	4.46	996.7
*	*	*	*	*	*	*	*	5.07	1062.4
*	*	*	*	*	*	*	*	5.90	1104.2

Test T-5-4B

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.24	110.42	0.50	176.08	0.45	95.50	0.18	101.47	0.40	131.3
0.89	220.85	0.92	253.67	1.17	173.10	0.60	211.89	0.94	235.7
1.51	289.49	1.42	304.41	1.98	247.71	0.95	310.38	1.46	310.3
1.90	343.21	2.04	382.00	3.28	337.24	1.35	376.03	2.11	435.7
2.32	405.88	3.10	495.41	4.64	456.61	2.02	486.46	2.84	510.3
3.02	450.64	4.07	564.05	7.32	593.90	2.70	534.21	4.27	599.8
3.76	486.46	5.02	608.82	10.38	656.57	3.95	623.74	5.89	674.4
4.59	534.21	6.47	683.43	13.91	793.85	5.03	686.41	9.22	787.8
5.93	596.88	9.25	769.98	17.97	913.23	7.03	772.96	12.76	916.2
6.57	611.80	11.16	826.68	19.74	931.13	8.95	853.54	14.24	955.0
7.78	668.51	13.40	904.27	*	*	11.88	969.93	16.97	1053.4
8.55	689.40	*	*	*	*	15.55	1125.12	18.90	1107.2
9.95	734.16	*	*	*	*	16.76	1151.98	20.35	1160.9
*	*	*	*	*	*	17.58	1184.81	*	*

Test T-5-7

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.08	280.53	0.49	716.26	0.33	459.60	0.15	340.22	0.14	387.9
0.16	465.57	0.65	1295.23	0.45	677.46	0.29	635.68	0.26	850.5
0.47	829.66	0.72	1578.75	0.59	975.90	0.37	868.46	0.35	1116.1
0.58	1160.93	0.84	1886.14	0.76	1229.57	0.53	1244.49	0.43	1489.2
0.70	1575.76	0.98	2405.43	0.97	1716.03	0.67	1560.84	0.48	1862.2
0.84	1793.62	1.11	2542.71	1.15	2247.25	0.81	1841.37	0.64	2154.7
1.12	2417.36	1.25	2978.43	1.30	2614.33	0.98	1963.74	0.76	2659.1
1.43	2483.02	*	*	1.55	3026.18	1.20	2157.72	*	*
1.95	2748.63	*	*	*	*	*	*	*	*

Test T-5-8

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.05	149.22	0.09	217.86	0.05	110.42	0.05	77.59	0.08	176.0
0.10	229.80	0.16	417.82	0.24	361.11	0.13	379.02	0.15	310.3
0.15	459.60	0.28	552.11	0.48	570.02	0.24	543.16	0.20	379.0
0.34	677.46	0.44	764.01	0.69	731.18	0.29	725.21	0.38	677.4
0.40	790.87	0.62	880.40	0.91	904.27	0.40	1017.68	0.63	990.8
0.55	928.15	0.69	1017.68	1.11	1014.70	0.64	1214.65	0.74	1166.9
0.69	1128.10	0.87	1166.90	1.30	1175.85	0.84	1486.23	0.98	1396.7
0.87	1328.06	1.04	1316.12	1.60	1298.21	1.15	1730.95	1.23	1533.9
1.06	1450.42	1.21	1486.23	1.93	1465.34	1.40	1901.06	1.42	1698.1
1.26	1727.97	1.38	1554.87	2.32	1569.79	*	*	1.71	1862.2
1.66	1877.19	1.71	1850.33	*	*	*	*	*	*

Test T-5-9A

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.39	196.59	0.27	145.96	0.17	187.66	0.21	181.70	0.26	157.8
0.66	378.29	0.50	285.96	0.46	294.89	0.38	342.55	0.52	285.9
0.96	542.12	0.78	449.78	0.84	434.89	0.54	491.49	0.82	437.8
1.14	637.44	1.05	583.83	1.18	589.78	0.72	631.48	1.13	586.8
1.45	804.25	1.41	747.65	1.56	735.74	0.92	762.55	1.48	744.6
1.79	941.27	1.74	887.65	2.03	869.78	1.22	917.44	1.89	890.6
2.24	1125.95	2.10	1045.52	2.48	1030.63	1.56	1084.25	2.30	1045.5
2.60	1224.25	2.39	1090.20	3.08	1179.57	1.89	1224.25	2.71	1182.5
3.11	1411.90	2.51	1200.42	3.64	1361.27	2.30	1361.27	3.34	1352.3
3.45	1525.09	2.88	1319.56	4.08	1516.16	2.75	1498.29	3.85	1489.3
4.07	1694.88	3.37	1483.39	4.77	1620.41	3.29	1659.14	4.59	1626.3
4.67	1846.79	3.90	1635.31	5.94	1787.22	3.90	1808.07	5.36	1775.3
5.38	1995.73	4.42	1766.37	7.51	1915.30	4.72	1957.01	6.70	1962.9
6.43	2123.81	5.18	1936.16	10.60	2064.24	5.91	2099.98	8.02	2076.1
7.83	2269.77	6.02	2067.22	13.23	2207.22	8.02	2180.41	10.38	2219.1
11.48	2430.62	7.14	2219.13	16.19	2362.11	8.56	2248.92	14.19	2382.9
18.06	2311.47	8.89	2377.00	18.80	2469.34	9.88	2400.83	18.09	2543.8
*	*	11.28	2514.02	22.69	2552.75	12.40	2469.34	29.25	2594.4
*	*	14.95	2639.13	34.39	2630.19	14.04	2546.79	36.60	2713.6
*	*	18.84	2829.77	25.24	2579.55	18.07	2704.66	42.11	2835.7
*	*	27.54	2981.68	*	*	20.65	2874.45	*	*
*	*	*	*	*	*	22.68	3029.34	*	*

Test T-5-9B

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.04	166.81	0.15	140.00	0.14	142.98	0.18	178.72	0.12	169.7
0.20	300.85	0.34	300.85	0.34	321.70	0.34	321.70	0.34	390.2
0.54	467.66	0.55	425.95	0.51	464.68	0.55	497.44	0.50	548.0
0.86	616.59	0.82	580.85	0.77	631.48	0.72	628.51	0.71	708.9
1.23	768.50	1.12	744.68	0.94	729.78	0.91	765.53	0.81	920.4
1.57	914.46	1.44	890.63	1.26	905.52	1.14	914.46	0.99	1048.5
1.89	1051.48	1.82	1039.57	1.54	1033.61	1.38	1054.46	1.18	1206.3
2.24	1203.39	2.22	1170.63	1.86	1176.59	1.63	1203.39	1.44	1361.2
2.64	1346.37	2.75	1337.44	2.24	1349.35	1.93	1376.16	1.77	1489.3
3.06	1492.33	3.33	1465.52	2.51	1468.50	2.44	1581.69	2.05	1659.1
3.59	1638.29	4.12	1608.50	2.93	1635.31	2.95	1745.52	2.47	1775.3
4.19	1790.20	5.15	1769.35	3.32	1787.22	3.25	1811.05	2.84	1921.2
5.02	1933.18	6.07	1927.22	3.86	1927.22	3.97	1948.07	3.51	2097.0
6.21	2085.09	7.36	2061.26	4.52	2061.26	5.09	2091.05	4.36	2219.1
8.52	2231.05	11.31	2237.00	5.37	2222.11	6.59	2239.98	5.33	2374.0
10.36	2308.49	14.92	2377.00	6.39	2379.98	8.08	2317.43	7.71	2525.9
16.17	2400.83	17.11	2528.92	8.12	2517.00	10.43	2430.62	9.91	2659.9
18.39	2561.68	19.72	2642.11	10.84	2692.74	12.18	2531.90	12.10	2633.1
20.50	2692.74	24.63	2832.74	14.09	2820.83	14.96	2713.60	15.42	2880.4
25.49	2838.70	28.57	2937.00	25.36	2939.98	24.73	2859.55	23.56	2993.5
30.62	2966.79	*	*	*	*	*	*	*	*

Test T-6-1

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.23	191.00	0.86	304.41	0.49	238.75	0.32	146.24	0.32	196.9
0.57	432.74	1.22	558.08	0.76	414.83	0.65	364.10	0.77	396.9
0.81	575.99	1.41	677.46	1.23	617.77	0.88	501.38	1.17	620.7
1.31	758.04	1.70	829.66	1.87	823.69	1.18	707.30	1.60	731.1
2.89	993.81	2.06	1017.68	2.40	1092.29	1.77	820.71	1.85	784.9
3.25	1086.32	4.07	1268.37	2.96	1289.26	2.34	1017.68	3.06	1035.5
3.93	1366.86	4.73	1426.54	3.40	1423.56	2.73	1166.90	3.72	1223.6
4.93	1596.65	5.61	1614.56	3.86	1528.01	3.18	1357.90	4.23	1387.7
6.21	1722.00	6.47	1704.09	4.52	1635.45	3.70	1504.14	5.44	1662.3
*	*	7.79	1742.89	*	*	4.21	1656.34	7.22	1713.0

Test T-6-2

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.17	107.44	0.19	95.50	0.13	65.66	0.13	92.52	0.26	68.6
0.65	250.69	0.38	244.72	0.39	202.94	0.63	304.41	0.58	262.6
1.23	384.99	0.63	367.08	0.94	393.94	0.92	432.74	0.84	387.9
1.65	608.82	1.02	522.27	1.35	513.32	1.31	581.96	1.26	549.1
1.95	677.46	1.52	704.32	1.88	638.66	1.73	686.41	1.92	731.1
2.66	937.10	2.04	853.54	2.48	814.74	2.43	904.27	2.33	844.5
3.20	1038.57	2.59	999.77	2.81	898.30	*	*	2.83	1011.7
*	*	2.99	1092.29	3.24	1035.59	*	*	3.11	1059.4

Test T-6-4A

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.55	29.84	2.00	62.67	0.73	56.70	1.51	56.70	0.55	29.8
1.89	86.55	3.09	95.50	2.28	122.36	2.16	95.50	1.89	86.5
3.91	161.16	4.67	125.34	3.62	179.06	3.66	143.25	3.91	161.1
5.83	199.95	6.16	143.25	5.81	191.00	5.47	193.99	5.83	199.9
8.66	250.69	8.16	173.10	15.68	322.32	7.83	229.80	8.66	250.6
21.39	322.32	11.23	202.94	17.67	382.00	15.42	325.30	21.39	322.3
22.57	349.17	15.92	331.27	19.39	423.78	16.57	373.05	22.57	349.1
24.37	384.99	18.40	370.07	21.56	459.60	17.96	417.82	24.37	384.9
26.65	438.71	20.54	373.05	*	*	18.95	423.78	26.65	438.7
28.85	444.68	23.47	414.83	*	*	20.63	450.64	28.85	444.6
*	*	29.60	429.75	*	*	*	*	*	*

Test T-6-4B

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.48	101.47	0.95	155.19	0.56	74.61	0.87	143.25	0.48	101.4
0.86	158.17	1.28	232.78	1.49	188.02	1.63	259.64	0.86	158.1
1.45	229.80	1.86	331.27	2.33	295.46	2.05	301.42	1.45	229.8
2.03	319.33	2.62	450.64	3.26	379.02	2.68	387.97	2.03	319.3
2.79	417.82	3.02	474.52	4.22	444.68	4.01	507.35	2.79	417.8
3.82	522.27	3.46	522.27	5.40	489.44	4.90	549.13	3.82	522.2
4.62	567.04	4.12	564.05	6.89	549.13	9.88	602.85	4.62	567.0
5.91	650.60	5.21	611.80	9.20	635.68	11.45	662.54	5.91	650.6
7.18	737.15	5.91	647.61	*	*	12.92	683.43	7.18	737.1

Test T-6-6

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.37	125.34	0.29	152.20	0.62	119.38	0.44	217.86	0.24	161.1
1.28	304.41	0.57	334.25	0.97	244.72	0.60	274.56	0.65	384.9
1.62	444.68	0.82	459.60	1.54	507.35	0.77	396.93	0.90	489.4
1.95	584.94	1.11	581.96	2.08	731.18	1.03	570.02	1.30	725.2
2.35	701.33	1.67	772.96	2.50	847.57	1.43	772.96	1.72	856.5
2.79	883.38	1.86	892.34	2.93	1014.70	1.83	946.05	2.16	1044.5
3.10	963.96	2.64	1202.71	3.51	1181.82	2.44	1187.79	2.57	1151.9
3.60	1151.98	3.26	1354.92	*	*	3.08	1381.78	2.97	1322.0
3.94	1253.45	*	*	*	*	*	*	3.51	1444.4
4.54	1411.62	*	*	*	*	*	*	*	*
5.92	1578.75	*	*	*	*	*	*	*	*

Test T-6-7

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.79	301.42	0.24	379.02	0.18	331.27	0.34	295.46	0.64	244.7
1.12	575.99	0.39	519.29	0.21	432.74	0.43	370.07	0.83	429.7
1.45	680.44	0.47	617.77	0.29	522.27	0.58	507.35	0.93	581.9
1.88	1175.85	0.50	775.94	0.44	686.41	0.78	758.04	1.04	668.5
2.43	1396.70	0.60	859.51	0.58	844.59	0.98	880.40	1.61	966.9
2.53	1593.67	0.79	1157.95	0.86	949.04	1.47	1169.88	1.91	1268.3
2.69	1793.62	1.06	1283.29	*	*	1.79	1390.73	2.06	1423.5
3.00	1996.56	1.18	1411.62	*	*	2.05	1644.40	2.35	1665.3
*	*	1.46	1614.56	*	*	*	*	*	*

Test T-6-8

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.10	98.49	0.15	134.30	0.14	56.70	0.15	92.52	0.34	104.4
0.25	307.39	0.33	349.17	0.35	250.69	0.33	191.00	0.58	355.1
0.38	483.47	0.59	656.57	0.53	459.60	0.60	411.85	0.72	441.6
0.64	814.74	0.65	719.24	0.64	558.08	0.76	549.13	0.91	593.9
0.78	1026.63	0.74	844.59	0.77	692.38	0.99	796.83	1.03	728.1
0.94	1172.87	0.94	1047.52	0.87	874.43	1.15	999.77	1.22	969.9
1.11	1304.18	*	*	1.10	1098.26	1.71	1420.57	1.50	1184.8
1.36	1456.39	*	*	44.13	65.66	*	*	1.71	1298.2
1.85	1596.65	*	*	*	*	*	*	*	*

Test T-6-9A

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.19	26.81	0.22	32.77	0.13	32.77	0.21	56.60	0.11	17.8
0.72	104.25	0.52	107.23	0.31	77.45	0.57	116.17	0.33	41.7
1.45	202.55	0.95	193.62	0.52	119.15	1.20	190.64	0.63	134.0
2.84	238.30	1.23	262.13	0.87	178.72	1.75	262.13	0.92	199.5
3.34	274.04	1.52	342.55	1.67	247.23	2.70	336.59	1.15	259.1
4.06	345.53	1.81	390.21	2.45	330.64	4.06	470.63	1.71	321.7
4.53	402.12	2.34	473.61	3.40	428.93	4.79	571.91	2.25	408.0
5.17	488.51	3.06	548.08	4.13	488.51	5.45	646.38	2.83	476.5
5.69	557.02	4.15	634.46	4.86	548.08	5.97	705.95	3.74	565.9
6.33	640.42	5.13	702.97	5.81	628.51	6.69	783.40	4.10	634.4
7.04	714.89	5.67	777.44	6.69	697.02	7.47	854.89	4.54	714.8
7.96	780.42	6.30	857.87	8.11	774.46	8.62	929.35	4.93	777.4
8.78	848.93	7.20	941.27	9.55	857.87	10.10	997.86	5.44	860.8
11.04	926.38	8.07	1006.80	11.12	929.35	11.48	1021.69	6.04	929.3
13.63	985.95	9.43	1078.29	14.30	988.93	13.98	1012.76	6.59	997.8
15.38	1006.80	11.59	1134.88	16.78	977.01	17.87	1048.50	7.23	1066.3
18.87	1006.80	13.39	1167.65	19.29	911.48	22.55	962.12	8.14	1146.8
30.31	810.21	15.63	1173.61	25.50	968.08	*	*	9.29	1230.2
*	*	17.76	1167.65	26.51	828.08	*	*	11.05	1292.7
*	*	24.18	1027.65	*	*	*	*	11.79	1322.5
*	*	*	*	*	*	*	*	12.85	1319.5
*	*	*	*	*	*	*	*	13.93	1352.3
*	*	*	*	*	*	*	*	15.17	1370.2
*	*	*	*	*	*	*	*	18.51	1405.9
*	*	*	*	*	*	*	*	20.43	1277.8

Test T-6-9B

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.63	74.47	0.55	80.42	0.26	71.49	0.08	38.72	0.58	68.5
0.87	148.93	0.90	169.79	0.47	134.04	0.25	128.08	0.82	166.8
1.14	223.40	1.13	226.38	0.71	217.45	0.38	199.57	1.01	223.4
1.32	291.91	1.55	333.61	0.92	274.04	0.50	265.10	1.24	297.8
1.52	342.55	1.77	375.32	1.15	354.47	0.67	348.51	1.46	363.4
1.81	437.87	2.23	455.74	1.46	440.85	0.85	425.95	1.70	431.9
2.11	524.25	2.94	539.14	1.72	506.38	1.02	506.38	2.00	512.3
2.41	595.74	3.44	589.78	2.10	583.83	1.21	560.00	2.39	613.6
2.82	658.29	4.59	670.21	2.54	658.29	1.42	643.40	2.69	664.2
3.99	705.95	5.09	732.76	3.53	699.99	1.64	720.85	3.24	732.7
5.04	756.59	5.61	813.19	4.48	711.91	1.82	780.42	4.53	780.4
5.68	857.87	6.09	893.61	4.84	729.78	2.06	863.82	5.11	813.1
5.97	905.52	6.57	971.06	5.28	804.25	2.28	932.33	5.70	884.6
6.45	962.12	7.02	1042.54	5.80	875.74	2.59	1024.67	6.27	962.1
6.69	1036.59	7.58	1114.03	6.44	956.16	3.06	1146.80	6.77	1027.6
7.80	1111.06	8.42	1209.35	7.05	1030.63	3.43	1230.20	7.47	1105.1
8.58	1179.57	9.23	1268.93	7.67	1090.20	3.83	1316.59	8.29	1185.5
9.85	1254.03	10.22	1328.50	8.66	1170.63	4.23	1379.14	9.15	1257.0
12.37	1298.71	12.50	1402.97	10.65	1233.18	4.88	1453.61	10.34	1328.5
14.84	1280.84	14.66	1385.10	12.07	1251.05	5.78	1492.33	12.15	1358.2
16.73	1254.03	17.39	1346.37	12.95	1259.99	6.28	1507.22	14.86	1367.2
17.94	1227.22	18.81	1325.52	14.85	1257.01	7.21	1477.44	25.43	1143.8
27.00	997.86	*	*	16.09	1227.22	8.00	1444.67	*	*
*	*	*	*	22.45	1134.88	*	*	*	*

Test T-6-10A

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.13	20.89	0.42	56.70	0.39	56.70	0.15	29.84	0.25	32.8
0.25	71.63	1.08	182.05	0.86	110.42	0.50	101.47	0.70	116.3
0.65	134.30	1.38	235.77	1.37	214.88	0.76	170.11	1.03	173.1
0.93	211.89	1.77	295.46	1.70	277.55	1.10	232.78	1.35	241.7
1.12	265.61	2.14	340.22	2.39	361.11	1.36	292.47	1.88	316.3
1.31	313.36	2.79	376.03	3.26	423.78	2.11	379.02	2.62	370.0
1.60	376.03	4.29	453.63	4.61	483.47	2.88	423.78	4.85	432.7
1.99	429.75	5.54	516.30	6.36	531.22	*	*	6.33	507.3
2.59	492.43	*	*	6.96	567.04	*	*	7.45	578.9
3.37	531.22	*	*	*	*	*	*	*	*

Test T-6-10B

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.43	26.86	0.38	29.84	0.49	35.81	0.42	17.91	0.55	23.8
0.93	68.64	1.06	95.50	0.76	62.67	0.91	62.67	1.12	56.7
1.56	113.41	1.93	152.20	1.18	98.49	1.57	116.39	1.83	122.3
2.32	179.06	3.05	214.88	1.49	125.34	2.14	179.06	2.58	196.9
2.78	193.99	*	*	1.98	167.13	2.88	217.86	3.37	241.7
3.31	217.86	*	*	2.38	173.10	3.41	235.77	4.42	259.6
3.93	238.75	*	*	2.72	191.00	*	*	*	*
5.76	271.58	*	*	3.51	235.77	*	*	*	*

Test T-6-11

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00				
0.20	107.23	0.07	35.74	0.16	101.28				
0.37	214.47	0.24	80.42	0.35	175.74				
0.49	277.02	0.48	196.59	0.45	214.47				
0.61	351.49	0.61	274.04	0.58	259.15				
0.75	405.10	0.78	366.38	0.72	345.53				
0.89	479.57	1.03	485.53	0.84	425.95				
1.06	568.93	1.20	571.91	1.01	536.17				
1.20	619.57	1.39	661.27	1.16	604.68				
1.34	676.16	1.57	726.80	1.29	682.12				
1.48	726.80	1.78	810.21	1.41	744.68				
1.63	786.38	1.93	860.84	1.53	795.31				
1.77	839.99	2.08	917.44	1.65	848.93				
1.93	890.63	2.33	988.93	1.98	994.89				
2.18	979.99	2.55	1051.48	2.14	1054.46				
2.43	1054.46	2.82	1117.01	2.36	1128.93				
2.70	1134.88	3.08	1161.69	2.52	1200.42				
2.88	1191.48	3.43	1239.14	2.68	1239.14				
3.08	1251.05	3.86	1328.50	2.98	1331.48				
3.29	1307.65	4.43	1399.99	3.23	1408.93				
3.49	1355.31	5.21	1474.46	3.56	1495.31				
4.14	1385.10	5.98	1501.26	3.94	1563.82				
4.66	1465.52	7.31	1566.80	4.31	1635.31				
5.17	1319.56	8.37	1602.54	4.75	1709.77				
5.70	1391.05	8.93	1611.48	5.24	1781.26				
6.39	1334.46	10.23	1653.18	6.59	1840.84				
7.14	1245.10	11.47	1674.03	8.04	1876.58				
7.67	1140.84	12.92	1694.88	9.38	1906.37				
8.28	994.89	14.74	1697.86	10.52	1924.24				
9.02	866.80	16.05	1662.11	11.58	1903.39				
		16.76	1611.48	12.03	1852.75				
		18.09	1516.16	13.01	1909.35				
		18.62	1468.50	14.48	1933.18				
		19.53	1257.01	17.09	1933.18				
		20.18	1119.99	19.02	1906.37				
				20.07	1873.60				
				21.47	1790.20				

Test T-7-1

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.79	364.10	1.02	304.41	1.15	393.94	0.92	346.19	1.10	283.5
0.82	510.33	1.08	420.80	1.40	758.04	0.95	450.64	1.22	549.1
0.94	755.05	1.33	805.79	1.68	1250.46	1.10	719.24	1.48	1062.4
1.03	978.88	1.51	1125.12	2.00	1739.91	1.28	1047.52	1.63	1387.7
1.13	1253.45	1.67	1420.57	2.18	1996.56	1.45	1322.09	1.82	1686.1
1.36	1704.09	1.82	1653.36	2.37	2157.72	1.62	1686.19	1.94	1984.6
1.55	1910.02	2.07	1996.56	2.61	2488.99	1.79	1987.61	2.19	2405.4
1.74	2348.72	2.28	2274.11	2.92	2811.30	1.99	2339.77	2.33	2593.4
1.89	2572.55	2.62	2757.59	3.29	3139.59	2.24	2688.94	2.59	3032.1
2.16	2927.70	3.08	3285.82	3.63	3414.15	2.64	3336.56	3.06	3584.2
2.40	3139.59	3.39	3497.72	4.18	3733.48	3.09	3772.28	3.44	3849.8
2.93	3673.80	3.74	3867.78	4.82	4022.97	3.48	4103.55	3.85	4166.2
3.58	3996.11	4.19	4100.57	5.82	4231.88	4.02	4324.40	4.68	4381.1
4.71	4157.27	4.56	4297.54	8.37	4345.29	5.18	4410.94	*	*
*	*	6.16	4464.66	*	*	*	*	*	*

Test T-7-2

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.16	191.00	0.32	289.49	0.09	170.11	0.56	131.31	0.16	131.3
0.35	414.83	0.64	543.16	0.28	358.13	0.96	310.38	0.41	283.5
0.50	620.76	0.84	677.46	0.62	704.32	1.33	462.58	0.73	441.6
0.78	889.35	0.99	835.63	0.91	978.88	1.70	650.60	1.01	546.1
0.89	1005.74	1.24	925.16	1.05	1107.21	2.11	841.60	1.32	713.2
1.02	1086.32	1.58	1131.09	1.31	1292.25	2.28	975.90	1.63	877.4
1.20	1265.39	2.08	1211.67	1.46	1420.57	2.59	1056.48	1.89	1011.7
1.43	1441.47	2.16	1295.23	1.66	1545.92	3.15	1304.18	2.36	1175.8
1.52	1533.98	2.33	1411.62	1.86	1689.17	3.69	1489.22	2.90	1363.8
1.90	1805.56	2.63	1736.92	2.16	1868.23	4.59	1724.98	3.57	1554.8
2.32	2002.53	2.86	1874.20	*	*	5.20	1889.13	4.40	1775.7
2.56	2181.60	*	*	*	*	6.35	2148.77	5.38	1936.8
2.82	2309.93	*	*	*	*	7.33	2295.00	6.48	2086.1
*	*	*	*	*	*	8.14	2477.05	*	*

Test T-7-4A

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.30	393.94	0.16	173.10	0.20	256.66	0.63	244.72	0.11	134.3
0.51	528.24	0.51	483.47	0.47	581.96	0.89	462.58	0.24	280.5
0.67	695.37	0.59	516.30	0.54	659.55	1.01	596.88	0.60	608.8
0.89	877.41	0.79	752.07	0.66	871.44	1.19	752.07	0.78	808.7
0.91	957.99	0.99	856.52	0.81	1017.68	1.42	937.10	1.15	1178.8
1.14	1116.17	1.24	1041.56	0.84	1086.32	1.86	1202.71	1.50	1351.9
1.19	1199.73	1.70	1360.89	0.93	1250.46	1.97	1298.21	1.77	1495.1
1.34	1316.12	2.08	1536.97	1.04	1420.57	2.08	1423.56	2.15	1644.4
1.51	1423.56	2.49	1724.98	1.12	1584.72	2.19	1533.98	2.57	1751.8
1.63	1551.89	2.90	1921.95	1.26	1742.89	2.49	1763.78	3.33	1838.3
1.79	1689.17	3.47	2142.80	*	*	3.19	1936.88	4.70	2017.4
1.94	1760.80	*	*	*	*	3.00	2059.24	5.28	2208.4
2.22	1972.69	*	*	*	*	3.24	2175.63	6.23	2512.8
*	*	*	*	*	*	3.59	2327.83	*	*

Test T-7-4B

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.07	116.39	0.07	104.45	0.09	179.06	0.14	167.13	0.14	188.0
0.24	337.24	0.18	244.72	0.37	411.85	0.37	379.02	0.37	396.9
0.47	486.46	0.58	602.85	0.61	734.16	0.63	555.10	0.58	787.8
0.72	761.02	0.78	841.60	0.91	1107.21	0.79	692.38	1.01	1044.5
1.02	1002.76	1.30	1348.95	1.09	1286.28	1.23	1092.29	1.31	1441.4
1.31	1238.53	1.65	1677.23	1.32	1566.81	1.69	1417.59	1.60	1751.8
1.60	1480.26	1.72	1772.73	1.51	1841.37	1.95	1629.48	1.88	2005.5
2.17	1877.19	2.08	2112.96	1.86	2145.78	2.13	1733.94	2.13	2232.3
2.57	2092.06	2.39	2363.64	2.24	2456.16	2.32	1907.03	2.48	2533.7
3.11	2405.43	2.79	2632.24	2.81	2838.16	2.57	2059.24	2.82	2715.8
3.70	2644.18	3.32	2954.56	*	*	3.01	2348.72	3.41	3047.0
4.45	2909.79	*	*	*	*	3.65	2668.05	4.26	3378.3
5.26	3076.92	*	*	*	*	4.39	3017.23	5.11	3542.4
*	*	*	*	*	*	6.42	3276.87	*	*

Test T-8-1

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.54	178.72	0.28	208.51	0.19	98.30	0.19	172.76	0.20	104.2
0.70	285.96	0.40	309.78	0.52	265.10	0.32	282.98	0.48	285.9
0.96	461.70	0.59	440.85	0.87	396.17	0.49	390.21	0.79	437.8
1.16	604.68	0.75	527.23	1.22	565.95	0.79	568.93	1.02	527.2
1.45	750.63	1.08	699.99	1.43	667.23	1.11	685.10	1.49	685.1
1.86	860.84	1.57	837.01	2.06	828.08	1.58	816.16	2.28	863.8
2.72	1048.50	2.16	979.99	2.81	982.97	2.69	968.08	2.85	988.9
3.38	1170.63	2.75	1134.88	3.48	1114.03	3.35	1143.82	3.52	1108.0
4.19	1307.65	3.23	1262.97	4.27	1304.67	4.49	1337.44	4.50	1257.0
4.94	1441.69	3.86	1417.86	4.86	1414.88	5.03	1429.78	5.27	1382.1
7.06	1712.75	5.42	1757.43	5.75	1575.73	5.65	1548.92	6.28	1602.5
9.35	1927.22	6.75	2001.69	6.51	1706.80	6.61	1733.60	6.86	1715.7
*	*	*	*	8.40	2028.49	8.21	2037.43	8.66	2028.4

Test T-8-2

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.32	181.70	0.40	193.62	0.36	145.96	0.44	178.72	0.33	193.6
0.43	288.93	0.64	417.02	0.63	280.00	0.77	345.53	0.56	393.1
0.64	440.85	0.76	512.34	0.91	455.74	0.96	473.61	0.73	488.5
1.03	604.68	0.94	601.70	1.19	592.76	1.20	604.68	0.94	592.7
1.37	723.82	1.22	741.70	1.40	667.23	1.64	759.57	1.34	723.8
1.89	890.63	1.65	893.61	1.61	726.80	2.32	926.38	1.88	887.6
2.60	1048.50	1.98	982.97	1.91	810.21	2.96	1045.52	2.29	991.9
3.28	1167.65	2.31	1072.33	2.28	902.55	3.51	1146.80	2.52	1039.5
4.28	1328.50	2.50	1102.12	2.65	982.97	3.83	1200.42	2.88	1114.0
*	*	2.73	1167.65	2.98	1057.44	4.22	1251.05	3.39	1233.1
*	*	3.16	1254.03	3.49	1167.65	4.72	1334.46	3.90	1310.6
*	*	4.90	1322.54	3.98	1257.01	5.31	1402.97	4.25	1352.3
*	*	*	*	4.43	1319.56	*	*	4.67	1382.1
*	*	*	*	4.83	1391.05	*	*	*	*
*	*	*	*	5.43	1459.56	*	*	*	*

Test T-8-2A

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.37	291.91	0.46	309.78	0.36	309.78	0.51	375.32	0.54	378.2
0.69	622.55	0.87	637.44	0.78	667.23	0.86	676.16	0.90	607.6
0.86	744.68	1.12	768.50	0.97	792.33	1.24	926.38	1.50	911.4
1.11	935.31	1.32	893.61	1.19	944.25	1.46	1063.40	1.81	1030.6
1.45	1039.57	1.60	1045.52	1.52	1128.93	1.69	1182.54	2.11	1161.6
1.86	1185.52	1.98	1224.25	1.70	1197.44	1.95	1328.50	2.67	1394.0
2.21	1313.61	2.23	1340.42	2.11	1397.01	2.25	1471.48	2.97	1507.2
2.65	1468.50	2.81	1572.75	2.40	1528.07	2.72	1671.05	3.32	1635.3
3.24	1674.03	2.96	1611.48	2.93	1727.65	3.06	1796.16	3.73	1805.0
3.38	1772.33	3.54	1796.16	3.20	1811.05	3.45	1945.09	4.11	1939.1
3.49	1921.26	3.86	1918.28	3.54	1951.05	3.83	2114.88	4.54	2088.0
3.98	2082.11	4.42	2085.09	3.95	2144.66	4.17	2231.05	4.98	2210.2
4.36	2213.17	4.88	2228.07	4.61	2329.34	4.57	2388.92	5.54	2412.7
4.81	2394.87	5.97	2397.85	4.75	2409.77	5.05	2514.02	5.98	2540.8
5.18	2519.98	6.32	2570.62	5.06	2543.81	5.42	2662.96	6.42	2636.1
6.04	2692.74	6.67	2683.81	5.46	2701.68	6.03	2802.96	7.91	2877.4
6.39	2805.94	7.12	2841.68	5.93	2853.59	7.35	3100.83	8.15	2951.8
6.78	2942.96	7.51	2984.66	6.40	3017.42	*	*	*	*

Test T-8-3A

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.14	175.74	0.12	202.55	0.20	184.68	0.12	142.98	0.17	151.9
0.22	312.76	0.17	318.72	0.34	318.72	0.23	339.57	0.30	303.8
0.33	470.63	0.33	577.87	0.54	571.91	0.40	560.00	0.43	488.5
0.47	613.61	0.55	768.50	0.79	777.44	0.42	598.72	0.56	640.4
0.64	744.68	0.76	902.55	1.02	884.67	0.61	759.57	0.73	774.4
0.92	884.67	1.00	1042.54	1.37	1024.67	0.85	908.50	1.01	908.5
1.32	1054.46	1.11	1105.10	1.55	1122.97	1.11	1018.72	1.32	1081.2
1.48	1105.10	1.36	1239.14	1.79	1212.33	1.32	1111.06	1.43	1125.9
1.67	1194.46	1.44	1254.03	2.06	1286.80	1.58	1236.16	1.57	1185.5
1.87	1262.97	1.67	1370.20	2.18	1331.48	1.79	1301.69	1.74	1257.0
2.12	1352.33	1.84	1435.73	2.38	1408.93	1.92	1349.35	2.00	1343.3
2.37	1411.90	2.01	1492.33	2.67	1492.33	2.17	1435.73	2.21	1426.8
2.82	1432.75	2.41	1525.09	2.98	1566.80	2.48	1510.20	2.36	1456.5
*	*	*	*	*	*	2.80	1548.92	2.80	1572.7

Test T-8-3B

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.33	128.08	0.41	154.89	0.51	151.91	0.44	169.79	0.45	184.6
0.95	288.93	0.84	318.72	0.98	318.72	0.78	327.66	0.91	312.7
1.41	488.51	1.26	470.63	1.49	458.72	1.20	452.76	1.29	476.5
1.75	583.83	1.78	622.55	2.14	607.65	1.77	583.83	1.73	589.7
2.32	708.93	2.35	738.72	2.92	744.68	2.54	726.80	2.50	738.7
3.27	875.74	3.43	908.50	3.50	828.08	3.52	866.80	3.71	905.5
4.39	1021.69	4.03	956.16	3.95	893.61	4.18	959.14	4.22	959.1
4.98	1078.29	4.72	1051.48	4.55	971.06	4.74	1018.72	4.83	1024.6
6.01	1149.78	5.62	1137.86	5.29	1069.35	5.58	1108.08	5.72	1114.0
8.37	1197.44	6.39	1203.39	5.94	1125.95	6.28	1173.61	6.88	1188.5
9.73	1316.59	9.00	1289.78	6.67	1206.37	6.99	1242.12	8.69	1265.9
*	*	*	*	7.27	1251.05	8.09	1328.50	10.64	1227.2
*	*	*	*	9.32	1334.46	9.65	1399.99	*	*
*	*	*	*	*	*	10.51	1453.61	*	*

Test T-8-5

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.11	172.76	0.29	274.04	0.26	190.64	0.10	220.42	0.12	178.7
0.23	348.51	0.33	327.66	0.35	321.70	0.16	348.51	0.29	452.7
0.33	551.06	0.52	601.70	0.43	470.63	0.23	494.46	0.39	622.5
0.37	619.57	0.67	798.29	0.51	613.61	0.30	616.59	0.51	798.2
0.47	780.42	0.80	929.35	0.60	759.57	0.43	765.53	0.66	985.9
0.56	908.50	1.06	1149.78	0.73	944.25	0.58	917.44	0.75	1087.2
0.74	1093.18	1.16	1227.22	0.82	1054.46	0.78	1078.29	0.90	1239.1
0.85	1185.52	1.42	1379.14	0.96	1197.44	0.95	1173.61	1.06	1385.1
1.15	1349.35	1.74	1522.12	1.19	1373.18	1.33	1376.16	1.19	1480.4
1.52	1504.24	2.17	1682.97	1.47	1507.22	1.57	1486.37	1.45	1584.6
1.86	1638.29	2.22	1650.20	1.79	1623.39	1.86	1611.48	1.85	1805.0
2.28	1775.31	2.44	1787.22	2.27	1799.13	2.30	1796.16	2.07	1879.5
2.81	1933.18	2.61	1852.75	2.48	1837.86	2.48	1843.82	2.18	1939.1
3.34	2064.24	2.83	1945.09	2.74	1921.26	2.64	1894.45	2.33	1983.8
*	*	3.04	2022.54	3.07	2010.62	2.92	1989.77	2.66	2070.2
*	*	3.28	2076.15	3.39	2094.03	3.19	2085.09	3.23	2177.4
*	*	3.66	2162.54	3.72	2129.77	3.58	2168.49	*	*
*	*	4.66	2239.98	*	*	3.86	2186.37	*	*
*	*	*	*	*	*	*	*	*	*

Test T-9-1

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.36	193.99	0.83	259.64	1.34	337.24	1.20	337.24	1.45	313.3
0.90	373.05	1.24	393.94	1.80	438.71	1.68	441.69	2.10	486.4
1.58	567.04	1.69	516.30	2.79	620.76	2.94	686.41	2.88	626.7
2.18	656.57	2.27	662.54	3.65	740.13	3.82	790.87	3.79	769.9
3.18	841.60	3.38	838.62	4.79	880.40	5.30	975.90	5.36	966.9
4.27	952.02	4.43	996.79	5.90	999.77	6.63	1077.37	7.00	1113.1
5.51	1104.23	6.04	1151.98	7.64	1172.87	8.57	1253.45	8.87	1286.2
7.44	1268.37	7.55	1304.18	9.28	1307.17	10.02	1366.86	11.40	1438.4
9.33	1432.51	9.25	1438.48	11.55	1462.36	14.12	1563.83	15.89	1578.7
12.03	1548.90	11.93	1590.69	14.10	1566.81	20.71	1763.78	21.12	1724.9
16.41	1739.91	15.69	1716.03	*	*	24.32	1901.06	25.11	1838.3
20.23	1862.27	*	*	*	*	*	*	*	*

Test T-9-2

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.25	119.38	0.33	164.14	1.36	83.56	0.32	89.53	0.21	104.4
0.61	322.32	0.79	292.47	1.83	232.78	1.06	274.56	0.57	250.6
1.04	495.41	1.20	393.94	2.40	382.00	1.54	364.10	1.09	429.7
1.56	629.71	1.77	516.30	3.32	513.32	2.43	552.11	1.74	561.0
1.90	698.35	2.20	593.90	4.36	653.58	3.38	686.41	2.36	662.5
2.69	847.57	2.99	719.24	5.99	874.43	4.73	859.51	3.55	874.4
3.37	955.01	4.20	901.29	6.78	972.91	5.78	972.91	4.53	1023.6
4.03	1080.35	5.57	1098.26	8.26	1229.57	7.21	1140.04	5.48	1172.8
4.89	1235.54	6.28	1202.71	9.82	1477.28	8.26	1259.42	6.45	1328.0
5.73	1399.68	7.19	1325.07	11.51	1730.95	9.80	1438.48	7.59	1531.0
6.64	1581.73	8.11	1480.26	*	*	12.45	1727.97	9.12	1796.6
8.01	1874.20	*	*	*	*	13.49	1865.25	*	*
*	*	*	*	*	*	14.87	1945.83	*	*
*	*	*	*	*	*	15.43	2059.24	*	*

Test T-9-4A

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
2.35	170.11	0.34	161.16	0.38	86.55	0.25	65.66	0.46	80.5
3.70	480.49	0.65	235.77	1.27	250.69	1.37	328.28	1.51	247.7
4.15	584.94	1.12	387.97	1.89	393.94	1.95	447.66	2.03	384.9
4.52	644.63	1.83	528.24	2.90	596.88	2.50	558.08	2.71	540.1
5.03	746.10	2.71	659.55	3.38	683.43	2.90	629.71	3.55	683.4
5.81	889.35	3.42	778.93	4.69	877.41	3.27	710.29	4.68	841.6
6.67	1014.70	4.59	937.10	5.26	949.04	4.00	823.69	5.90	957.9
7.45	1092.29	6.07	1140.04	7.02	1208.68	4.74	916.21	8.00	1166.9
8.25	1232.56	7.24	1280.31	8.30	1390.73	5.71	1038.57	9.51	1301.2
9.24	1372.82	8.55	1432.51	10.43	1695.14	6.76	1178.84	12.08	1489.2
10.05	1519.06	9.65	1572.78	*	*	7.49	1271.35	15.67	1847.3
11.62	1724.98	*	*	*	*	8.77	1444.45	11.85	59.6
*	*	*	*	*	*	10.00	1608.59	*	*
*	*	*	*	*	*	11.28	1763.78	*	*

Test T-9-4B

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.31	226.81	0.35	179.06	0.30	193.99	0.22	173.10	2.45	379.0
0.54	355.14	0.62	301.42	0.68	468.55	0.54	379.02	3.52	671.4
0.88	543.16	1.31	543.16	0.93	623.74	1.09	689.40	3.69	692.3
1.22	686.41	1.93	683.43	1.49	937.10	1.52	871.44	4.07	814.7
1.53	826.68	2.68	850.55	1.85	1104.23	1.90	1011.71	4.42	925.1
1.74	907.26	4.00	1119.15	2.48	1351.93	2.78	1262.40	5.41	1208.6
2.05	1008.73	5.02	1319.10	3.01	1456.39	4.29	1554.87	6.55	1405.6
2.59	1146.01	5.89	1456.39	3.49	1578.75	6.50	1820.48	7.84	1602.6
3.38	1307.17	7.88	1710.06	4.73	1820.48	11.87	2014.47	10.49	1865.2
4.35	1465.34	13.47	1963.74	9.23	1966.72	*	*	18.67	1999.5
5.31	1596.65	16.63	2178.61	*	*	*	*	*	*
6.21	1692.15	*	*	*	*	*	*	*	*
6.77	1748.86	*	*	*	*	*	*	*	*

Test T-9-8

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	*	*	*	*
0.84	396.93	0.25	131.31	0.20	167.13	*	*	*	*
1.56	584.94	0.39	265.61	0.55	316.35	*	*	*	*
1.84	659.55	0.62	417.82	0.53	435.72	*	*	*	*
2.15	761.02	0.91	605.83	0.81	602.85	*	*	*	*
2.71	886.37	1.27	695.37	1.16	823.69	*	*	*	*
5.17	1044.54	1.76	775.94	1.50	916.21	*	*	*	*
6.13	1187.79	2.64	934.12	2.11	1053.49	*	*	*	*
6.94	1295.23	3.07	1071.40	2.91	1193.76	*	*	*	*
7.83	1390.73	3.96	1217.64	3.69	1357.90	*	*	*	*
8.85	1572.78	4.52	1342.98	4.30	1501.15	*	*	*	*
10.55	1927.92	5.41	1539.95	*	*	*	*	*	*
11.67	2098.03	*	*	*	*	*	*	*	*
12.70	2208.46	*	*	*	*	*	*	*	*

Test T-10-1A

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.14	95.32	0.26	166.81	0.40	175.74	0.18	160.85	0.22	202.5
0.23	166.81	0.91	294.89	0.65	342.55	0.41	300.85	0.38	384.2
0.33	256.17	1.34	443.83	0.93	533.19	0.74	464.68	0.53	518.2
0.44	339.57	1.85	592.76	1.17	622.55	1.08	598.72	0.63	580.8
0.54	414.04	2.47	741.70	1.60	771.48	1.54	750.63	0.94	765.5
0.62	464.68	3.54	890.63	2.16	905.52	2.17	899.57	1.30	902.5
0.72	527.23	4.99	1057.44	3.00	1063.40	3.09	1048.50	1.76	1045.5
0.82	583.83	7.45	1179.57	4.41	1203.39	4.19	1185.52	2.39	1179.5
0.92	646.38	9.90	1301.69	6.16	1295.73	5.89	1334.46	3.74	1334.4
1.03	697.02	10.89	1501.26	7.13	1358.29	9.06	1504.24	6.06	1486.3
1.18	774.46	12.12	1659.14	8.96	1420.84	9.87	1644.24	7.60	1623.3
1.31	837.01	13.51	1775.31	10.49	1510.20	10.99	1748.50	8.71	1697.8
1.51	917.44	15.42	1936.16	12.28	1679.99	11.41	1775.31	9.60	1766.3
1.67	988.93	*	*	*	*	*	*	10.69	1885.5
1.84	1033.61	*	*	*	*	*	*	*	*
2.17	1125.95	*	*	*	*	*	*	*	*
2.43	1191.48	*	*	*	*	*	*	*	*
2.78	1268.93	*	*	*	*	*	*	*	*
3.24	1334.46	*	*	*	*	*	*	*	*
3.72	1423.82	*	*	*	*	*	*	*	*
4.23	1498.29	*	*	*	*	*	*	*	*
4.70	1560.84	*	*	*	*	*	*	*	*
5.28	1638.29	*	*	*	*	*	*	*	*
6.32	1718.71	*	*	*	*	*	*	*	*
6.74	1787.22	*	*	*	*	*	*	*	*
7.59	1900.41	*	*	*	*	*	*	*	*
8.04	1951.05	*	*	*	*	*	*	*	*
8.99	1989.77	*	*	*	*	*	*	*	*
10.08	2099.98	*	*	*	*	*	*	*	*
10.63	2165.51	*	*	*	*	*	*	*	*
11.01	2222.11	*	*	*	*	*	*	*	*
12.83	2359.13	*	*	*	*	*	*	*	*
13.73	2385.94	*	*	*	*	*	*	*	*

T-10-1B

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.24	163.83	0.25	199.57	0.29	193.62	0.33	172.76	0.24	122.1
0.41	280.00	0.48	315.74	0.54	324.68	0.51	241.27	0.46	223.4
0.59	393.19	0.72	417.02	1.06	518.29	0.70	309.78	0.66	312.7
0.77	464.68	0.95	503.40	1.48	628.51	0.95	372.34	0.84	390.2
1.00	557.02	1.19	571.91	2.23	702.97	1.19	440.85	1.07	458.7
1.18	628.51	1.38	631.48	2.77	697.02	1.54	530.21	1.26	512.3
1.41	673.19	1.59	670.21	3.18	658.29	1.83	577.87	1.47	557.0
1.60	711.91	1.79	699.99	3.68	613.61	2.61	628.51	1.66	592.7
1.79	738.72	2.06	735.74	*	*	*	*	2.15	661.2
1.97	750.63	2.30	735.74	*	*	*	*	2.84	676.1
2.21	753.61	2.52	723.82	*	*	*	*	3.34	631.4
2.44	744.68	2.77	699.99	*	*	*	*	*	*
2.64	738.72	3.08	655.31	*	*	*	*	*	*
2.89	699.99	3.55	589.78	*	*	*	*	*	*
3.10	685.10	*	*	*	*	*	*	*	*
3.87	598.72	*	*	*	*	*	*	*	*

Test T-10-1C

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.13	98.30	0.15	113.19	0.16	131.06	0.11	92.34	0.13	104.2
0.31	202.55	0.55	342.55	0.35	244.25	0.32	226.38	0.33	280.0
0.49	285.96	0.77	431.91	0.54	339.57	0.57	333.61	0.56	384.2
0.71	369.36	0.96	479.57	0.71	420.00	0.76	425.95	0.74	473.6
0.90	411.06	1.14	521.27	0.94	503.40	0.94	482.55	0.91	536.1
1.11	458.72	1.50	536.17	1.12	554.04	1.16	509.36	1.07	598.7
1.37	506.38	1.72	512.34	1.37	592.76	1.42	509.36	1.27	658.2
1.59	515.32	1.93	476.59	1.57	601.70	1.71	473.61	1.45	705.9
1.87	497.44	2.14	446.80	1.78	574.89	1.91	449.78	1.67	723.8
2.12	470.63	2.87	381.27	2.04	518.29	2.15	422.98	1.87	708.9
2.92	363.40	4.24	306.81	2.59	458.72	2.86	363.40	2.07	699.9
3.87	282.98	8.90	238.30	3.16	390.21	*	*	2.59	622.5
*	*	*	*	3.91	321.70	*	*	3.43	524.2
*	*	*	*	3.70	247.23	*	*	*	*

Test T-10-1D

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.46	41.70	0.56	98.30	0.62	68.51	0.24	68.51	0.71	74.4
0.29	62.55	0.80	166.81	0.94	92.34	0.44	148.94	1.08	154.8
1.33	128.08	1.02	217.45	1.25	128.08	0.66	241.27	1.41	309.7
2.28	190.64	1.25	291.91	1.57	172.76	0.86	336.59	1.60	402.1
2.70	274.04	1.44	354.47	1.97	262.13	1.04	402.12	1.78	485.5
2.90	324.68	1.74	434.89	2.30	330.64	1.23	452.76	1.96	536.1
3.21	390.21	1.97	494.46	2.68	455.74	1.48	527.23	2.48	613.6
3.61	479.57	2.19	551.06	2.87	500.42	1.67	571.91	2.39	649.3
3.92	521.27	2.40	592.76	3.11	554.04	1.90	619.57	2.61	694.0
4.28	565.95	2.60	640.42	3.36	595.74	2.13	667.23	2.81	735.7
4.94	592.76	2.83	676.16	3.59	619.57	2.34	694.04	3.05	753.6
5.94	568.93	3.13	714.89	3.84	661.27	2.57	732.76	3.55	780.4
*	*	3.38	747.65	4.09	664.25	2.78	750.63	3.97	747.6
*	*	3.61	750.63	4.34	688.08	3.03	783.40	4.87	664.2
*	*	3.89	777.44	4.83	685.10	3.33	813.19	5.68	592.7
*	*	4.17	786.38	5.28	655.31	3.58	837.01	6.78	515.3
*	*	4.42	780.42	6.34	595.74	3.80	854.89	*	*
*	*	4.69	786.38	*	*	4.09	872.76	*	*
*	*	5.67	777.44	*	*	4.35	884.67	*	*
*	*	6.81	759.57	*	*	4.60	890.63	*	*
*	*	*	*	*	*	5.08	908.50	*	*
*	*	*	*	*	*	5.59	923.40	*	*
*	*	*	*	*	*	6.68	899.57	*	*

Test T-10-2A

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.17	116.17	0.07	47.66	0.19	89.36	0.10	89.36	0.11	148.9
0.36	175.74	0.17	134.04	0.32	145.96	0.20	193.62	0.21	303.8
0.35	214.47	0.28	202.55	0.44	208.51	0.34	318.72	0.30	405.1
0.58	342.55	0.39	271.06	0.58	268.08	0.44	378.29	0.39	476.5
0.77	428.93	0.51	327.66	0.77	315.74	0.54	455.74	0.49	589.7
0.87	461.70	0.62	378.29	0.94	384.25	0.63	509.36	0.61	664.2
0.99	497.44	0.76	434.89	1.32	491.49	0.74	562.97	0.71	717.8
1.10	539.14	1.11	562.97	1.50	551.06	0.83	604.68	0.80	774.4
1.22	574.89	1.30	622.55	1.70	604.68	0.94	649.36	0.91	816.1
1.34	592.76	1.68	714.89	2.15	664.25	1.21	753.61	1.09	875.7
1.59	655.31	1.86	768.50	2.56	750.63	1.43	834.04	1.19	911.4
1.71	676.16	2.20	807.23	2.96	822.12	1.67	896.59	1.56	1012.7
1.90	699.99	2.65	851.91	3.21	881.70	2.05	985.95	1.99	1093.1
2.25	762.55	3.15	938.29	3.70	977.01	2.51	1051.48	2.78	1176.5
2.75	768.50	3.51	1000.84	4.45	1102.12	3.41	1134.88	3.11	1224.2
3.16	923.40	3.97	1084.25	5.04	1197.44	3.86	1191.48	3.61	1289.7
3.59	1000.84	4.37	1164.67	5.43	1265.95	4.42	1268.93	4.15	1379.1
4.09	1057.44	4.73	1233.18	5.96	1346.37	5.01	1340.42	4.78	1447.6
4.69	1140.84	5.14	1307.65	6.56	1414.88	5.78	1420.84	*	*
5.34	1218.29	5.51	1379.14	*	*	6.79	1459.56	*	*
6.09	1304.67	5.94	1447.65	*	*	*	*	*	*
7.04	1376.16	6.77	1462.54	*	*	*	*	*	*
7.46	1444.67	*	*	*	*	*	*	*	*
8.15	1516.16	*	*	*	*	*	*	*	*

