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Determination of Minimum Embedment Depth for Polyester Resin Capsule Anchors Securing Bridge-Mounted Signs

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This study was conducted in cooperation with the U.S. Department of Transportation, Federal Highway Administration, under the research project entitled "Minimum Embedment Depth for Adhesive Anchors Securing Bridge-Mounted Signs."

16. ABSTRACT
The purposes of this study were to determine the minimum embedment depths required for commercially available 3/4-inch-diameter polyester resin capsule anchor systems to withstand direct tensile design loads of 6300 and 3150 pounds with acceptable short-term creep over a 100-hour time period.

Short-term creep behavior was determined for thirty-six 3/4-inch-diameter resin capsule anchors and is presented and discussed. Four series of tests were conducted. Nine threaded rods in each of the first and third test series were installed in 5-inch-deep holes at 4 3/8 and 2 3/4-inch edge distances, respectively, Creep was monitored while the rods were subjected to a 9450-pound sustained axial tensile test load. In the second and fourth test series, nine threaded rods in each test series were installed in 4-inch-deep holes at 4 3/8 and 2 3/4-inch edge distances. Creep was monitored while the rods were subjected to a 4725-pound sustained axial tensile test load.

It was determined that for the 3/4-inch-diameter ASTM A-307 threaded roads installed with resin capsule anchors and under conditions tested, allowable tensile design loads of 6300 pounds for rods embedded five inches and 3150 pounds for rods embedded four inches are acceptable. Short-term creep values for all systems tested were substantially lower than the maximum permitted. All three brands of resin capsule anchors that were tested performed satisfactorily.

17. KEYWORDS
Resin capsule anchors, polyester resin, embedment depth, creep, edge distance, sustained load

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STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION
DIVISION OF ENGINEERING SERVICES
OFFICE OF TRANSPORTATION LABORATORY

DETERMINATION OF MINIMUM EMBEDMENT DEPTH FOR POLYESTER RESIN CAPSULE ANCHORS SECURING BRIDGE-MOUNTED SIGNS

Study Made by .... Structural Materials Branch

Under the Supervision of ...... J. J. Folsom, P.E.

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Co-Investigator .... J. P. Dusel, Jr., P.E.

Report Prepared by .... J. P. Dusel, Jr., P.E. and
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Chief, Office of Transportation Laboratory

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It was determined that for the 3/4-inch-diameter ASTM A-307 threaded rods installed with resin capsule anchors and under conditions tested, allowable tensile design loads of 6300 pounds for rods embedded five inches and 3150 pounds for rods embedded four inches are acceptable. Short-term creep values for all systems tested were substantially lower than the maximum permitted. All three brands of resin capsule anchors that were tested performed satisfactorily.

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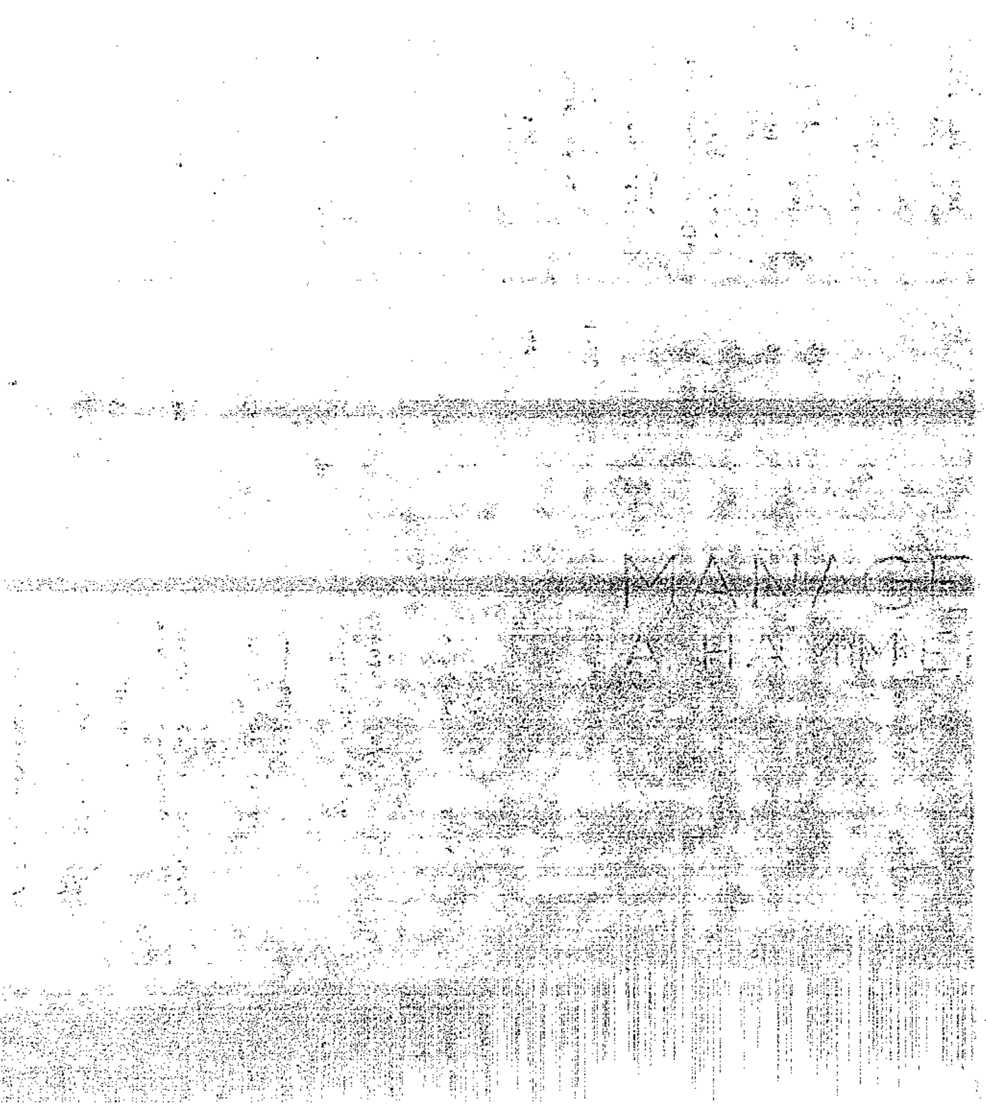
CONVERSION