Test T-10-2B

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.77	59.57	0.56	95.32	0.69	68.51	0.82	89.36	0.61	41.7
4.19	140.00	1.51	151.91	4.02	125.11	1.38	119.15	4.46	128.0
8.06	208.51	3.95	208.51	6.91	175.74	4.45	190.64	7.56	202.5
10.62	277.02	6.12	250.21	8.66	214.47	7.62	253.19	9.67	288.9
12.18	342.55	7.52	271.06	10.54	291.91	9.98	342.55	10.69	351.4
13.32	420.00	9.29	327.66	11.47	378.29	11.13	428.93	11.28	399.1
14.21	512.34	10.95	411.06	12.03	440.85	11.71	482.55	12.11	515.3
14.89	580.85	11.70	455.74	12.51	515.32	12.30	568.93	12.65	574.8
15.69	673.19	12.10	488.51	12.85	604.68	12.64	622.55	13.27	661.2
16.04	732.76	12.41	530.21	13.18	670.21	13.08	708.93	13.75	726.8
16.67	807.23	12.89	574.89	13.59	756.59	13.58	795.31	14.33	795.3
17.21	887.65	13.42	640.42	13.93	857.87	14.06	857.87	14.85	887.6
17.65	974.03	13.84	694.04	14.25	935.31	14.50	929.35	15.82	1024.6
18.36	1072.33	14.78	837.01	14.48	982.97	15.11	1015.74	16.32	1096.1
18.71	1122.97	16.12	866.80	14.71	1033.61	15.66	1087.23	16.80	1167.6
19.06	1185.52	16.99	938.29	14.95	1078.29	16.19	1164.67	17.43	1245.1
19.63	1254.03	17.64	982.97	15.37	1167.65	16.83	1233.18	18.03	1316.5
20.11	1319.56	18.19	1042.55	15.59	1209.35	17.53	1322.54	18.72	1402.9
20.78	1399.99	19.10	1119.99	15.83	1248.08	18.17	1376.16	19.57	1459.5
21.44	1489.35	19.32	1155.74	16.07	1277.86	18.81	1462.54	20.88	1483.3
22.05	1566.80	20.05	1236.16	16.34	1334.46	19.71	1542.97	21.61	1537.0
22.85	1632.33	20.56	1295.73	16.56	1364.24	*	*	22.48	1539.9
*	*	21.19	1379.14	16.78	1399.99	*	*	*	*
*	*	21.84	1429.78	17.02	1414.88	*	*	*	*
*	*	22.64	1539.99	17.57	1480.41	*	*	*	*
*	*	24.08	1611.48	*	*	*	*	*	*

Test T-10-2C

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.27	131.06	0.16	86.38	0.18	89.36	0.18	89.36	0.07	80.4
0.40	205.53	0.27	151.91	0.31	160.85	0.36	163.83	0.23	202.5
0.53	259.15	0.37	211.49	0.45	223.40	0.49	288.93	0.34	285.9
0.62	303.83	0.51	309.78	0.61	327.66	0.61	378.29	0.45	366.3
0.80	402.12	0.63	387.23	0.77	411.06	0.71	452.76	0.56	422.9
0.93	461.70	0.75	440.85	0.91	461.70	0.85	530.21	0.68	470.6
1.06	521.27	0.88	503.40	1.02	503.40	0.99	589.78	0.79	518.2
1.20	565.95	1.04	548.08	1.18	548.08	1.13	643.40	0.93	557.0
1.44	643.40	1.19	595.74	1.36	595.74	1.58	747.65	1.22	634.4
1.77	726.80	1.63	685.10	1.86	673.19	2.03	831.06	1.56	717.8
2.08	807.23	2.00	756.59	2.35	741.70	2.51	911.48	1.95	798.2
2.44	869.78	2.56	863.82	2.92	831.06	2.98	965.10	2.30	860.8
2.76	947.23	2.77	914.46	3.37	884.67	3.66	1042.54	2.73	935.3
3.14	1015.74	3.16	991.91	3.91	985.95	4.09	1122.97	3.13	1024.6
3.46	1087.23	3.47	1051.48	4.32	1051.48	4.64	1197.44	3.49	1081.2
3.82	1152.76	3.87	1134.88	4.78	1122.97	5.13	1259.99	3.95	1167.6
4.19	1236.16	4.29	1209.35	5.39	1200.42	5.60	1346.37	4.61	1271.9
4.91	1319.56	4.68	1280.84	5.91	1271.90	6.23	1423.82	5.00	1301.6
5.31	1382.12	5.19	1355.31	6.29	1340.42	6.65	1474.46	5.68	1379.1
5.77	1456.58	5.64	1420.84	6.71	1417.86	*	*	*	*
6.41	1528.07	6.83	1364.24	7.20	1480.41	*	*	*	*

Test T-10-11

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00				
0.20	50.64	0.12	65.53	0.14	71.49				
0.38	80.42	0.29	145.96	0.31	157.87				
0.57	125.11	0.41	202.55	0.44	256.17				
0.93	214.47	0.53	241.27	0.65	345.53				
1.21	282.98	0.68	297.87	0.86	420.00				
1.47	351.49	0.93	372.34	1.13	506.38				
1.73	414.04	1.14	414.04	1.32	554.04				
2.08	509.36	1.53	491.49	1.57	610.63				
2.43	577.87	1.77	536.17	2.21	711.91				
2.91	655.31	2.10	580.85	2.91	783.40				
3.43	720.85	2.80	673.19	3.80	860.84				
3.98	783.40	3.49	720.85	5.04	896.59				
5.77	845.95	4.78	789.36	5.93	881.70				
6.02	845.95	5.59	798.29	6.82	884.67				
6.76	819.14	7.21	860.84	7.78	938.29				
7.97	819.14	8.31	944.25	8.82	1006.80				
8.40	848.93	9.07	1012.76	9.80	1081.27				
8.99	899.57	10.05	1102.12	10.87	1167.65				
9.73	944.25	10.86	1167.65	12.20	1236.16				
10.82	1021.69	12.12	1259.99	14.08	1262.97				
11.76	1084.25	13.22	1331.48	14.54	1233.18				
13.13	1170.63	14.46	1382.12	15.02	1131.91				
14.43	1200.42	15.65	1313.61	15.24	1021.69				
15.20	1173.61	15.98	1227.22						
19.47	1108.08	16.33	1182.54						

Test T-11-AC

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.23	98.30	0.21	71.49	0.18	86.38	0.20	74.47	0.18	113.1
0.35	134.04	0.39	151.91	0.37	163.83	0.38	140.00	0.40	235.3
0.67	235.32	0.56	226.38	0.55	244.25	0.56	202.55	0.58	294.8
0.99	294.89	0.74	294.89	0.73	321.70	0.73	274.04	0.75	372.3
1.36	381.27	0.92	357.44	0.94	411.06	0.91	336.59	0.92	417.0
2.08	446.80	1.10	372.34	1.13	464.68	1.08	372.34	1.11	476.5
2.76	443.83	1.29	396.17	1.31	497.44	1.26	408.08	1.30	527.2
3.34	420.00	1.47	417.02	1.48	515.32	1.46	440.85	1.48	560.0
4.25	393.19	1.69	428.93	1.70	536.17	1.68	443.83	1.70	589.7
5.21	366.38	2.21	414.04	1.93	548.08	2.34	461.70	1.91	601.7
5.98	336.59	3.14	357.44	2.14	562.97	3.38	434.89	2.14	601.7
6.85	321.70	4.57	285.96	2.36	568.93	5.16	357.44	2.86	571.9
7.71	309.78	6.67	232.34	2.96	598.72	6.35	318.72	4.14	515.3
9.12	288.93	8.34	199.57	3.68	601.70	8.39	282.98	5.53	458.7
11.68	288.93	9.49	187.66	5.00	583.83	10.69	262.13	8.49	378.2
15.14	277.02	11.57	190.64	9.91	571.91	13.49	247.23	10.73	381.2
15.90	330.64	14.38	190.64	11.25	580.85	17.51	244.25	12.24	417.0
16.49	372.34	16.15	268.08	13.82	586.80	19.89	306.81	12.63	446.8
18.11	440.85	16.91	354.47	15.69	619.57	20.97	336.59	14.18	500.4
*	*	17.67	408.08	17.28	646.38	23.46	381.27	14.63	518.2
*	*	18.42	425.95	19.75	646.38	23.41	351.49	15.99	592.7
*	*	21.11	402.12	20.52	634.46	*	*	16.93	616.5
*	*	*	*	*	*	*	*	18.88	568.9
*	*	*	*	*	*	*	*	19.69	536.1
*	*	*	*	*	*	*	*	20.34	509.3

Test T-11-BC

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.17	107.23	0.17	113.19	0.11	80.42	0.13	98.30	0.09	65.5
0.40	202.55	0.35	208.51	0.37	256.17	0.31	193.62	0.30	199.5
0.56	268.08	0.53	288.93	0.55	342.55	0.50	256.17	0.48	288.9
0.73	342.55	0.72	375.32	0.73	437.87	0.69	330.64	0.64	348.5
0.89	393.19	0.89	434.89	0.90	488.51	0.90	381.27	0.82	399.1
1.07	455.74	1.08	482.55	1.09	536.17	1.10	408.08	1.00	434.8
1.26	506.38	1.26	521.27	1.73	530.21	1.29	434.89	1.19	488.5
1.44	539.14	1.45	554.04	1.94	554.04	1.49	431.91	1.36	506.3
2.01	545.10	1.65	560.00	2.15	551.06	1.70	437.87	1.55	533.1
2.47	518.29	2.48	539.14	2.37	539.14	2.04	446.80	1.74	533.1
3.62	434.89	3.81	446.80	2.77	497.44	3.56	405.10	2.48	515.3
5.09	375.32	5.67	372.34	3.57	422.98	4.83	372.34	3.76	446.8
7.11	327.66	8.11	318.72	4.72	348.51	8.34	309.78	5.48	390.2
8.92	294.89	9.71	312.76	6.48	306.81	11.22	282.98	7.41	342.5
11.53	274.04	11.49	294.89	7.83	274.04	15.06	265.10	11.11	303.8
16.03	369.36	13.83	282.98	10.09	250.21	17.27	288.93	13.81	303.8
16.55	411.06	16.10	297.87	11.62	232.34	18.16	381.27	15.41	318.7
17.06	461.70	17.09	324.68	14.21	217.45	19.35	446.80	15.97	387.2
17.91	515.32	18.05	390.21	17.15	205.53	20.93	527.23	16.72	458.7
19.02	*	19.39	455.74	21.99	226.38	22.40	545.10	17.55	518.2
22.15	*	21.86	461.70	23.38	297.87	23.44	512.34	18.43	551.0
23.38	*	23.43	443.83	23.47	282.98	*	*	20.77	536.1
*	*	*	*	23.47	268.08	*	*	21.29	521.2

Test T-11-AW

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.38	128.08	0.01	8.94	0.20	140.00	0.18	157.87	0.24	166.8
0.30	280.00	0.13	62.55	0.56	309.78	0.34	268.08	0.38	235.3
0.41	366.38	0.29	116.17	0.94	452.76	0.44	315.74	0.50	303.8
0.52	414.04	0.74	285.96	1.34	592.76	0.56	384.25	0.75	411.0
0.63	488.51	1.10	437.87	1.93	753.61	0.79	479.57	1.15	565.9
0.74	542.12	1.42	583.83	2.46	881.70	1.10	592.76	1.55	691.0
0.86	586.80	1.74	729.78	3.09	1045.52	1.33	667.23	2.06	845.9
0.97	631.48	2.05	872.76	3.94	1185.52	1.77	783.40	2.79	1015.7
1.26	759.57	2.50	1030.63	5.84	1334.46	2.44	929.35	3.88	1143.8
1.72	899.57	3.55	1167.65	8.78	1373.18	3.38	1078.29	4.99	1245.1
2.31	1066.37	4.83	1307.65	10.74	1399.99	4.67	1215.31	5.57	1295.7
2.95	1191.48	5.82	1450.63	11.81	1405.95	7.43	1358.29	7.37	1367.2
4.25	1474.46	7.76	1596.58	14.19	1405.95	9.68	1399.99	9.02	1349.3
6.82	1539.99	9.23	1659.14	14.96	1382.12	11.81	1468.50	10.39	1310.6
8.88	1545.95	10.36	1682.97	17.82	1340.42	13.15	1507.22	11.31	1271.9
10.22	1525.09	12.31	1688.92	19.14	1313.61	13.93	1471.48	*	*
11.23	1516.16	13.40	1659.14	*	*	15.66	1447.65	*	*
13.58	1489.35	14.21	1611.48	*	*	18.13	1429.78	*	*
14.52	1426.80	15.03	1557.86	*	*	21.29	1456.58	*	*
17.36	1376.16	16.73	1480.41	*	*	23.31	1402.97	*	*

Test T-11-BW

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.20	220.42	0.13	142.98	0.04	47.66	0.05	65.53	0.08	95.3
0.33	339.57	0.25	262.13	0.18	208.51	0.19	238.30	0.19	220.4
0.44	408.08	0.36	339.57	0.31	318.72	0.32	363.40	0.32	306.8
0.56	470.63	0.48	405.10	0.42	402.12	0.43	464.68	0.44	396.1
0.78	586.80	0.64	497.44	0.54	479.57	0.56	562.97	0.57	470.6
0.90	643.40	0.85	607.65	0.66	548.08	0.81	723.82	0.81	592.7
1.04	697.02	1.12	720.85	0.96	711.91	1.09	875.74	1.17	747.6
1.47	872.76	1.55	884.67	1.30	860.84	1.54	1078.29	1.62	914.4
1.87	1015.74	2.03	1039.57	1.67	1015.74	1.80	1179.57	2.27	1108.0
2.39	1179.57	2.54	1188.50	2.00	1143.82	2.27	1319.56	2.59	1188.5
2.88	1310.63	3.10	1328.50	2.43	1301.69	2.83	1471.48	3.05	1337.4
3.50	1447.65	3.76	1474.46	2.92	1450.63	3.60	1608.50	3.66	1510.2
4.32	1754.45	4.69	1611.48	3.44	1596.58	5.15	1751.48	4.29	1623.3
5.19	1909.35	5.94	1772.33	4.08	1742.54	6.26	1939.13	5.74	1775.3
6.56	1977.86	7.62	1903.39	4.89	1888.50	7.17	2052.32	7.34	1921.2
7.61	2049.35	8.78	1992.75	5.92	2043.39	8.32	2201.26	8.27	2079.1
9.12	2126.79	10.00	2067.22	7.29	2186.37	9.54	2362.11	9.26	2216.1
10.85	2189.34	11.05	2153.60	8.47	2210.20	11.44	2502.11	10.64	2356.1
13.27	2189.34	12.12	2204.24	8.78	2123.81	13.47	2519.98	12.71	2448.4
14.91	2168.49	13.86	2245.94	9.48	2254.88	15.45	2522.96	16.46	2508.0
15.56	2147.64	14.71	2281.68	9.89	2332.32	16.92	2514.02	19.03	2499.1
16.07	2105.94	16.54	2302.54	10.73	2424.66	18.26	2487.21	22.68	2457.4
16.58	2019.56	17.28	2284.66	11.19	2481.26	19.67	2430.62		
		18.56	2201.26	12.60	2549.77				
				14.70	2615.30				
				16.44	2627.21				
				19.91	2633.17				
				21.88	2603.38				
				22.83	2514.02				
				22.82	2475.30				

Test T-12-1

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.08	74.47	0.17	202.55	0.10	101.28	0.10	95.32	0.10	65.5
0.26	274.04	0.31	414.04	0.25	268.08	0.23	321.70	0.23	202.5
0.38	452.76	0.40	562.97	0.37	396.17	0.34	485.53	0.37	354.4
0.48	592.76	0.51	699.99	0.47	518.29	0.43	652.34	0.48	482.5
0.58	741.70	0.61	848.93	0.57	646.38	0.52	804.25	0.59	607.6
0.67	881.70	0.71	1003.82	0.69	756.59	0.62	962.12	0.80	851.9
0.76	1006.80	0.82	1173.61	0.81	884.67	0.73	1128.93	0.93	979.9
0.87	1152.76	0.92	1304.67	0.96	1045.52	0.83	1289.78	1.06	1119.9
0.97	1277.86	1.05	1453.61	1.16	1218.29	0.94	1441.69	1.20	1259.9
1.17	1534.03	1.16	1602.54	1.29	1319.56	1.03	1587.65	1.34	1388.0
1.35	1730.62	1.29	1766.37	1.43	1441.69	1.15	1745.52	1.47	1501.2
1.48	1867.64	1.42	1894.45	1.63	1599.56	1.27	1900.41	1.61	1632.3
1.62	2019.56	1.53	2025.52	1.85	1730.62	1.37	2037.43	1.91	1879.5
1.77	2159.56	1.67	2162.54	2.09	1888.50	1.49	2183.39	2.08	2025.5
1.91	2287.64	1.87	2356.15	2.41	2037.43	1.62	2335.30	2.35	2228.0
2.11	2454.45	2.07	2511.04	2.72	2174.45	1.75	2466.36	2.57	2385.9
2.34	2630.19	2.25	2659.98	3.13	2314.45	1.98	2665.94	2.76	2511.0
2.56	2773.17	2.51	2841.68	3.64	2454.45	2.16	2808.91	3.02	2657.0
2.91	2975.72	2.74	2969.76	4.37	2606.36	2.35	2928.06	3.34	2817.8
3.15	3079.98	3.20	3205.08	5.57	2740.40	2.59	3056.15	3.73	2963.8
3.45	3193.17	3.70	3386.78	7.56	2829.77	2.90	3208.06	4.21	3112.7
4.11	3351.04	4.23	3520.82	8.59	1653.18	3.35	3351.04	4.88	3249.7
4.74	3273.59	5.26	3675.72	9.99	2147.64	4.00	3496.99	5.61	3276.5
5.67	3142.53	6.56	3723.38	10.77	2359.13	4.74	3523.80	5.99	3127.6
6.03	3371.89	7.49	3708.48	11.55	2472.32	5.31	3654.86	6.47	2662.9
7.33	3648.91	8.04	3678.69	12.74	2555.72	5.88	3794.86	6.84	2937.0
8.62	3744.23	9.56	3473.16	13.98	2603.38	6.84	3934.86	7.31	3187.2
9.83	3750.18	10.90	3193.17	15.30	2600.41	8.00	3997.42	7.63	3285.5
10.55	3714.44	12.21	2934.02	16.87	2579.55	8.63	3988.48	8.43	3404.6
11.56	3631.04					9.58	3940.82	9.53	3496.9
12.96	3479.12					10.62	3791.89	10.20	3499.9
14.86	3181.25					12.11	3476.14	10.87	3491.0
						13.63	3187.21	12.37	3401.6
						15.27	2880.40	13.75	3249.7

Test T-12-2

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.20	140.00	0.08	89.36	0.14	80.42	0.22	83.40	0.00	0.0
0.34	268.08	0.31	324.68	0.31	193.62	0.35	104.25	0.21	113.1
0.45	351.49	0.56	583.83	0.45	282.98	0.54	145.96	0.36	250.2
0.58	425.95	0.78	893.61	0.65	428.93	1.20	318.72	0.49	357.4
0.70	551.06	0.98	1194.46	0.98	601.70	1.89	643.40	0.65	479.5
0.83	688.08	1.22	1522.12	1.48	893.61	2.19	929.35	0.79	598.7
1.00	854.89	1.46	1817.01	1.94	1182.54	2.68	1292.76	0.98	762.5
0.99	1066.37	1.70	2079.13	2.32	1489.35	3.09	1566.80	1.11	890.6
1.24	1227.22	1.99	2391.90	2.73	1802.11	3.43	1793.18	1.41	1209.3
1.45	1313.61	2.32	2707.64	3.12	2085.09	3.82	2120.83	1.73	1525.0
1.55	1423.82	2.66	2981.68	3.56	2397.85	4.19	2442.53	1.99	1808.0
1.78	1644.24	3.10	3291.46	4.04	2680.83	4.53	2731.47	2.28	2102.9
1.95	1814.03	3.61	3601.25	4.61	2981.68	4.83	3020.40	2.57	2409.7
2.20	2058.28	4.10	3851.46	5.42	3273.59	5.20	3303.38	2.86	2701.6
2.41	2242.96	4.49	4015.29	6.66	3359.97	5.67	3610.18	3.21	3002.5
2.59	2412.75	5.02	4161.24	7.46	3309.34	6.20	3884.22	3.58	3288.4
2.68	2493.17	5.88	4208.90	7.77	3237.85	6.84	4182.09	4.01	3574.4
2.80	2603.38	6.41	4158.27	8.66	2960.83	7.53	4444.22	4.50	3878.2
2.90	2695.72	7.20	3979.54	10.08	2290.62	8.46	4551.45	5.23	4179.1
3.02	2797.00	7.77	3488.06			9.23	3601.25	6.40	4476.9
3.24	2978.70	8.43	2859.55			9.73	2475.30	7.59	4536.5
3.43	3145.51							7.90	4417.4
3.64	3288.48							8.94	3279.5
3.91	3443.38							9.10	3208.0
4.18	3583.38							9.39	3020.4
4.73	3717.42							9.91	2671.8
5.31	3863.37								
6.09	3881.25								
6.42	3830.61								
8.54	3261.68								
10.26	2737.43								
11.24	1182.54								

Test T-12-3A

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.09	107.23	0.07	50.64	0.13	101.28	0.12	101.28	0.25	122.1
0.22	274.04	0.19	169.79	0.28	244.25	0.28	268.08	0.42	223.4
0.34	461.70	0.32	285.96	0.51	422.98	0.43	390.21	0.60	354.4
0.44	649.36	0.45	428.93	0.74	634.46	0.59	509.36	0.80	527.2
0.59	971.06	0.59	586.80	1.06	935.31	0.82	726.80	0.94	649.3
0.69	1185.52	0.72	744.68	1.35	1239.14	1.00	908.50	1.13	816.1
0.78	1364.24	0.93	1000.84	1.61	1507.22	1.33	1295.73	1.48	1167.6
0.89	1566.80	1.10	1227.22	1.92	1811.05	1.51	1489.35	1.85	1489.3
1.00	1775.31	1.32	1513.18	2.24	2097.00	1.63	1629.35	2.18	1784.2
1.10	1971.90	1.57	1814.03	2.69	2409.77	1.79	1787.22	2.55	2076.1
1.20	2141.69	1.80	2132.75	3.34	2680.83	2.03	2061.26	3.01	2368.0
1.33	2379.98	2.02	2433.60	4.73	2868.49	2.32	2362.11	3.82	2657.0
1.53	2677.85	2.25	2719.55	5.10	2776.15	2.57	2668.92	4.85	2805.9
1.79	2960.83	2.55	3014.44	5.87	2624.23	2.81	2937.00	5.70	2850.6
2.12	3163.38	3.11	3321.25			3.13	3252.74	6.20	2823.8
2.30	3255.72	3.68	3589.33			3.53	3544.65	7.02	2791.0
3.56	3517.84	4.38	3875.29			4.06	3830.61	8.08	2657.0
3.85	3446.36	5.38	4185.07			5.01	4113.58	9.49	2496.1
4.60	3205.08	6.76	4360.82			5.67	4220.82	10.28	2326.3
4.98	2984.66	7.28	4319.12			6.12	4176.14		
6.11	2633.17	7.78	4152.31			6.75	3437.42		
		8.09	2067.22			7.21	3160.40		

Test T-12-3B

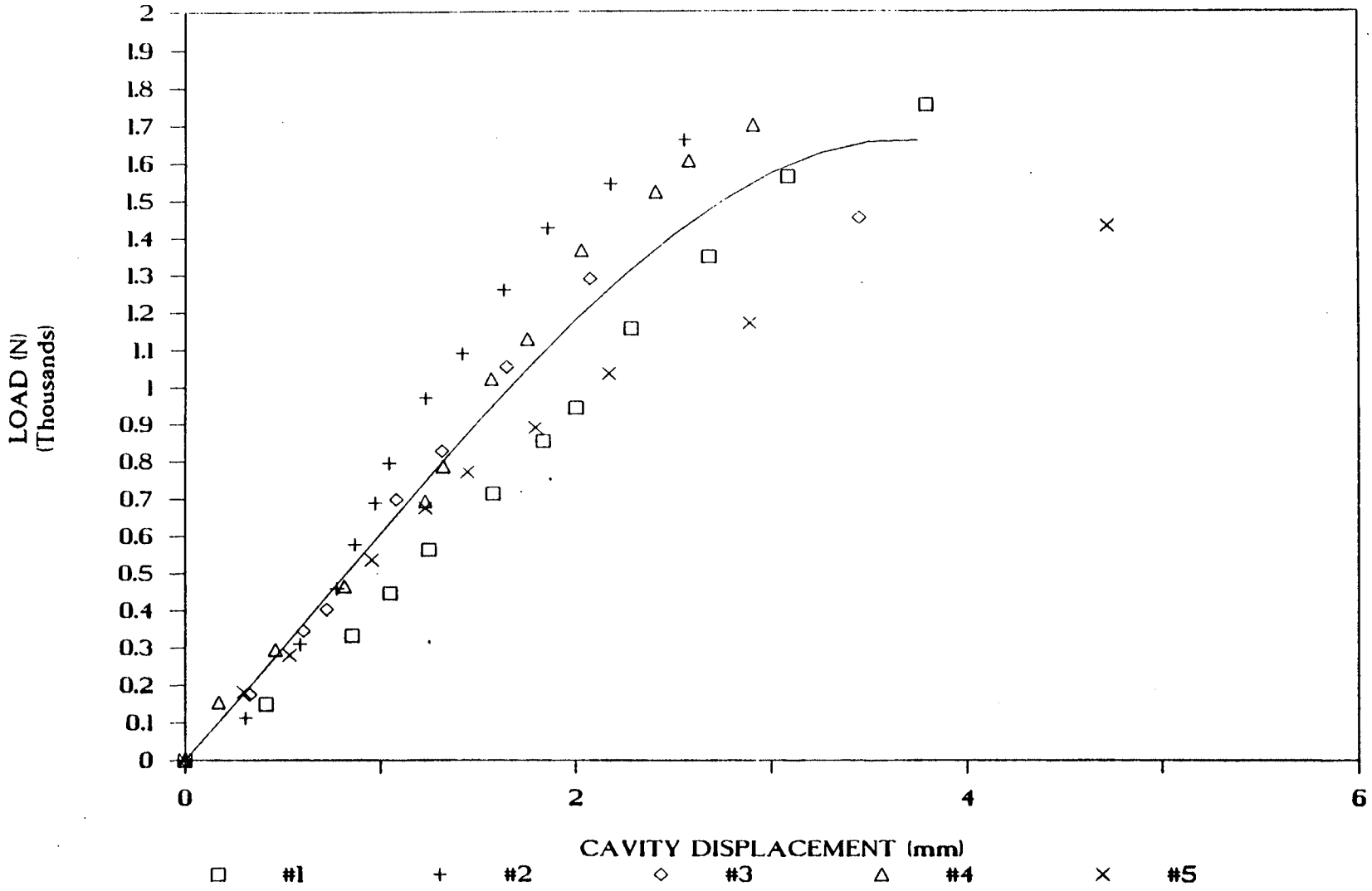
SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.01	0.00	0.08	62.55	0.22	148.94	0.20	137.02	0.17	128.0
0.21	145.96	0.24	160.85	0.40	294.89	0.46	318.72	0.44	280.0
0.34	235.32	0.48	312.76	0.65	458.72	0.72	461.70	0.73	458.7
0.47	315.74	0.67	434.89	0.82	598.72	0.94	607.65	0.96	589.7
0.75	512.34	0.91	601.70	1.28	914.46	1.43	905.52	1.24	726.8
0.96	667.23	1.04	676.16	1.66	1188.50	1.92	1182.54	1.48	869.7
1.25	902.55	1.30	831.06	2.07	1474.46	2.64	1480.41	2.10	1188.5
1.73	1292.76	1.76	1167.65	2.60	1808.07	3.90	1772.33	2.67	1501.2
2.00	1501.26	2.21	1489.35	3.10	2079.13	4.85	2067.22	3.53	1989.7
2.41	1814.03	2.54	1787.22	3.33	2195.30	5.83	2377.00	3.70	2105.9
2.80	2108.92	2.95	2129.77	3.72	2385.94	6.95	2662.96	4.07	2374.0
3.15	2371.05	3.22	2365.09	4.60	2671.89	7.62	2716.57	4.49	2674.8
3.52	2671.89	3.57	2665.94	6.13	2942.96	7.93	2662.96	4.95	2975.7
3.89	2996.57	3.92	2937.00	6.40	2966.79	9.60	2394.87	5.49	3276.5
4.26	3270.61	4.38	3264.66	7.19	3005.51			6.03	3559.5
4.78	3577.42	4.92	3538.70	8.14	2975.72			6.95	3869.3
5.71	3830.61	5.86	3741.25	9.06	2814.87			7.65	4048.0
6.01	3809.76	6.82	3666.78	9.76	2648.06			8.82	4089.7
7.39	3690.61	8.23	2805.94	11.31	2317.43			9.23	3973.5
7.61	3529.76							9.71	3821.6
10.09	3255.72							10.42	3502.9
								11.92	2234.0

Test T-12-4A

SPECIMEN #1		SPECIMEN #2		SPECIMEN #3		SPECIMEN #4		SPECIMEN #5	
mm	N	mm	N	mm	N	mm	N	mm	N
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.16	145.96	0.17	104.25	0.24	134.04	0.13	104.25	0.20	142.9
0.32	250.21	0.45	250.21	0.52	330.64	0.40	268.08	0.54	357.4
0.67	434.89	0.73	360.42	0.79	473.61	0.57	396.17	1.00	607.6
0.94	601.70	1.04	536.17	1.04	628.51	0.84	571.91	1.24	735.7
1.19	753.61	1.32	691.06	1.31	789.36	1.07	717.87	1.52	887.6
1.41	893.61	1.59	837.01	1.55	920.42	1.25	839.99	2.16	1188.5
1.89	1197.44	2.28	1188.50	1.86	1078.29	2.29	1423.82	2.90	1516.1
2.13	1334.46	2.79	1435.73	2.18	1236.16	2.54	1545.95	3.27	1799.1
2.40	1486.37	3.50	1775.31	2.79	1528.07	2.94	1763.39	3.65	2079.1
2.70	1641.26	4.09	2076.15	3.39	1805.09	3.49	2034.45	4.14	2427.6
2.97	1784.24	4.60	2344.24	4.12	2150.62	4.32	2466.36	4.72	2791.0
3.49	2073.18	5.20	2630.19	4.66	2412.75	4.65	2633.17	5.03	2960.8
4.02	2379.98	5.87	2925.08	5.35	2701.68	5.30	2931.04	5.37	3127.6
4.60	2692.74	6.82	3219.97	6.26	2993.59	5.70	3088.91	5.65	3264.6
5.20	2981.68	8.24	3452.31	6.93	3130.61	6.22	3228.91	6.16	3496.9
5.92	3270.61	8.47	3359.97	7.99	3270.61	6.92	3377.85	6.34	3562.5
6.73	3565.50	9.36	3166.36	8.45	3291.46	7.98	3485.08	6.70	3708.4
7.78	3851.46	10.31	2922.10	8.98	3282.53	8.28	3452.31	7.19	3863.3
8.96	3955.71	10.66	2508.07	11.24	2797.00	8.79	3368.91	7.78	4012.3
9.20	3881.25					9.38	3225.93	8.58	4107.6
9.61	3502.95					10.18	2937.00	8.94	4155.2
9.82	3354.02							9.50	4167.2
10.38	2960.83							9.72	4155.2
								10.59	3988.4
								11.27	3836.5
								11.87	3526.7
								12.39	3240.8

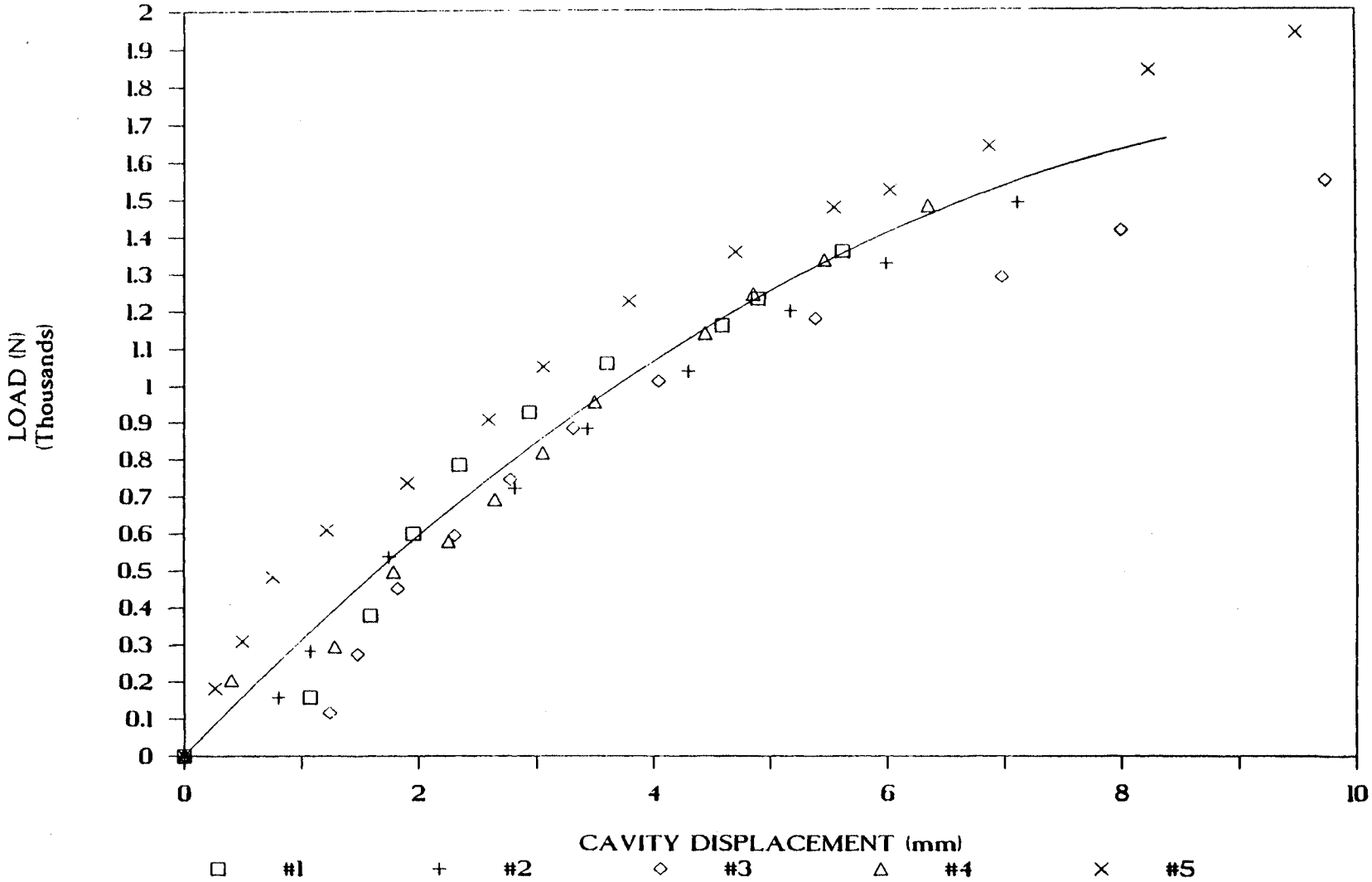
T-1-1

Test Results & Mean Curve



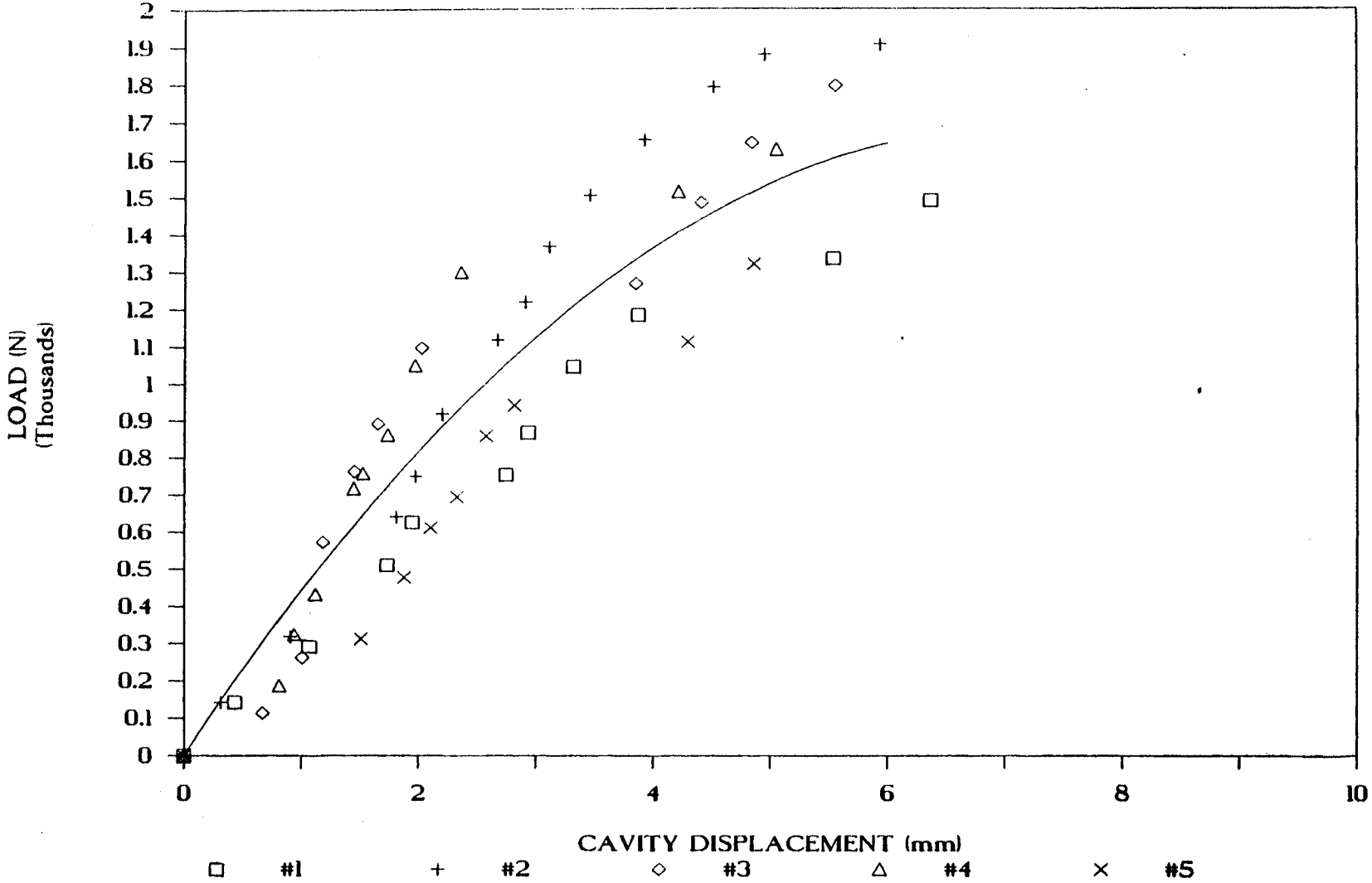
T-1-2

Test Results & Mean Curve



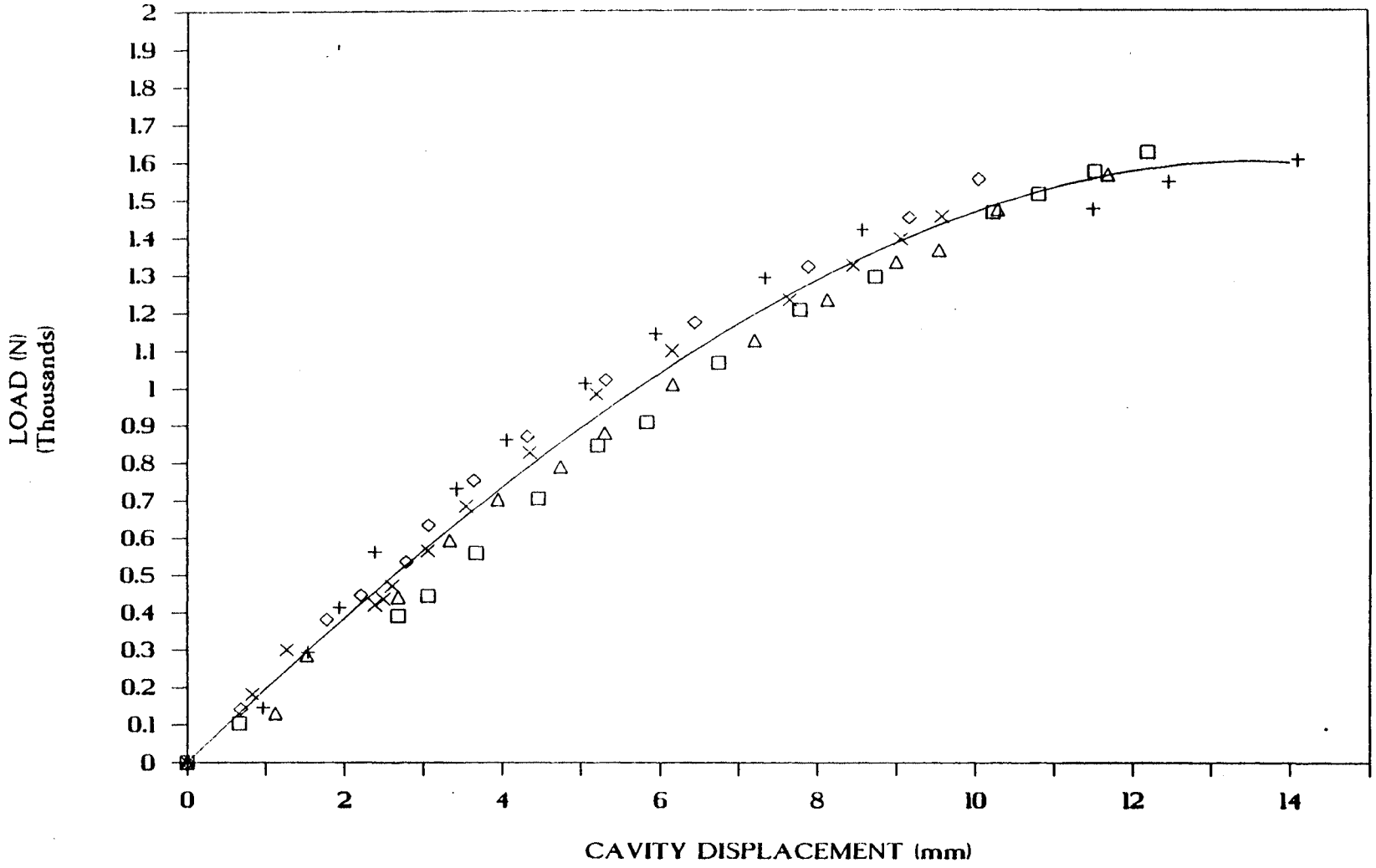
T-1-3A

Test Results & Mean Curve



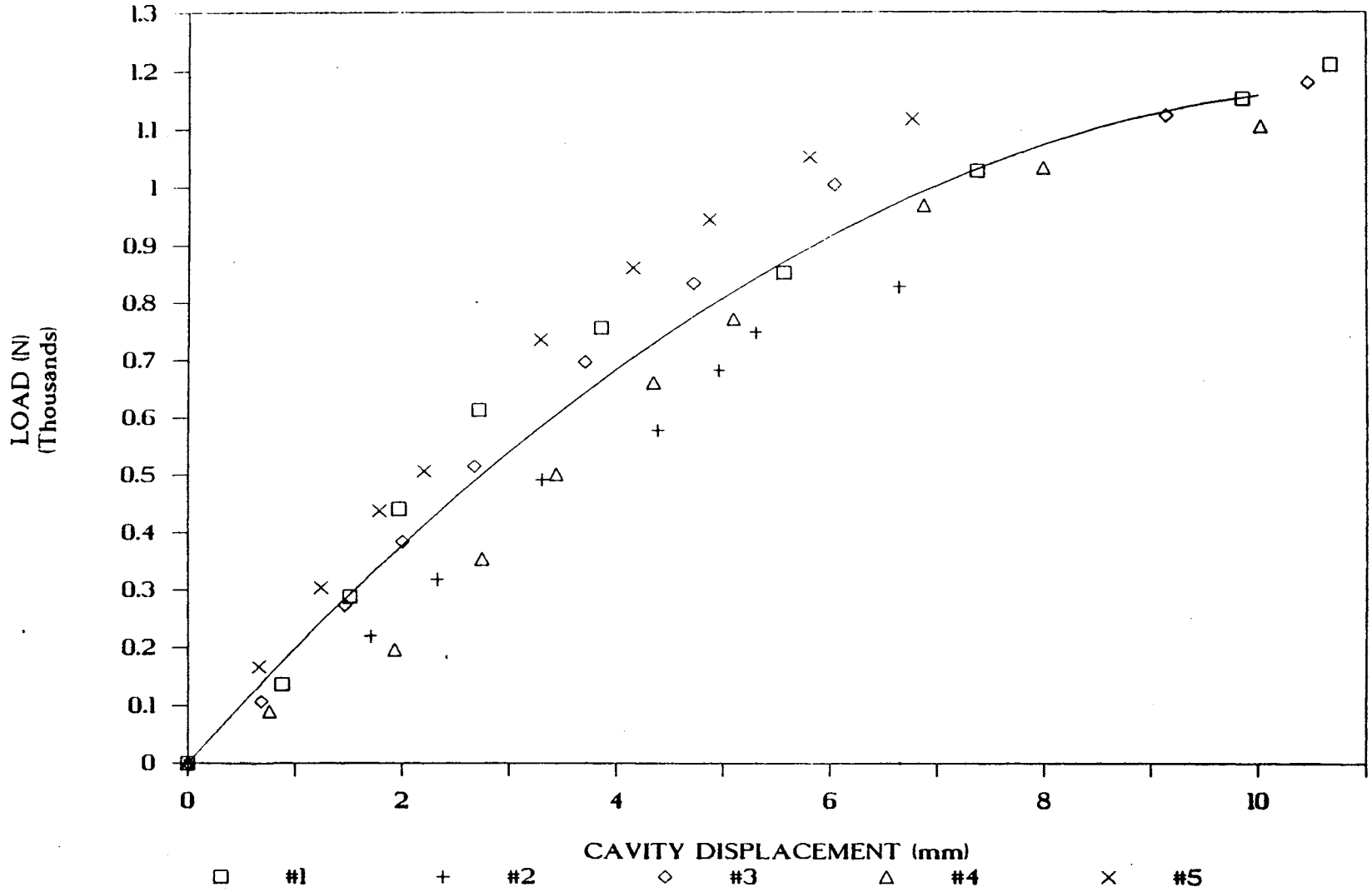
T-I-3B

Test Results & Mean Curve



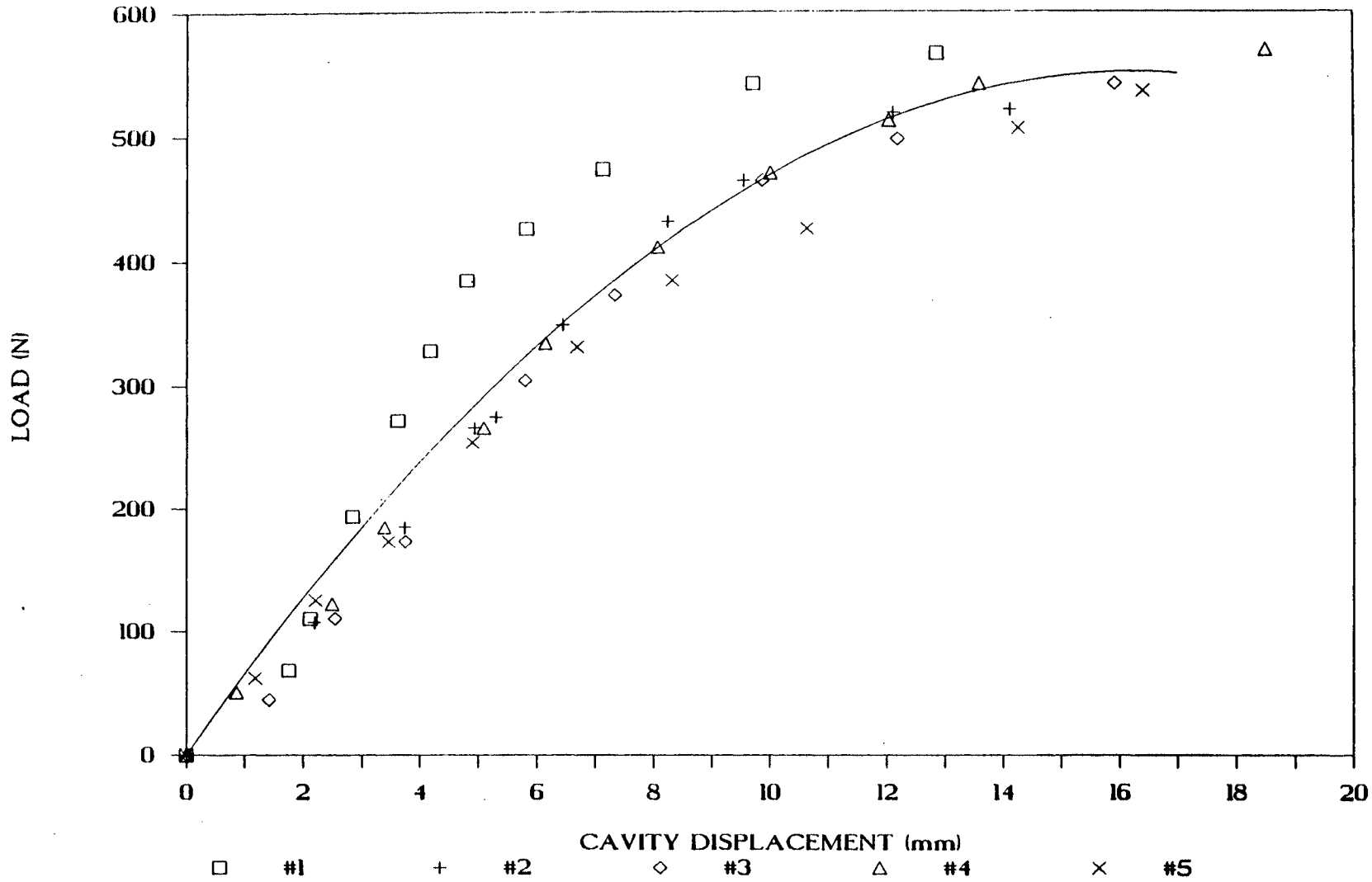
T-1-4A

Test Results & Mean Curve



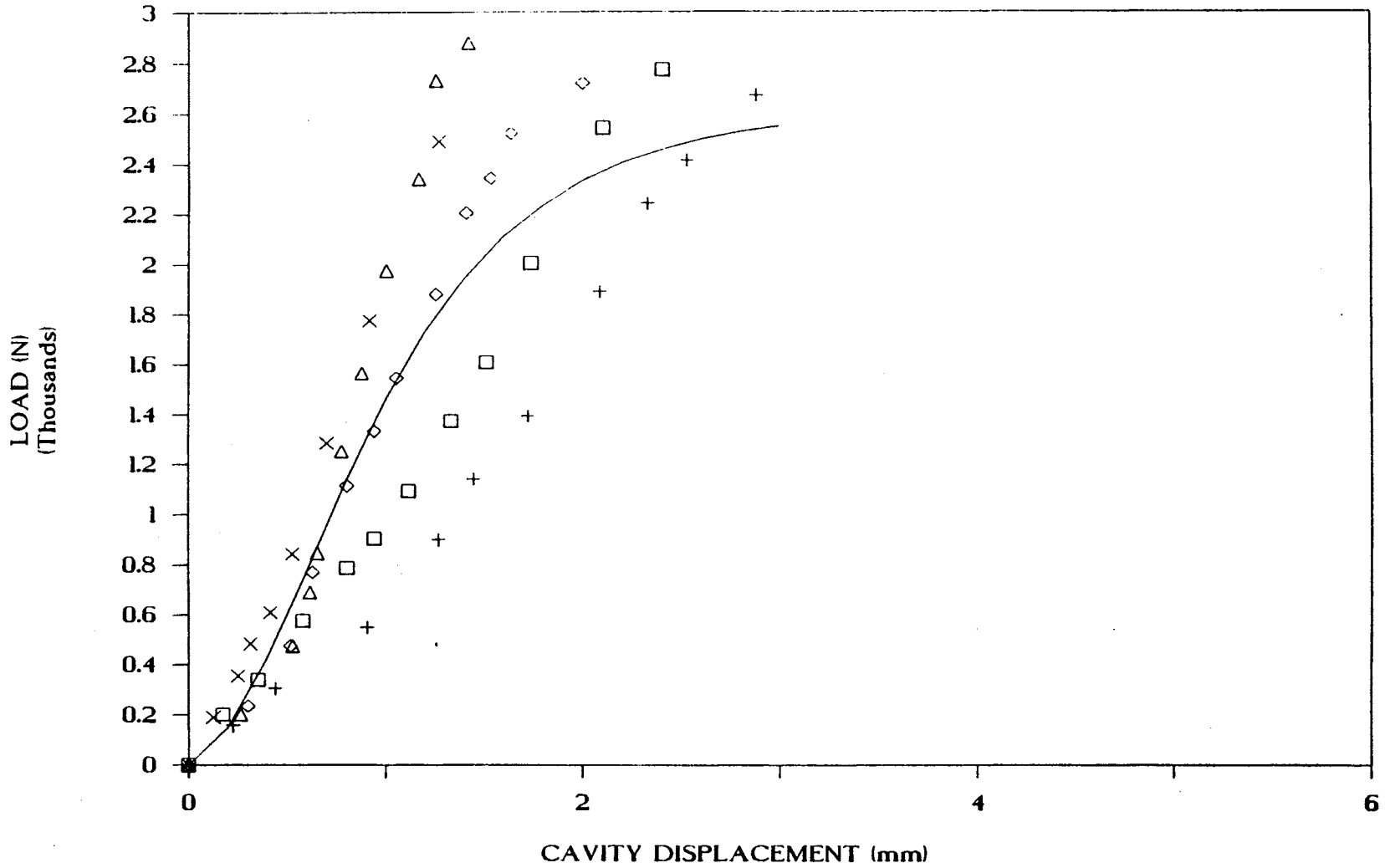
T-1-4B

Test Results & Mean Curve



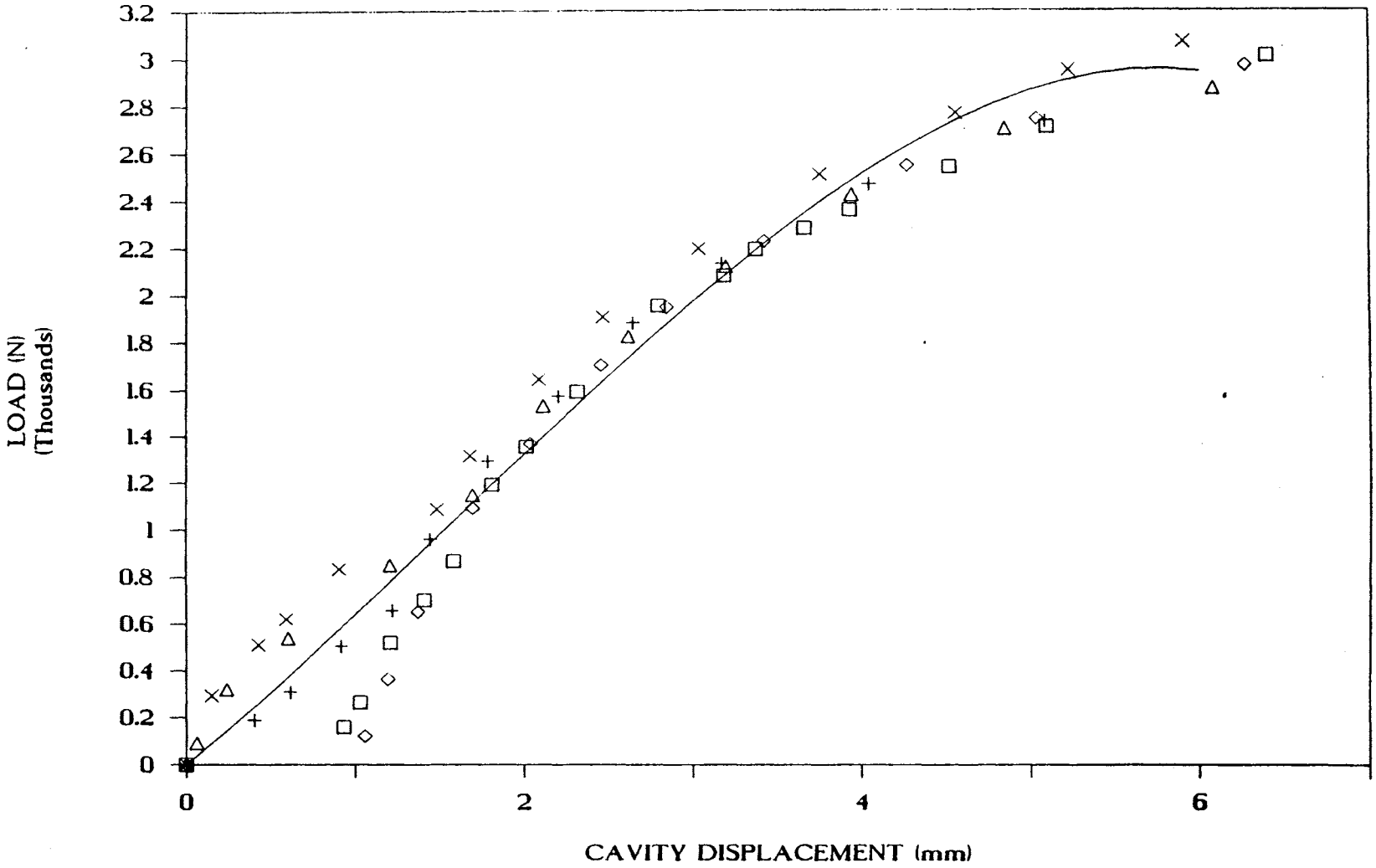
T-1-7

Test Results & Mean Curve



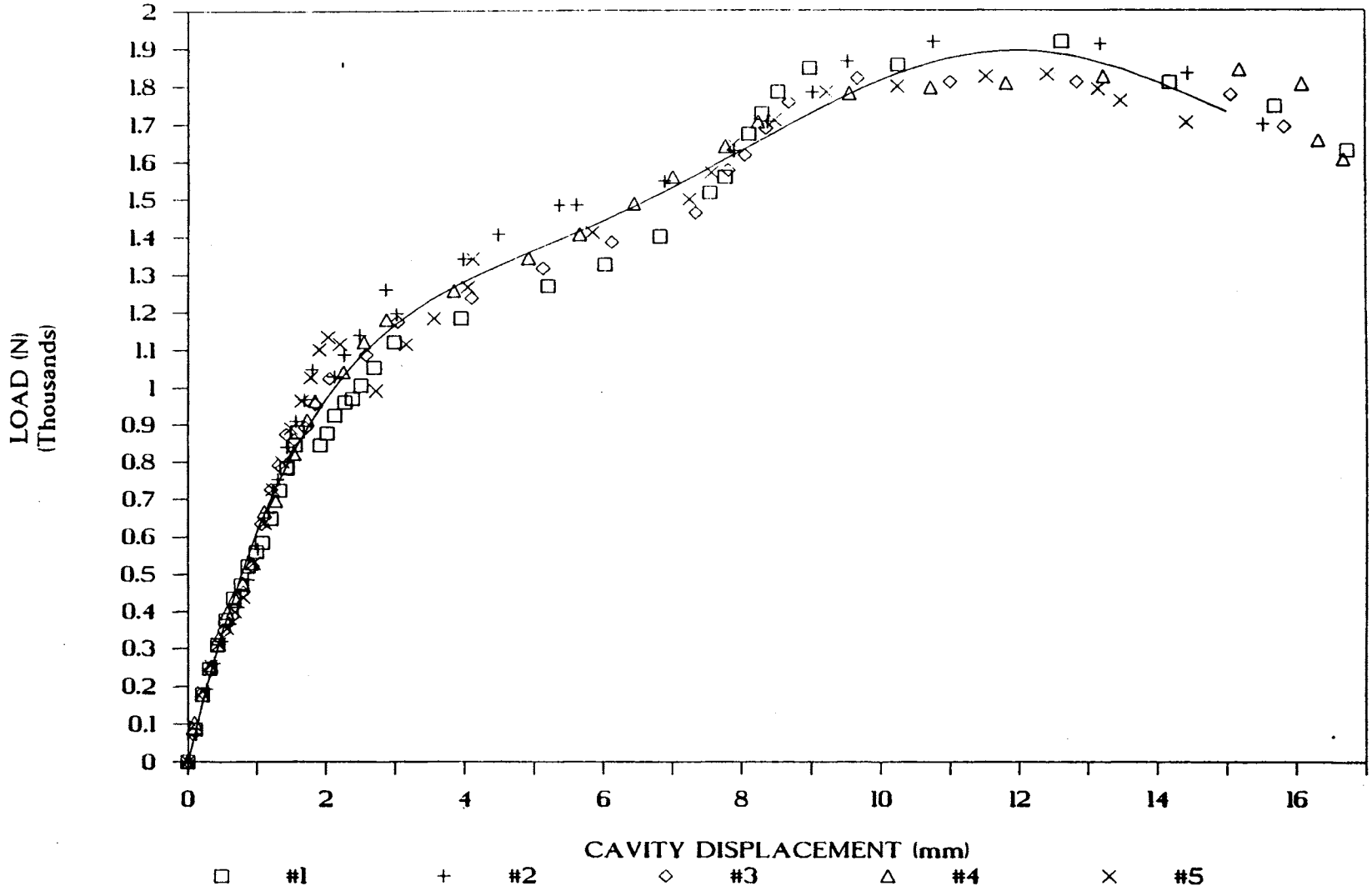
T-1-8

Test Results & Mean Curve



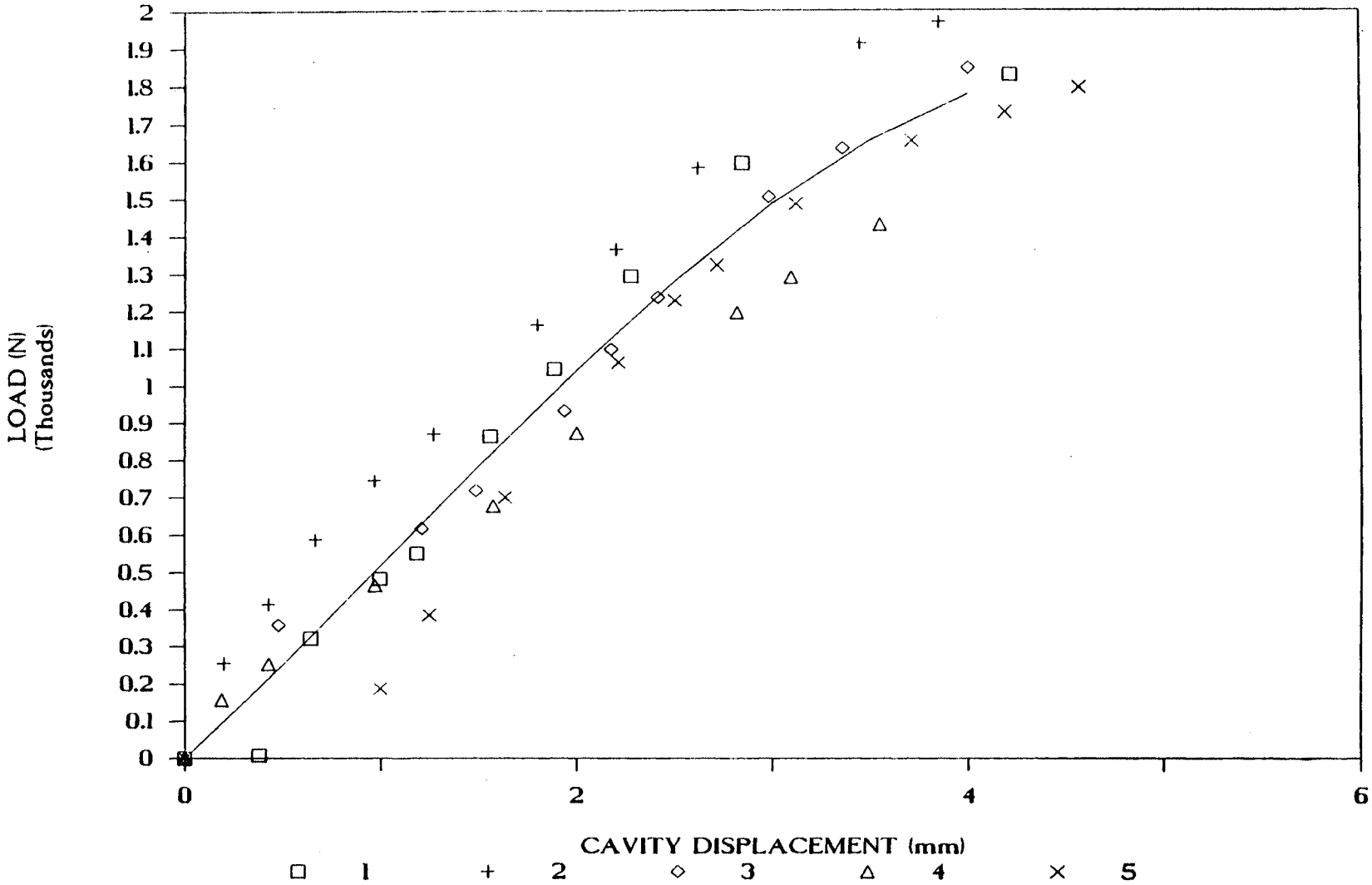
T-1-9

Test Results & Mean Curve



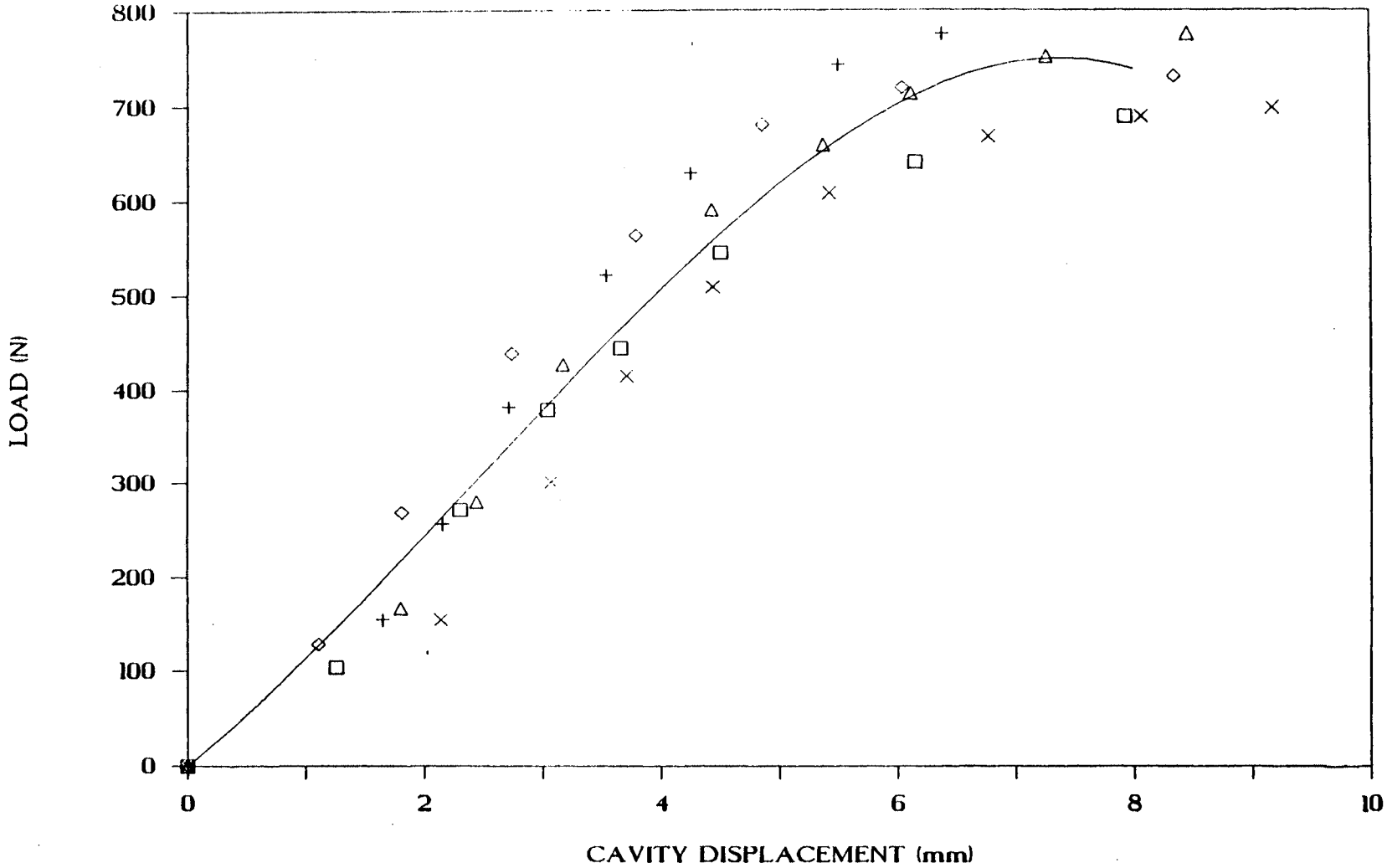
T-1-10A

Test Results & Mean Curve



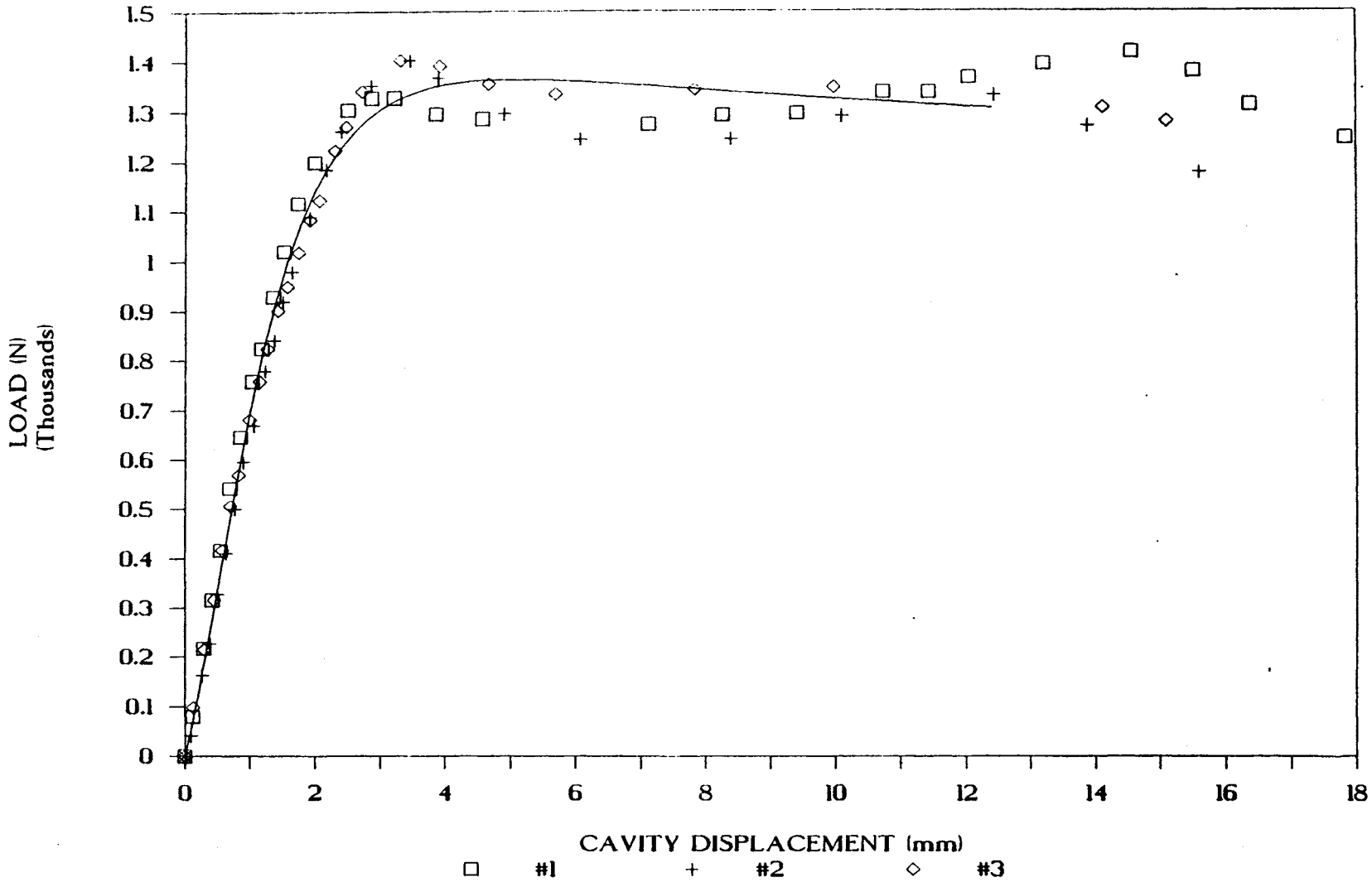
T-1-10B

Test Results & Mean Curve



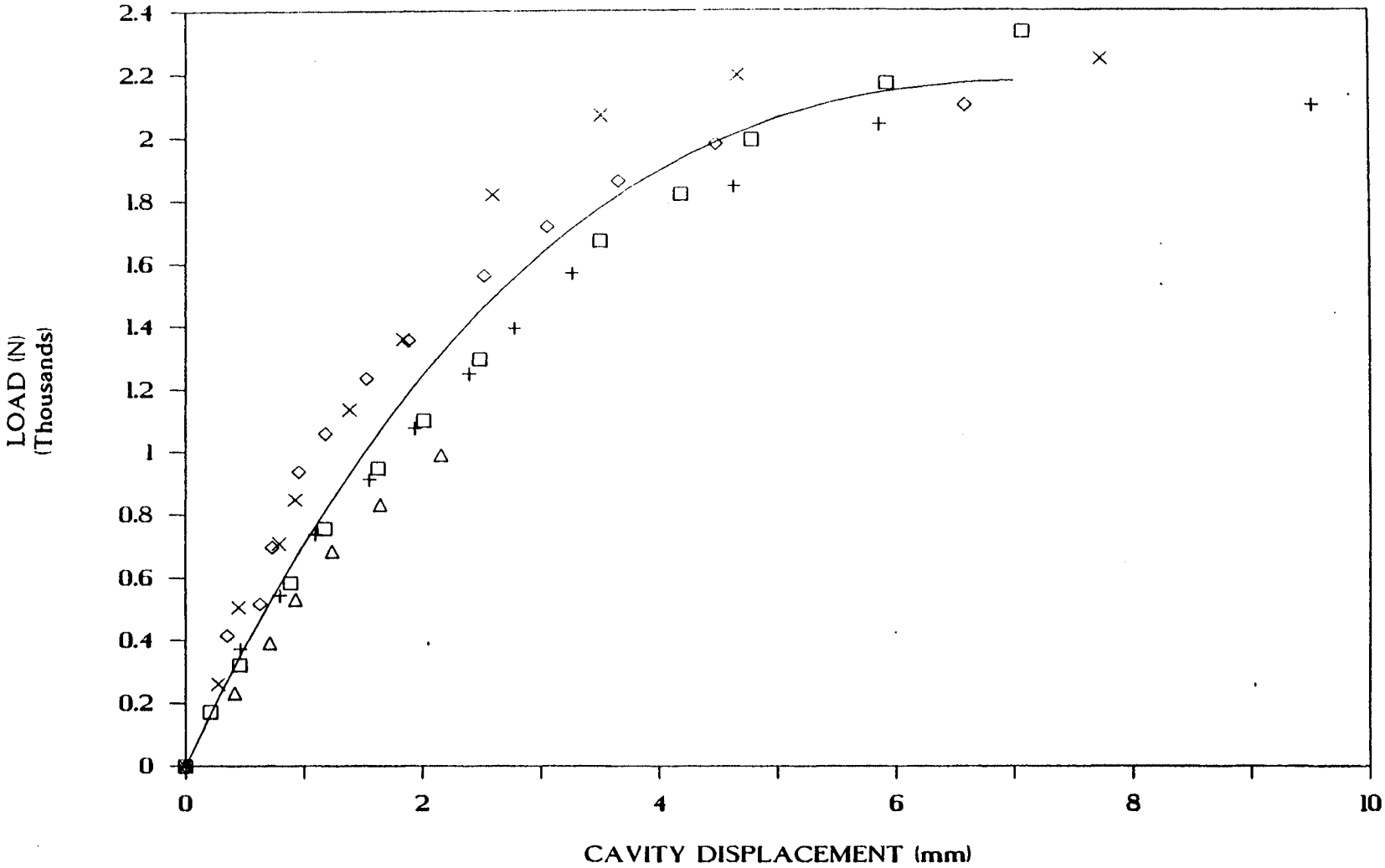
T-1-11

Test Results & Mean Curve



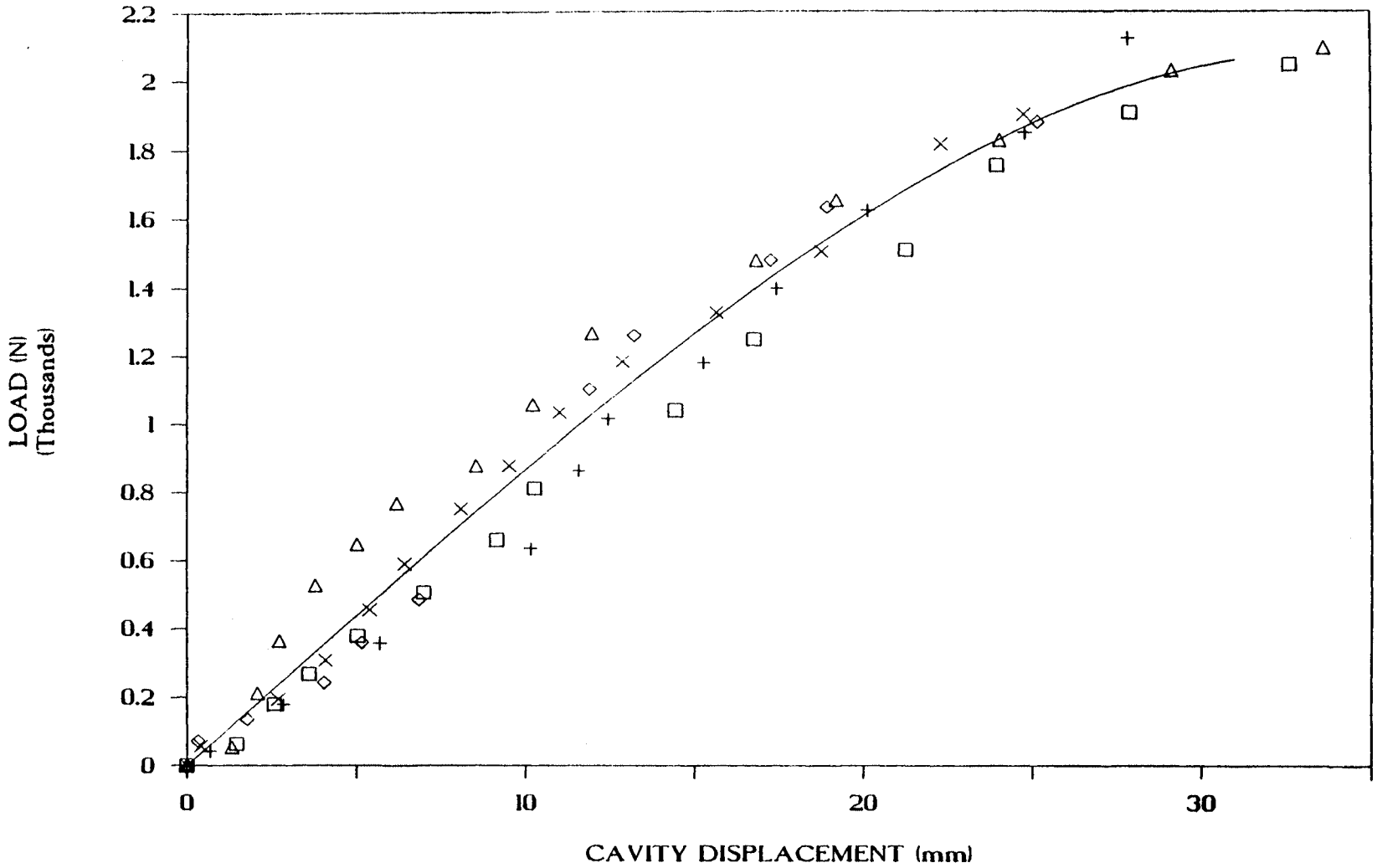
T-2-1

Test Results & Mean Curves



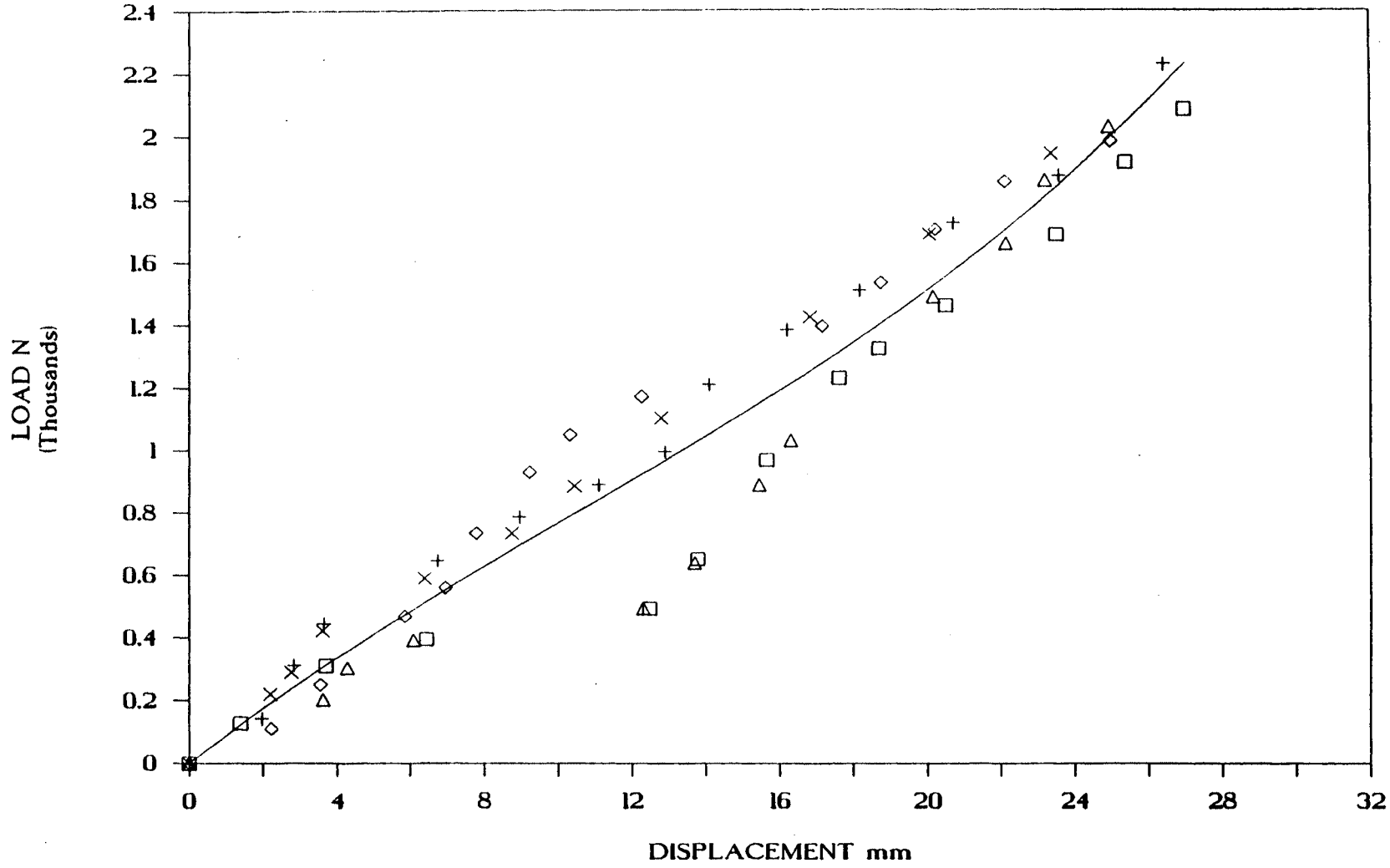
T-2-2

Test Results & Mean Curve



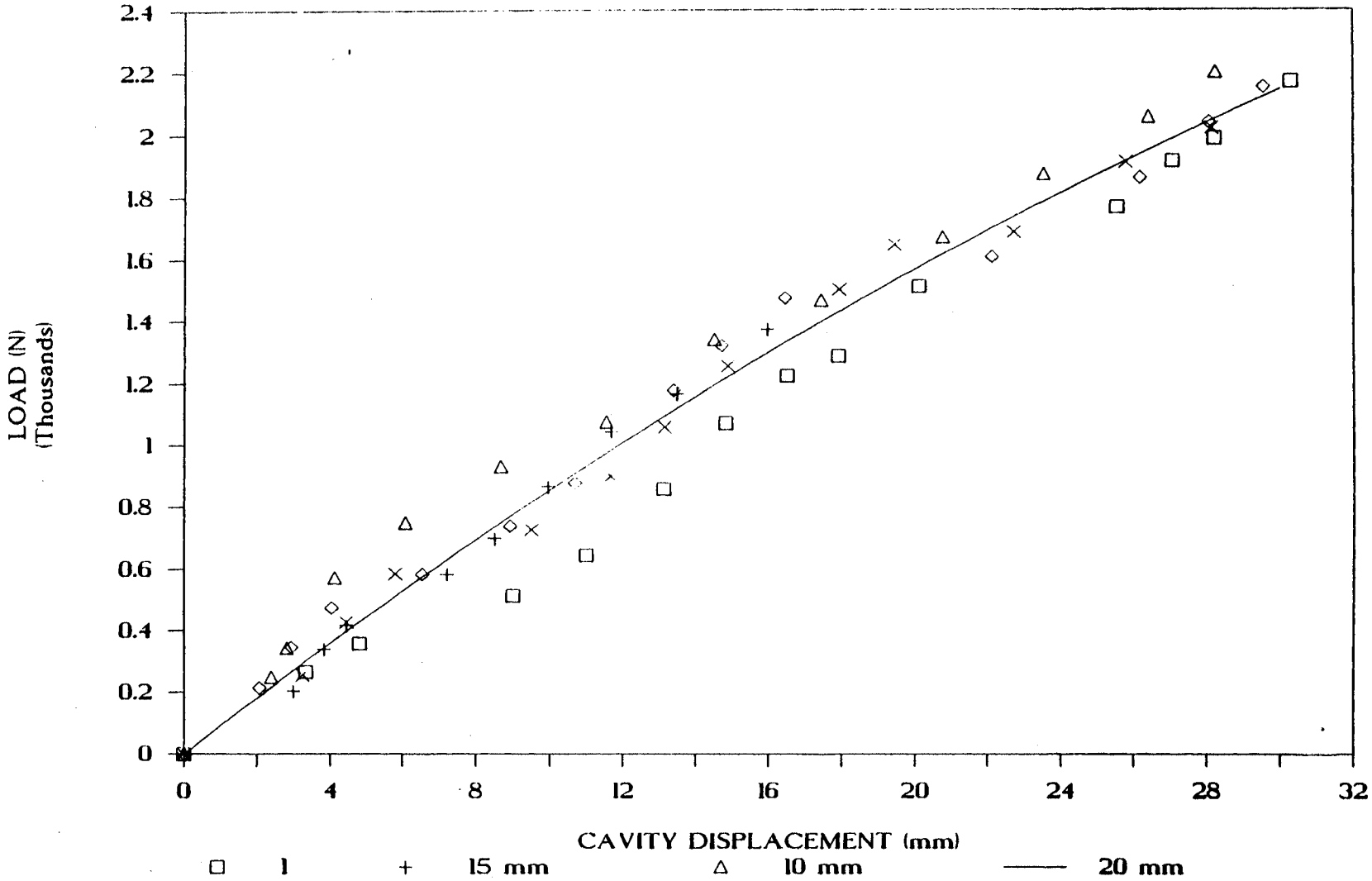
T-2-3A

Test Results & Mean Curve



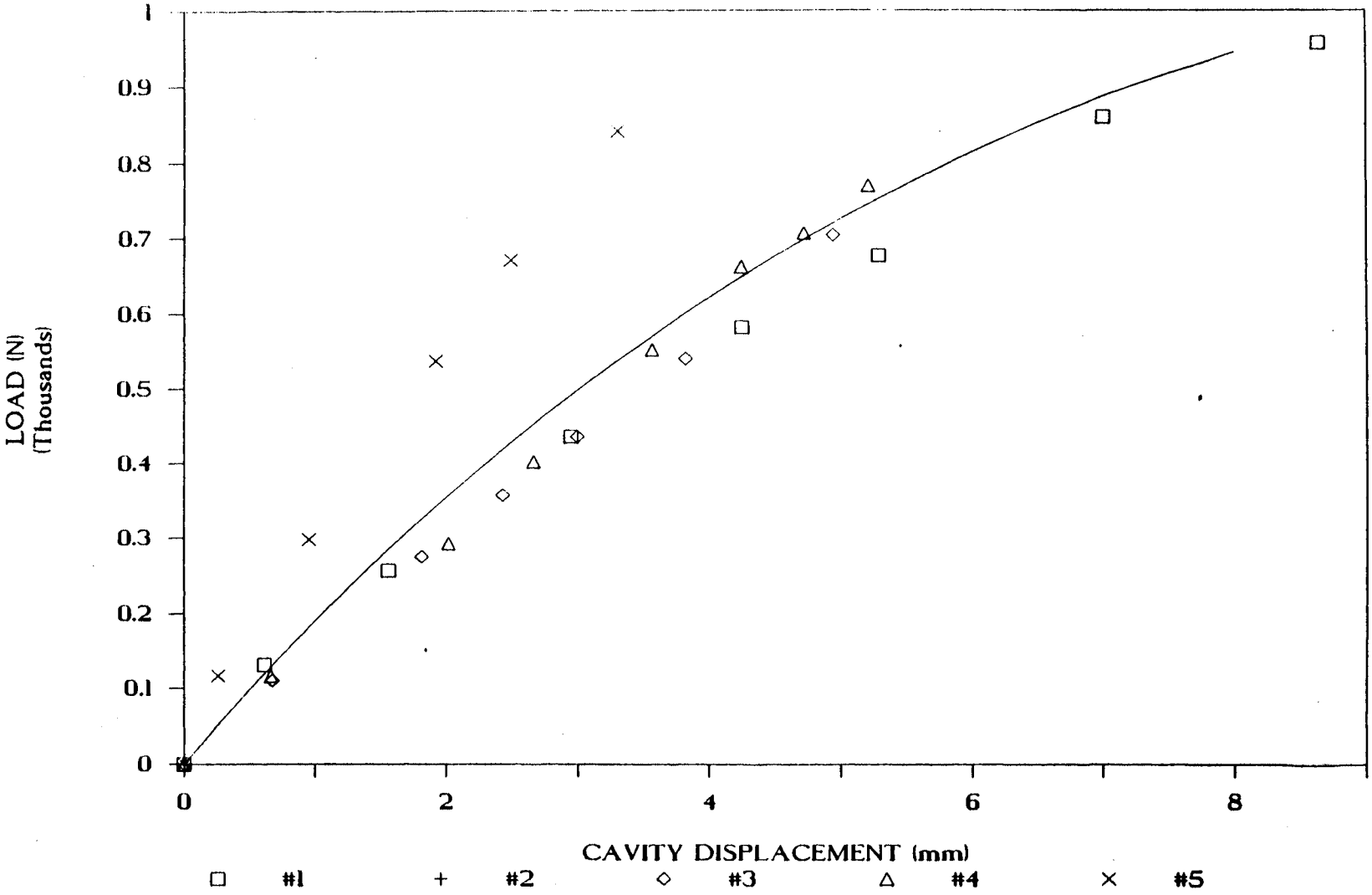
T-2-3B

Test Results & Mean Curve



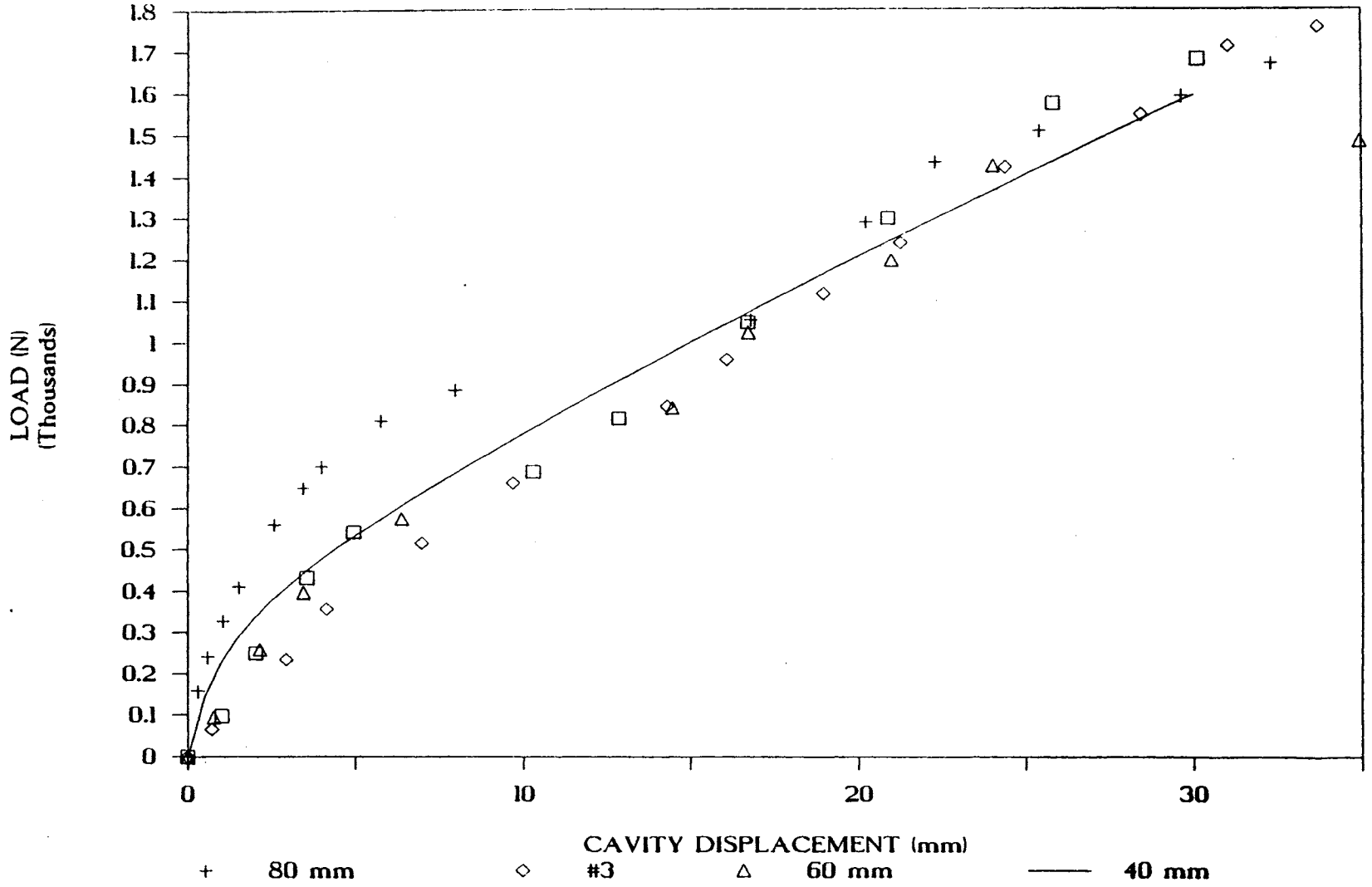
T-2-4A

Test Results & Mean Curve



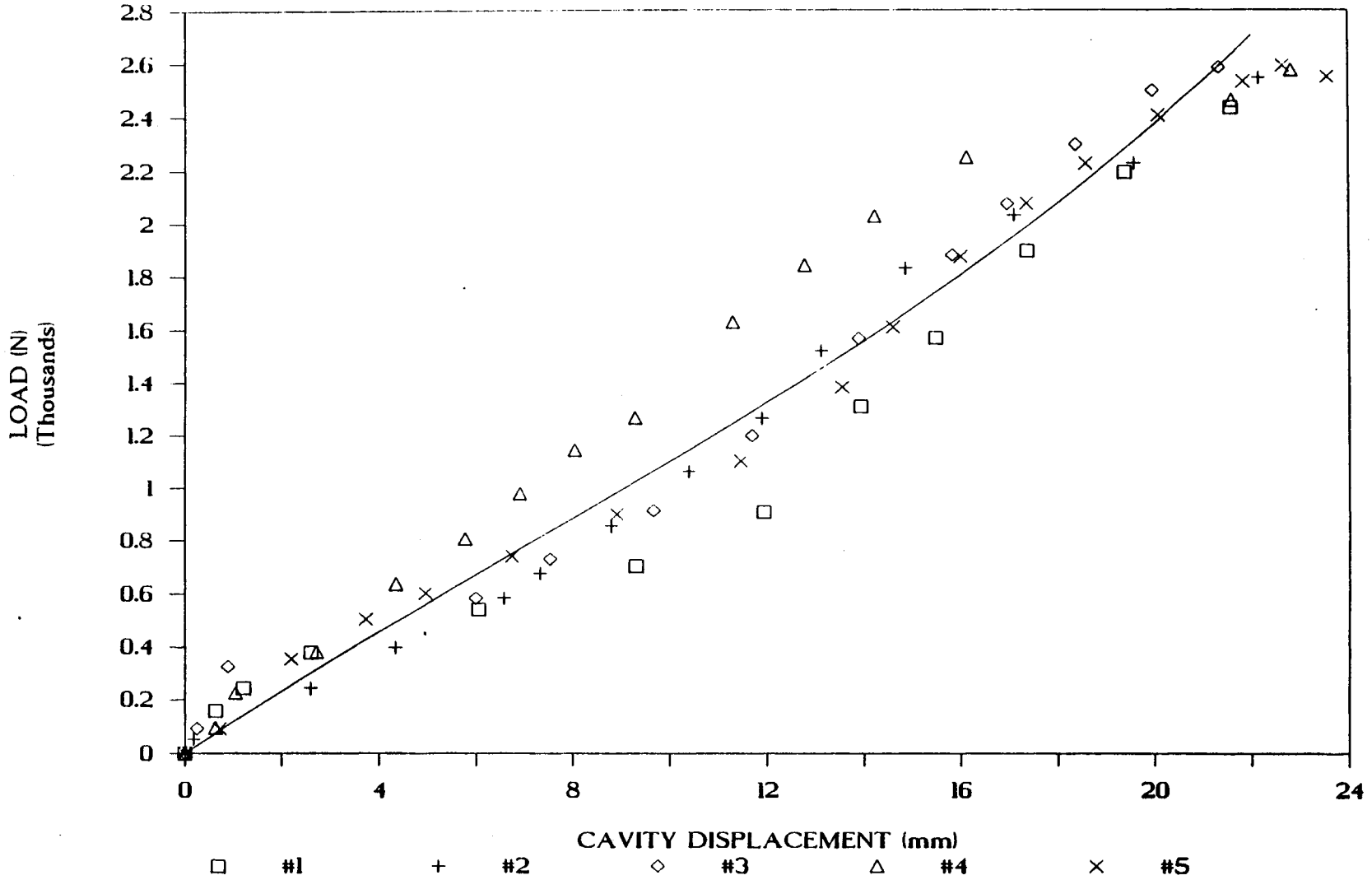
T-2-4B

Test Results & Mean Curve



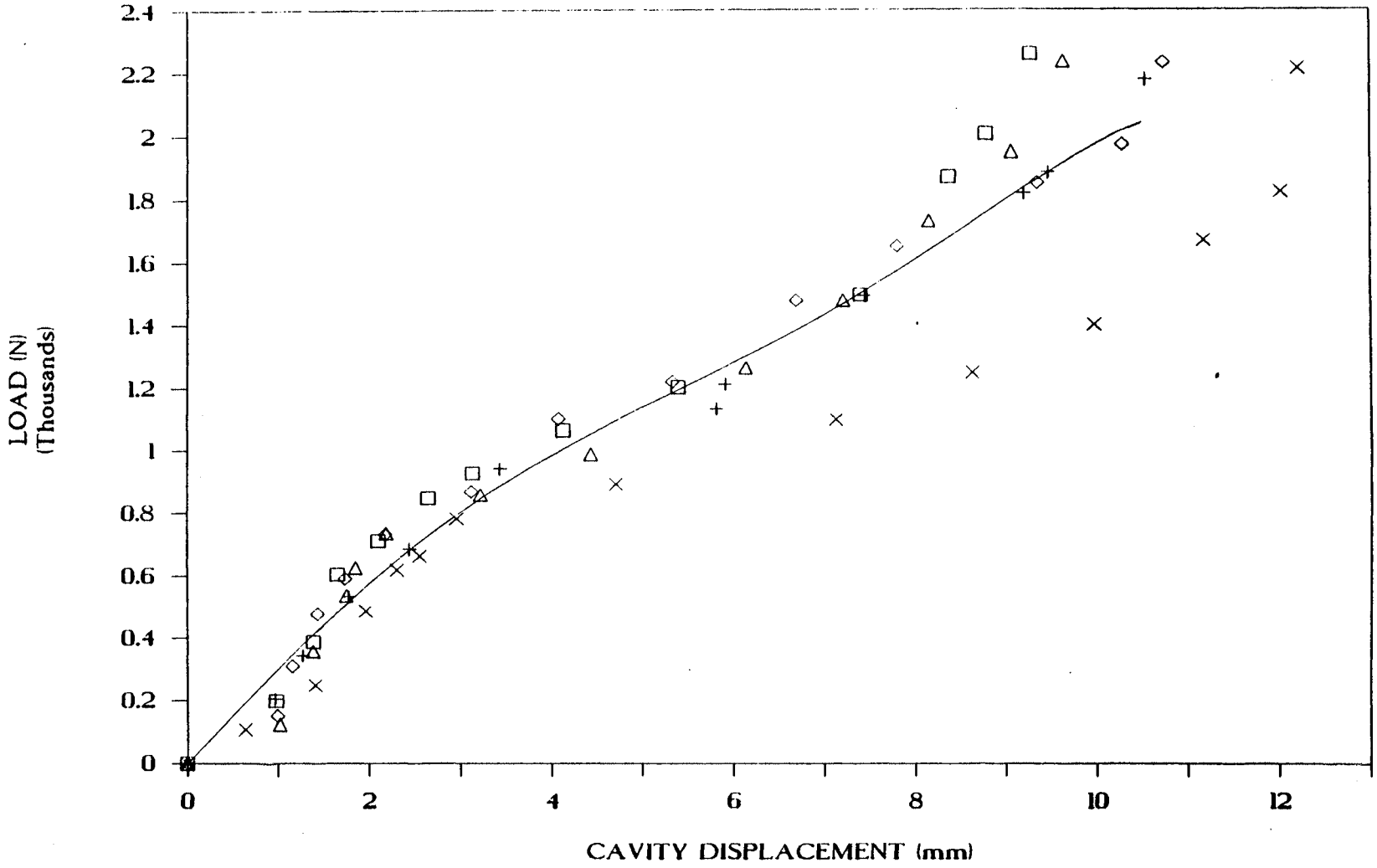
T-2-6

Test Results & Mean Curve



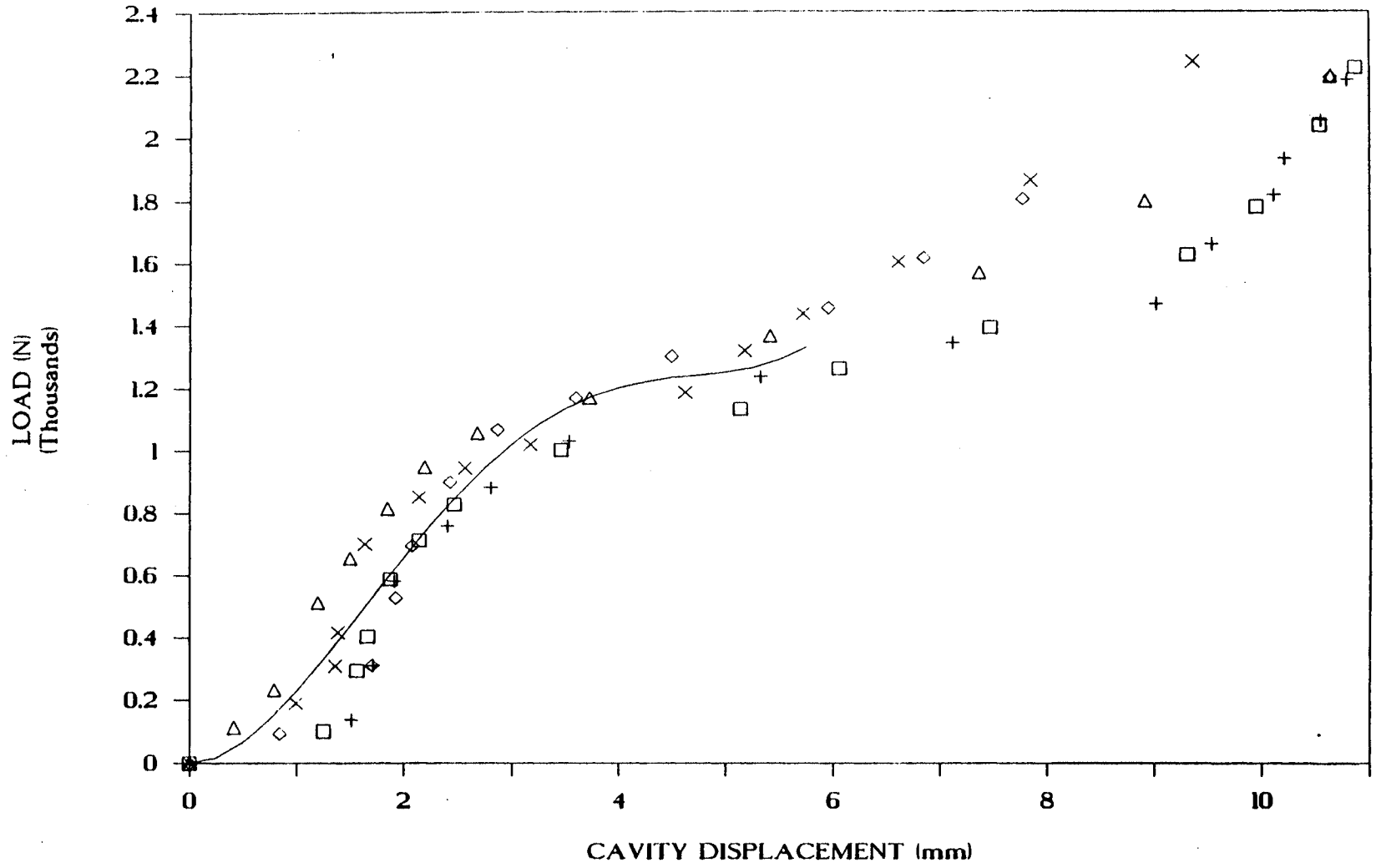
T-2-8

Test Results & Mean Curve



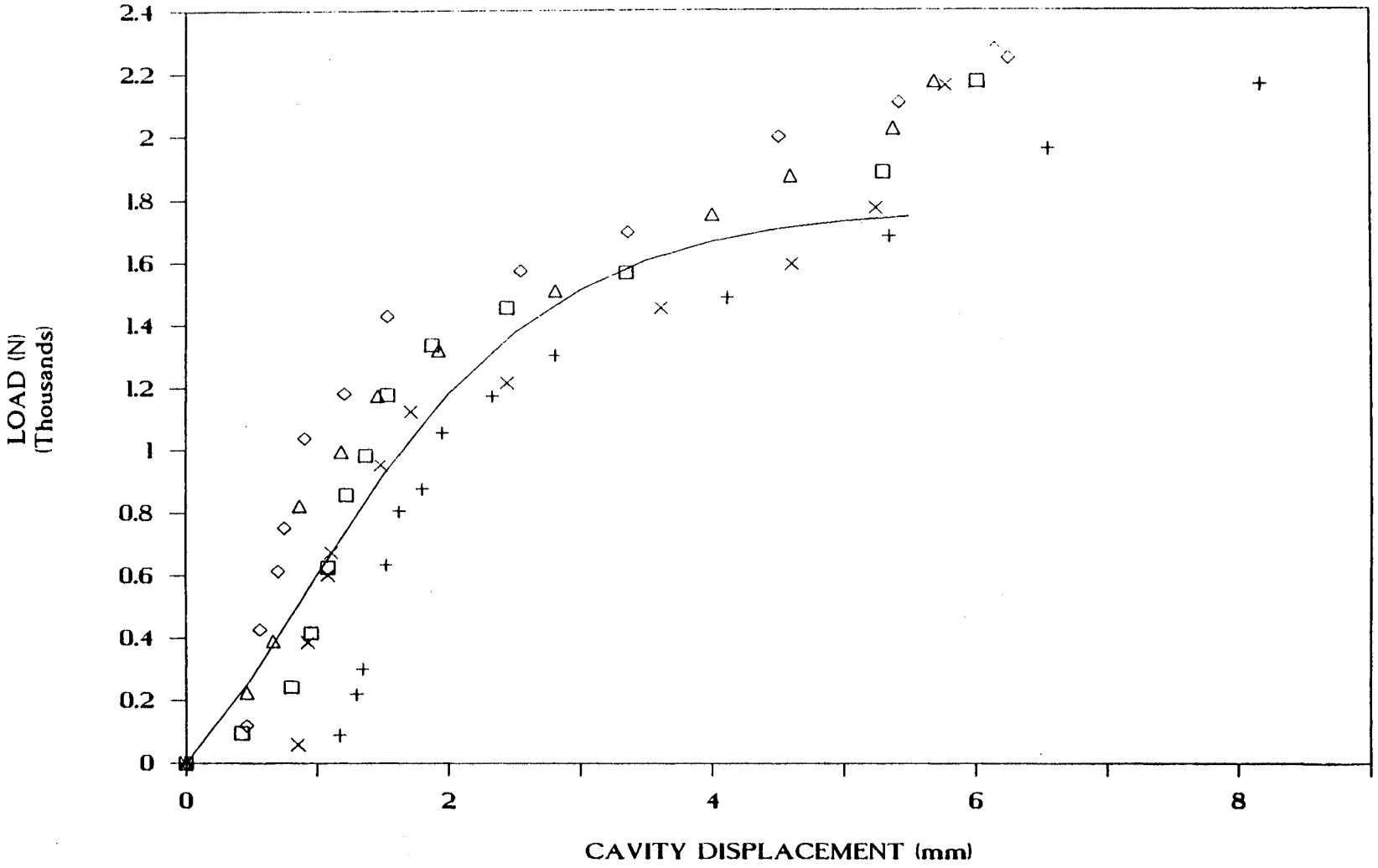
T-2-10A

Test Results & Mean Curve



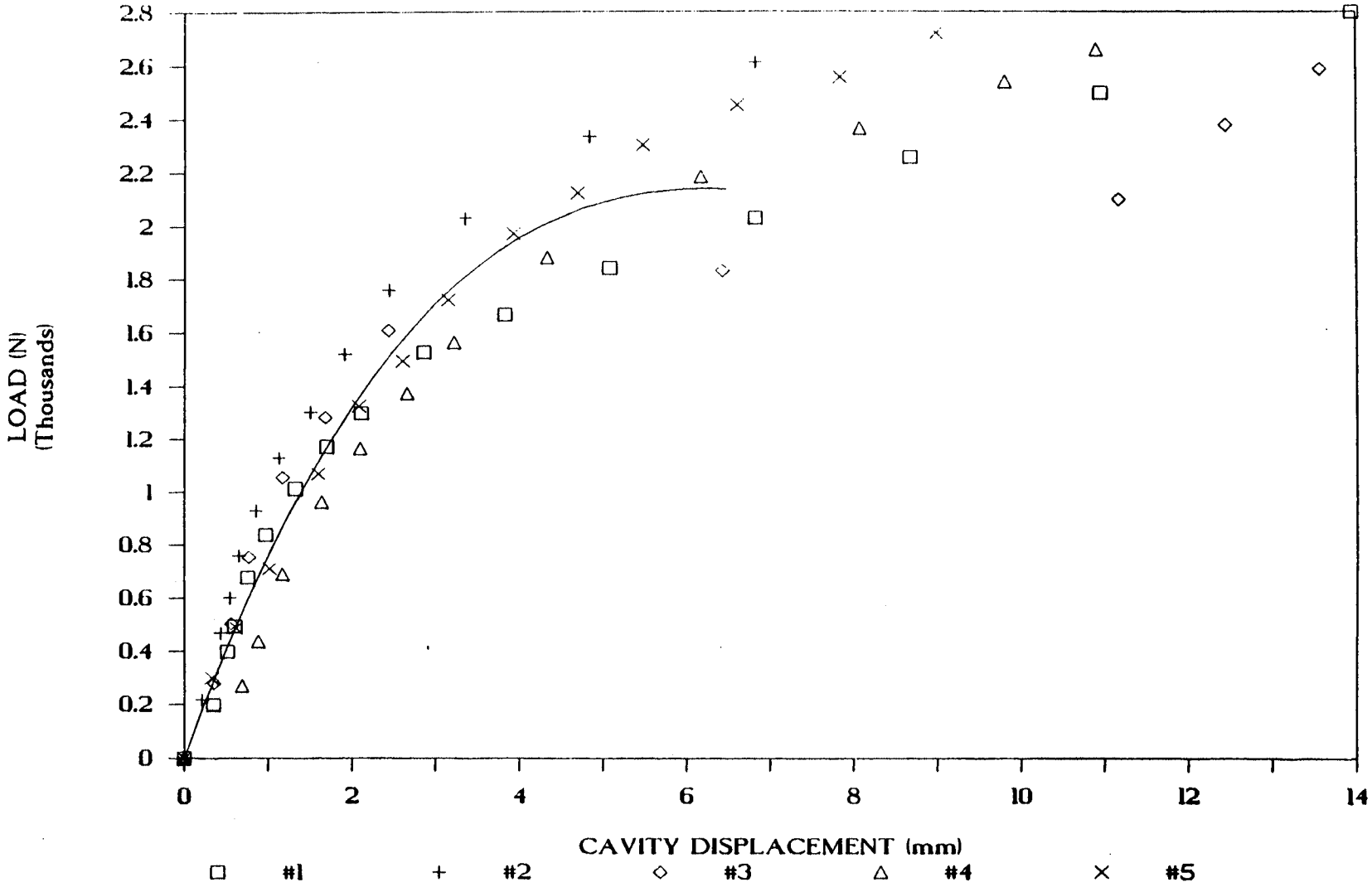
T-2-10B

Test Results & Mean Curve



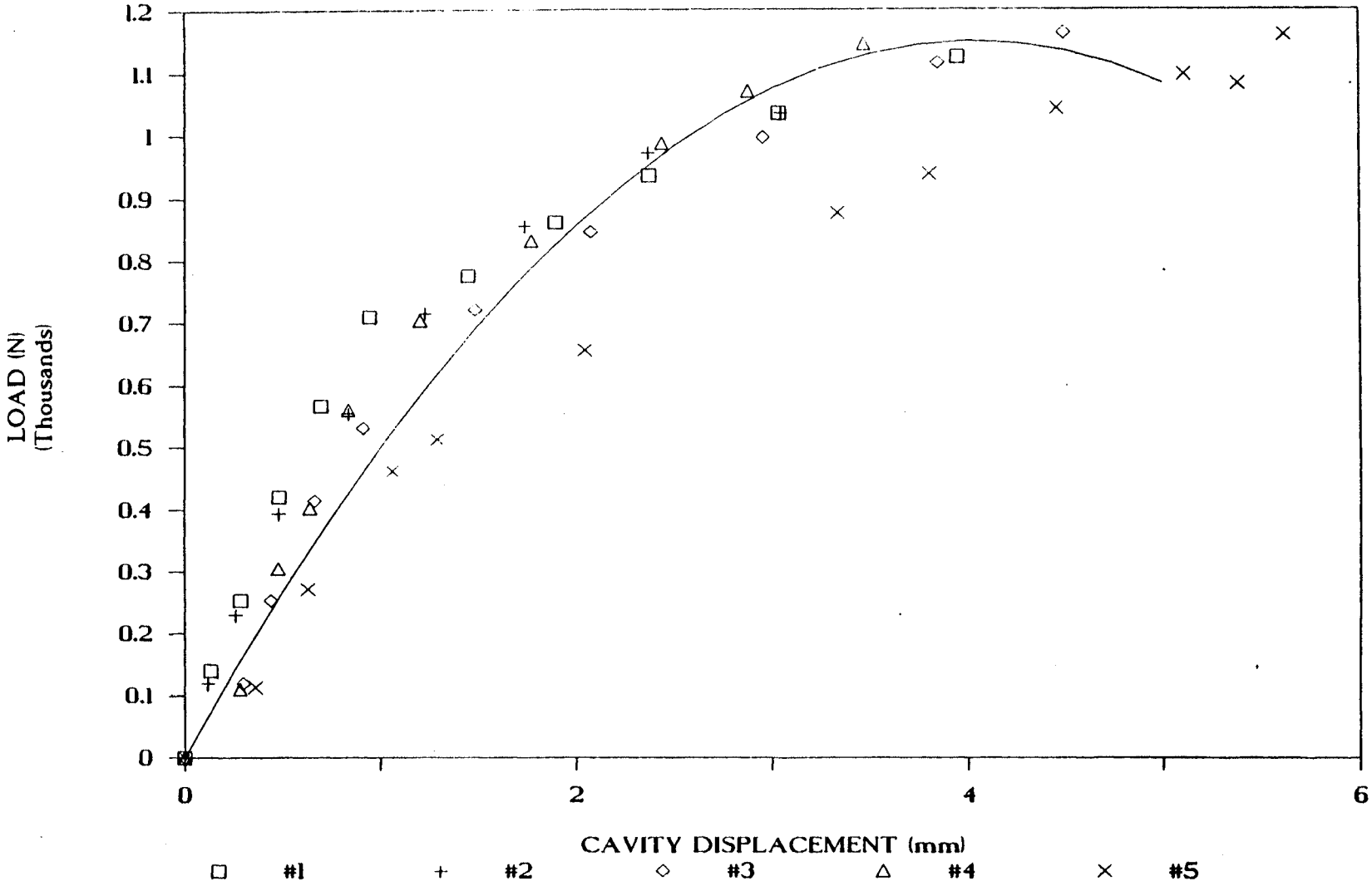
T-3-1

Test Results & Mean Curve



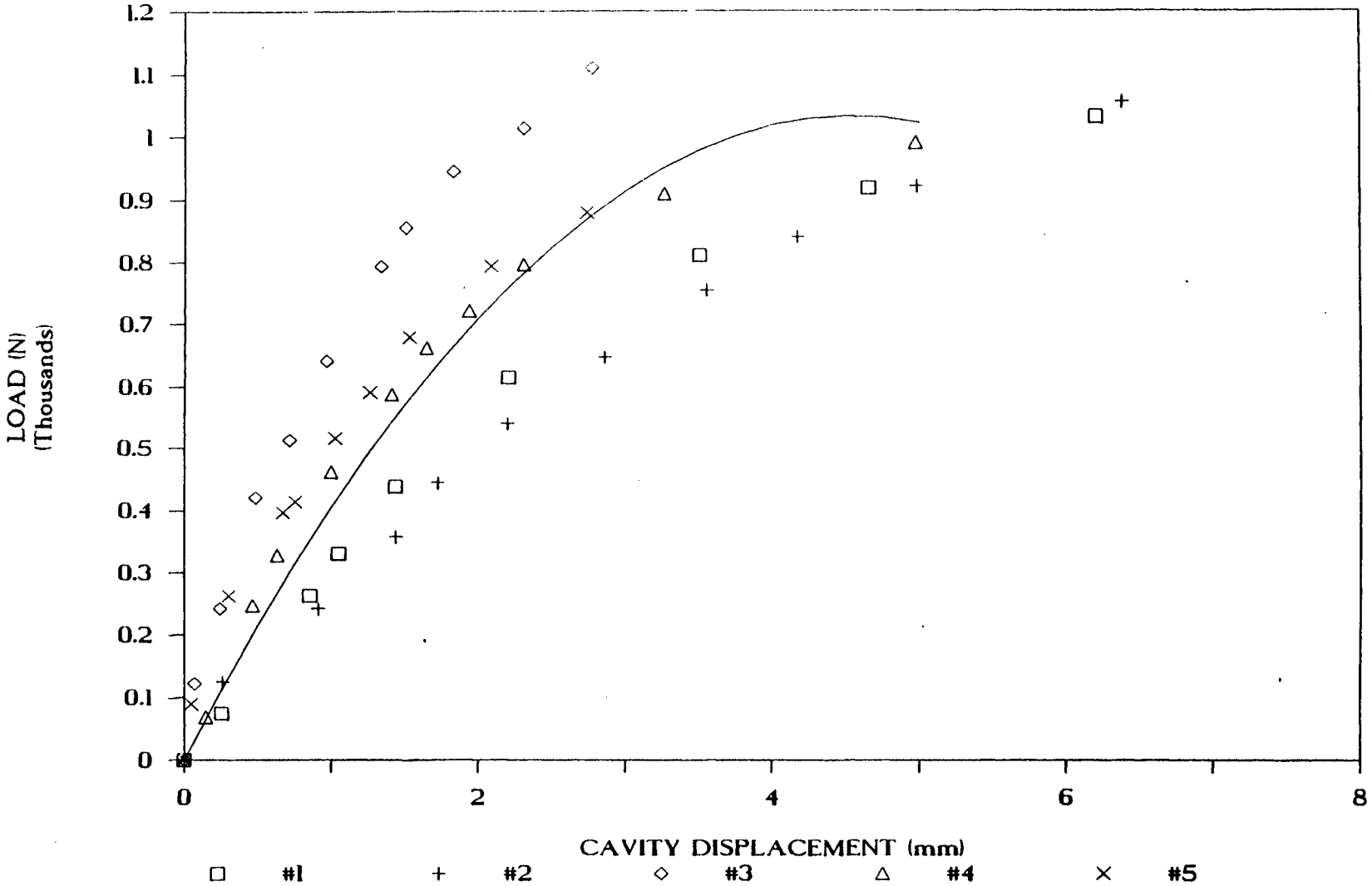
T-3-2

Test Results & Mean Curve



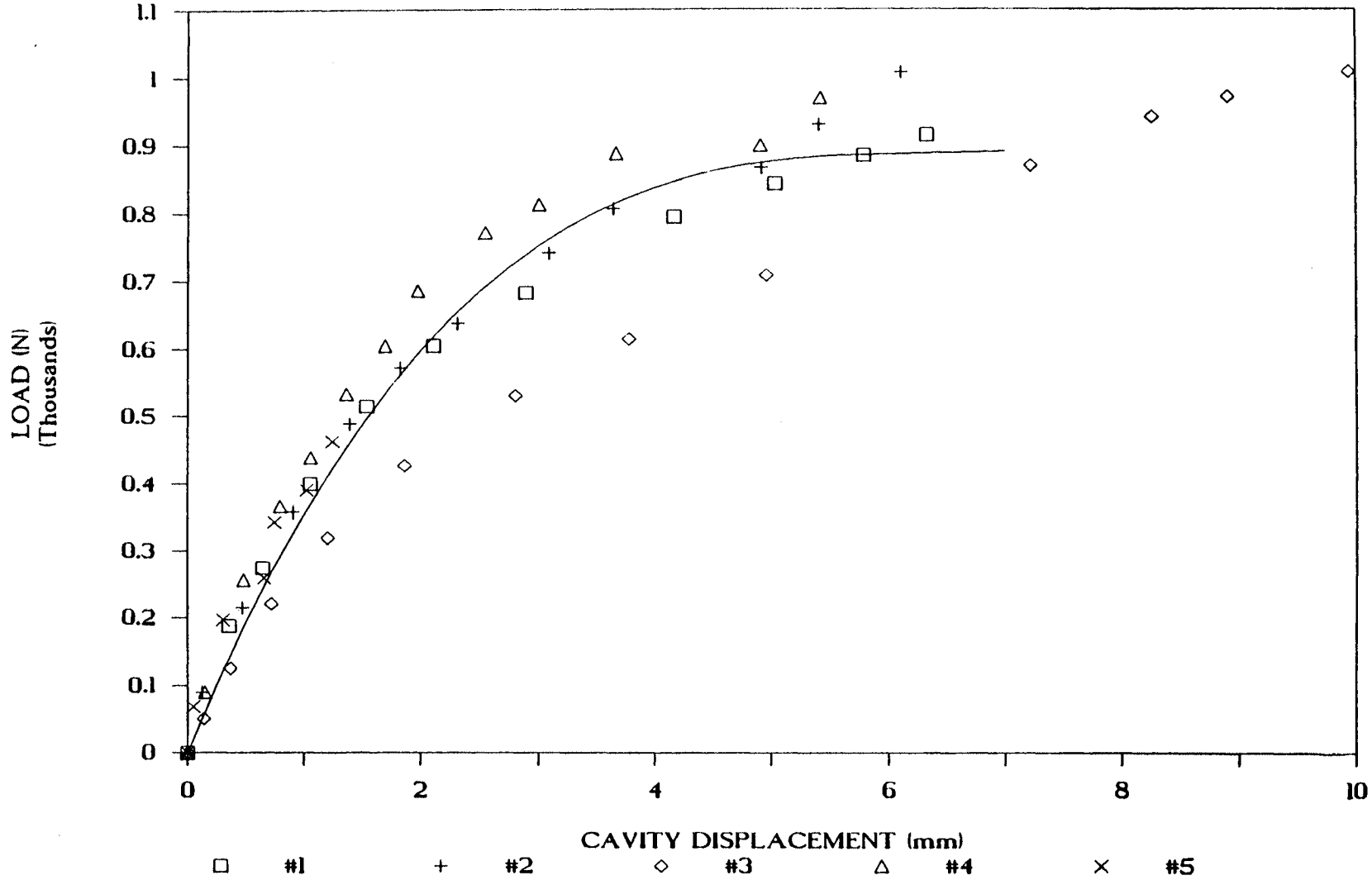
T-3-4A

Test Results & Mean Curve



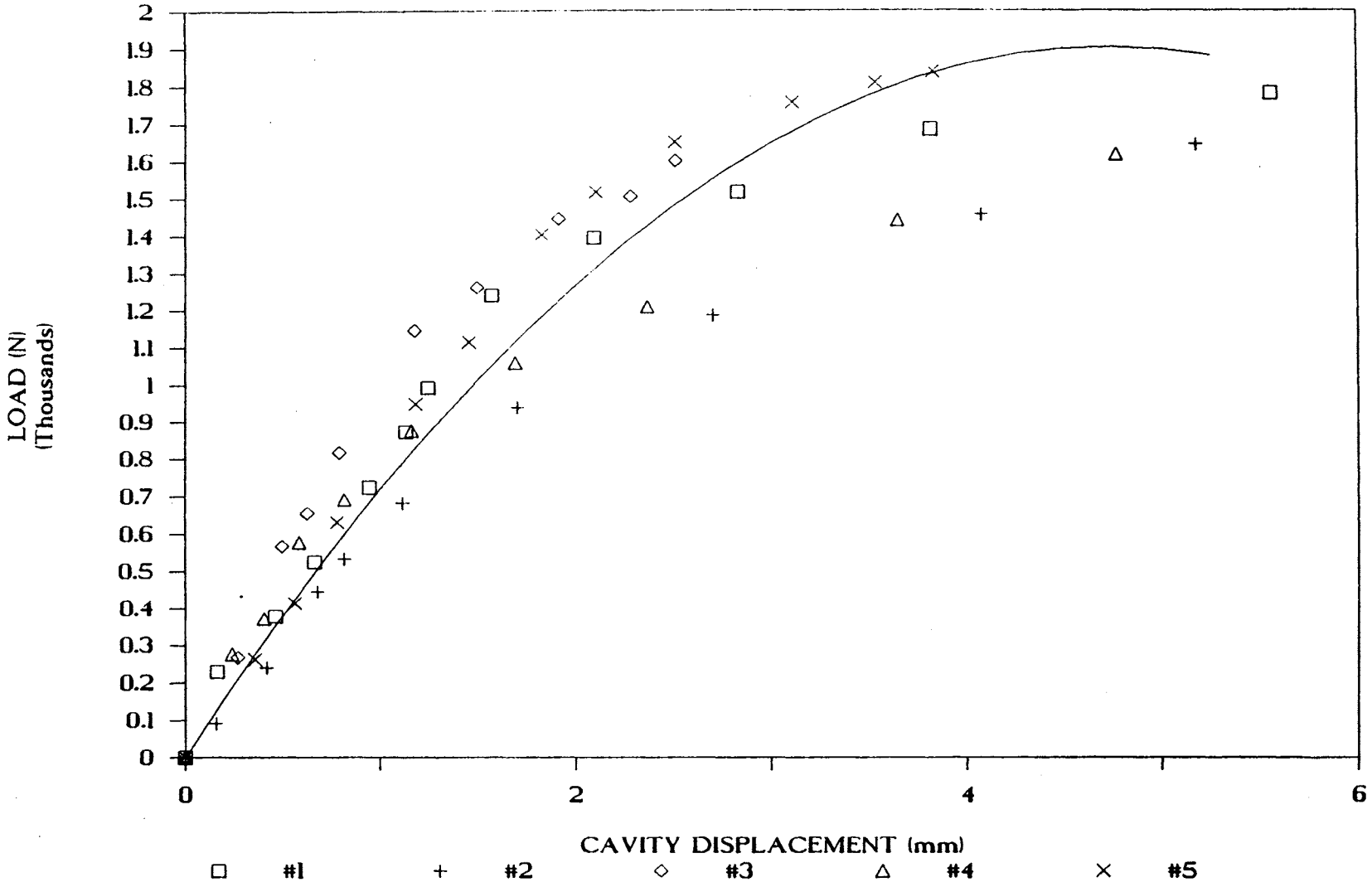
T-3-4B

Test Results & Mean Curve



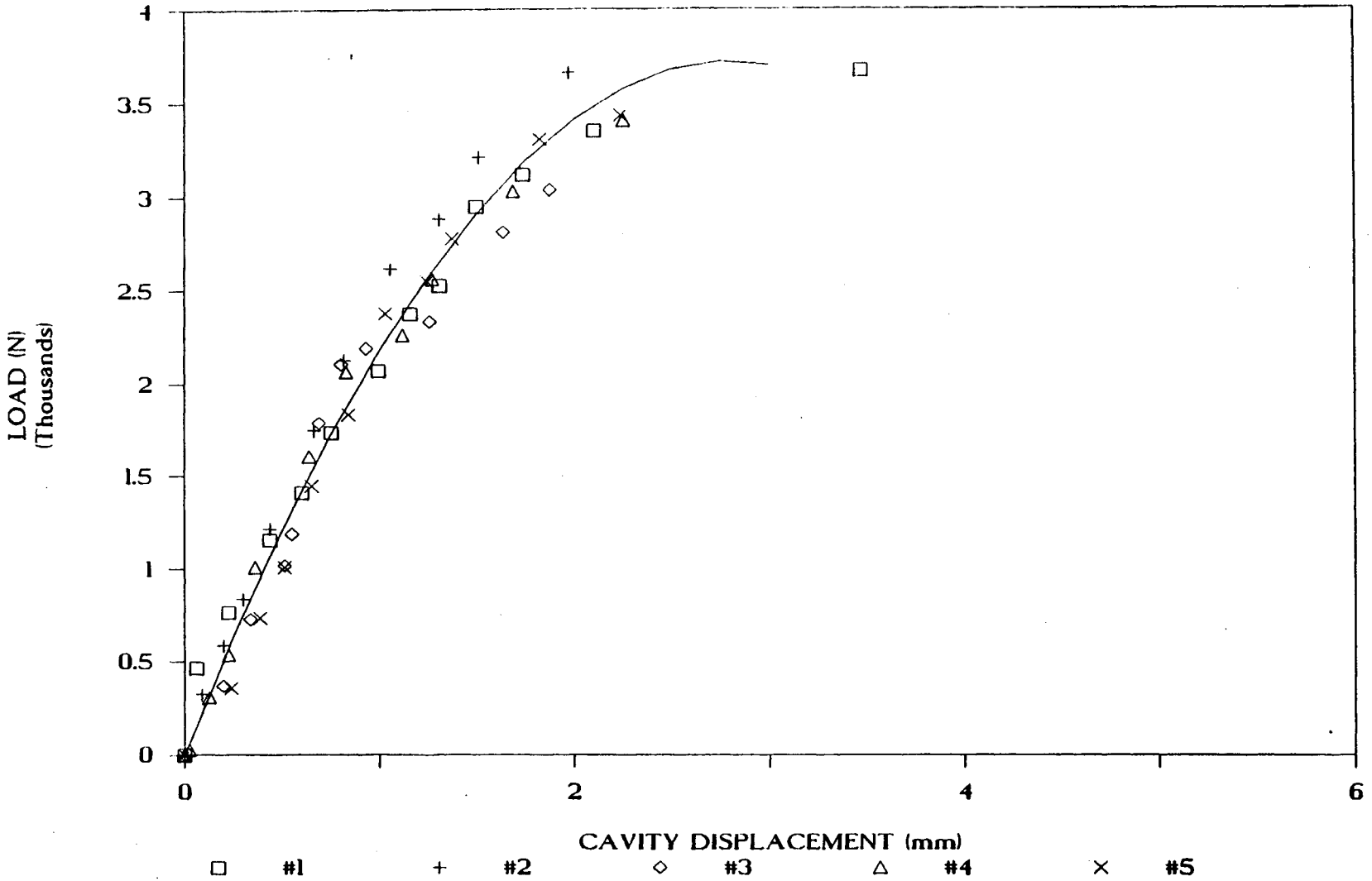
T-3-6

Test Results & Mean Curve



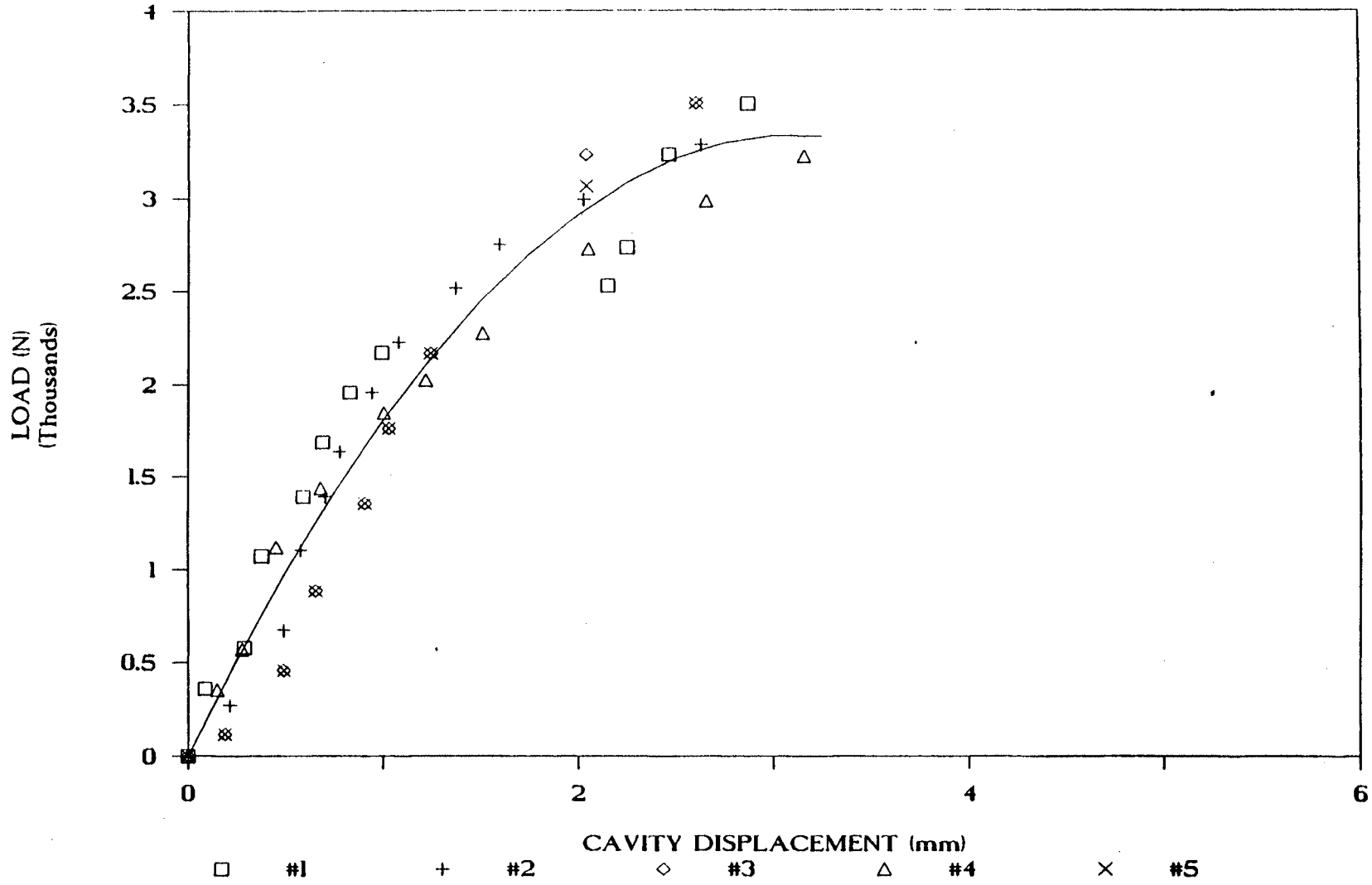
T-3-7

Test Results & Mean Curve



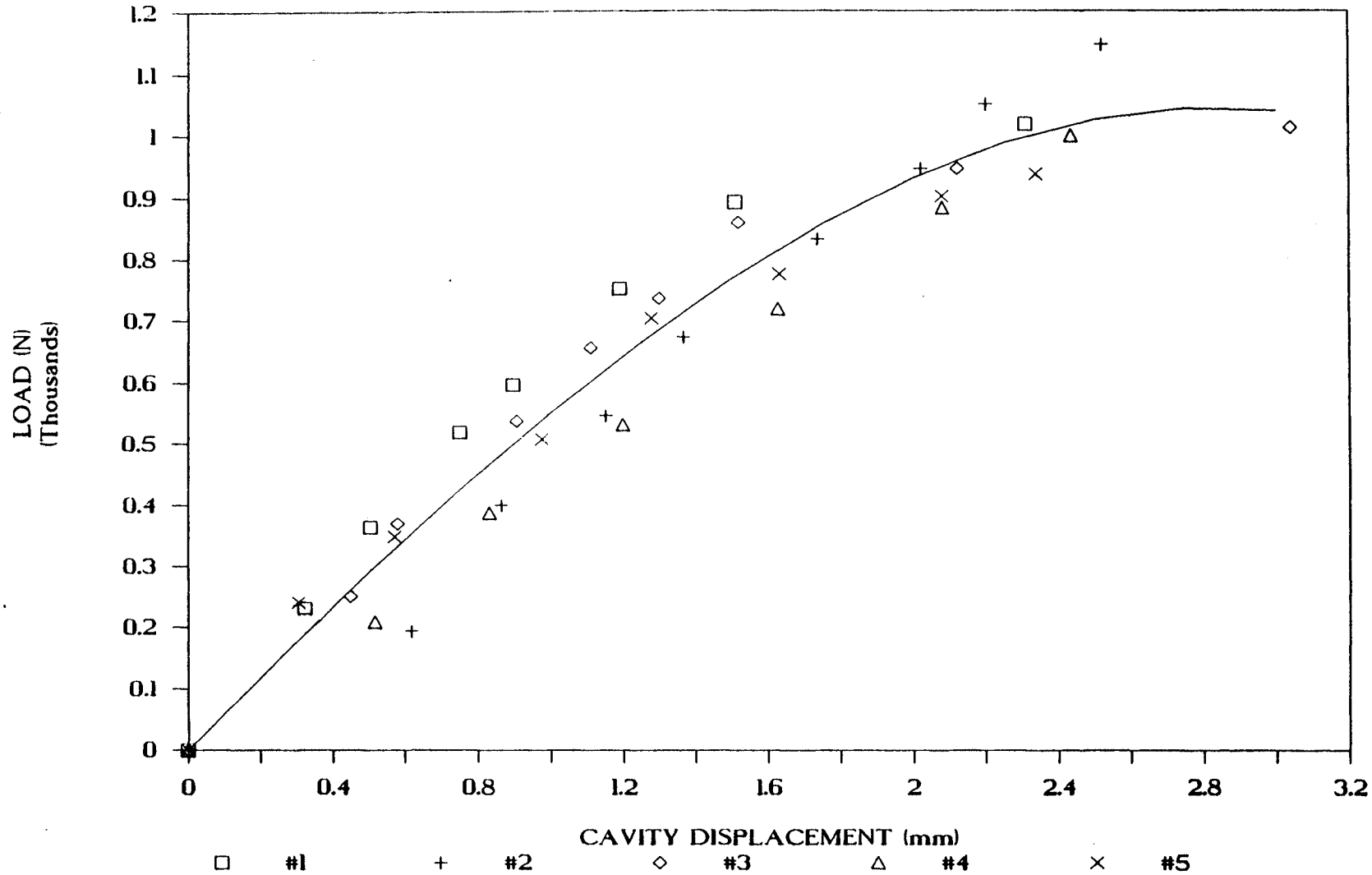
T-3-8

Test Results & Mean Curve



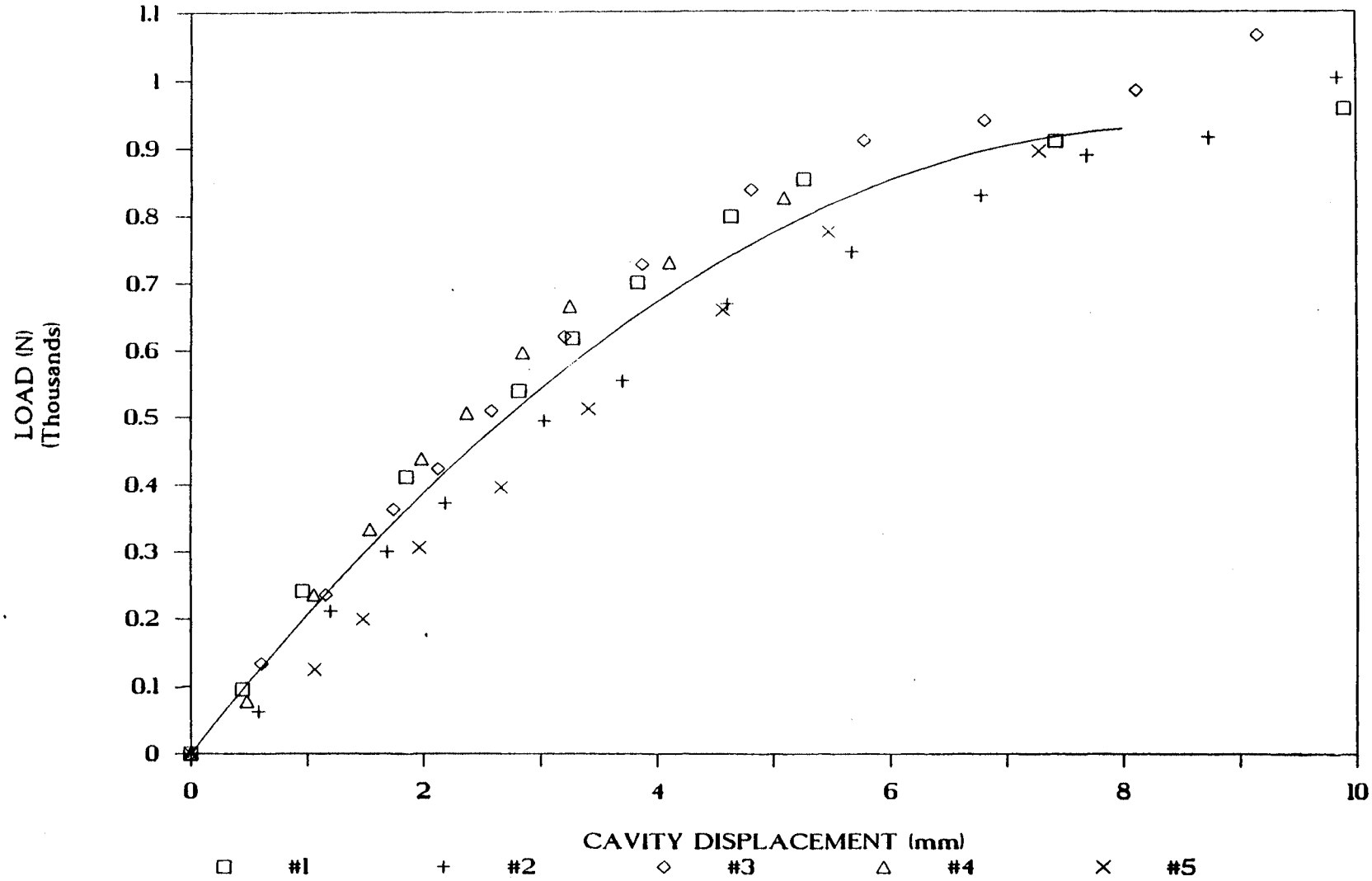
T-4-1

Test Results & Mean Curve



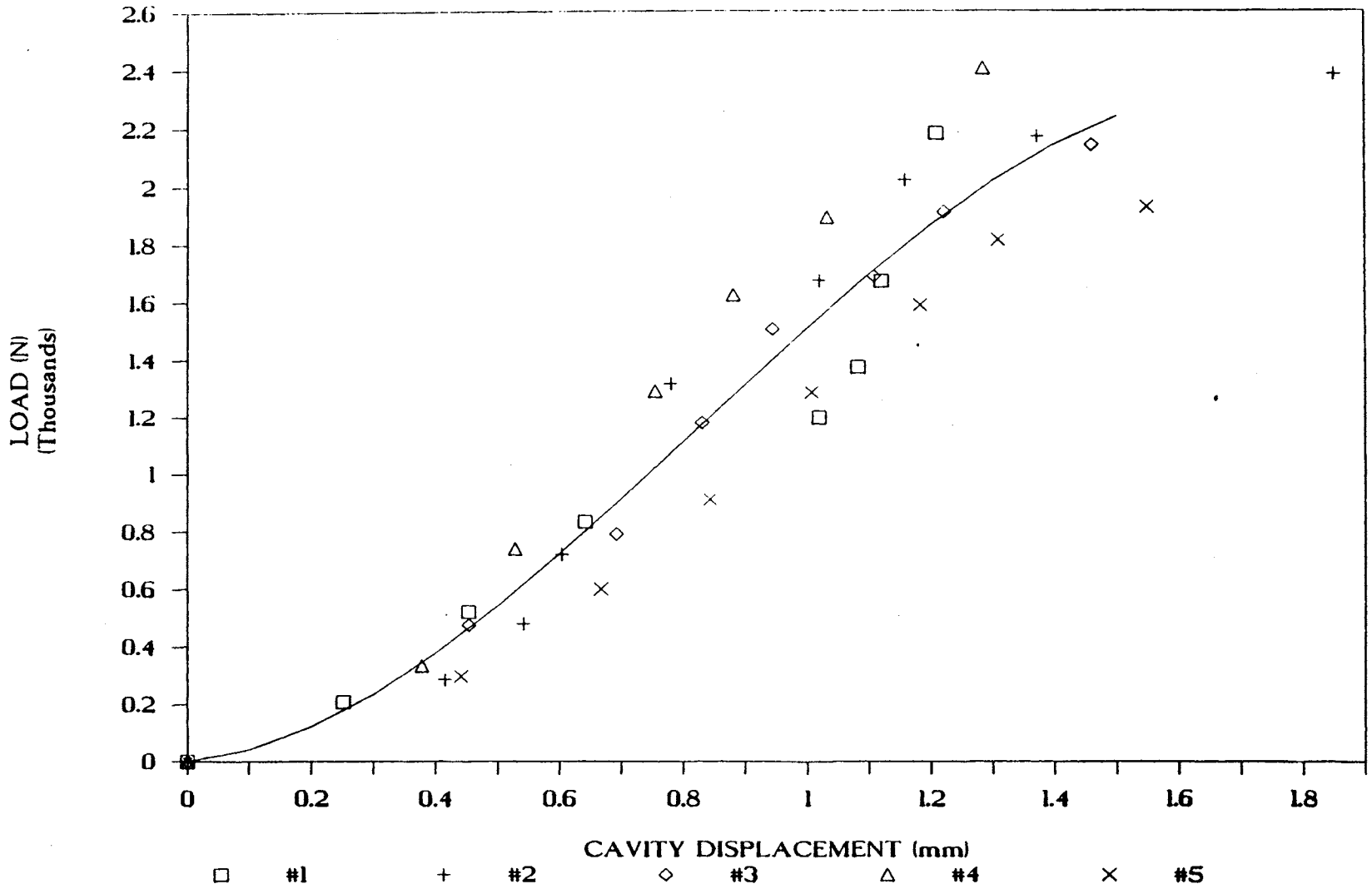
T-4-2

Test Results & Mean Curve



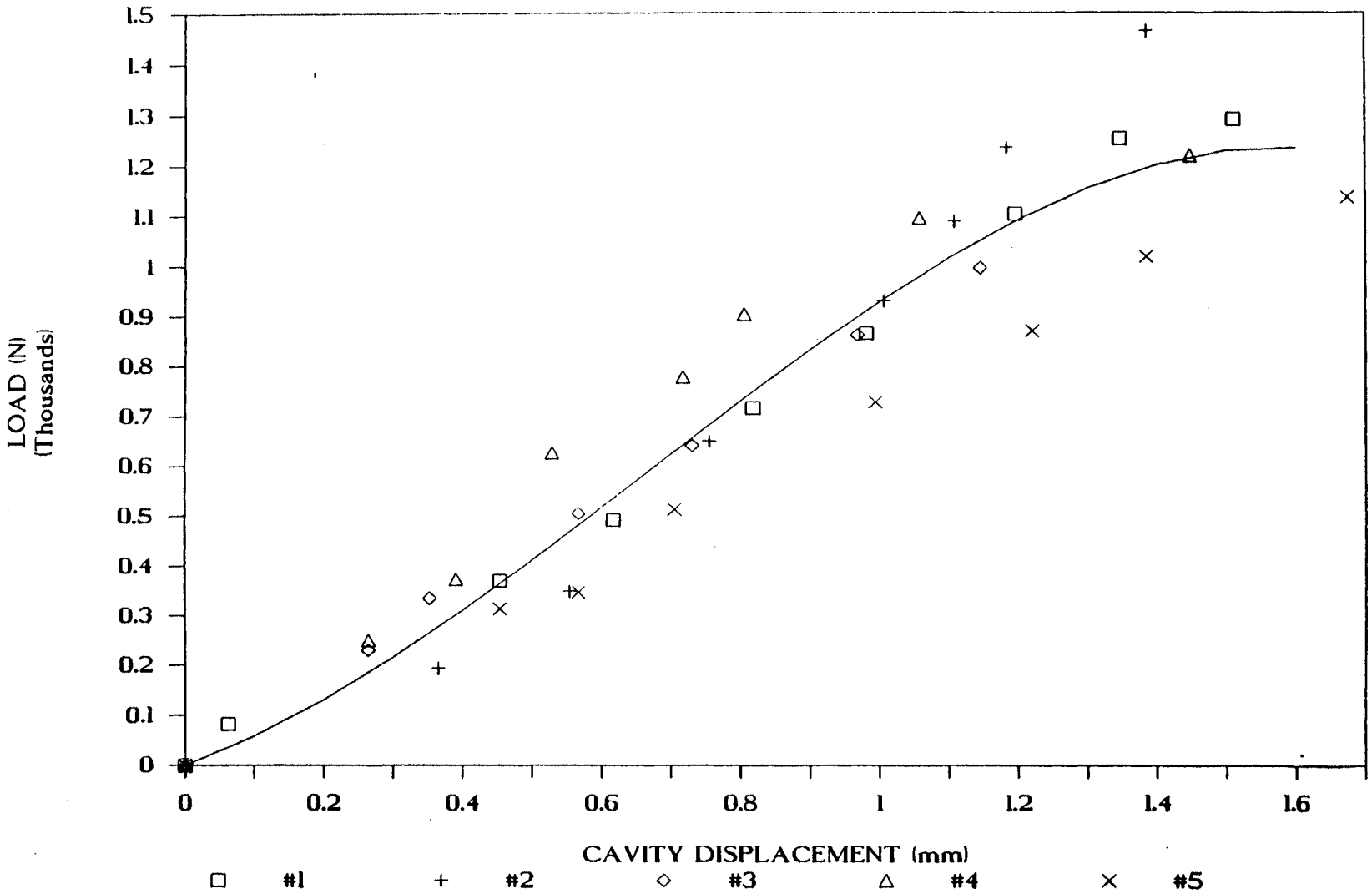
T-4-5

Test Results & Mean Curve



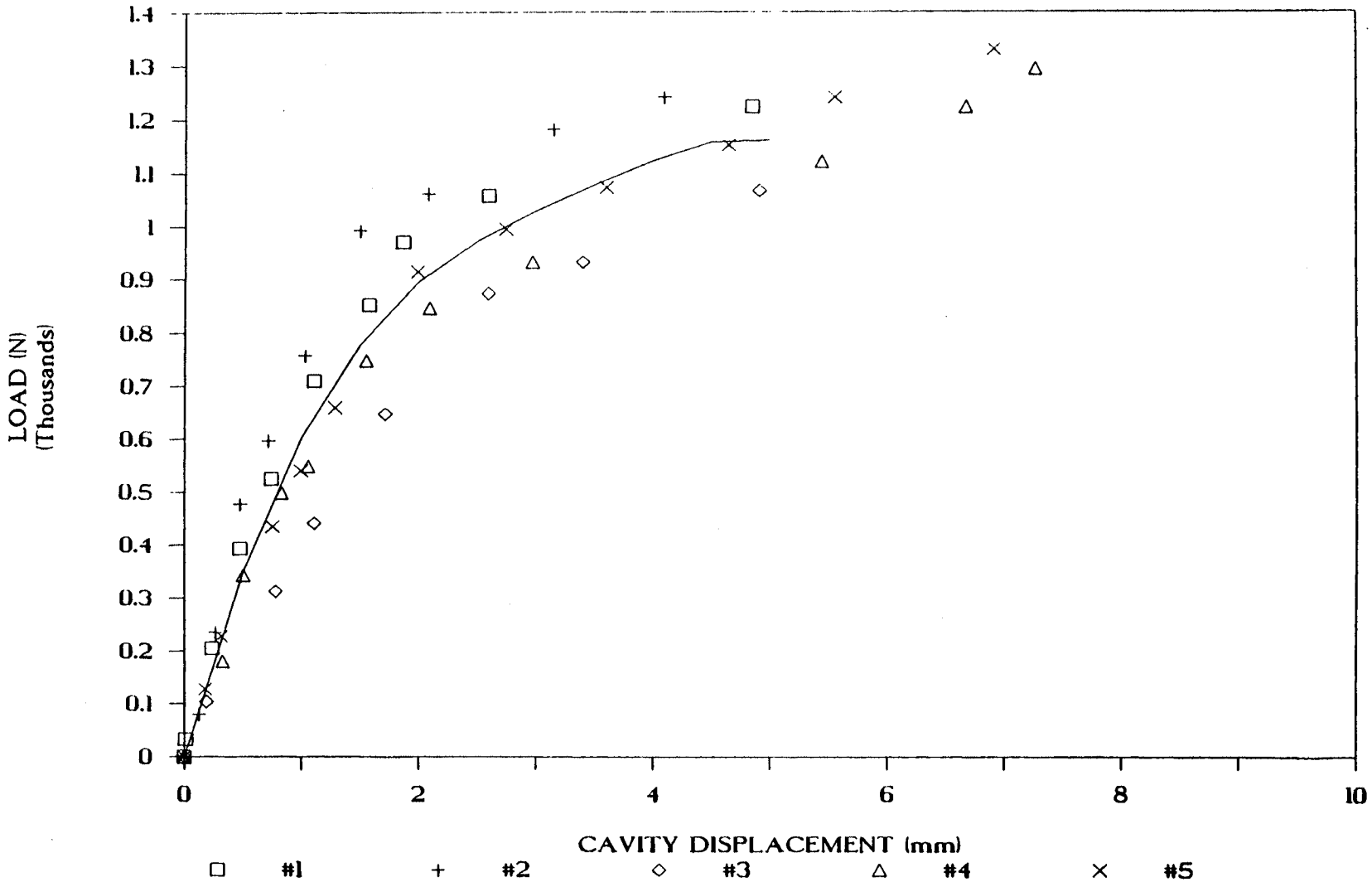
T-4-7

Test Results & Mean Curve



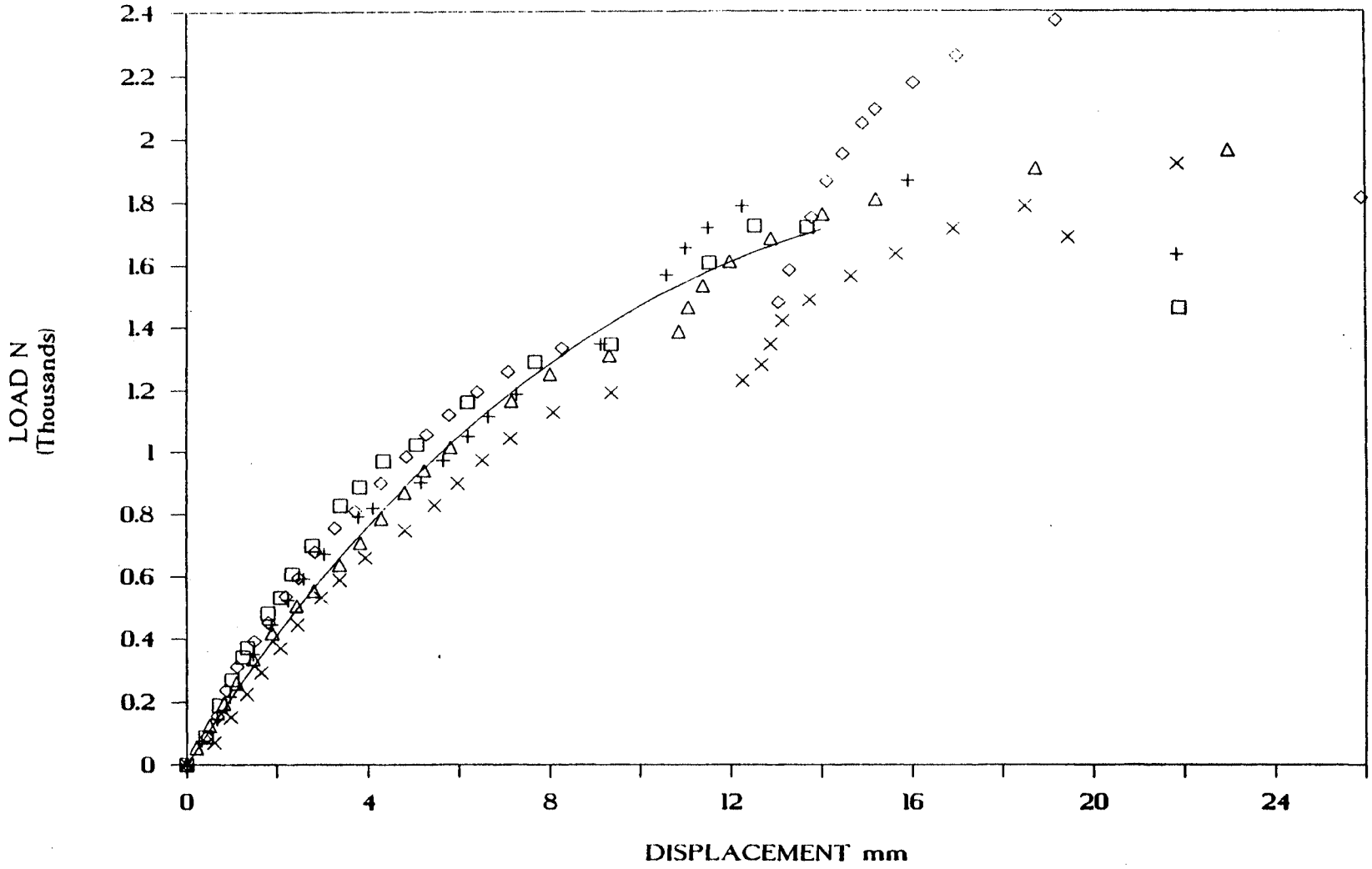
T-4-8

Test Results & Mean Curve



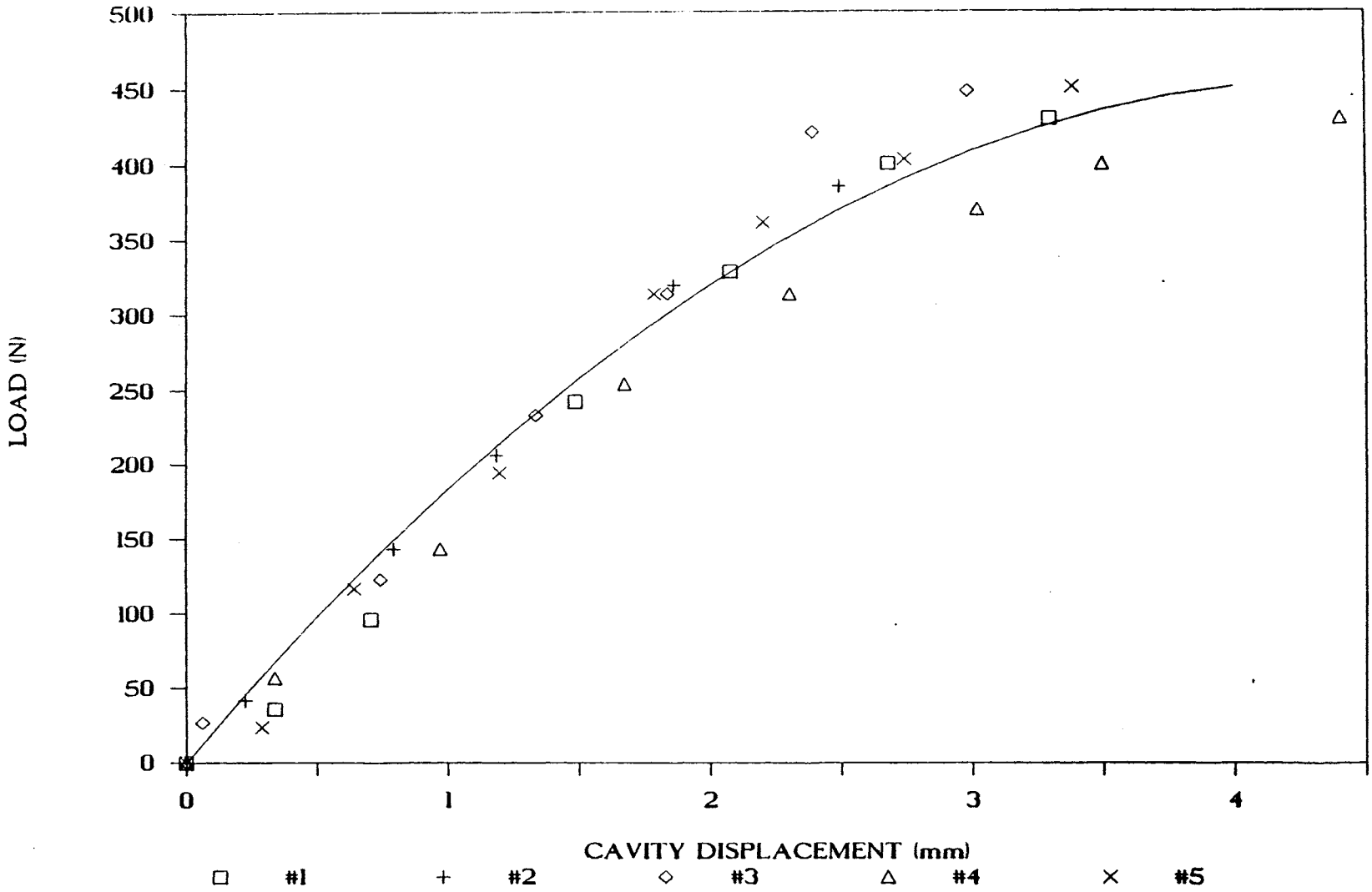
T-4-9

Test Results & Mean Curve



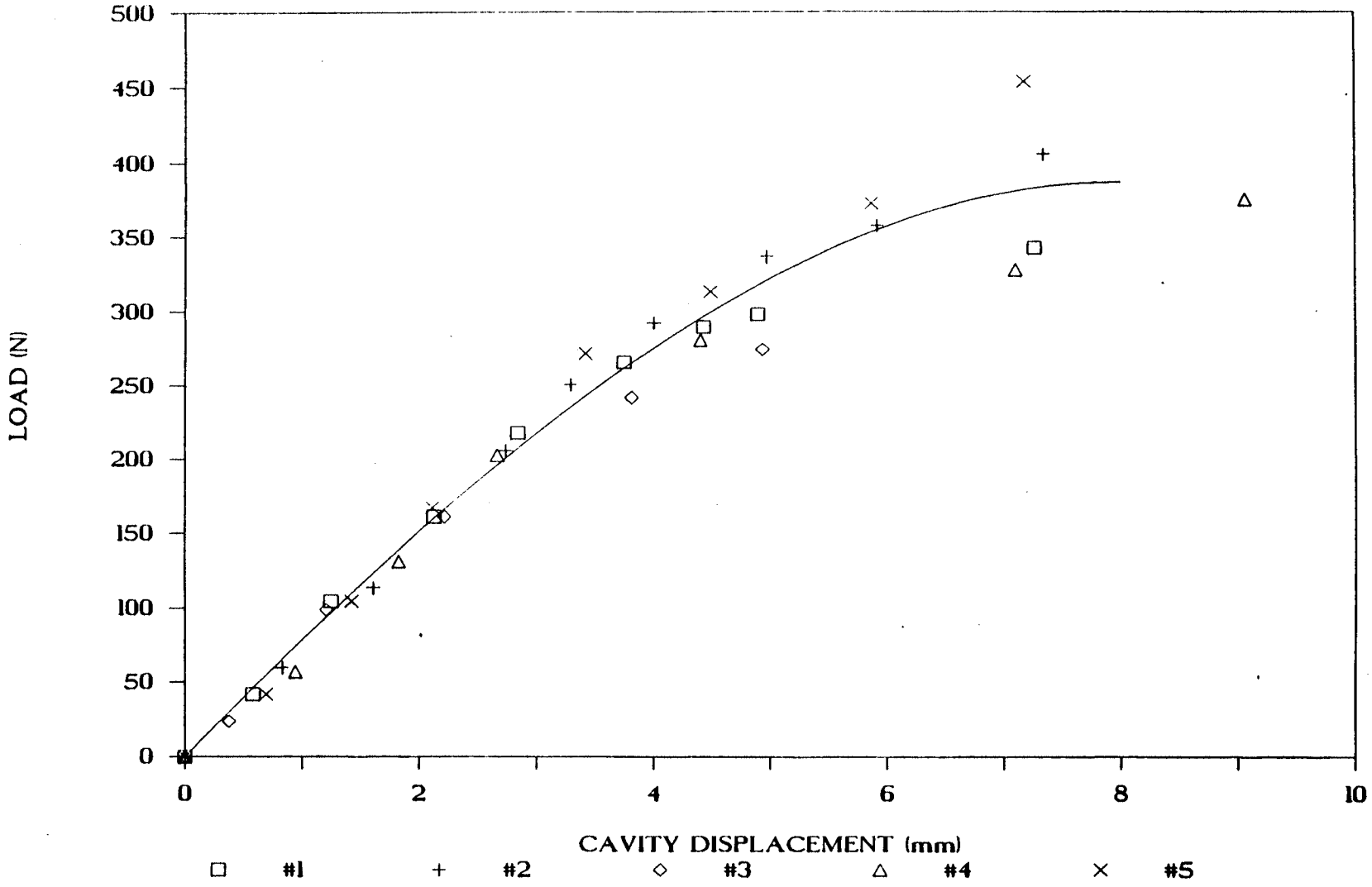
T-4-10A

Test Results & Mean Curve



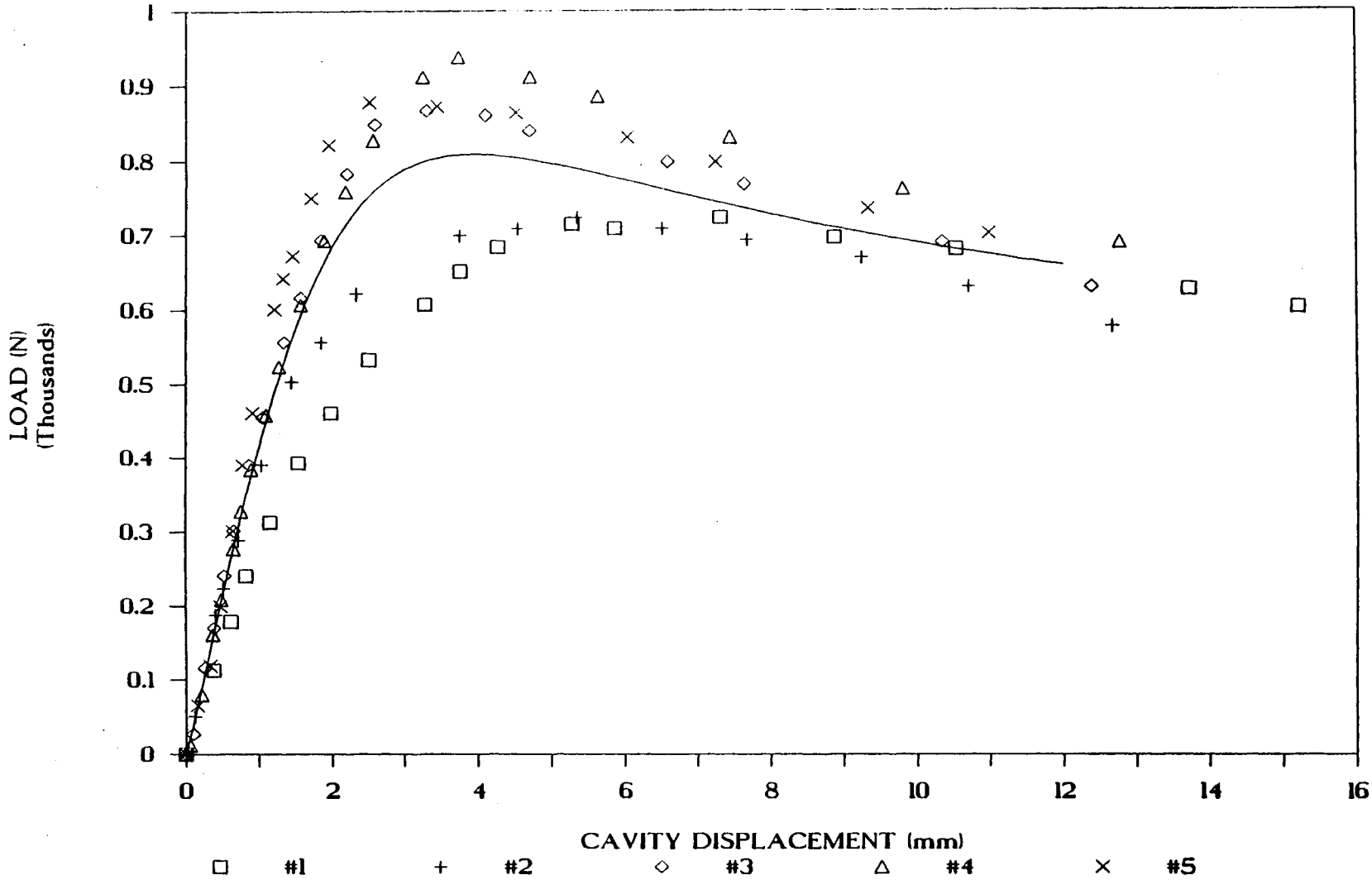
T-4-10B

Test Results & Mean Curve



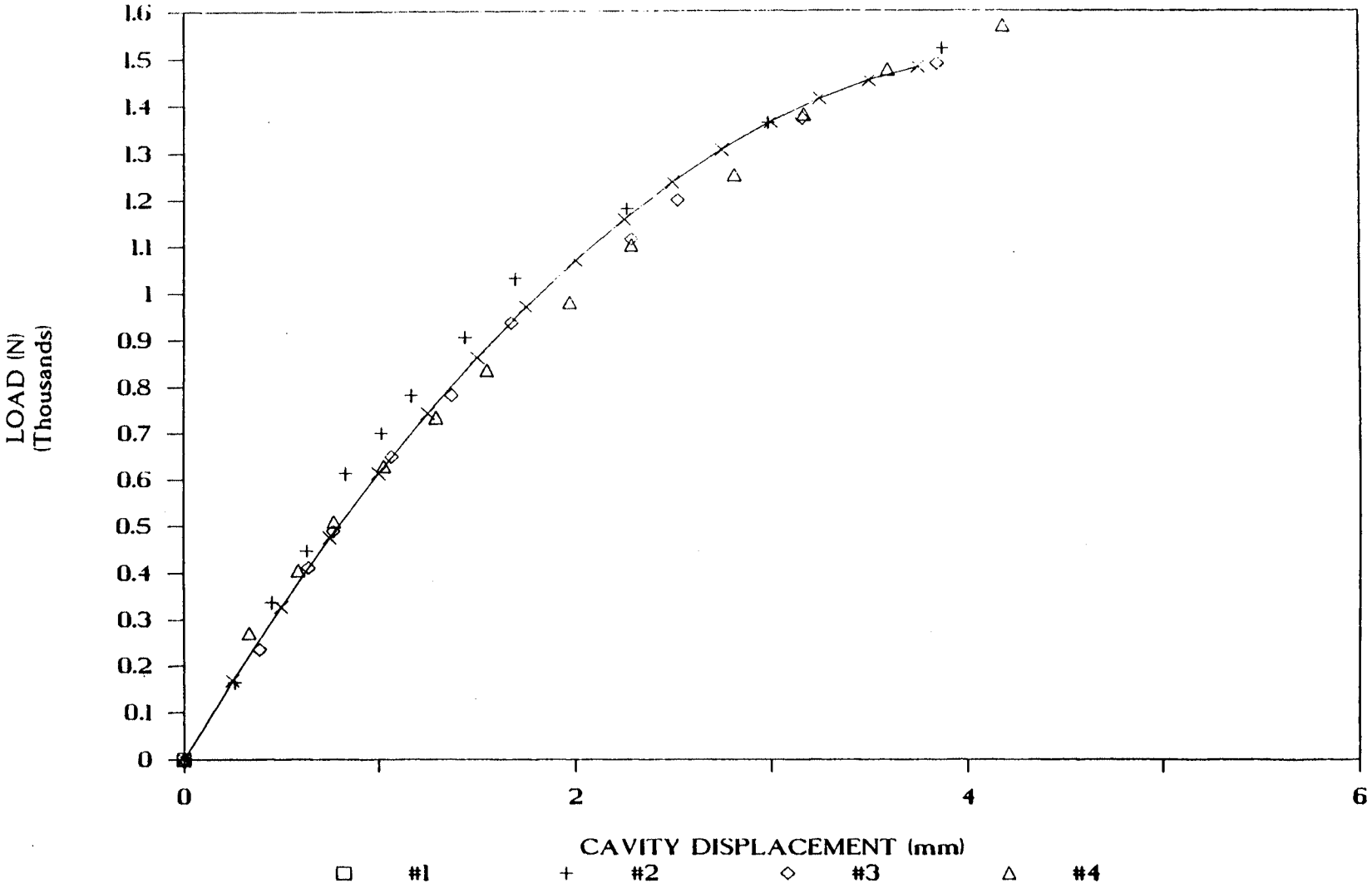
T-4-11

Test Results & Mean Curve



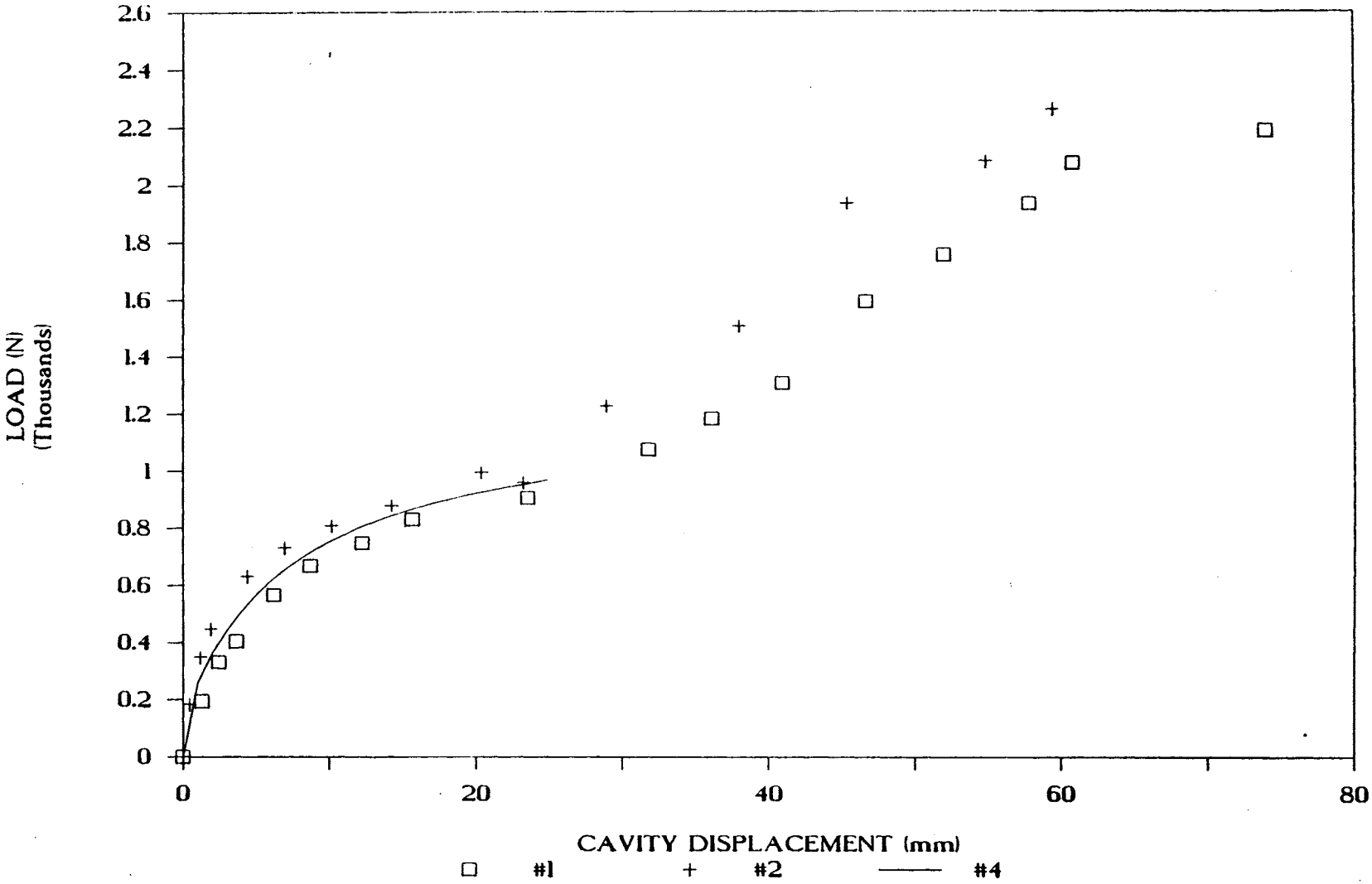
T-5-1

Test Results & Mean Curve



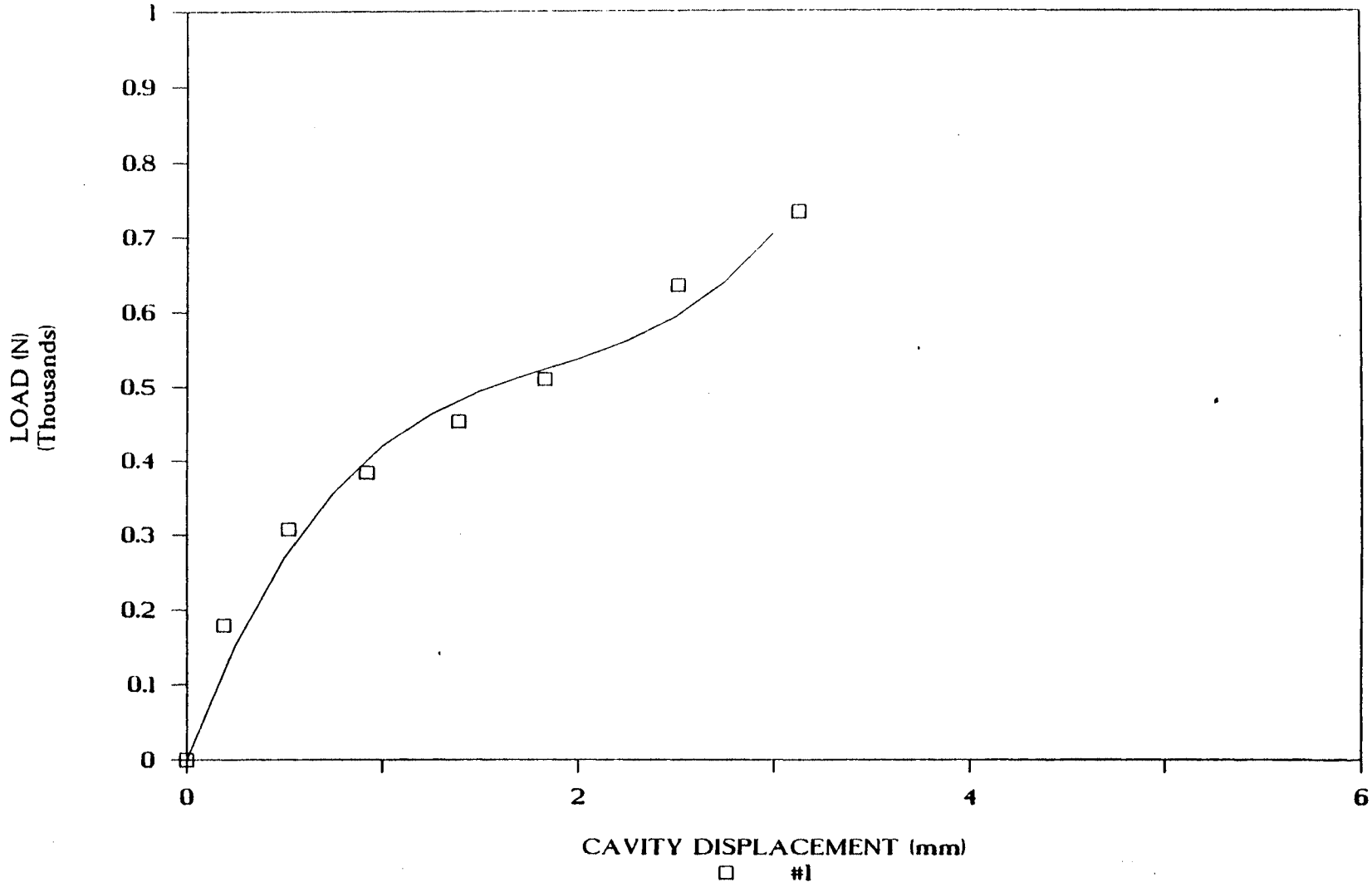
T-5-IC

Test Results & Mean Curve



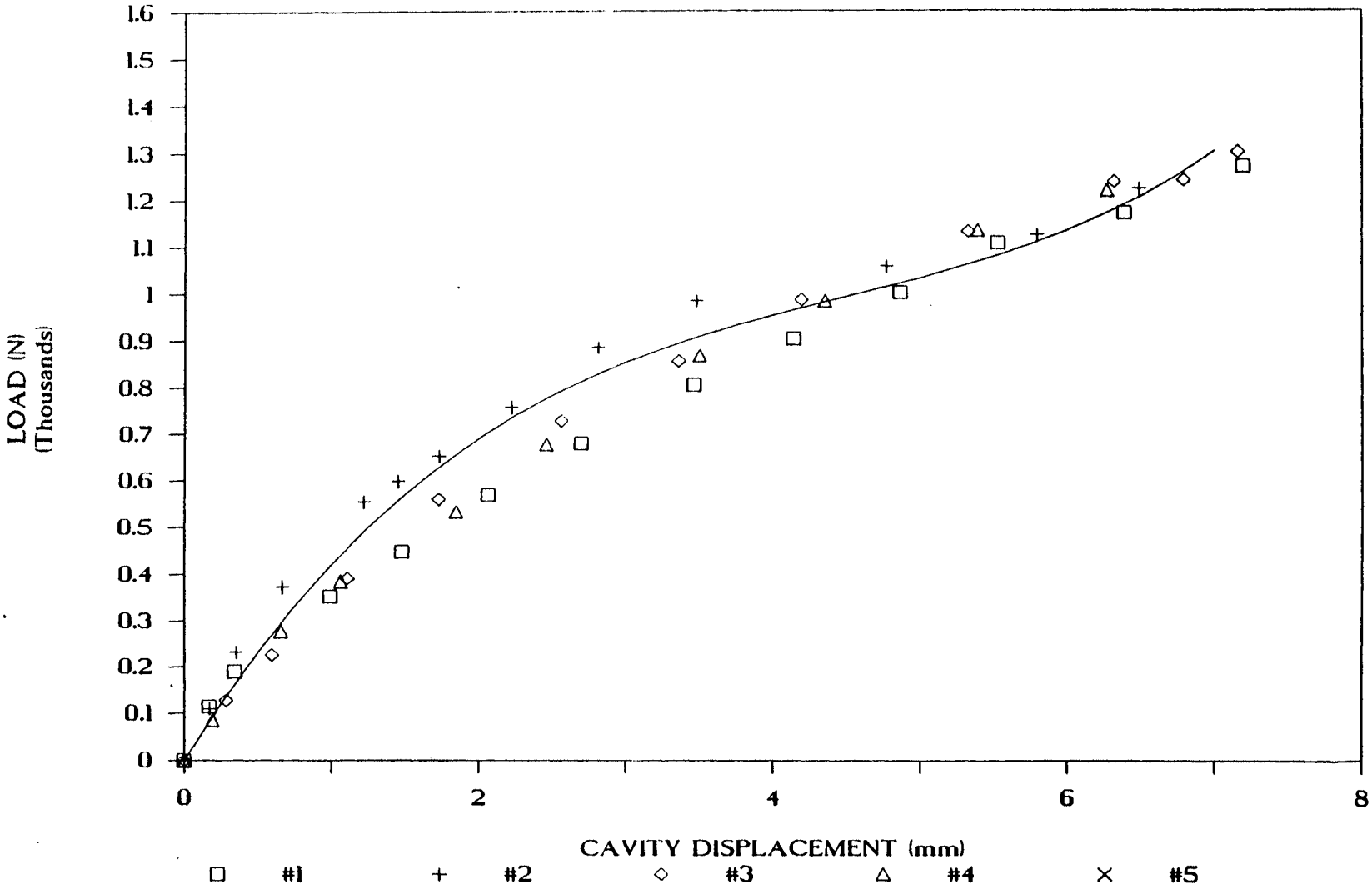
T-5-1 D

Test Results & Mean Curve



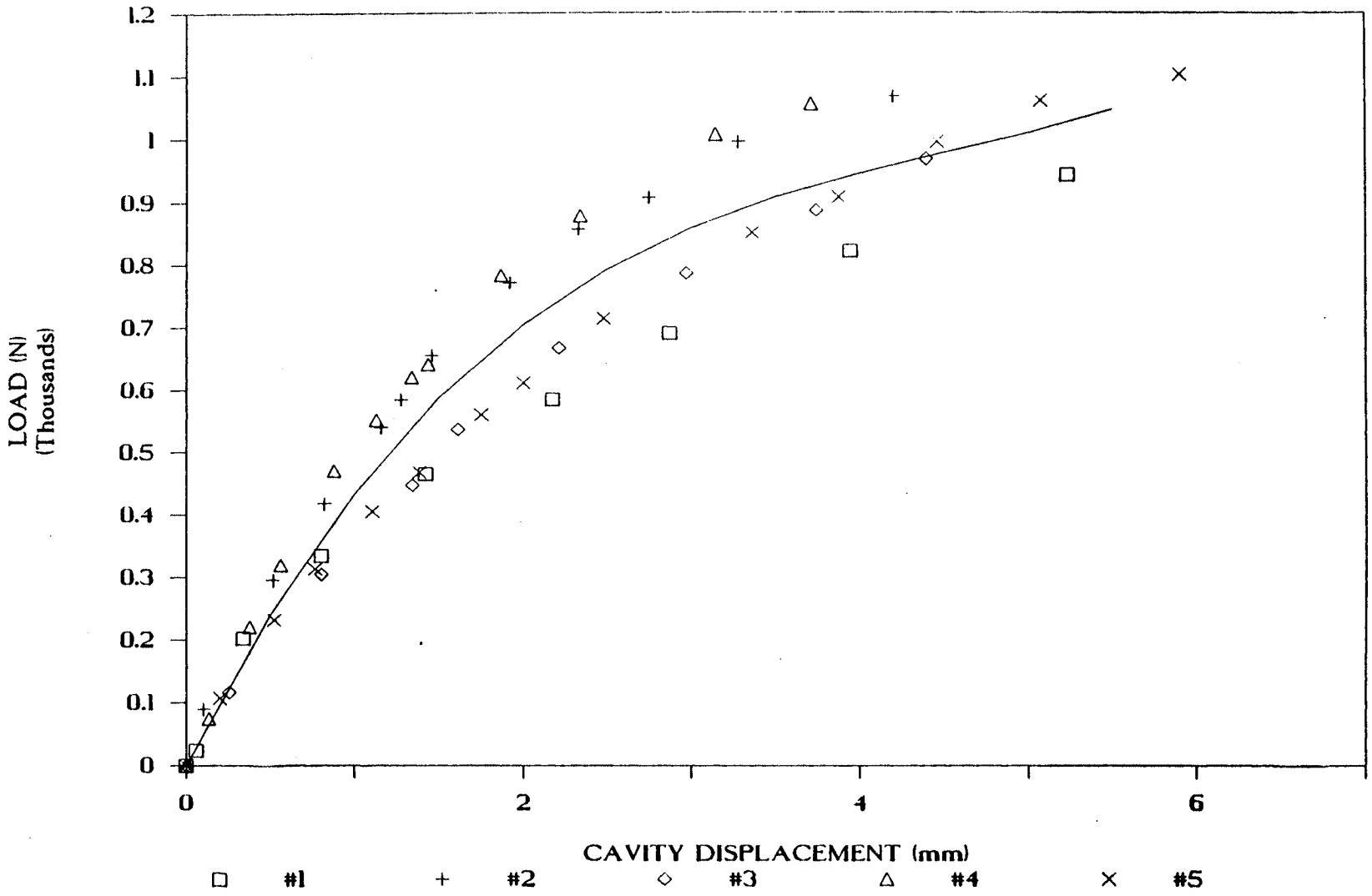
T-5-2

Test Results & Mean Curve



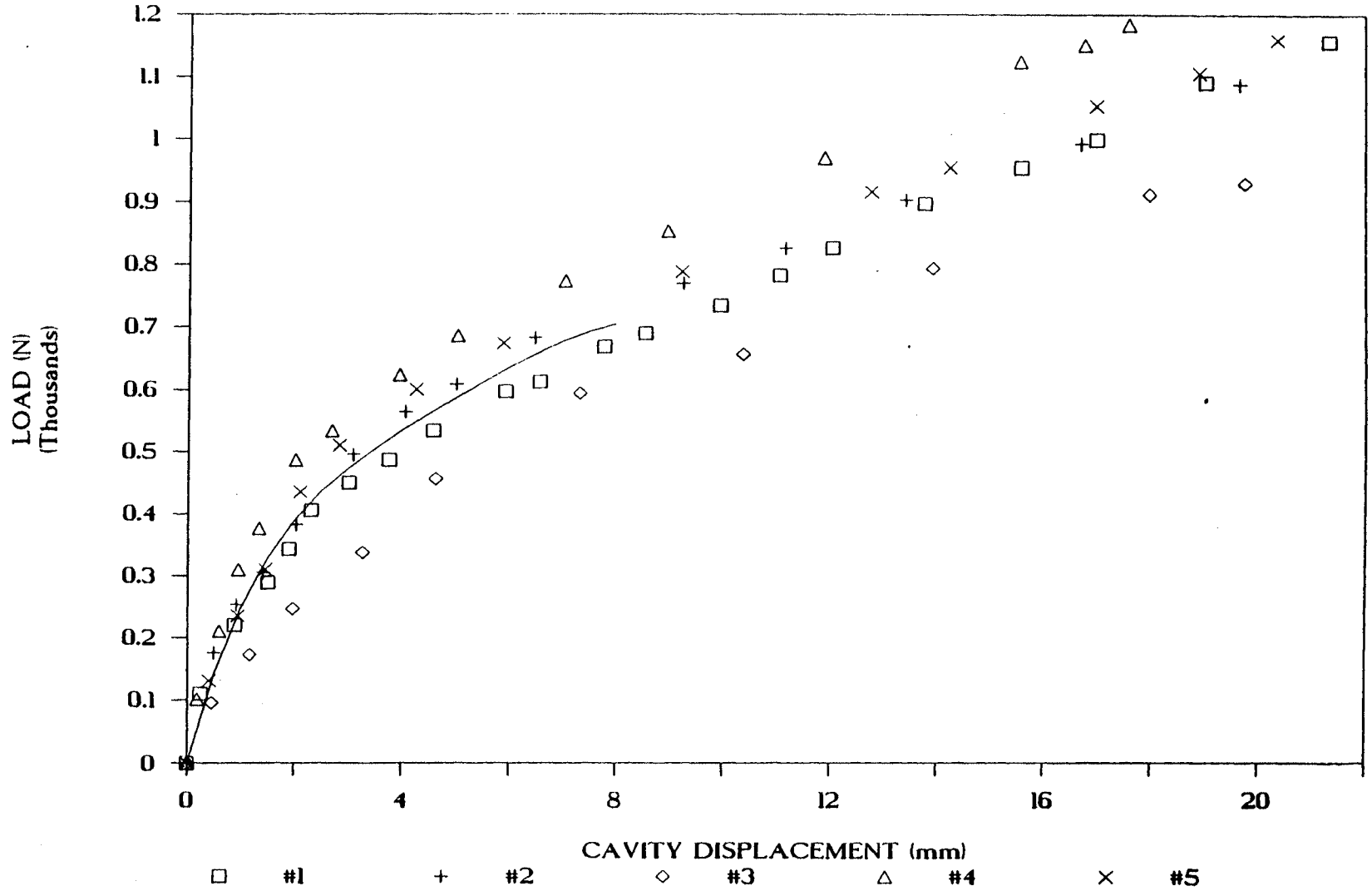
T-5-4A

Test Results & Mean Curve



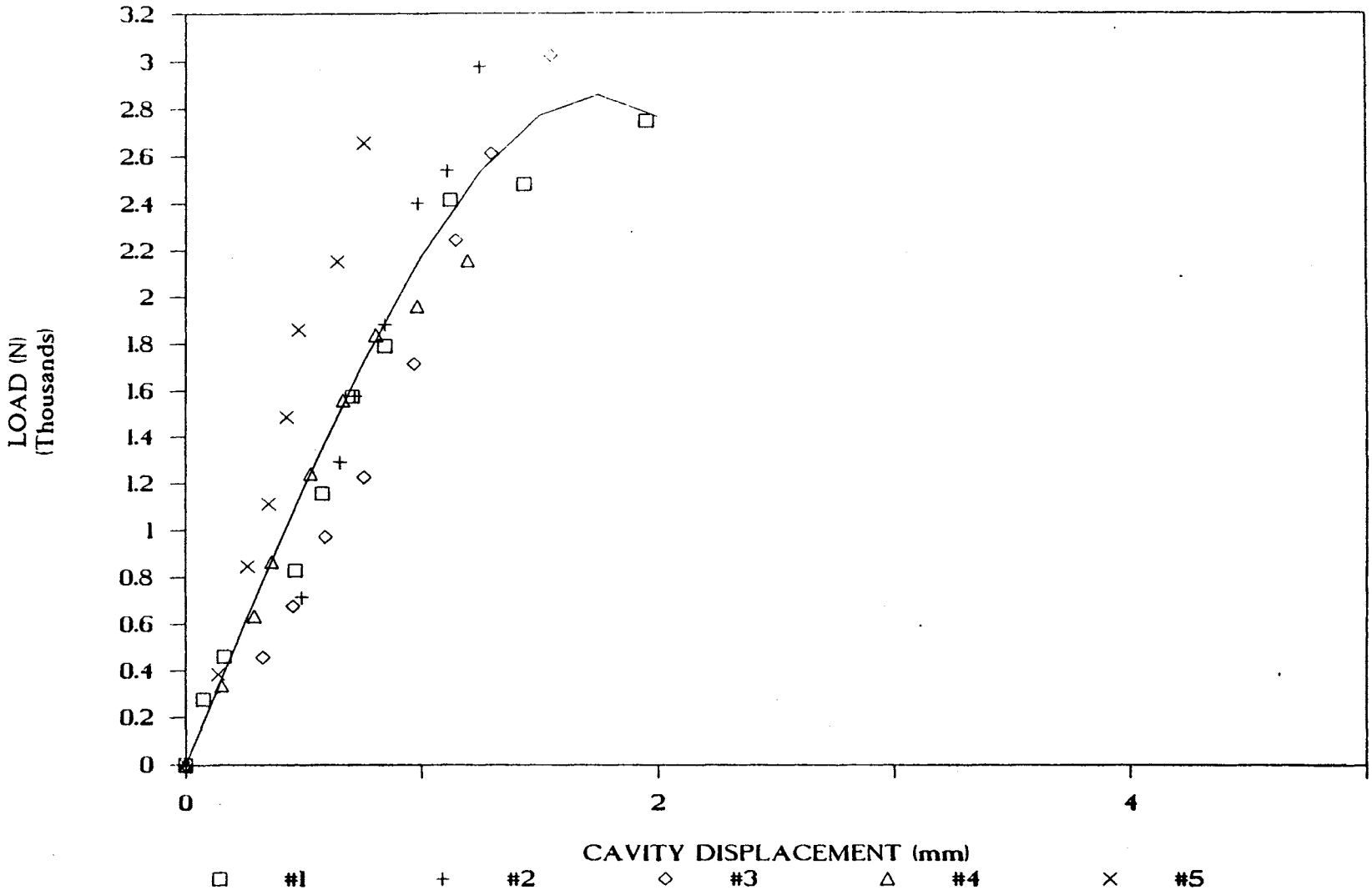
T-5-4B

Test Results & Mean Curve



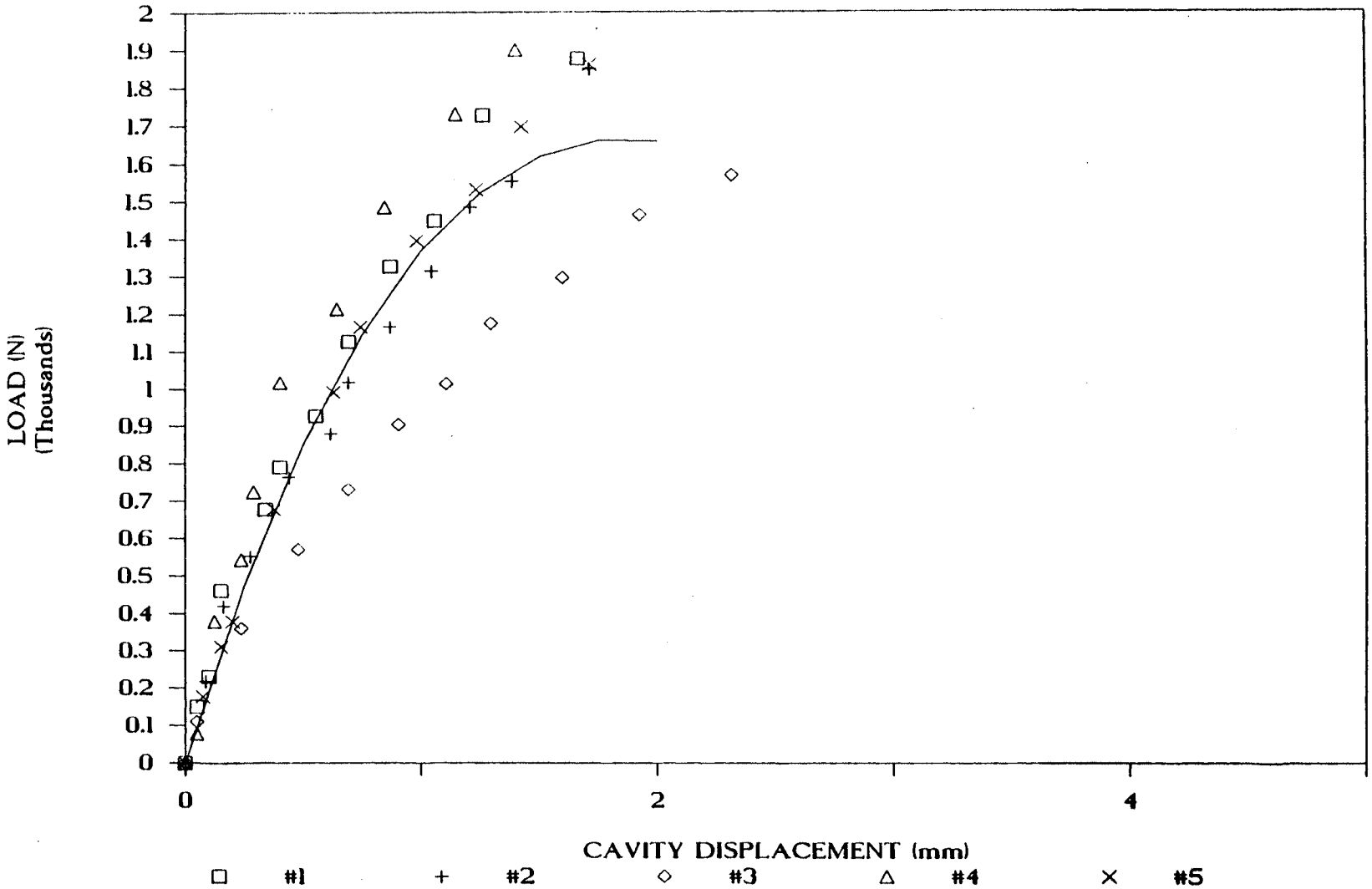
T-5-7

Test Results & Mean Curve



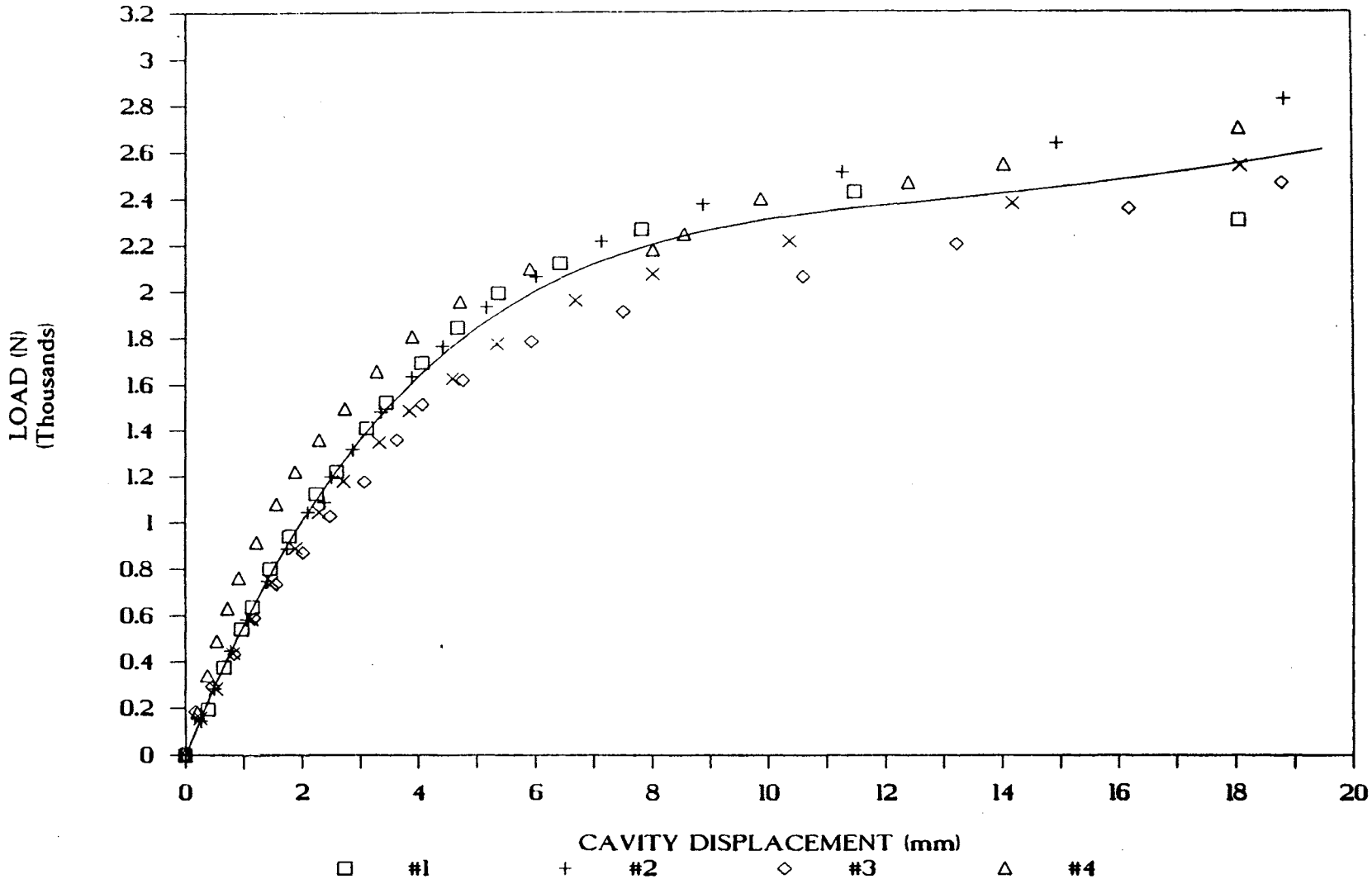
T-5-8

Test Results & Mean Curve



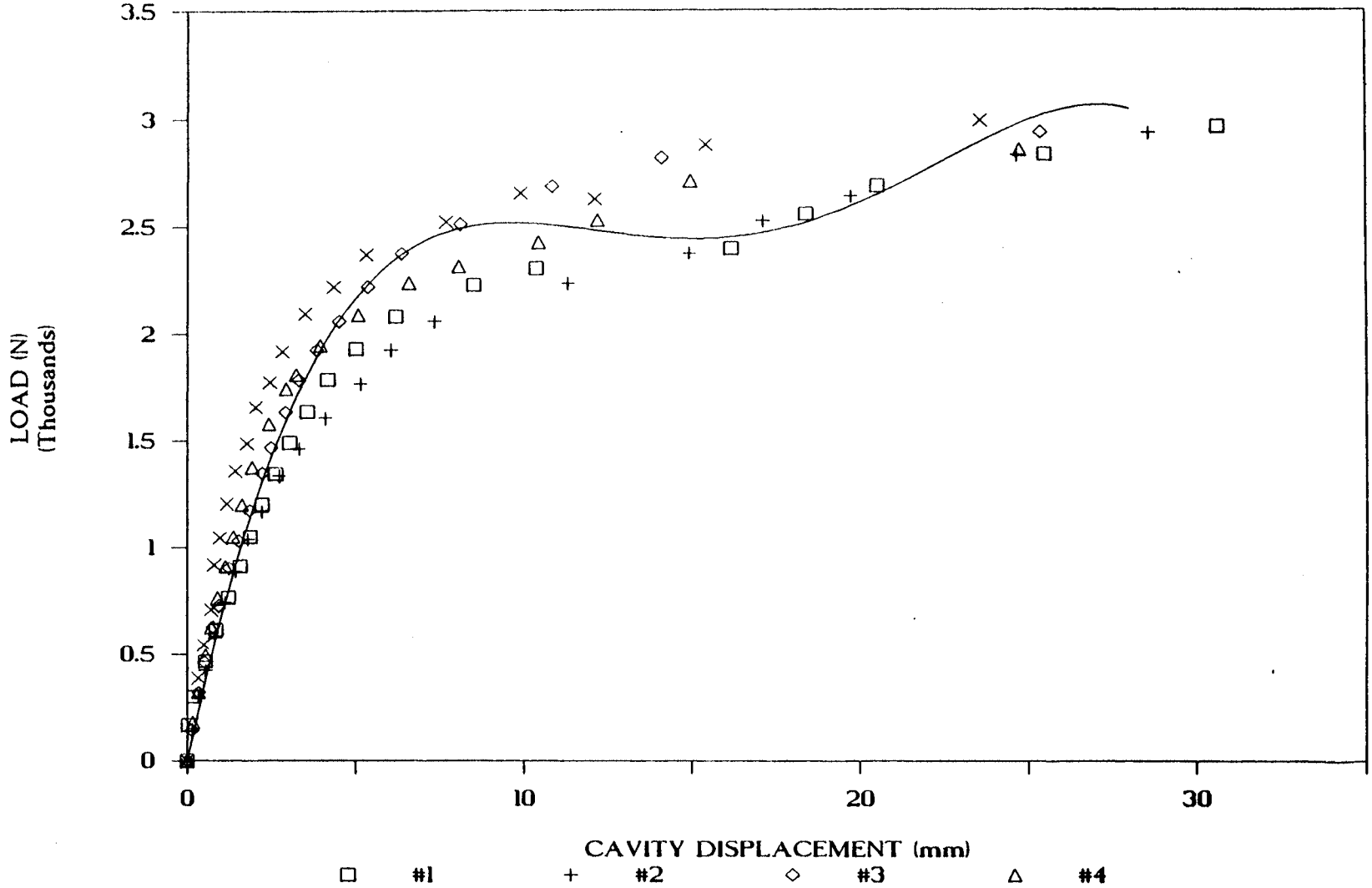
T-5-9A

Test Results & Mean Curve



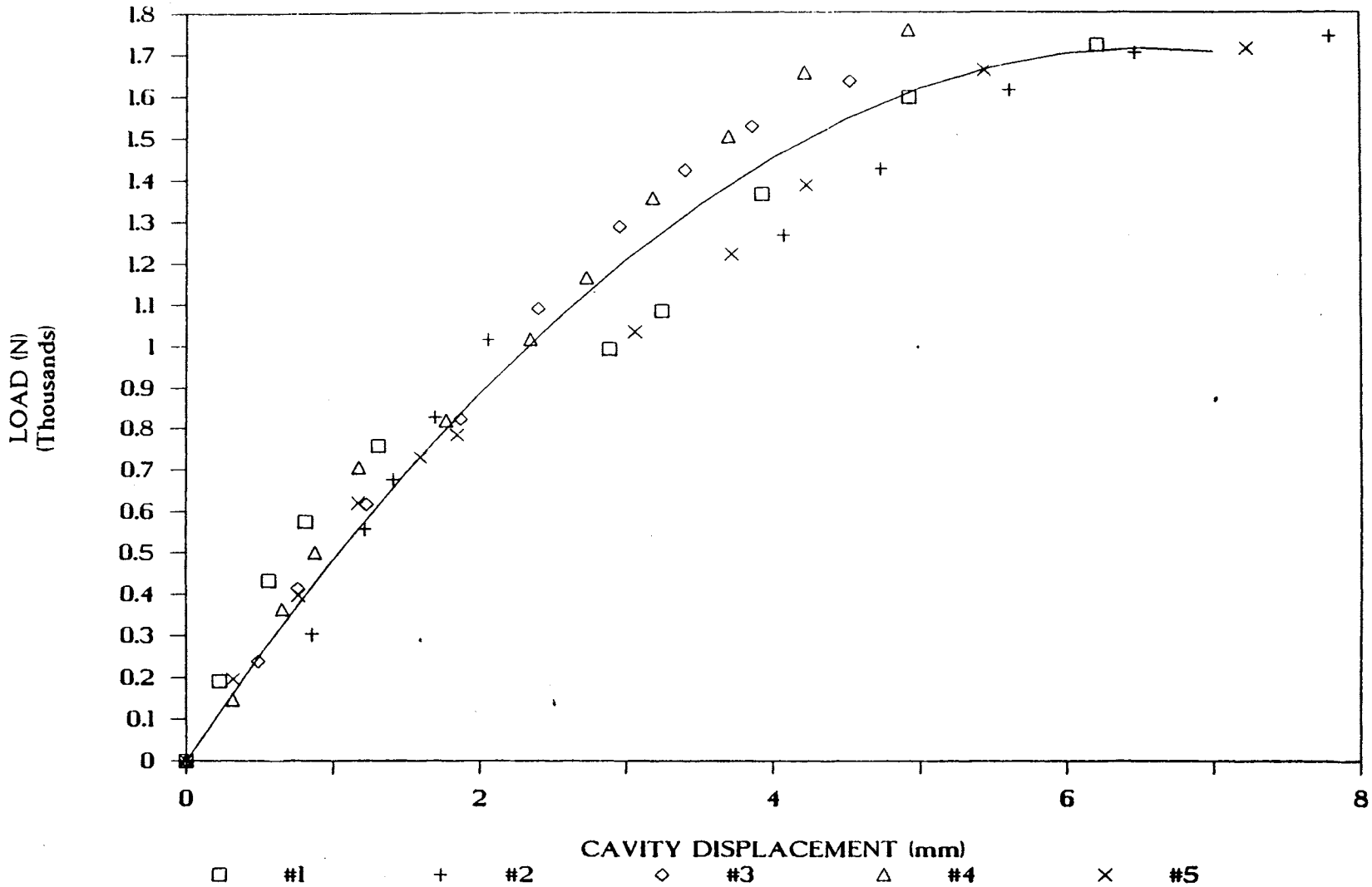
T-5-9B

Test Results & Mean Curve



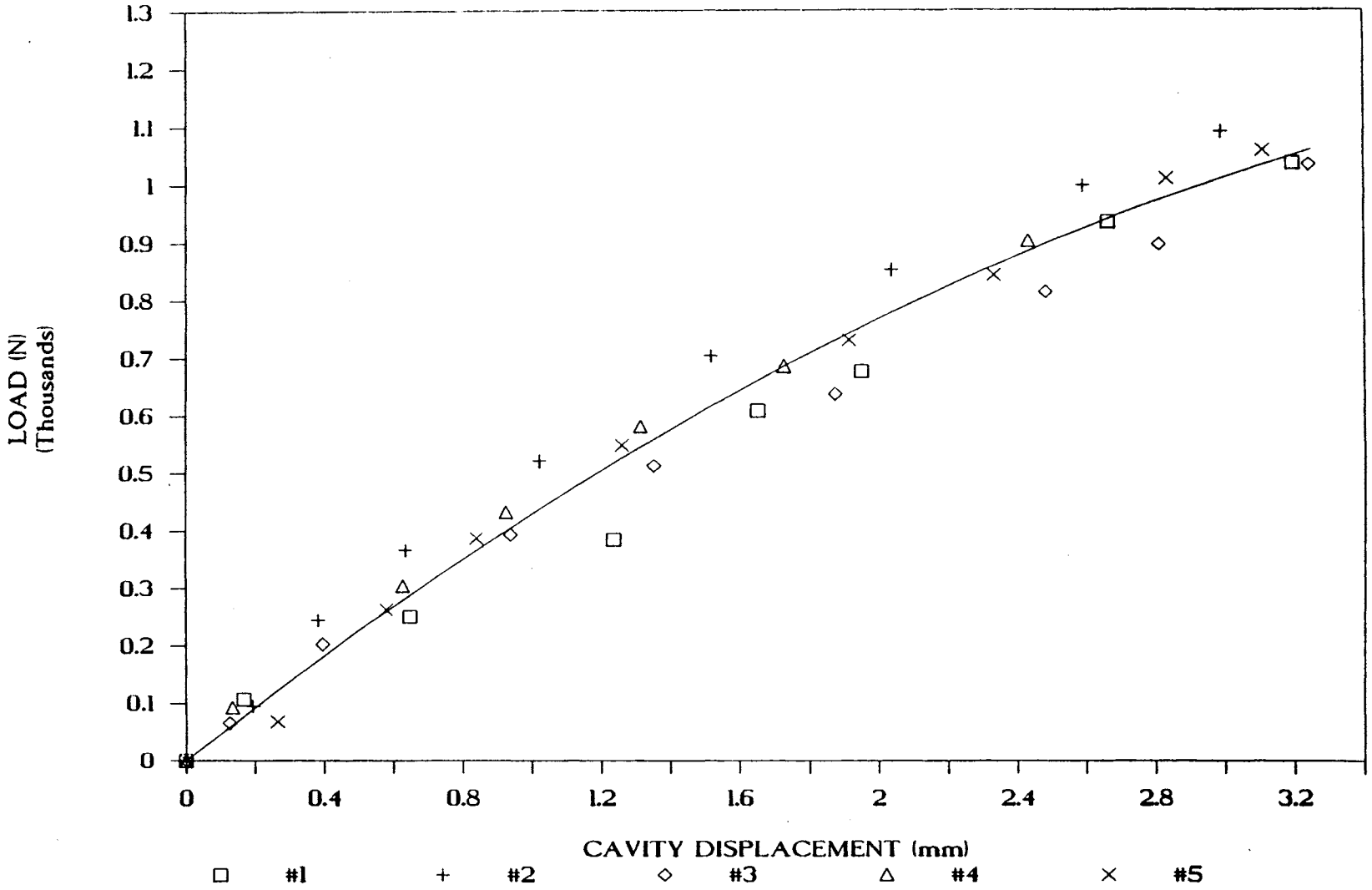
T-6-1

Test Results & Mean Curve



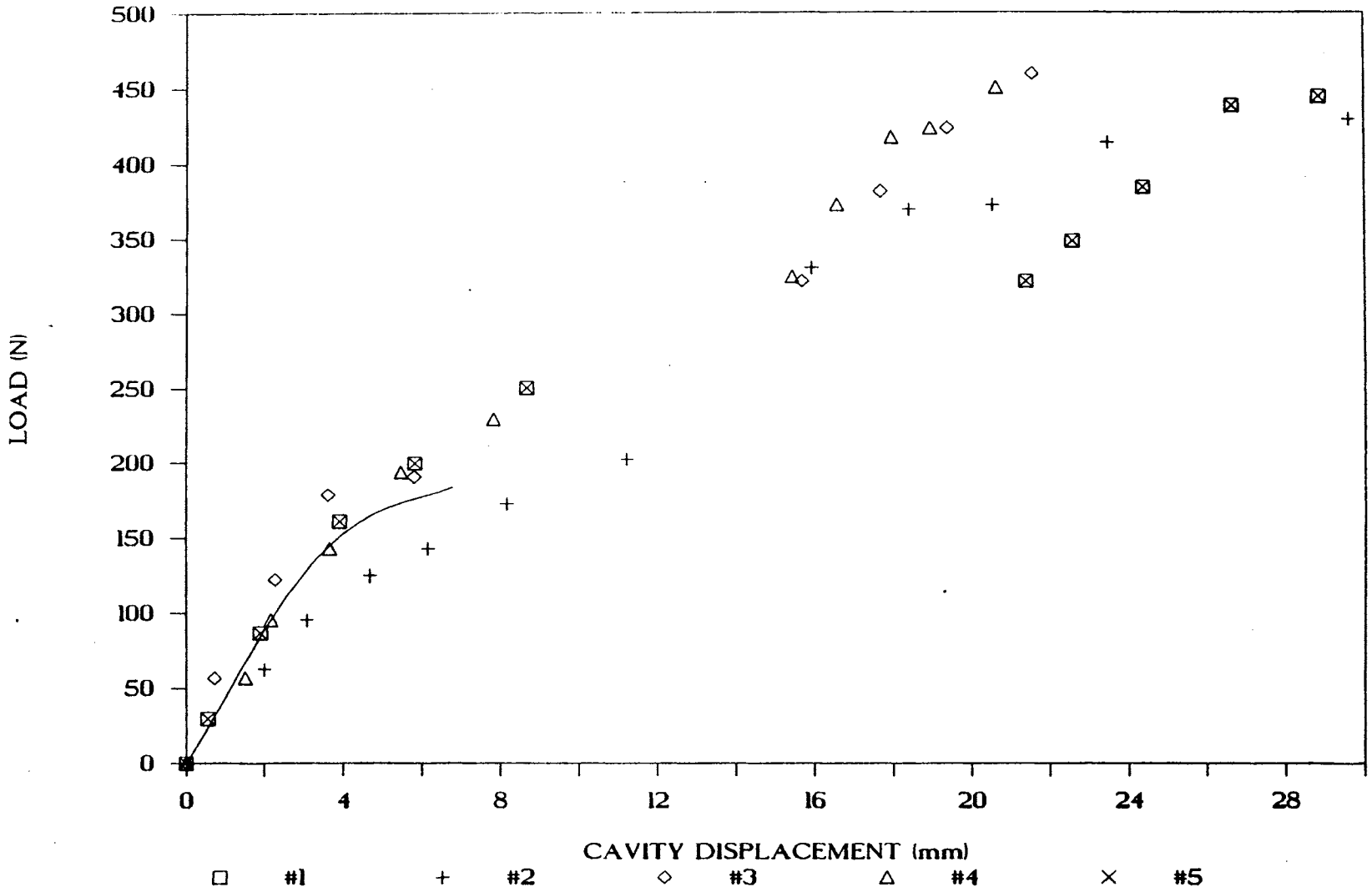
T-6-2

Test Results & Mean Curve



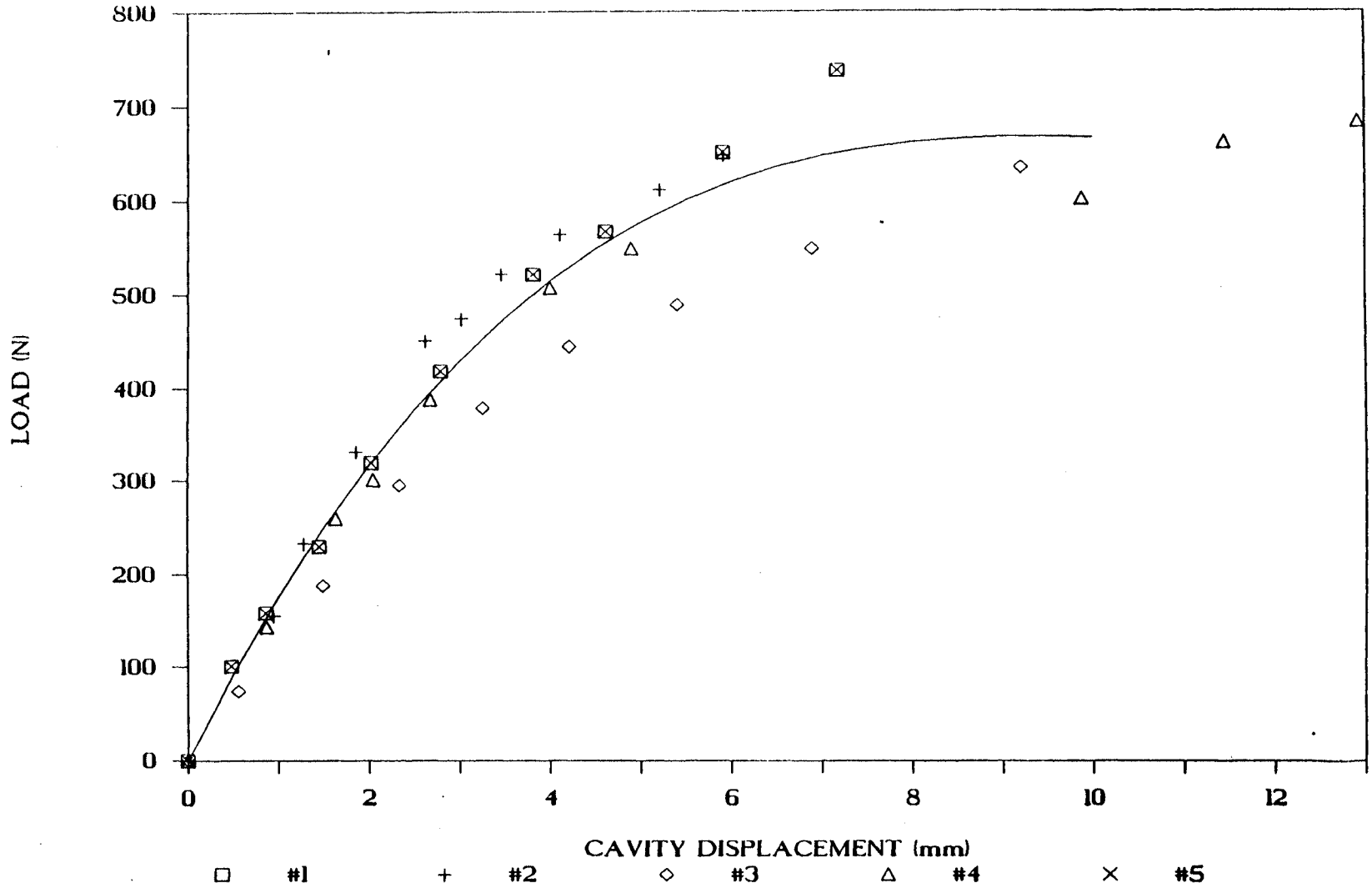
T-6-4A

Test Results & Mean Curve



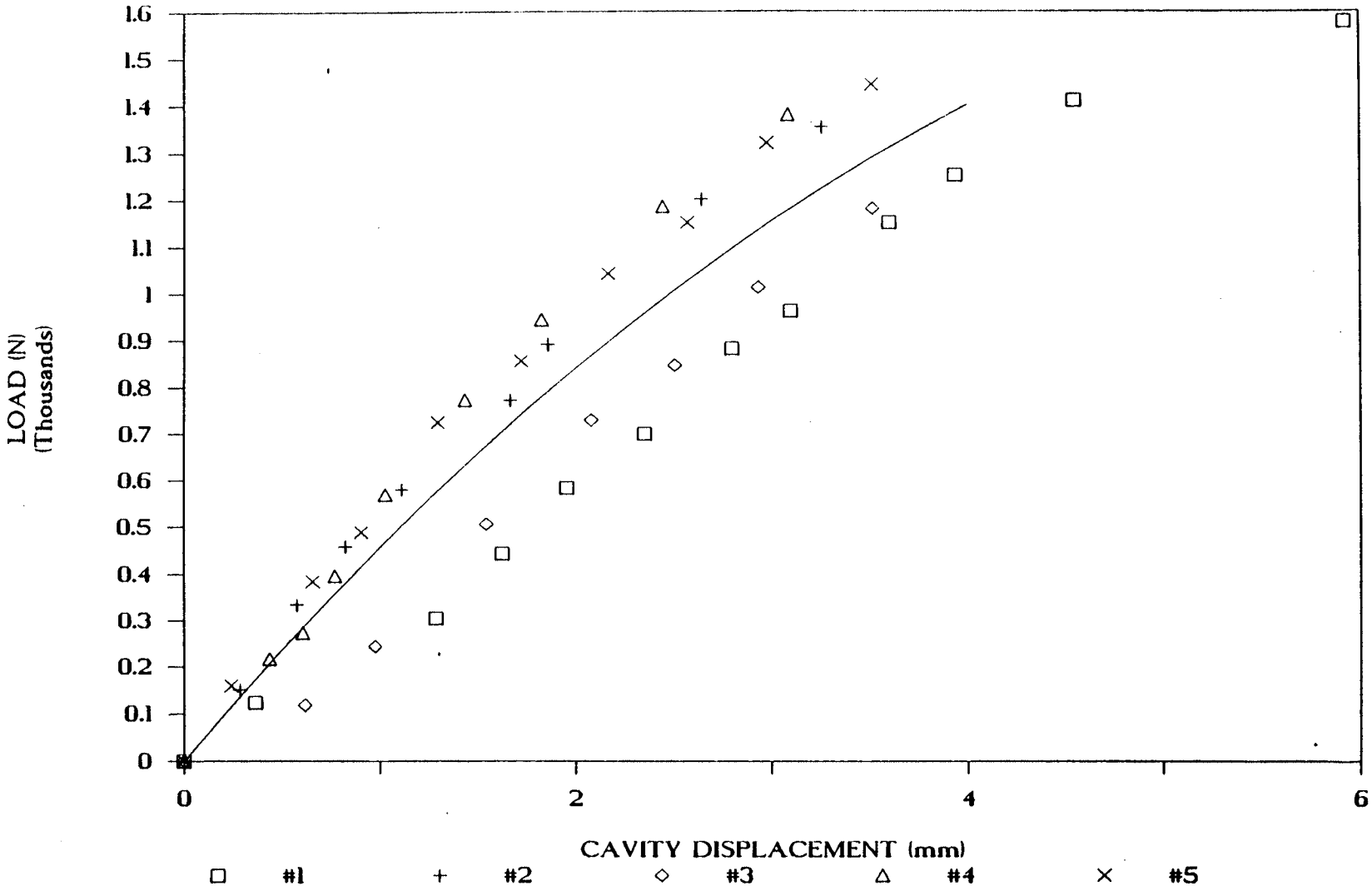
T-6-4B

Test Results & Mean Curve



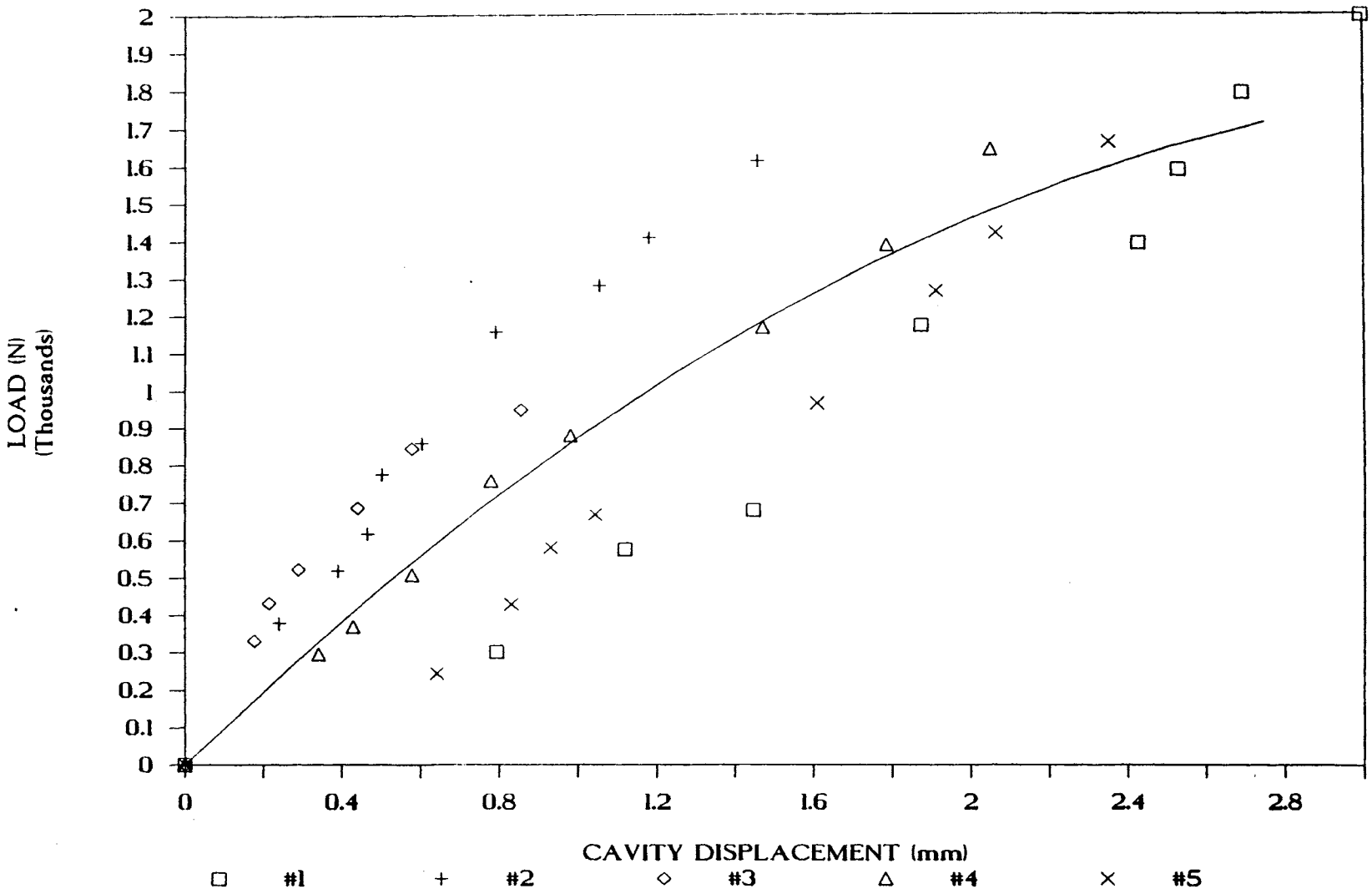
T-6-6

Test Results & Mean Curve



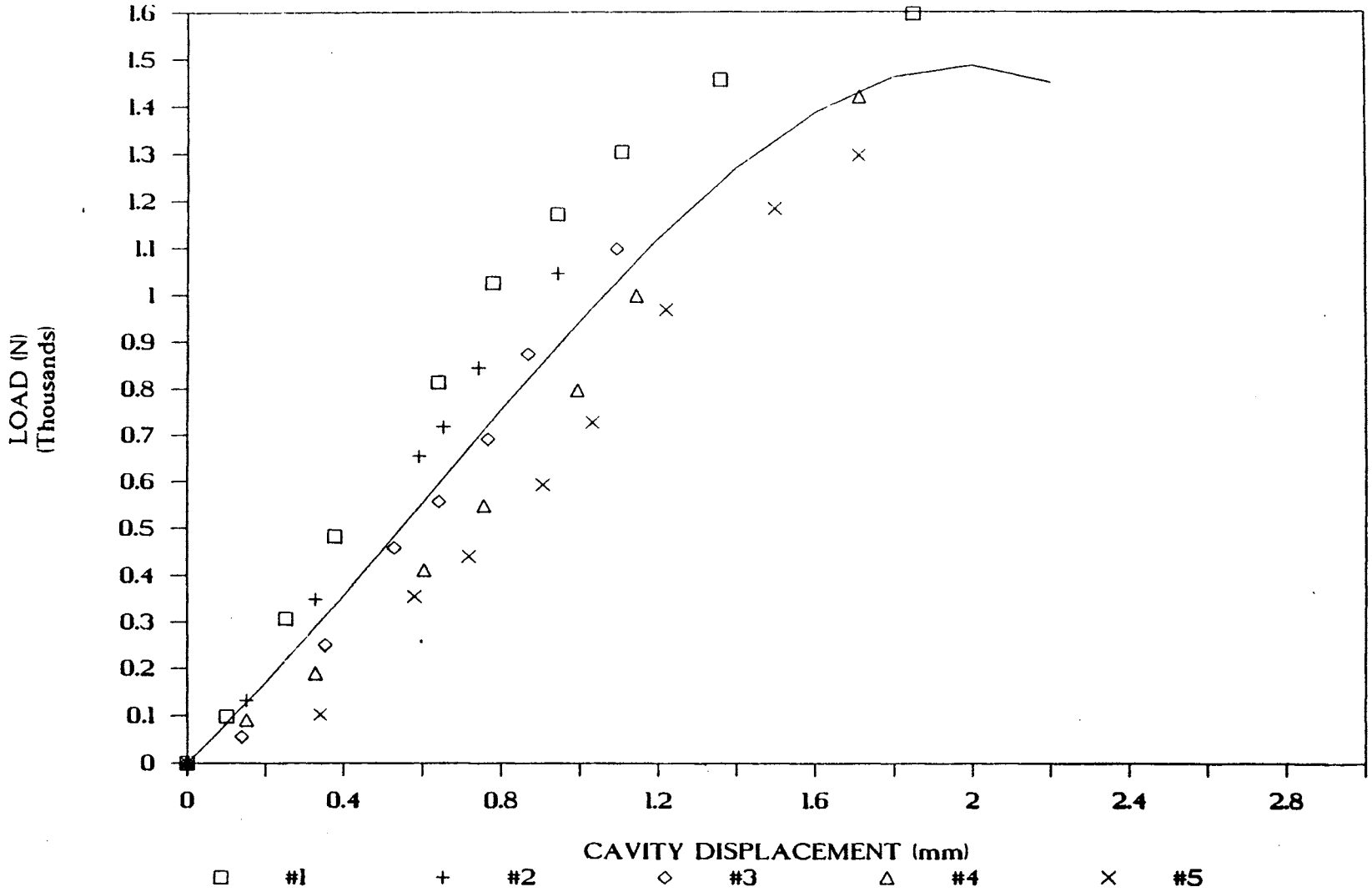
T-6-7

Testr Results & Mean Curve



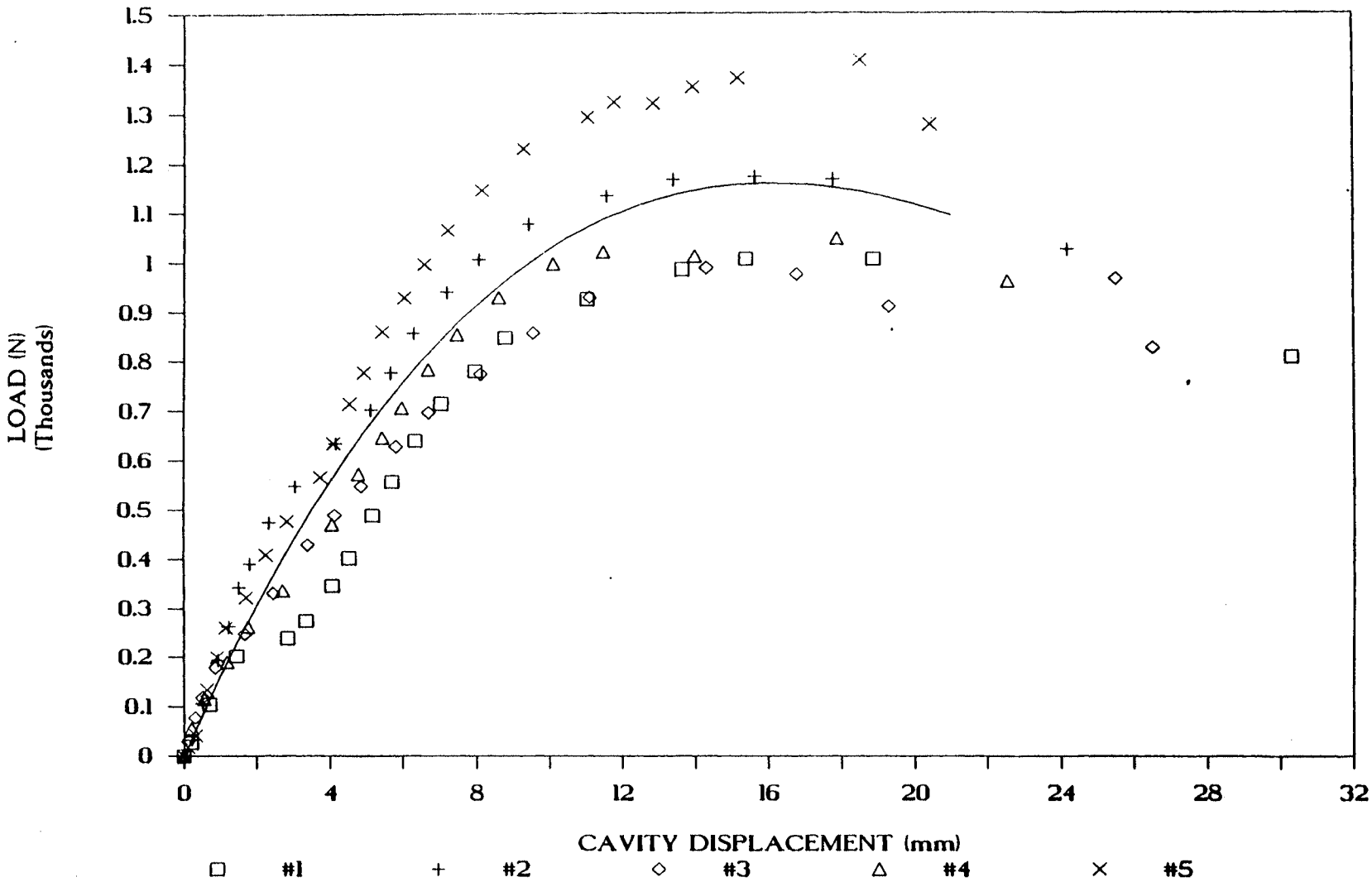
T-6-8

Test Results & Mean Curves



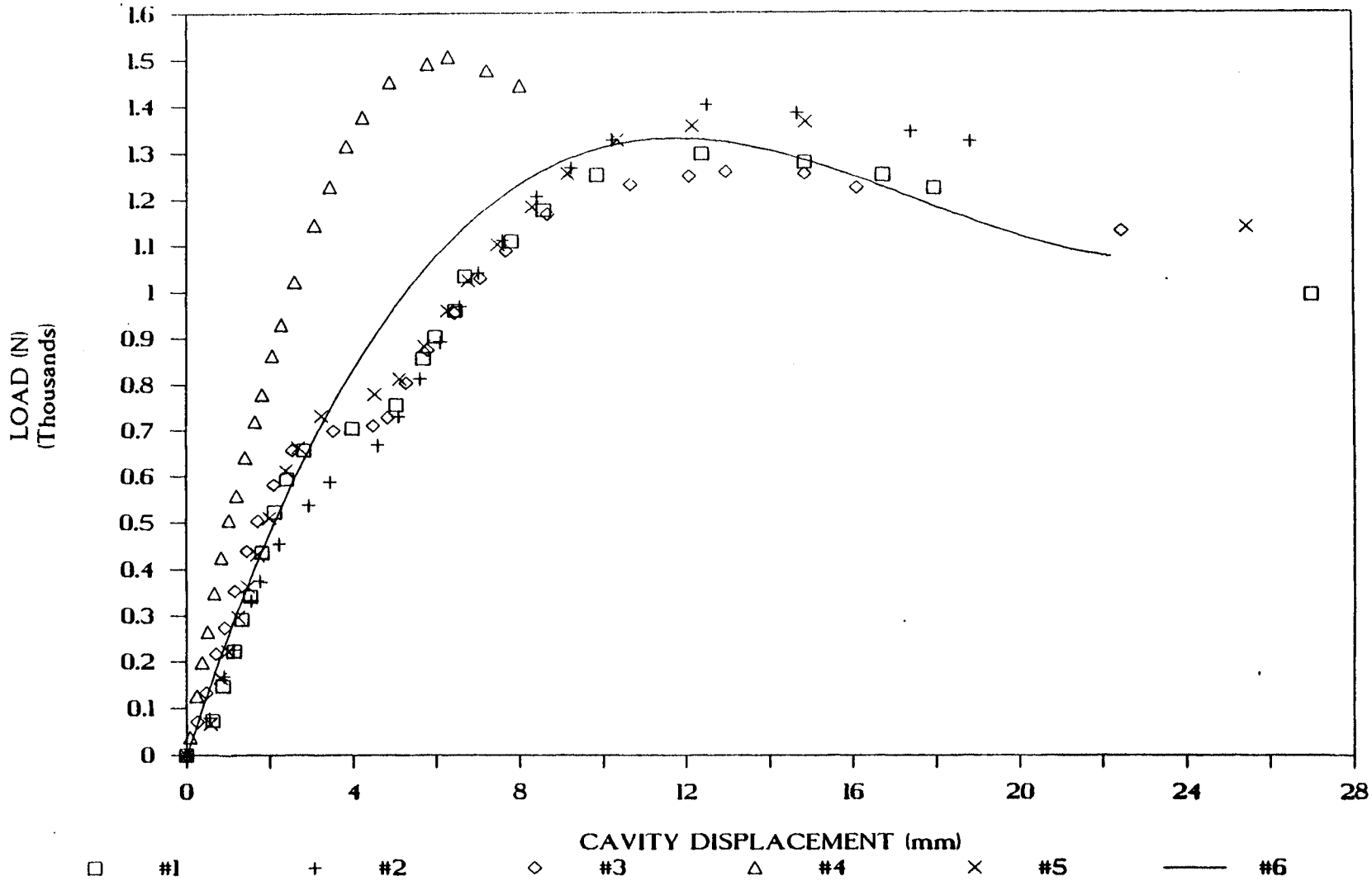
T-6-9A

Test Results & Mean Curve



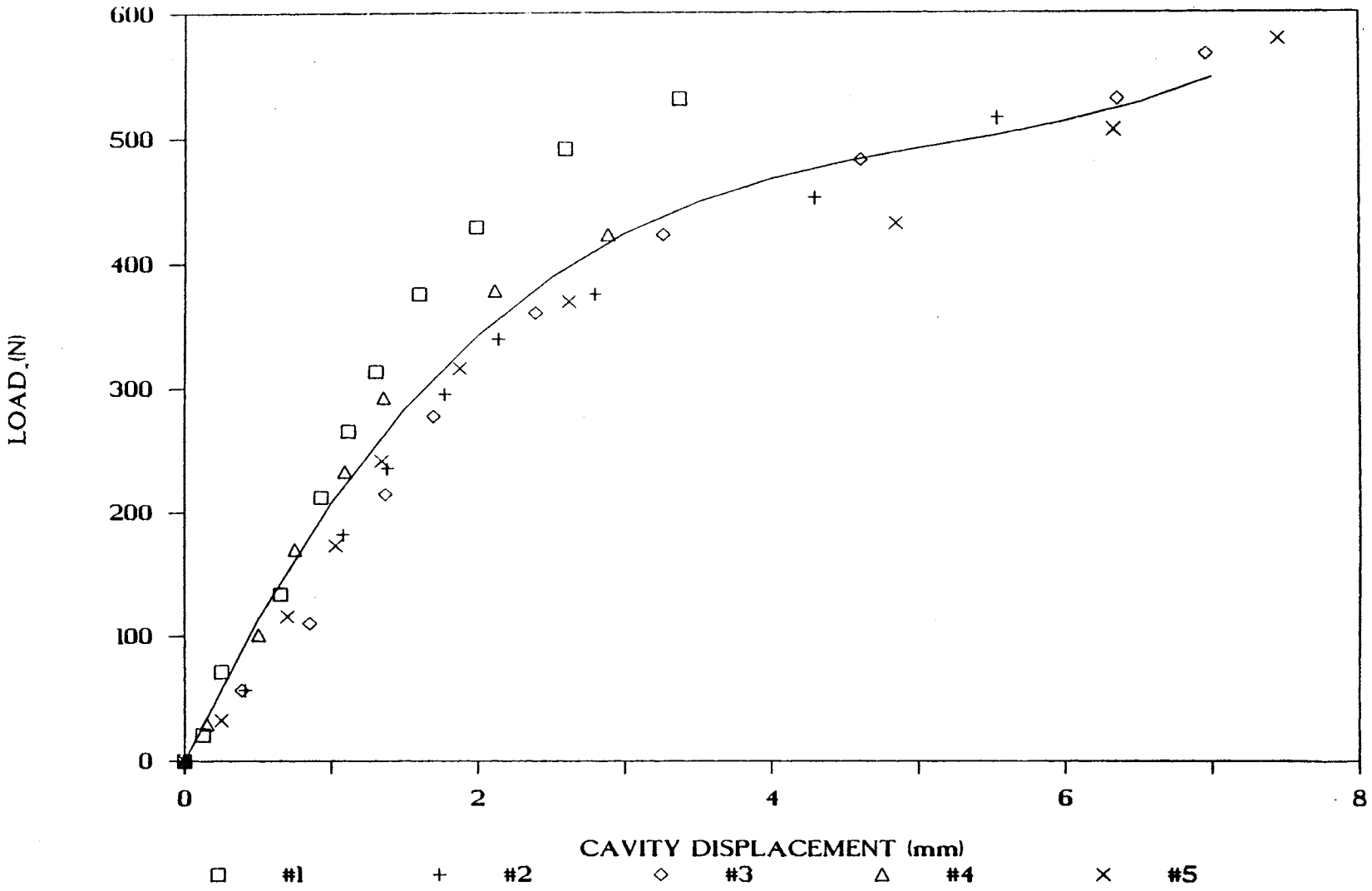
T-6-9B

Test Results & Mean Curve



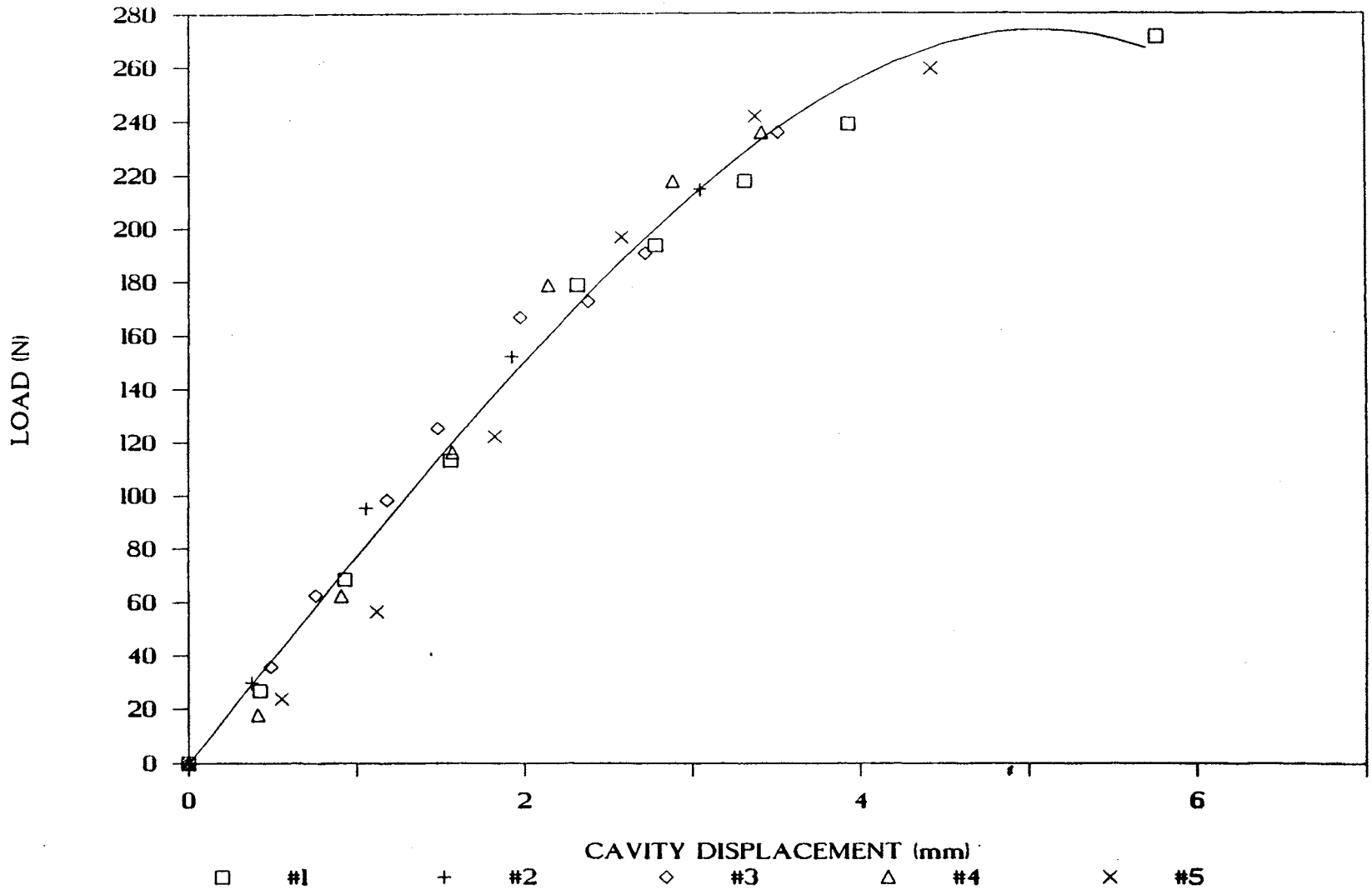
T-6-10A

Test Results & Mean Curve



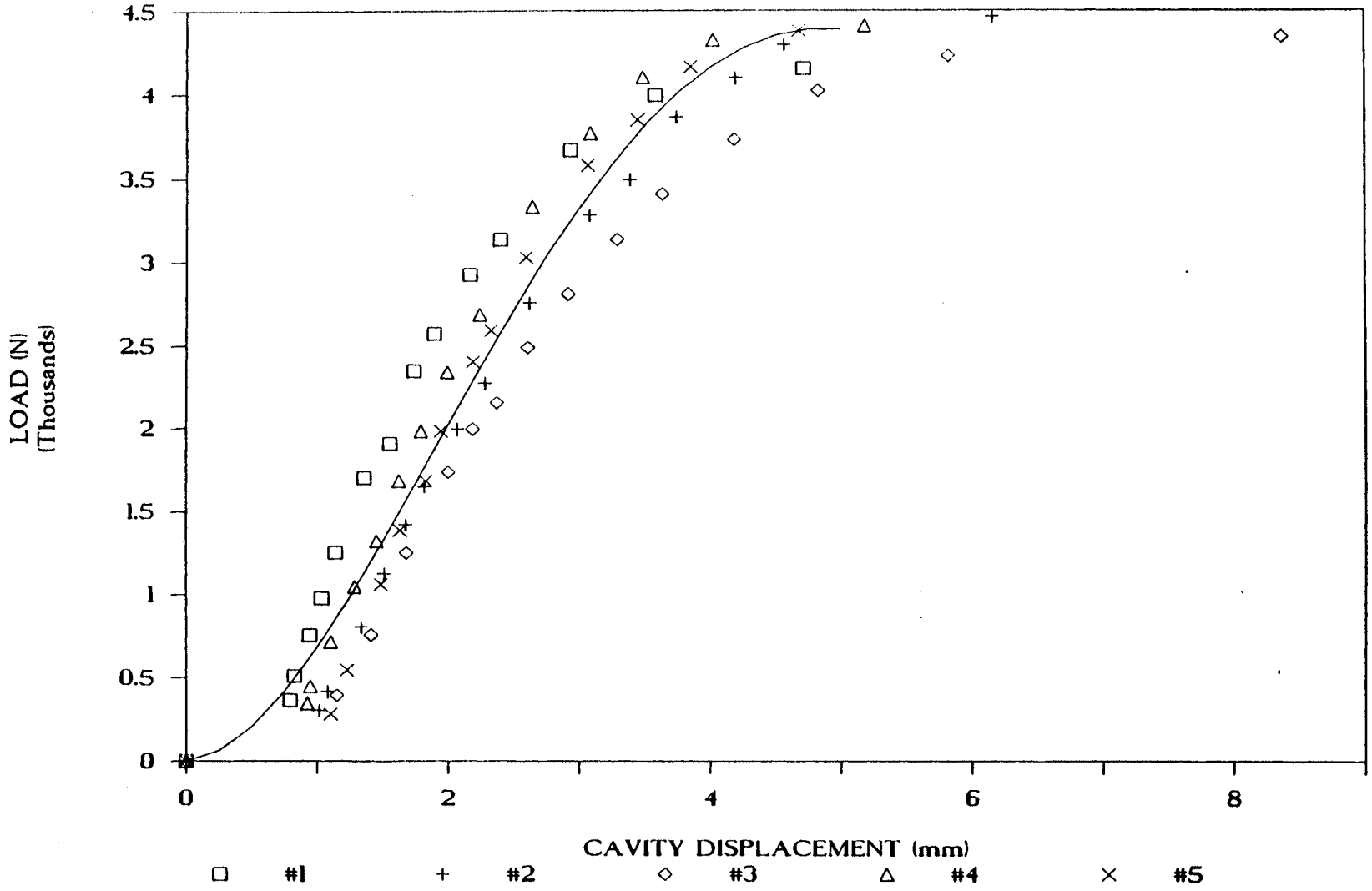
T-6-10B

Test Results & Mean Curve



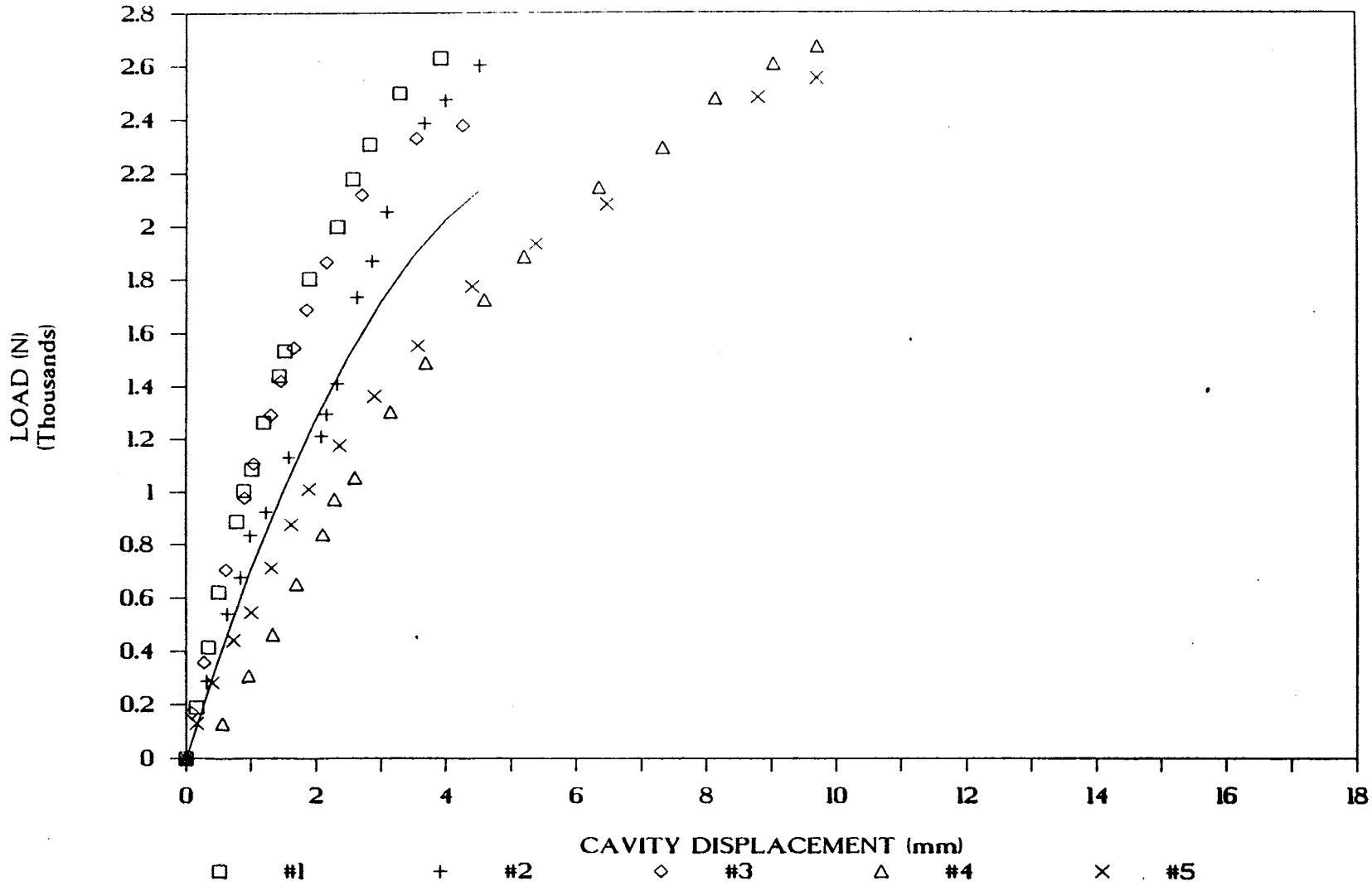
T-7-1

Test Results & Mean Curve



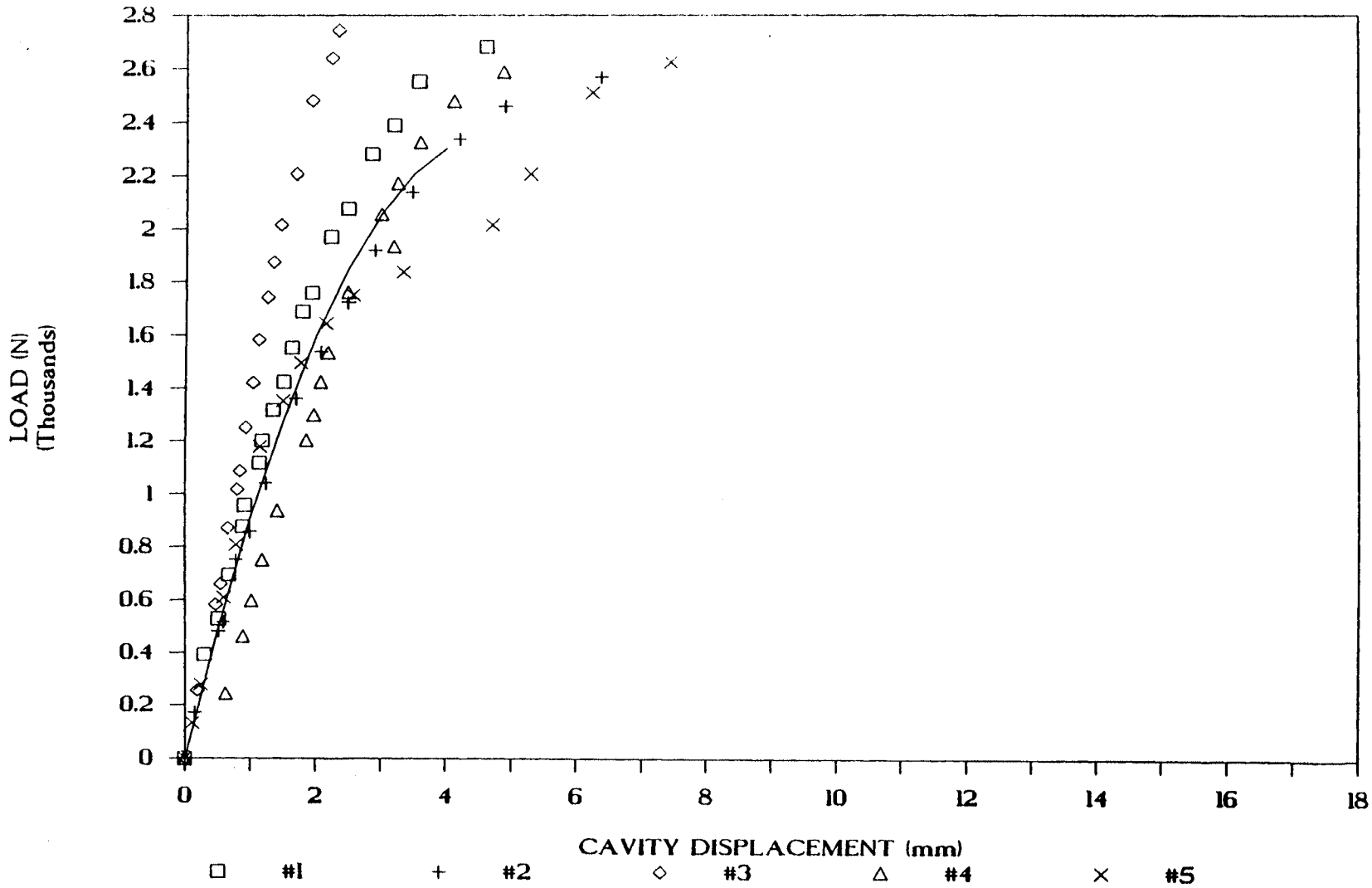
T-7-2

Test Results & Mean Curve



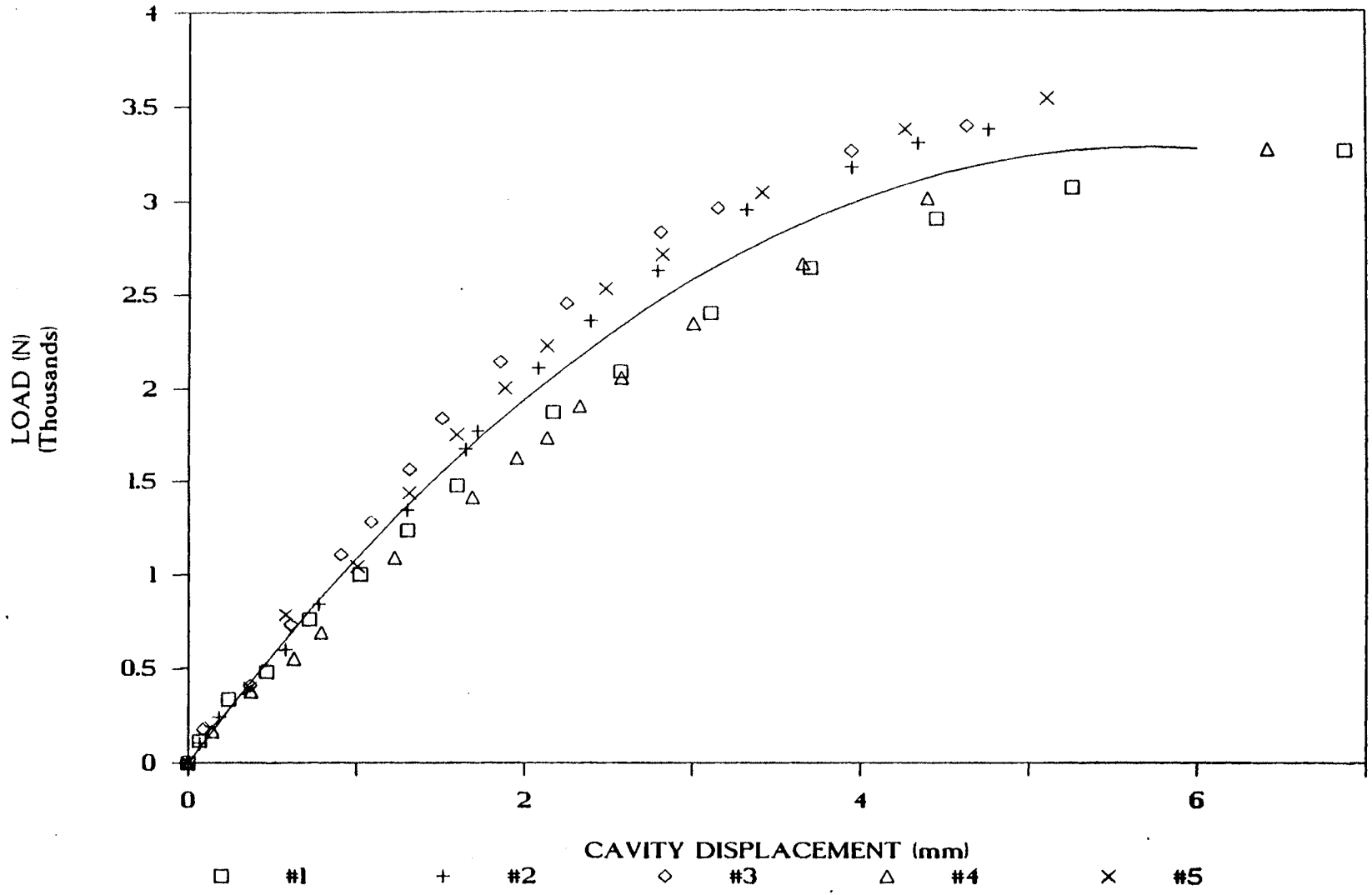
T-7-4A

Test Results & Mean Curve



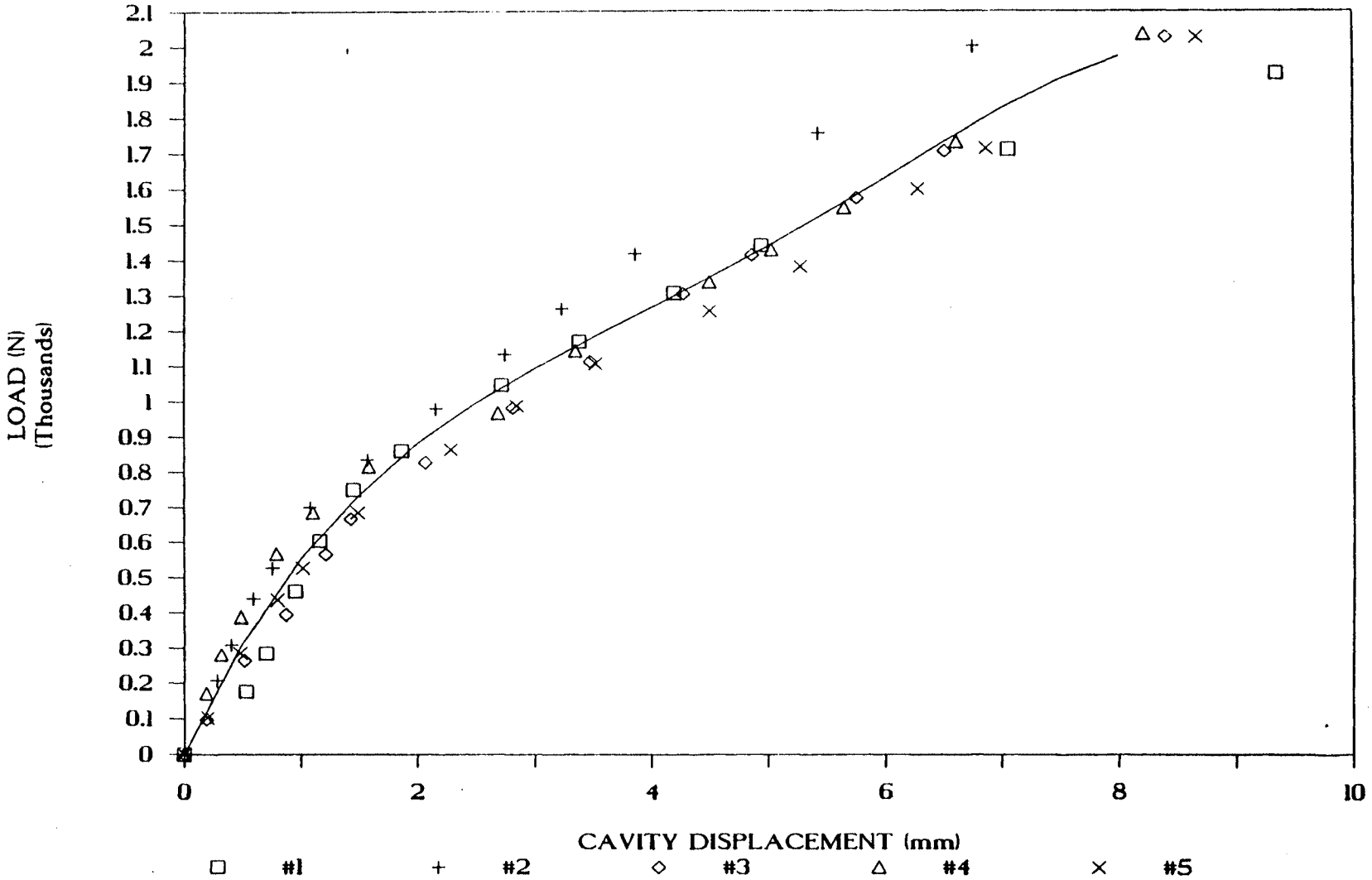
T-7-4B

Test Results & Mean Curve



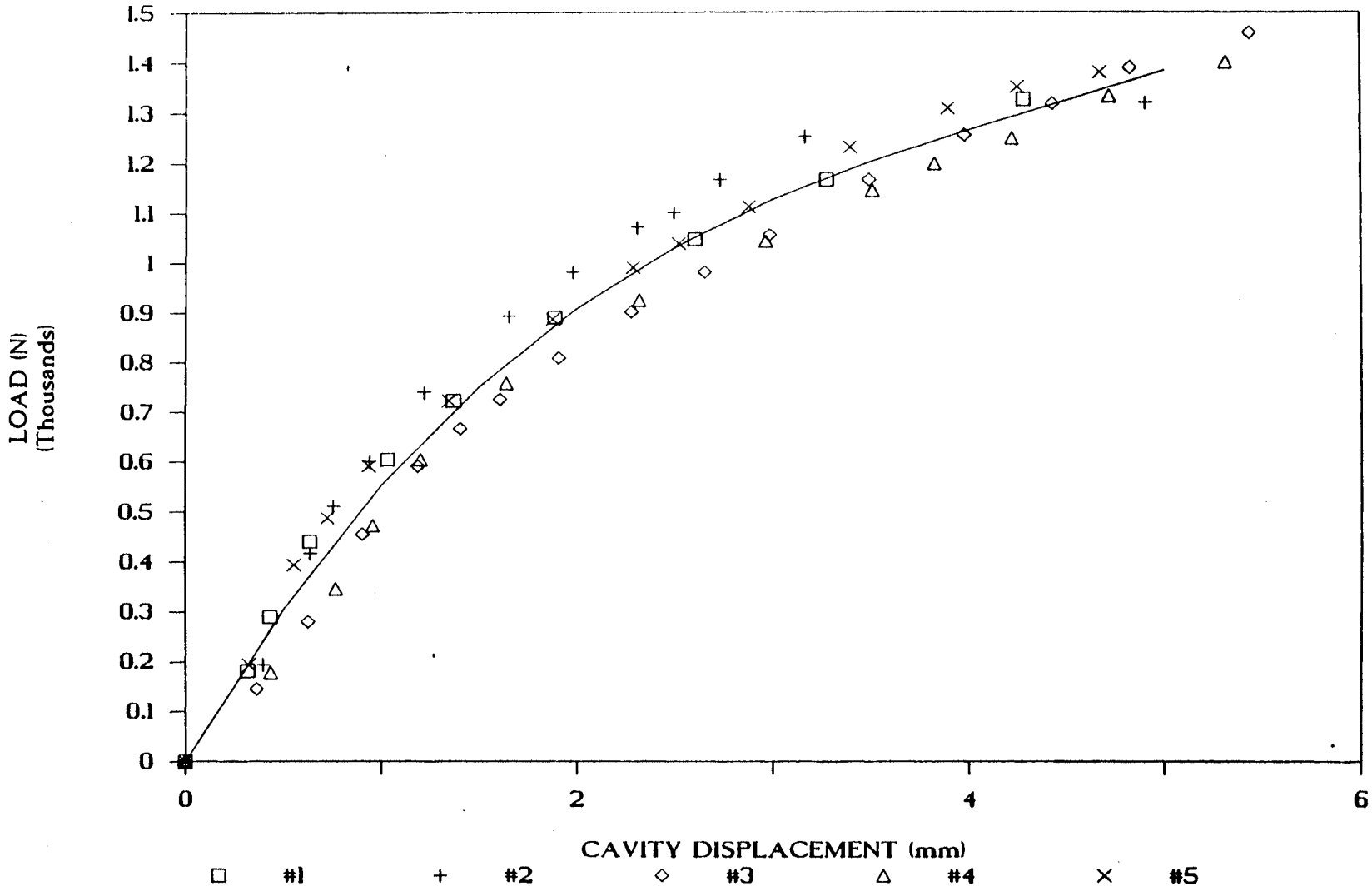
T-8-1

Test Results & Mean Curve



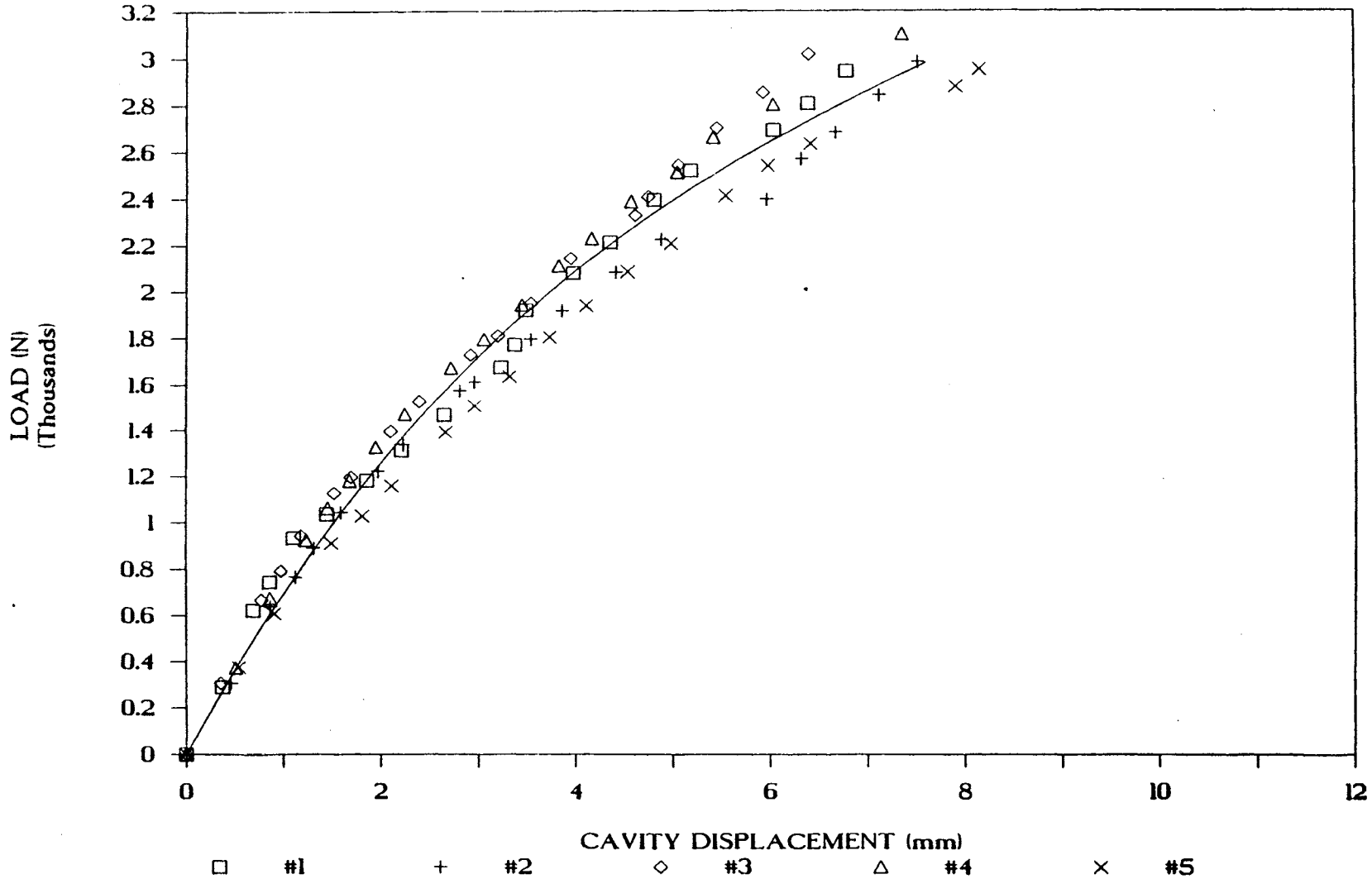
T-8-2

Test Results & Mean Curve



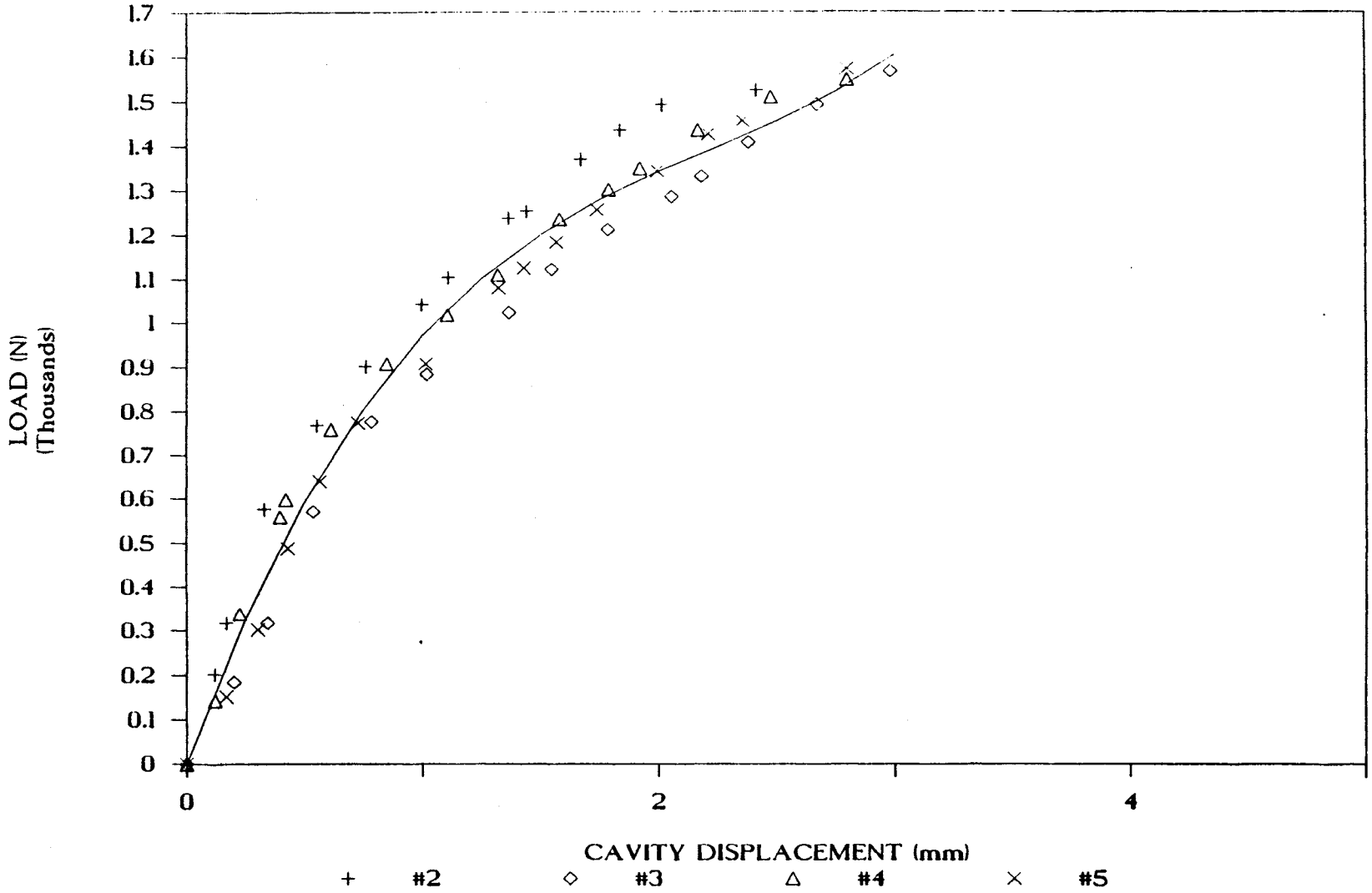
T-8-2A

Test Results & Mean Curve



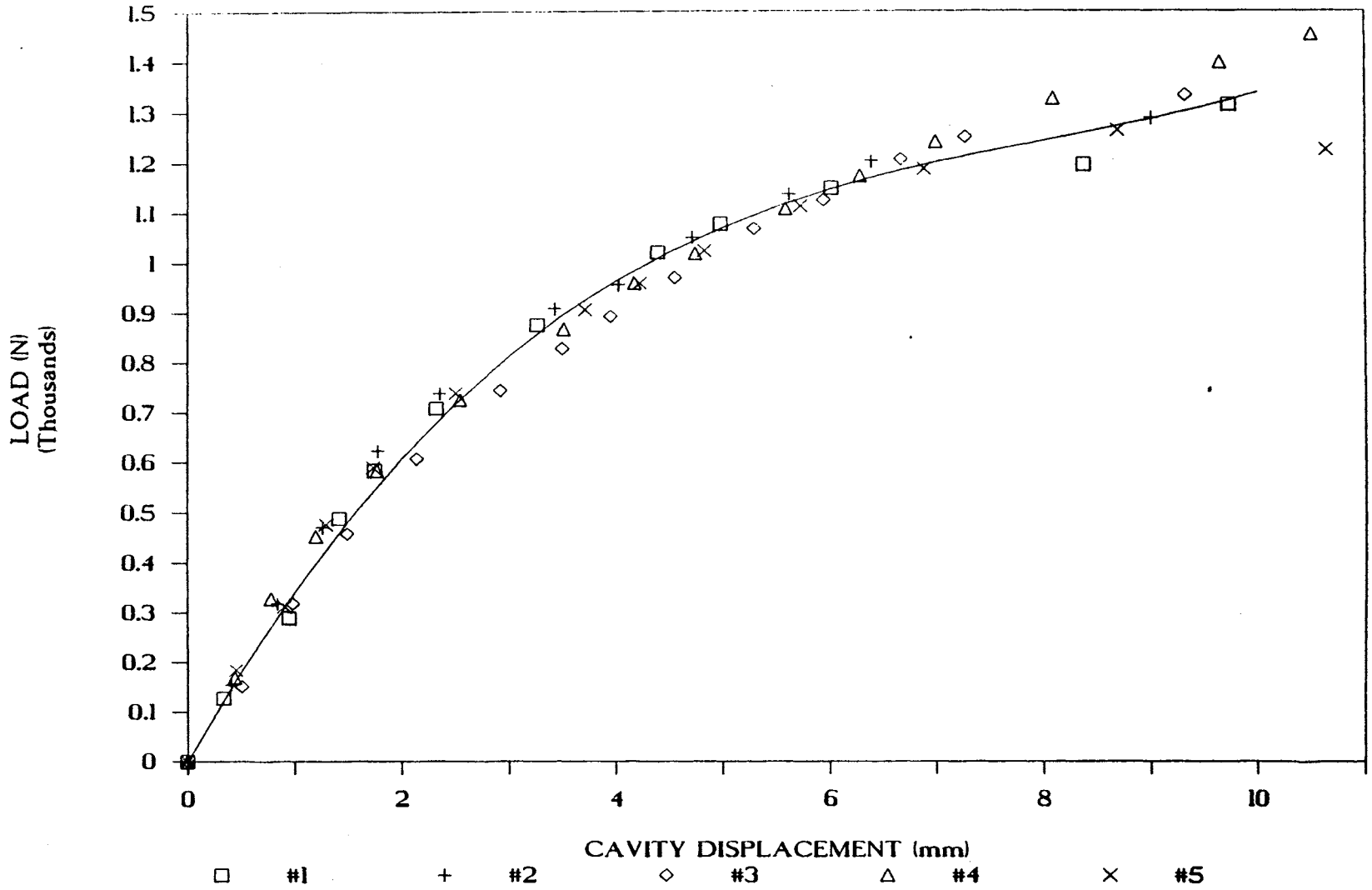
T-8-3A

Test Results & Mean Curve



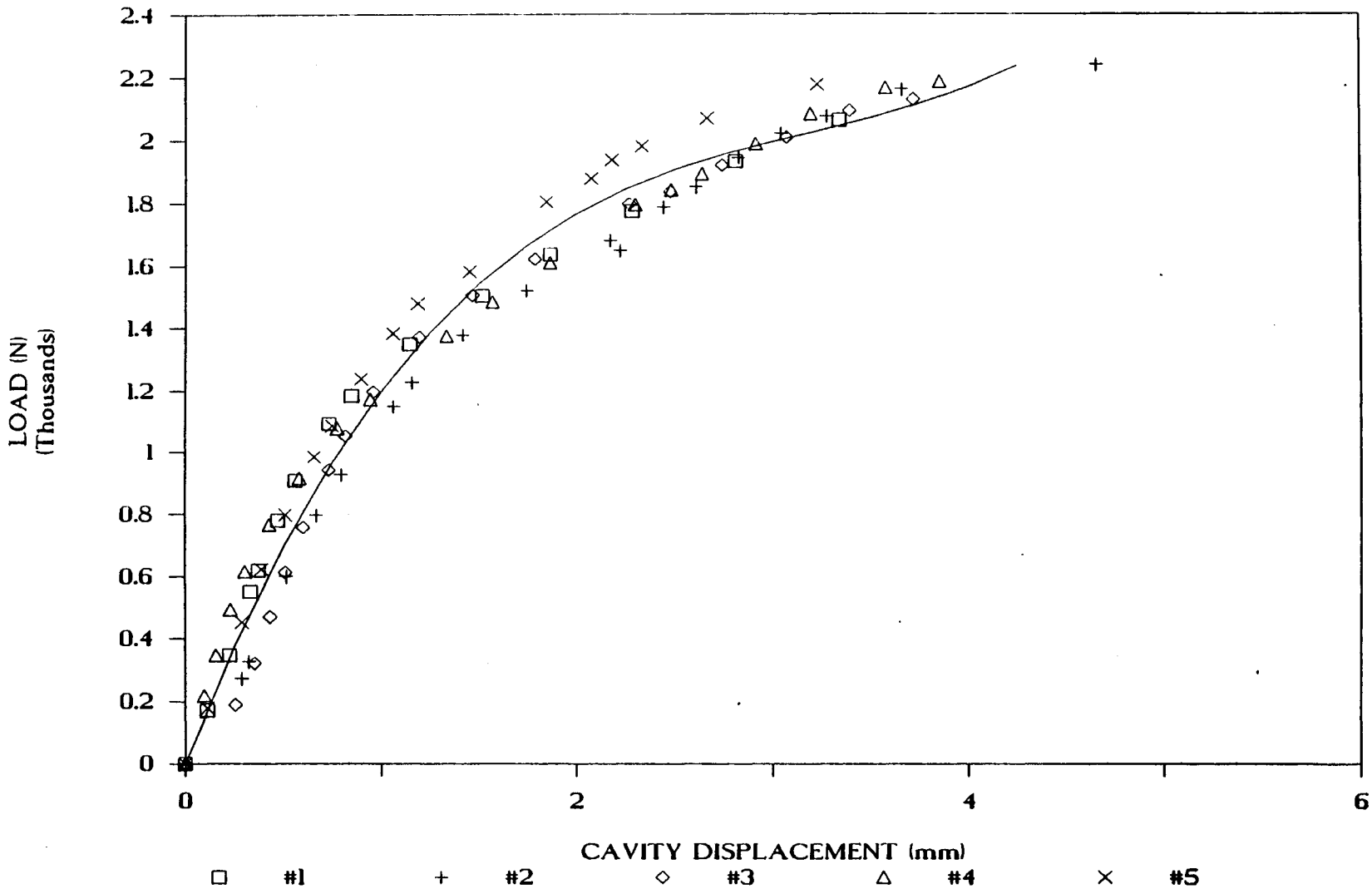
T-8-3B

Test Results & Mean Curve



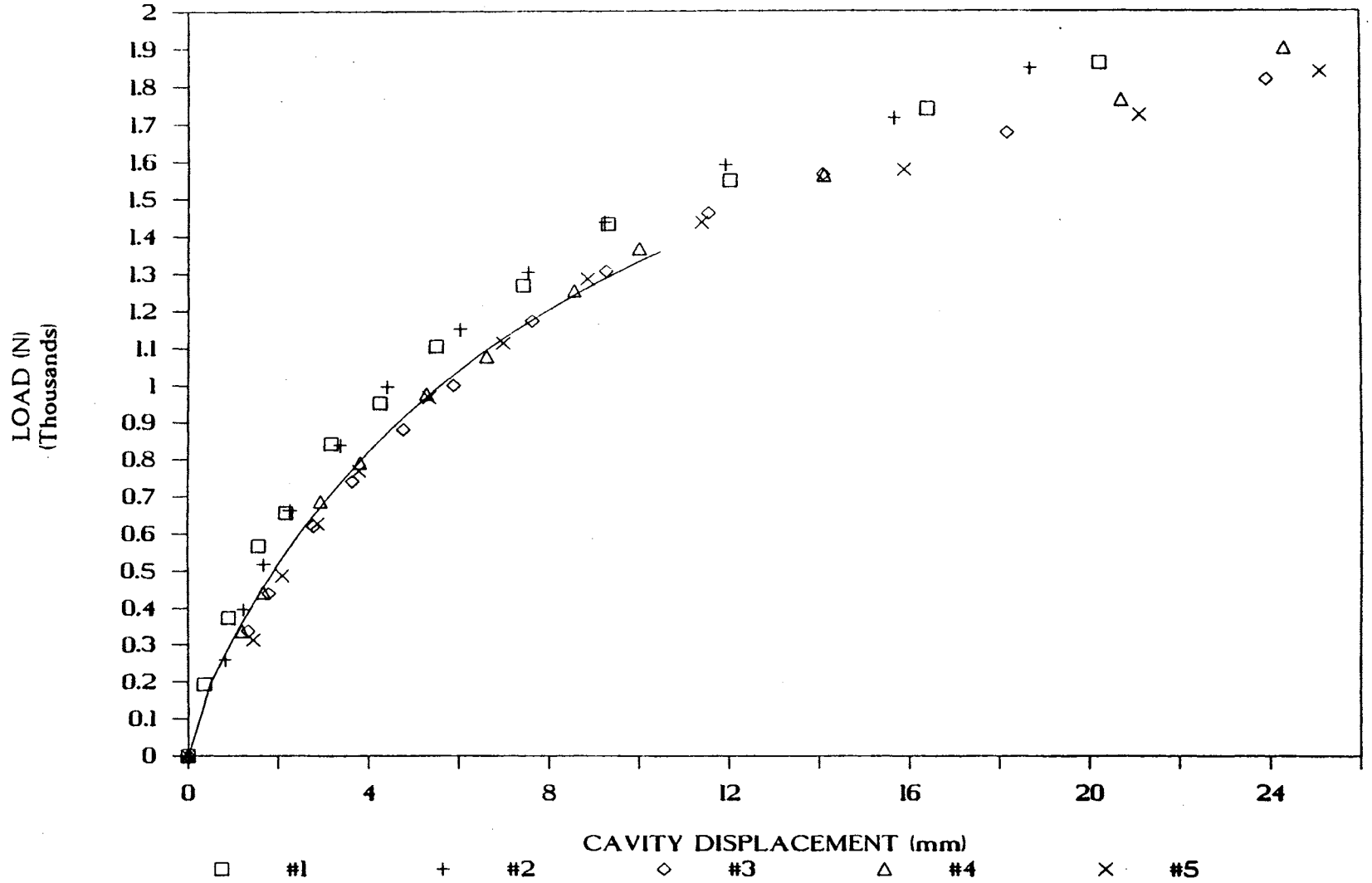
T-8-5

Test Results & Mean Curve



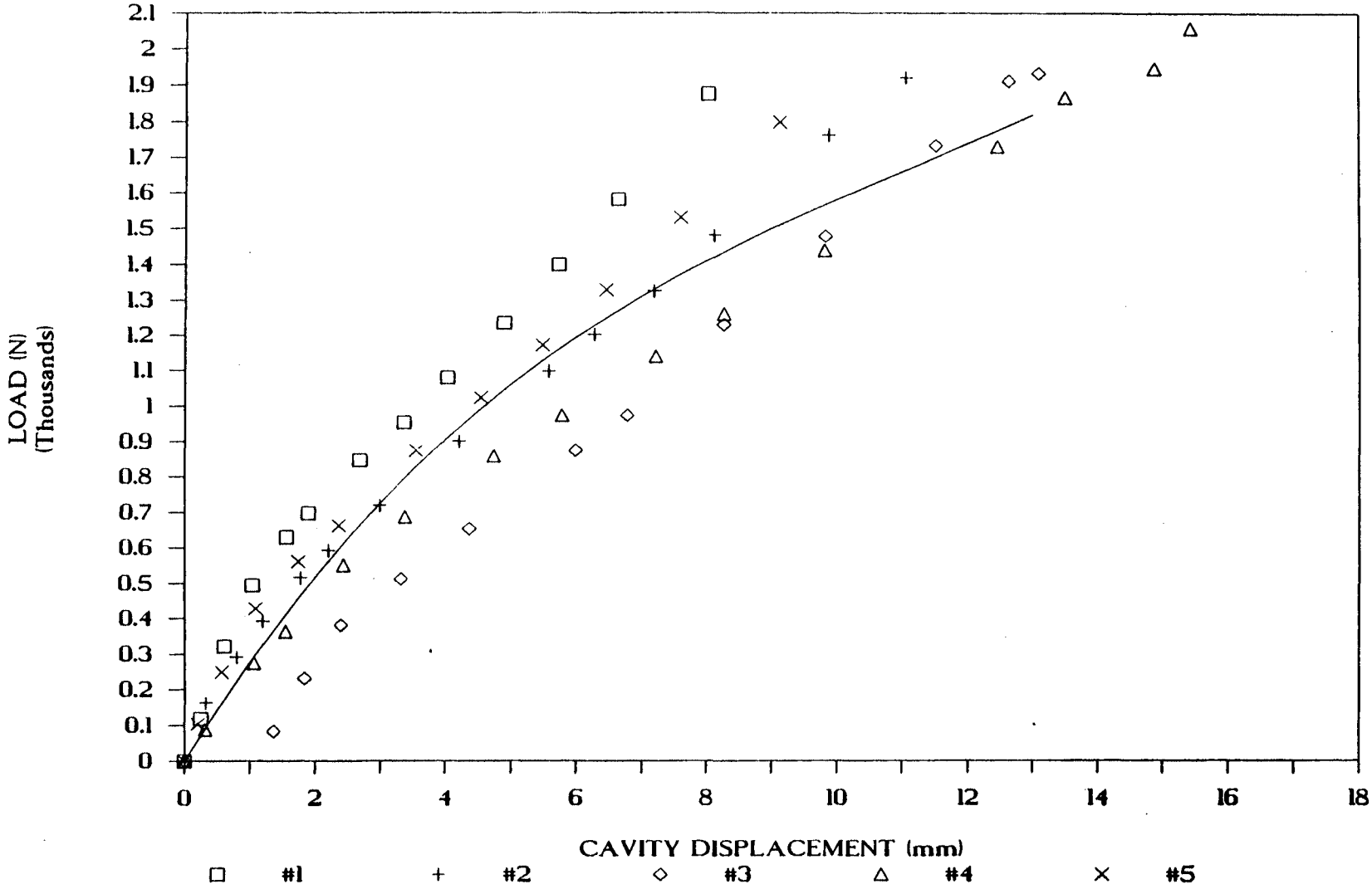
T-9-1

Test Results & Mean Curve



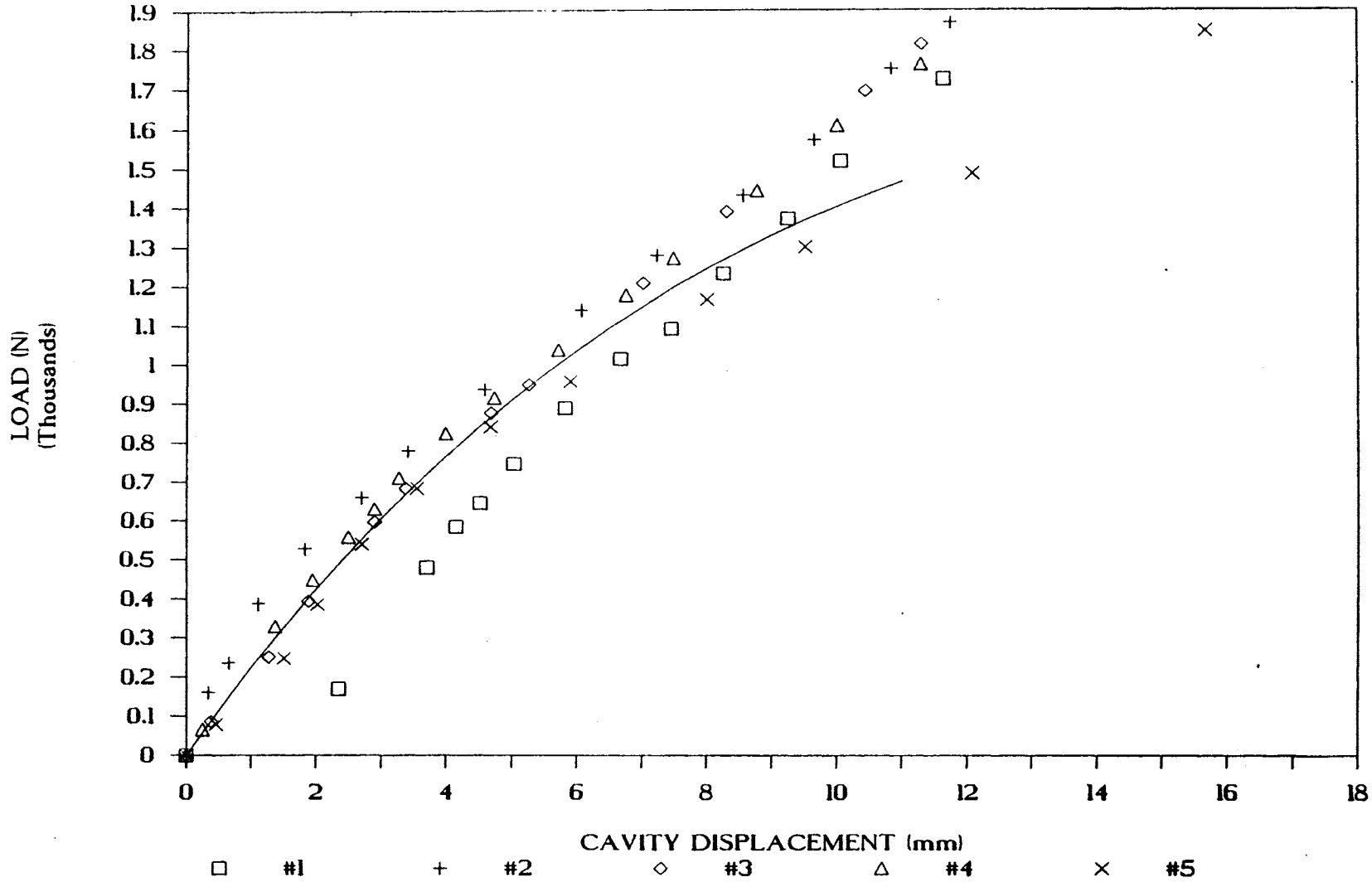
T-9-2

Test Results & Mean Curve



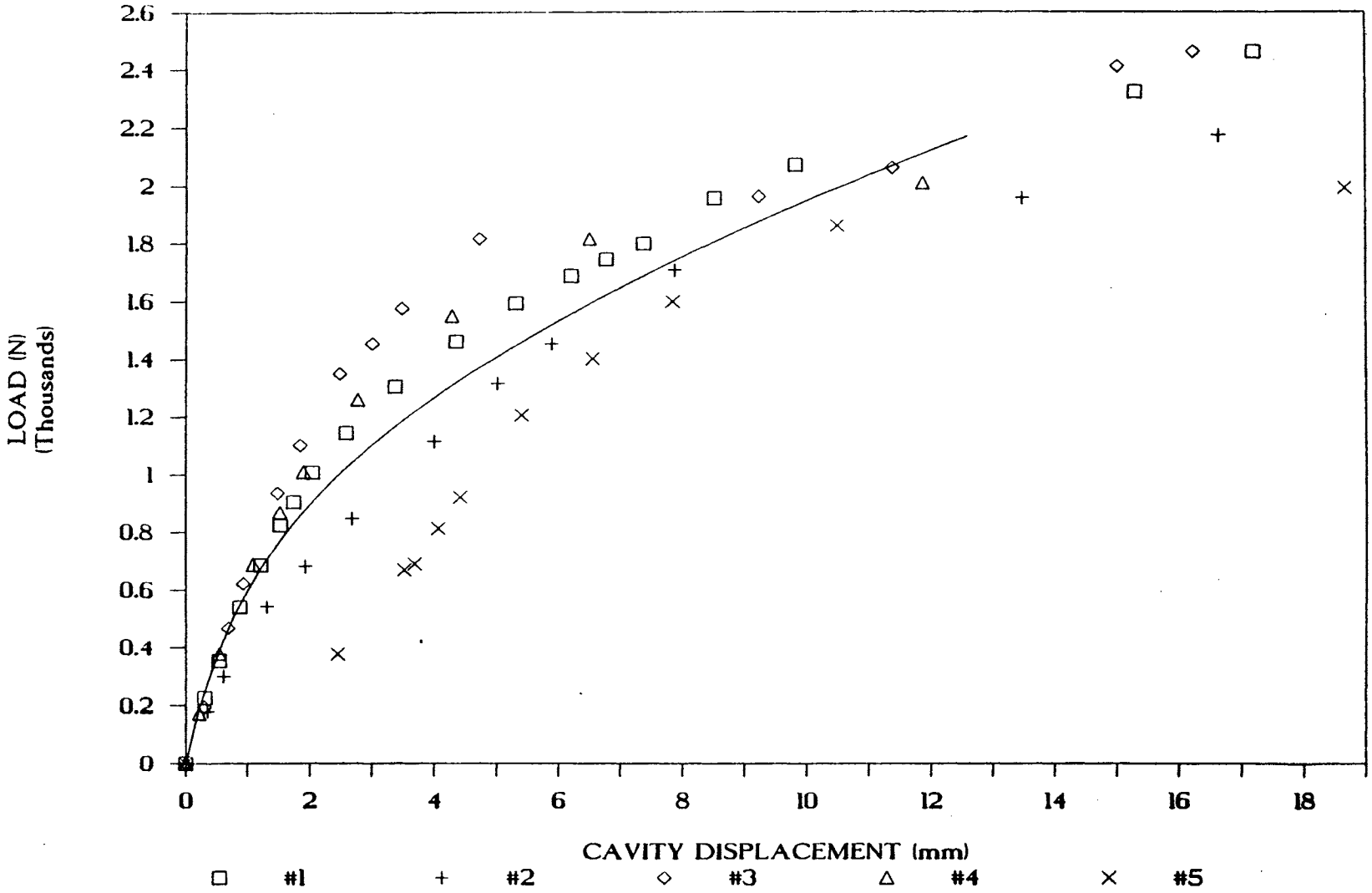
T-9-4A

Test Results & Mean Curve



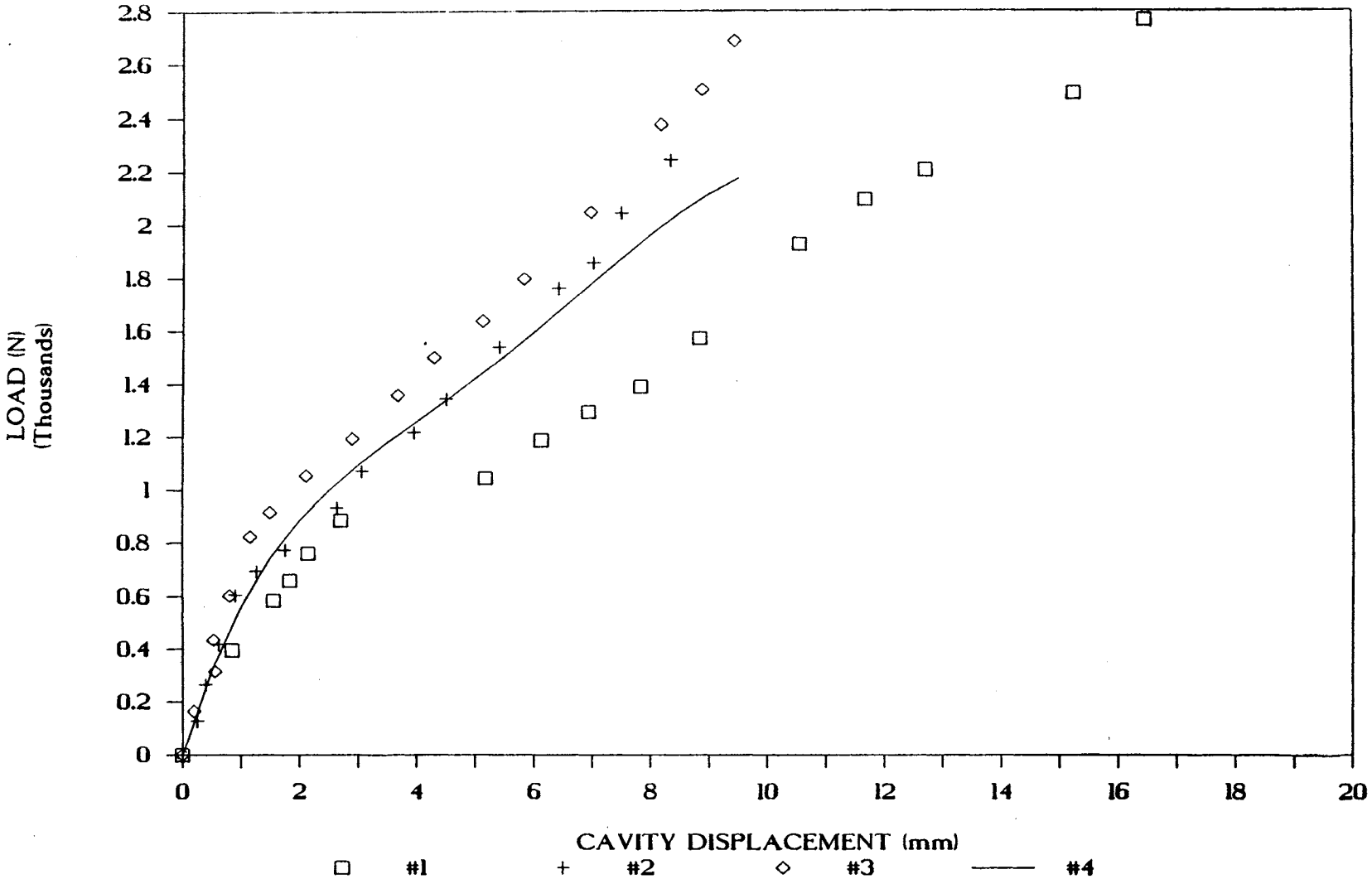
T-9-4B

Test Results & Mean Curve



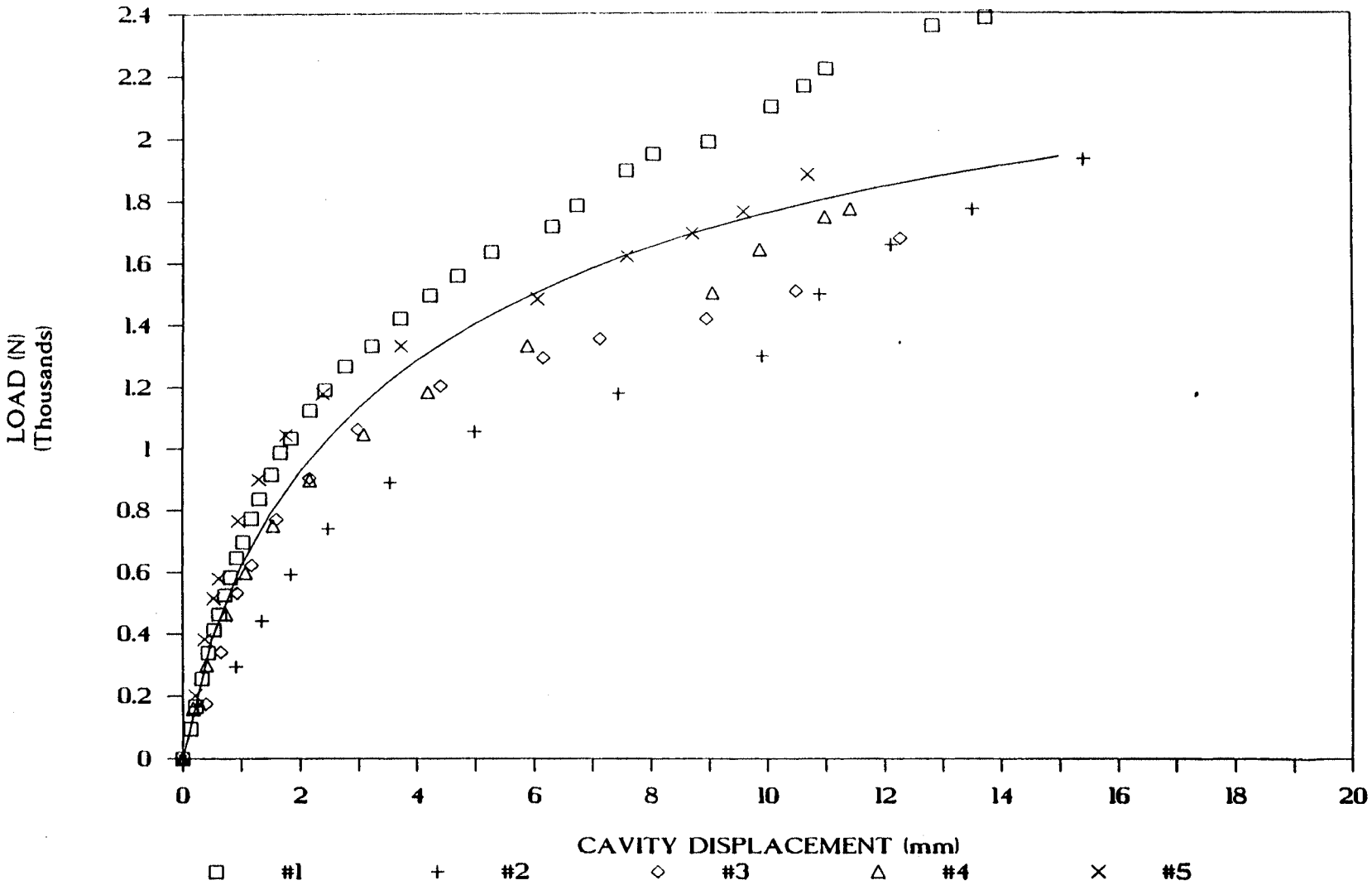
T-9-8

Test Results & Mean Curve



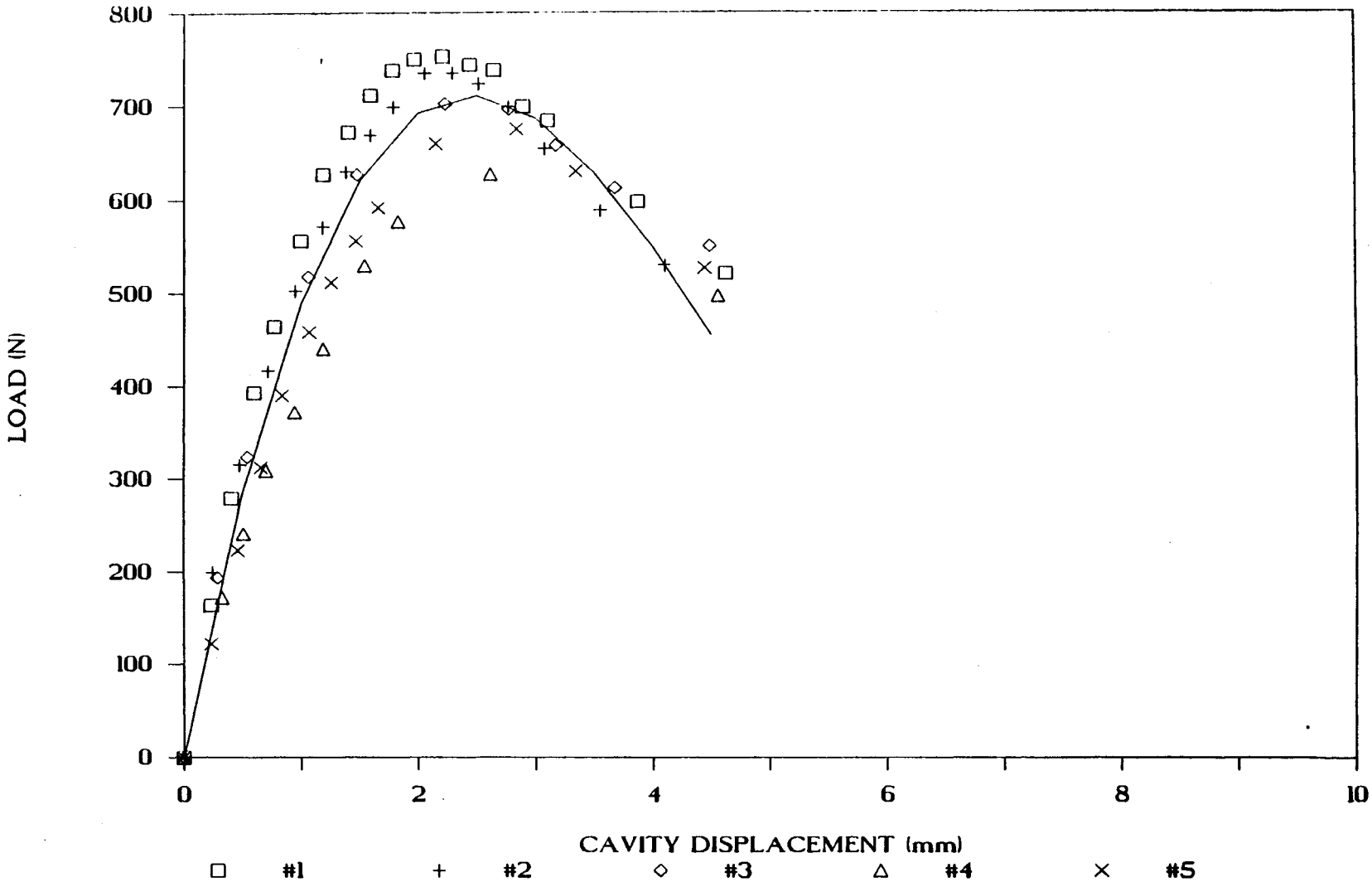
T-10-1A

Test Results & Mean Curve



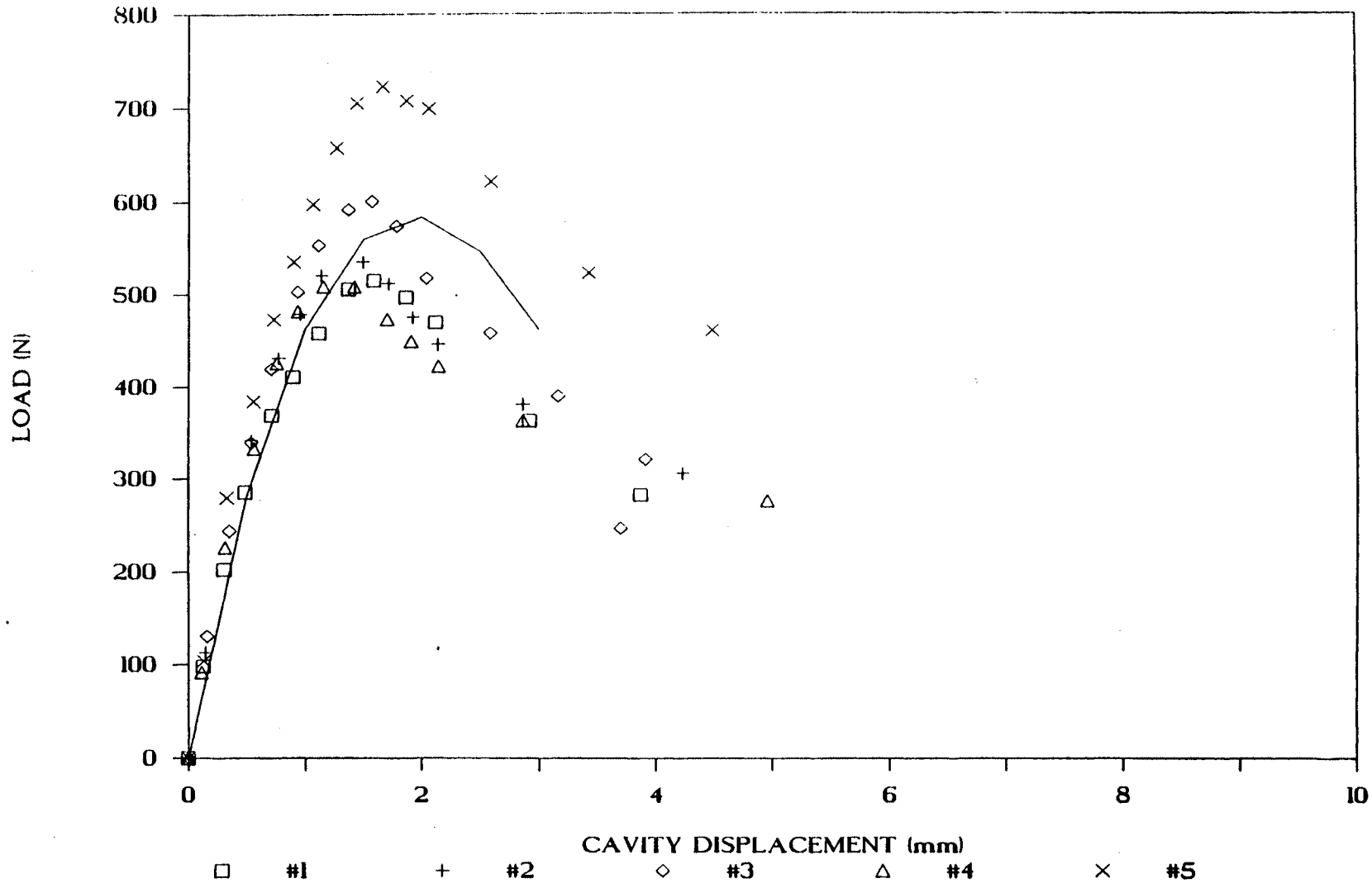
T-10-1B

Test Results & Mean Curve



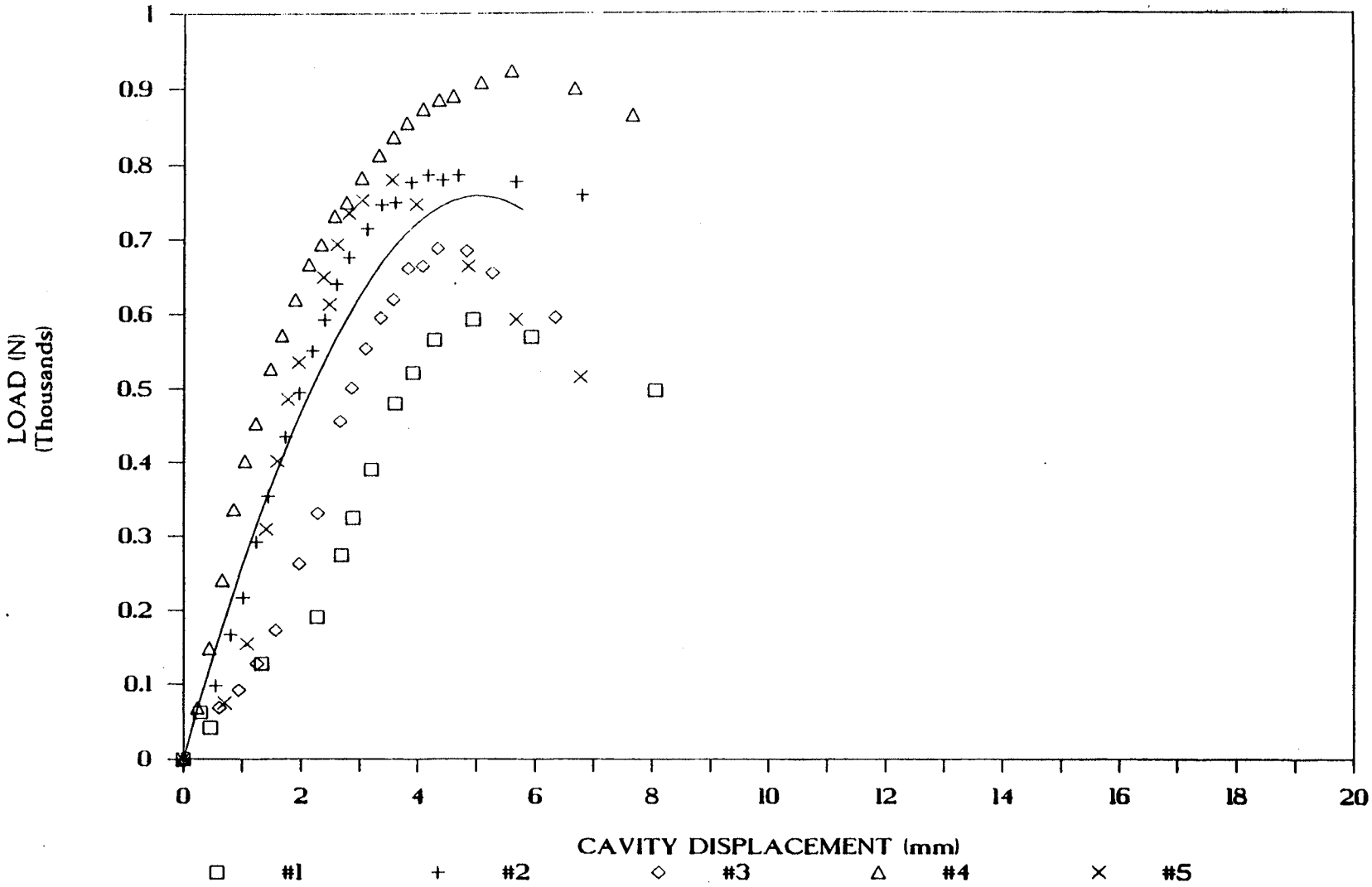
T-10-1C

Test Results & Mean Curve



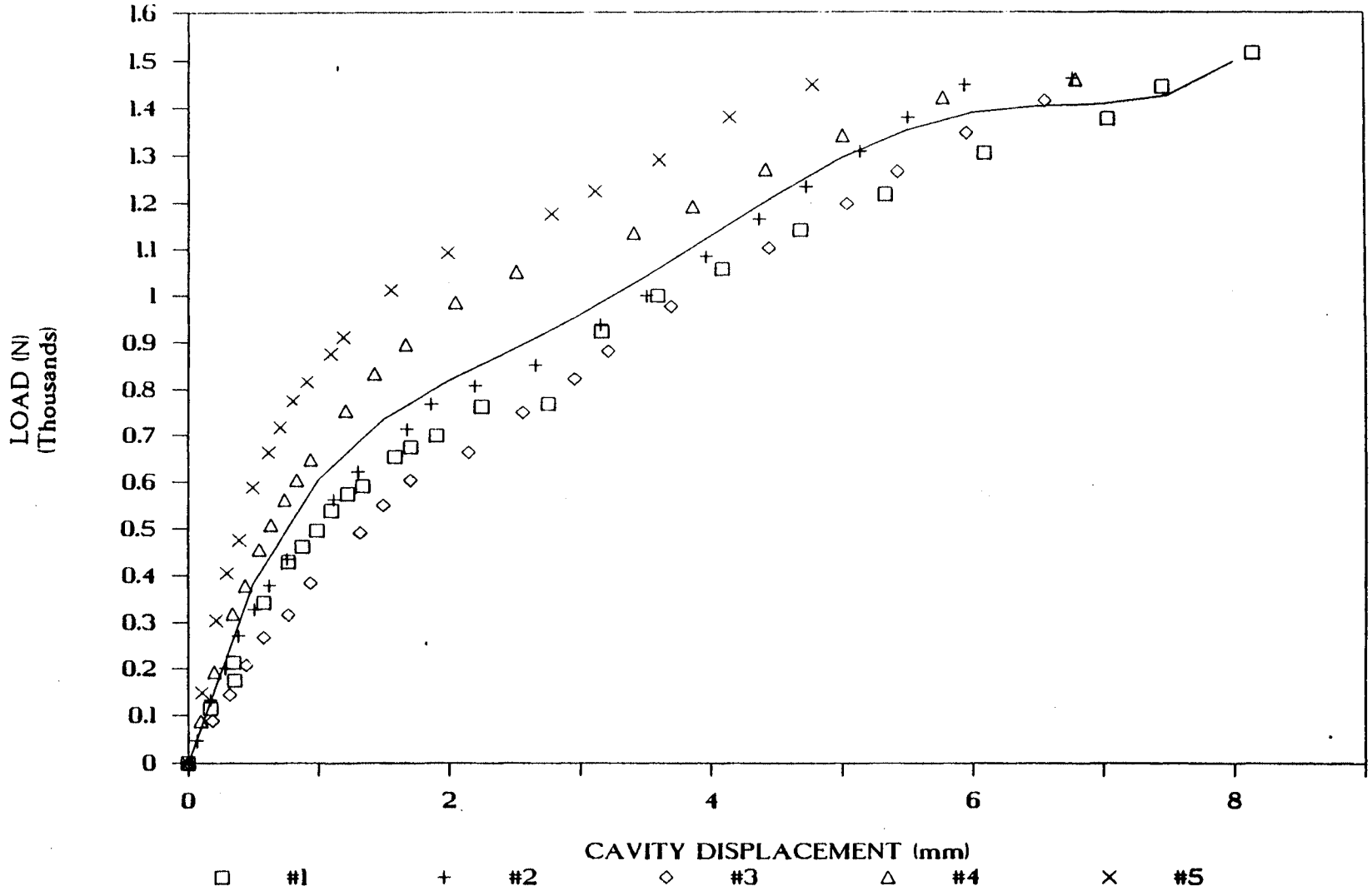
T-10-1D

Test Results & Mean Curve



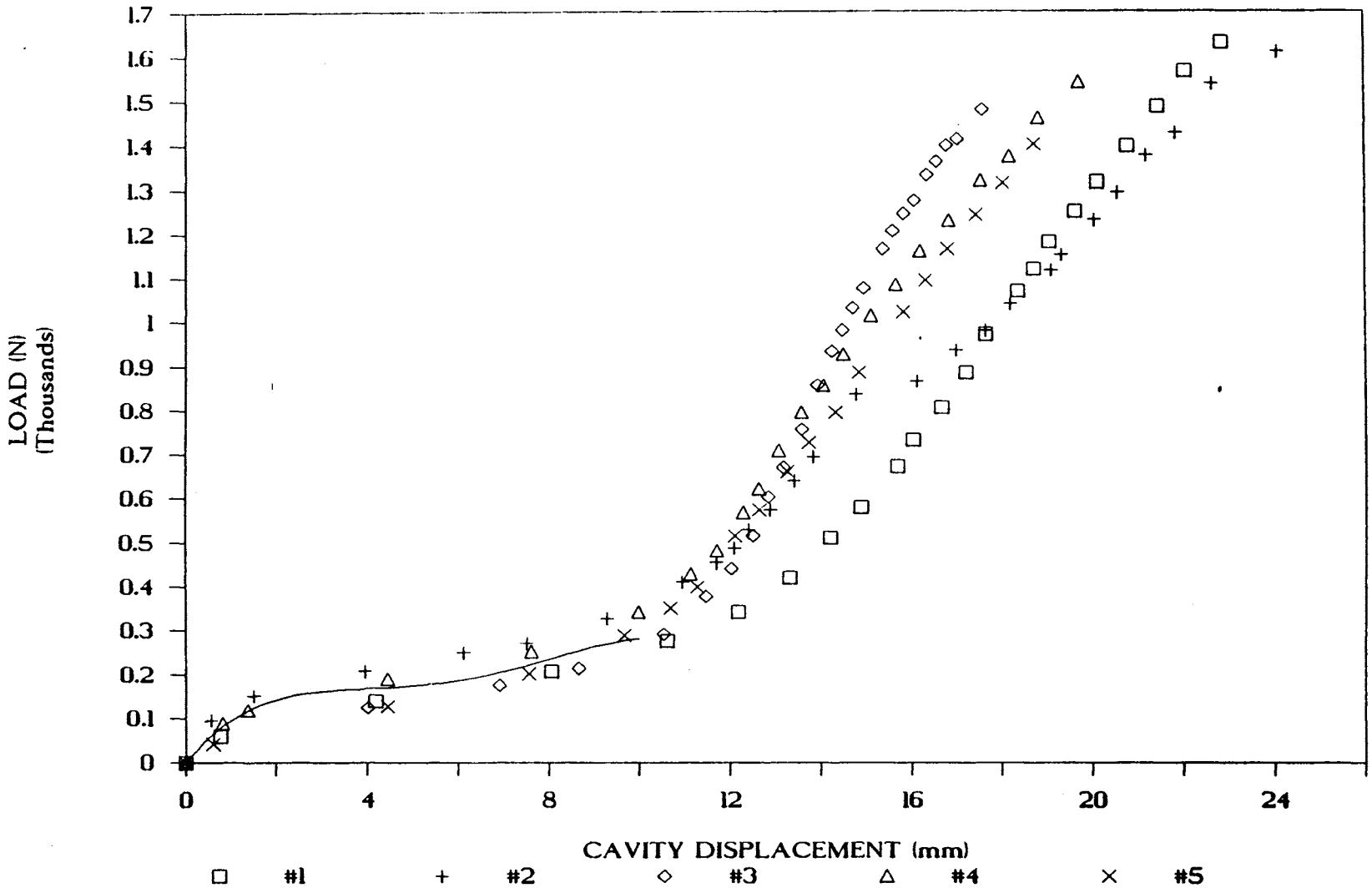
T-10-2A

Test Results & Mean Curve



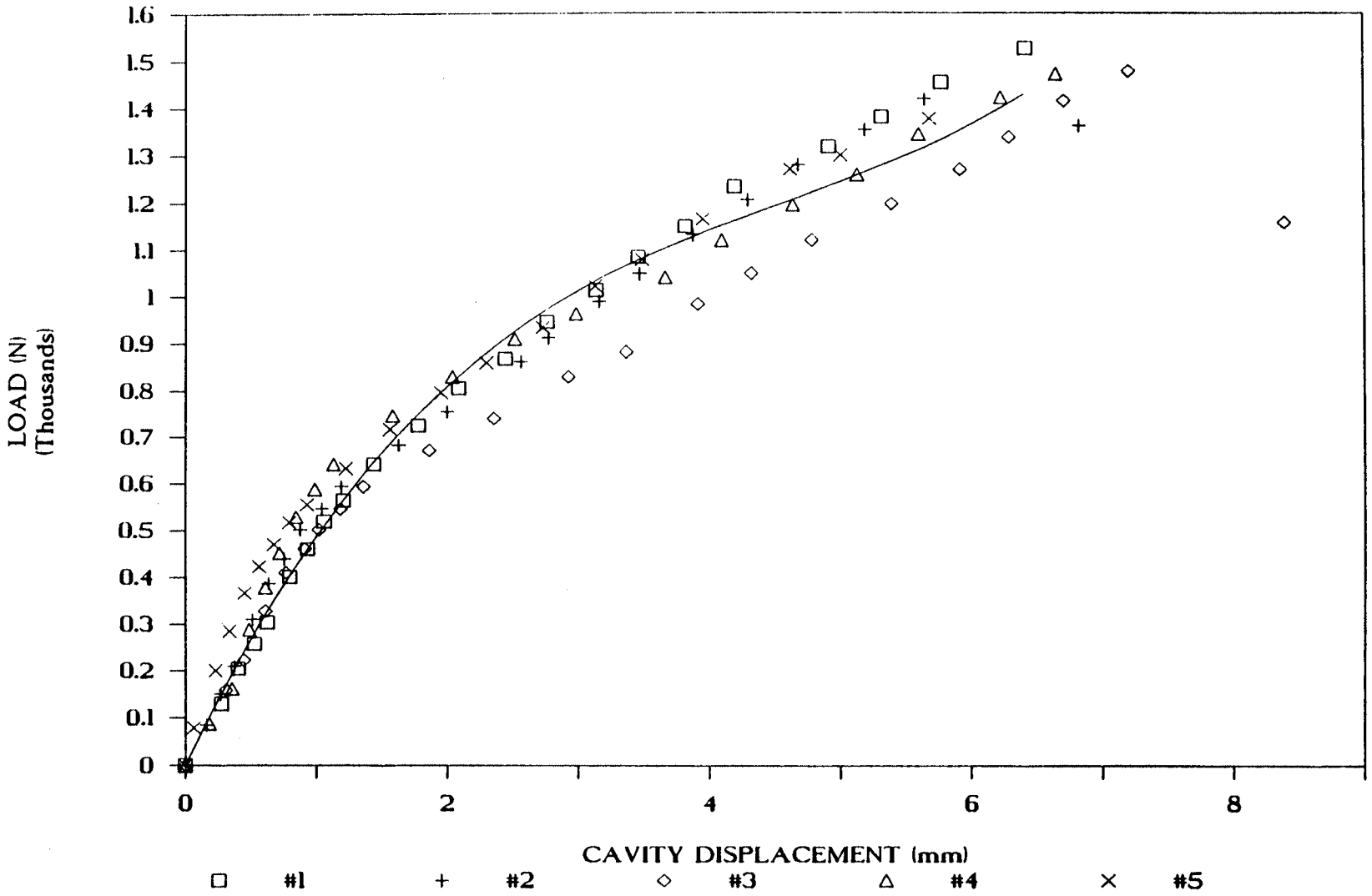
T-10-2B

Test Results & Mean Curve



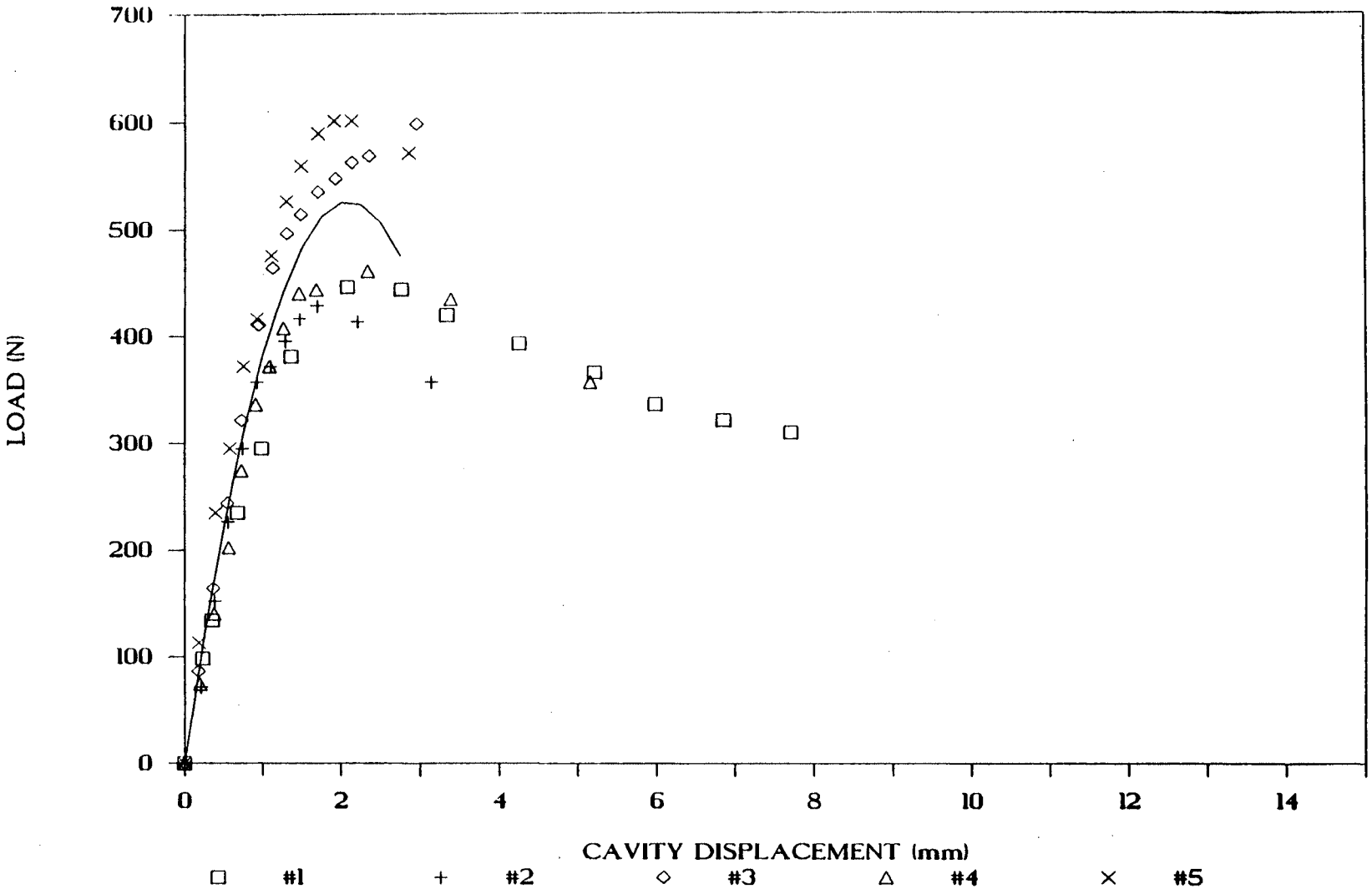
T-10-2C

Test Results & Mean Curve



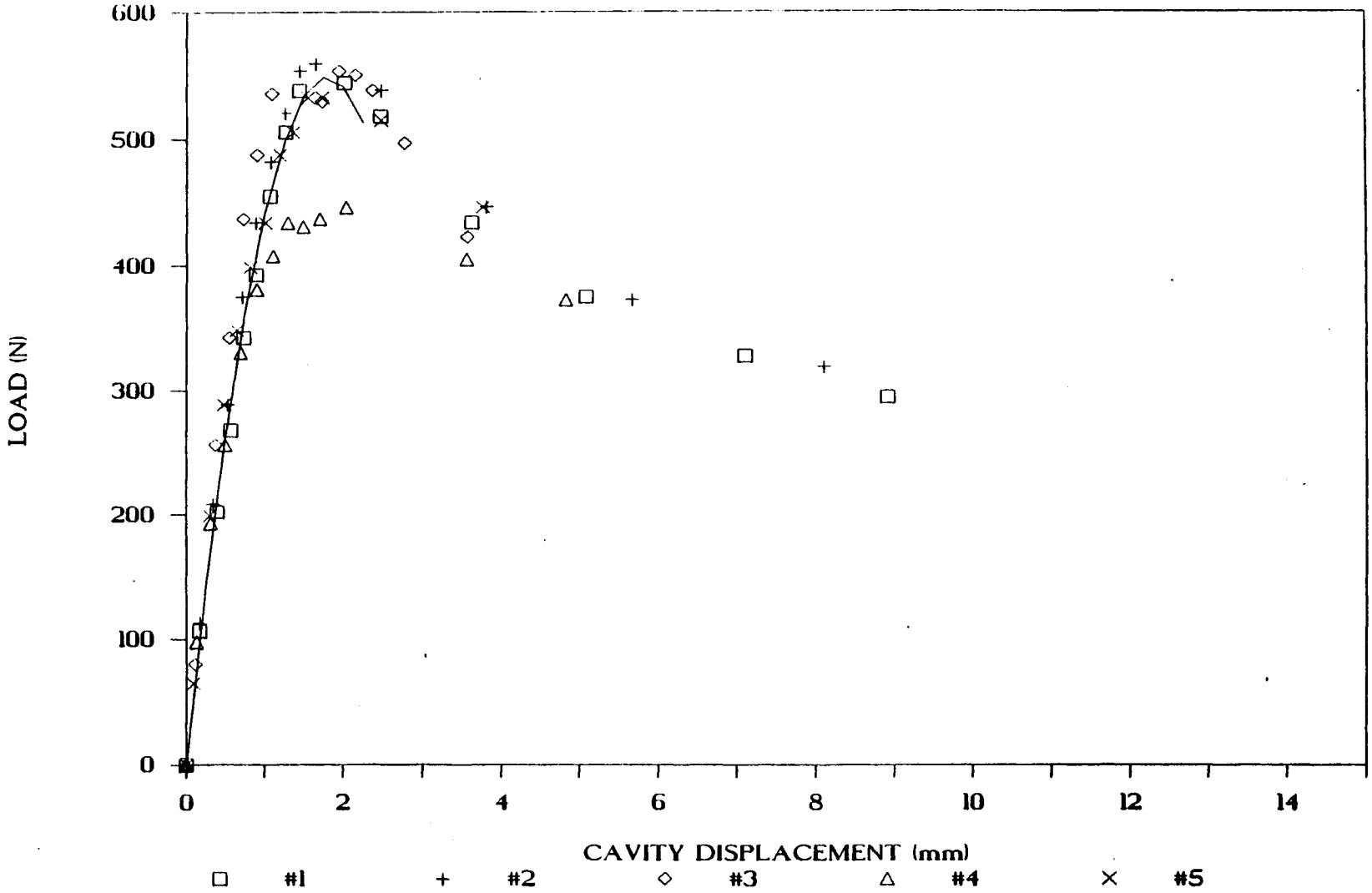
T-11AC-1

Test Results & Mean Curve



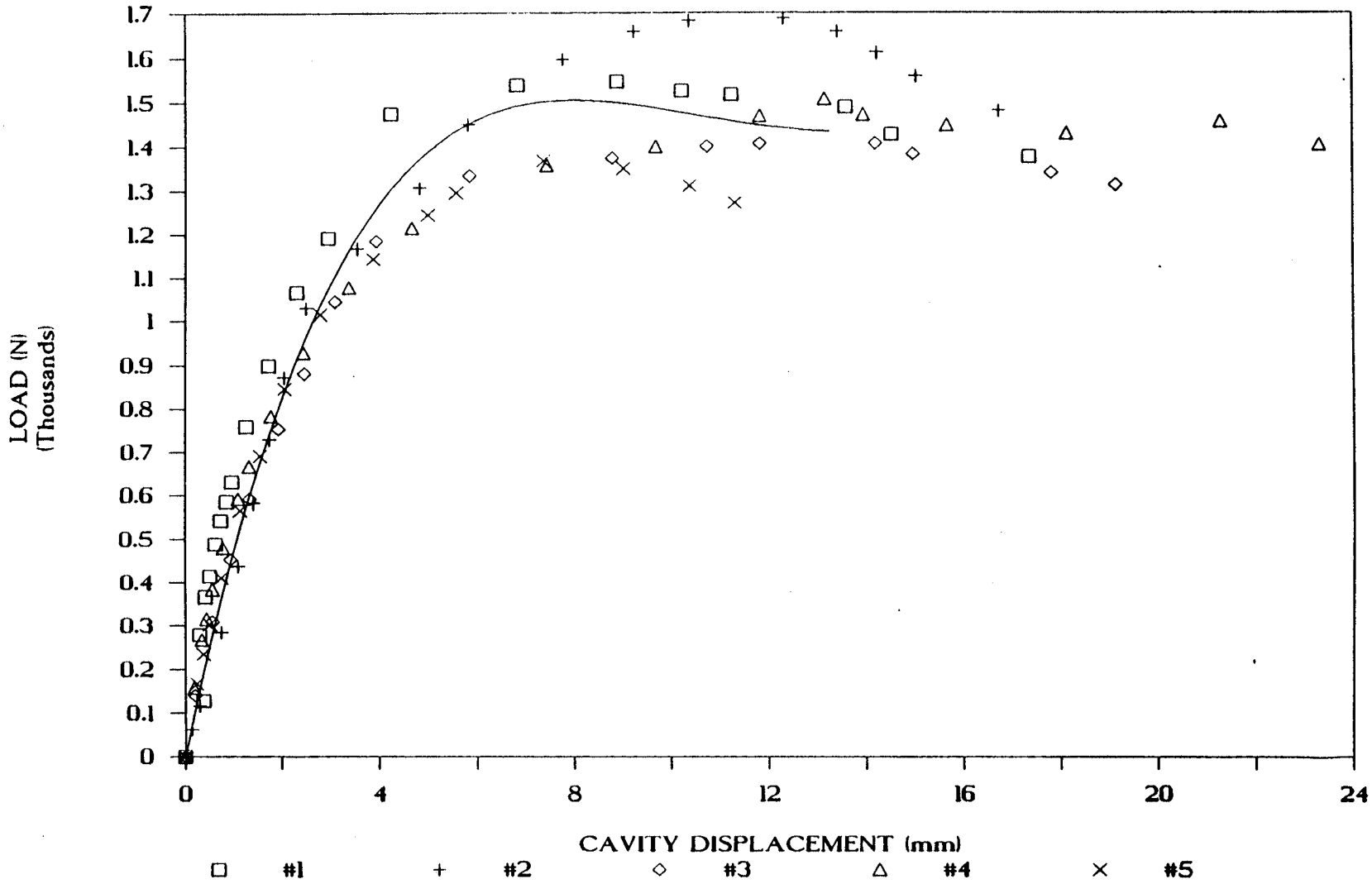
T-11BC-1

Test Results & Mean Curve



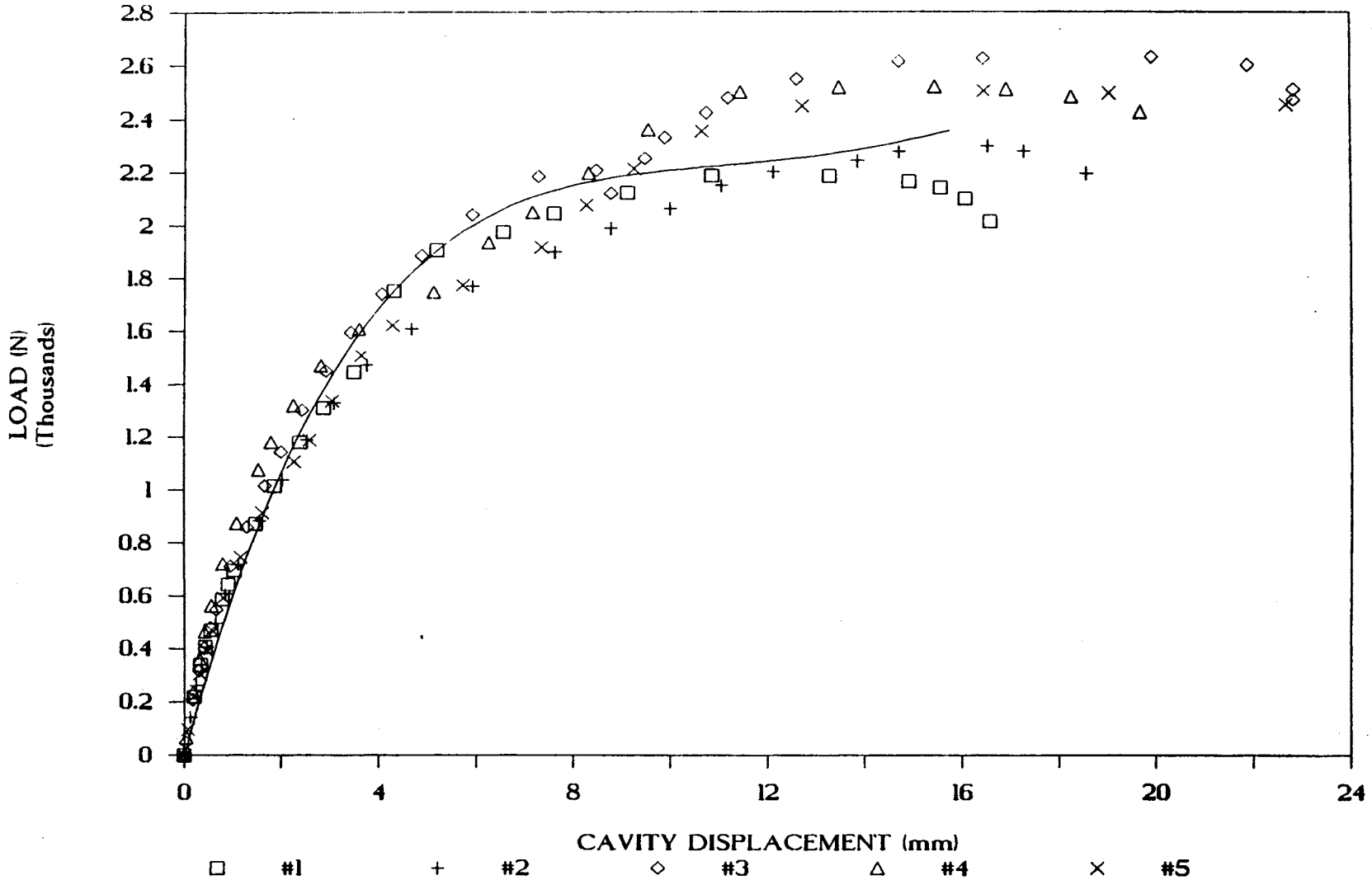
T-11AW-1

Test Results & Mean Curves



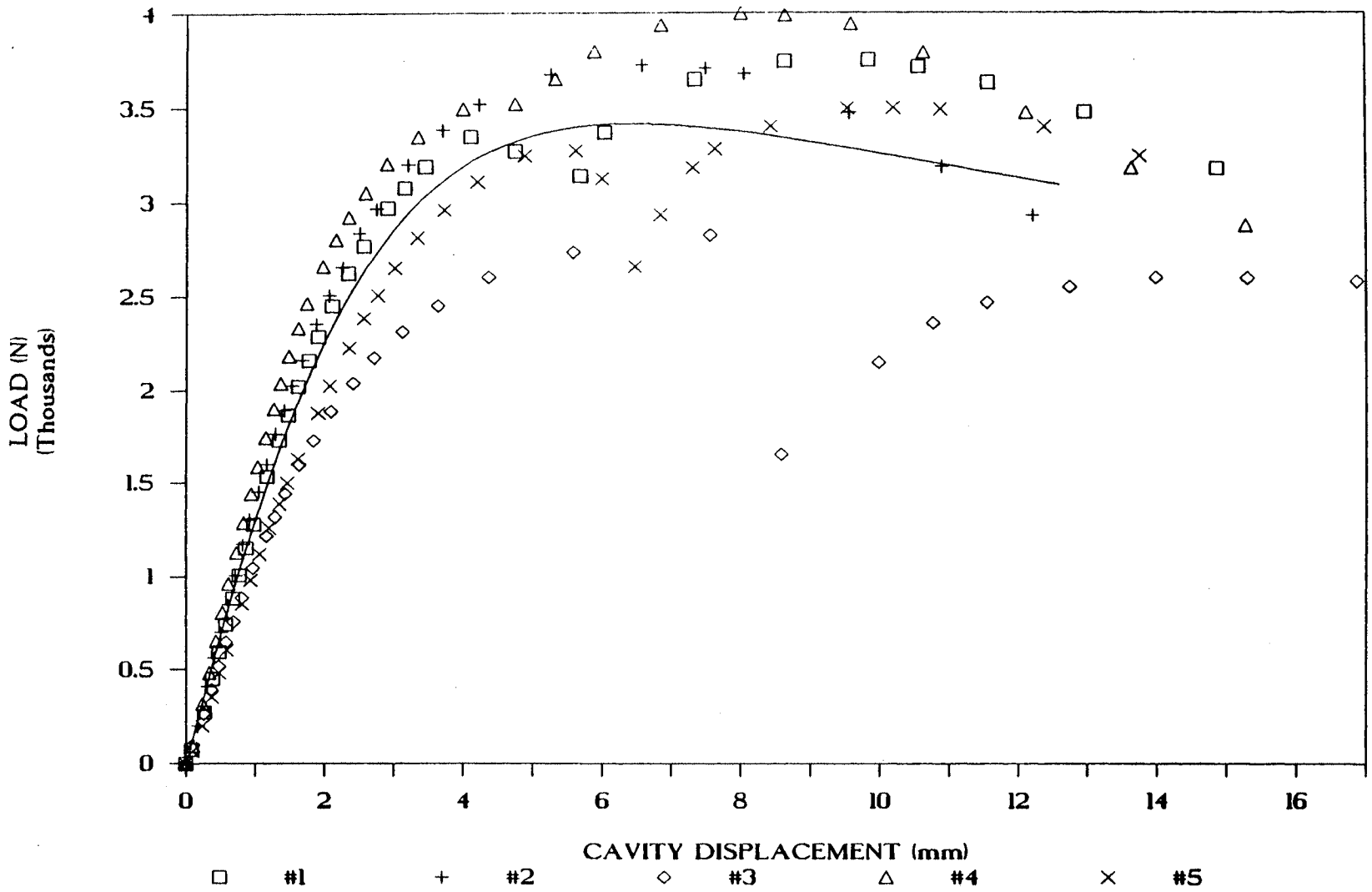
T-11BW-1

Test Results & Mean Curve



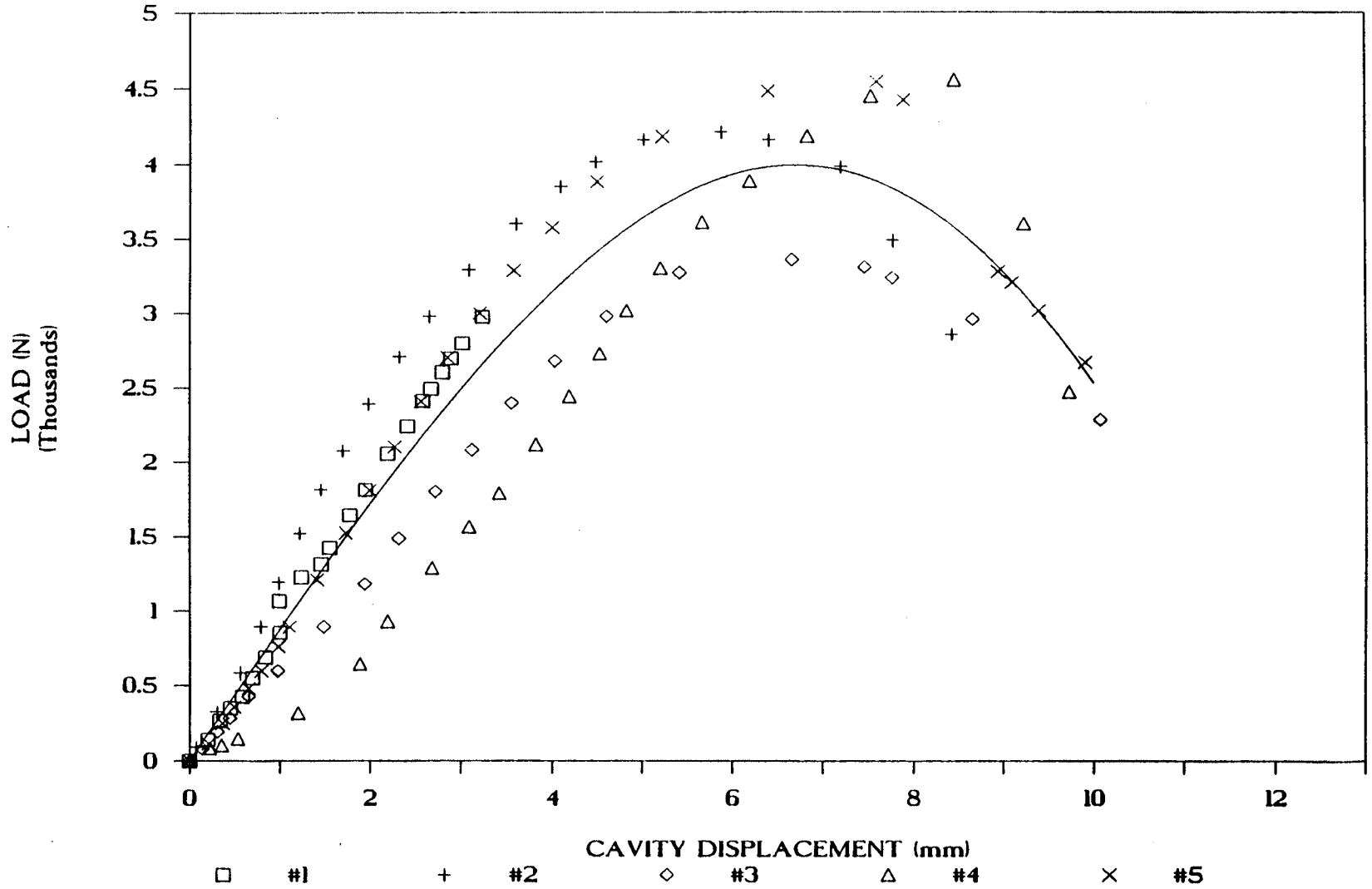
T-12-1

Test Results & Mean Curve



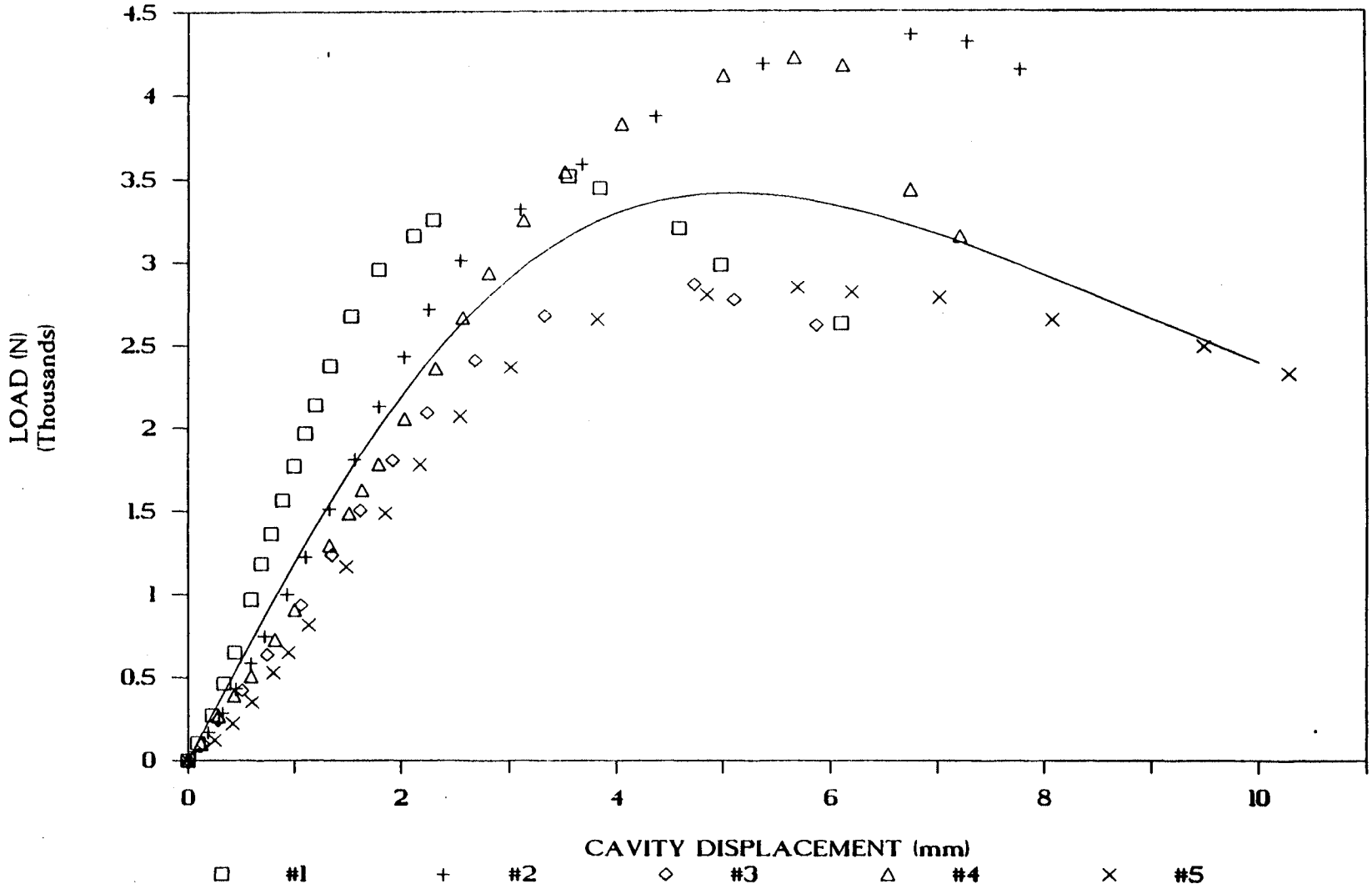
T-12-2

Test Results & Mean Curve



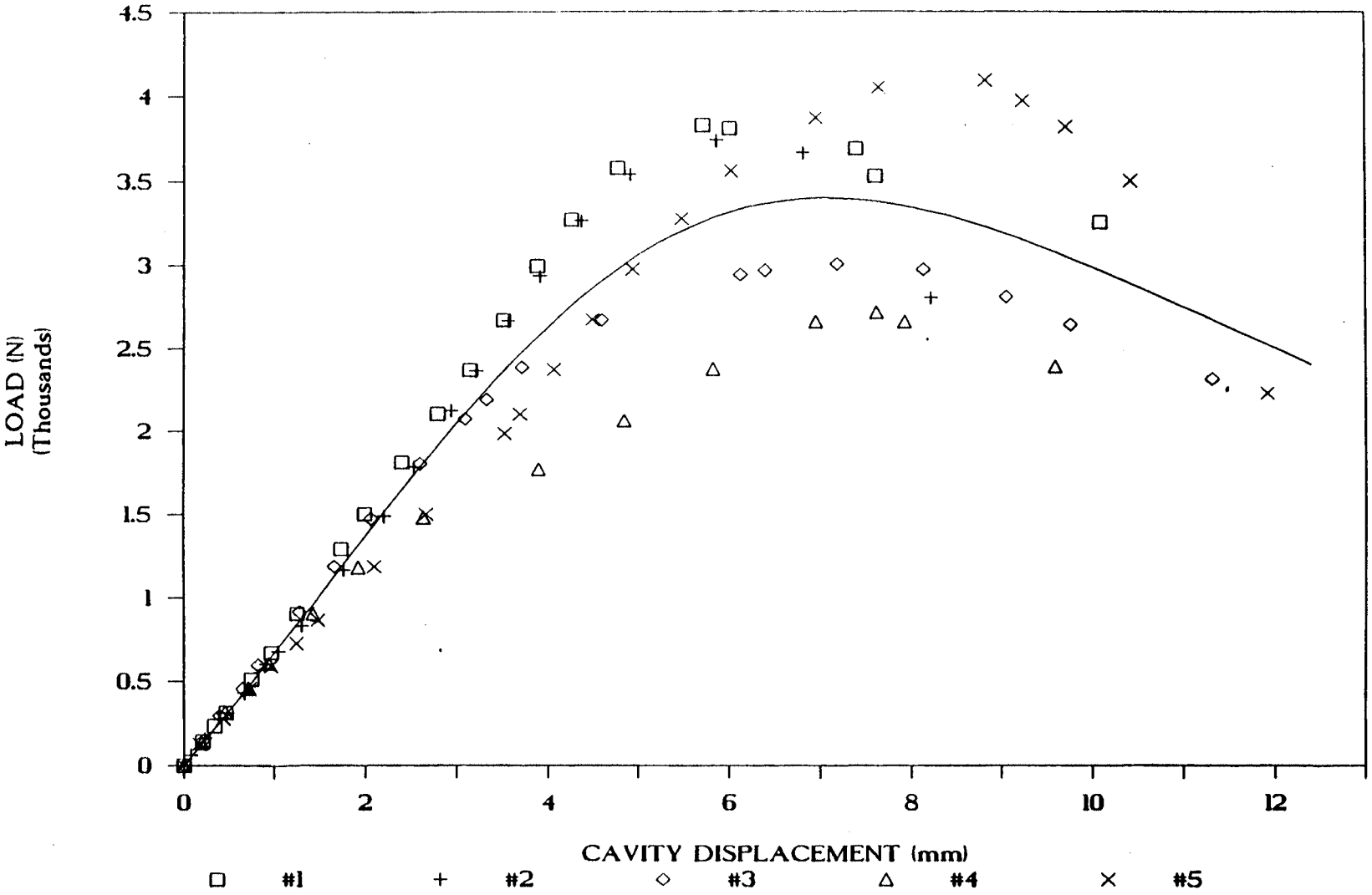
T-12-3a

Test Results & Mean Curve



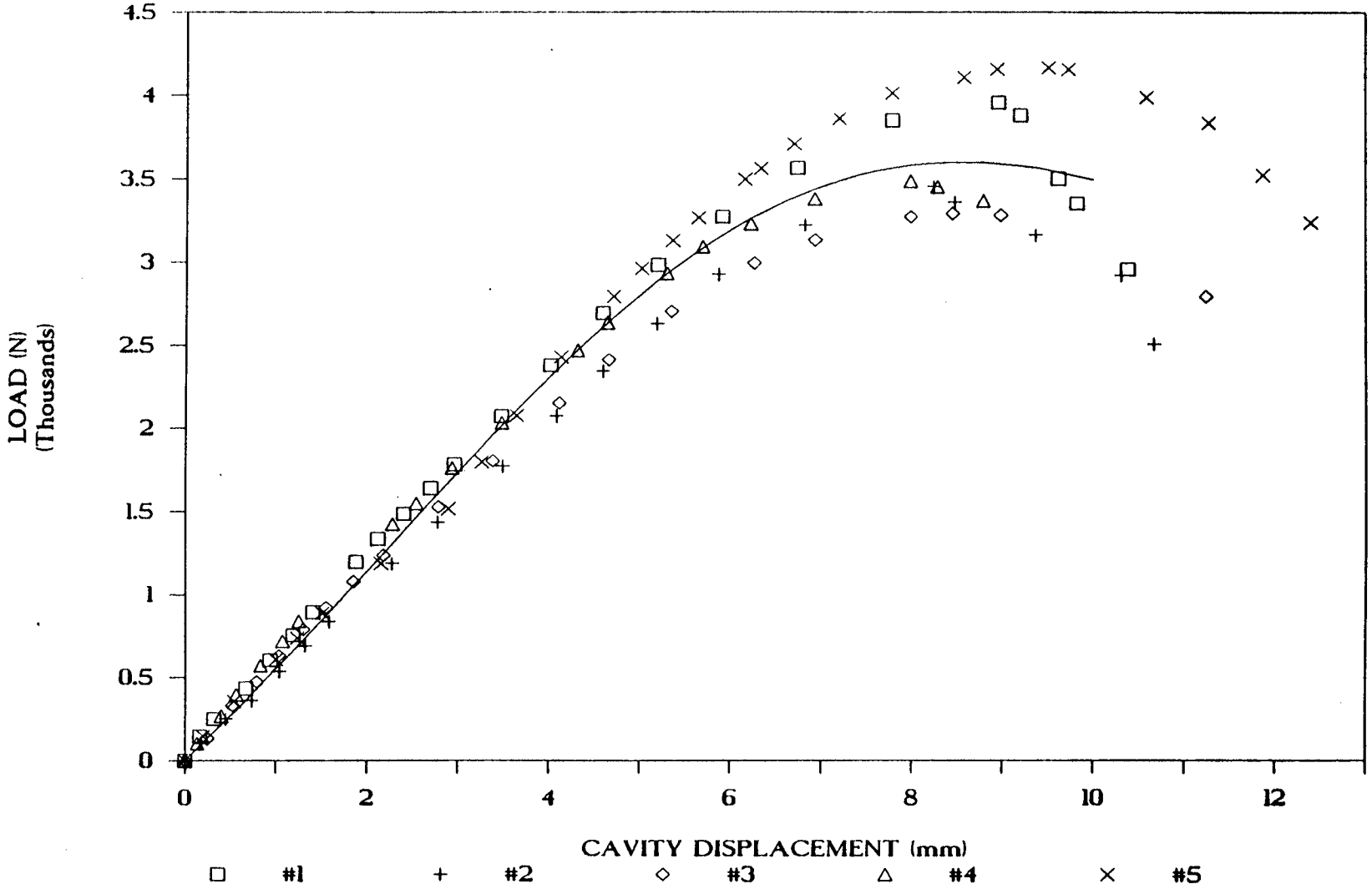
T-12-3B

Test Results & Mean Curve



T-12-4A

Test Results & Mean Curve



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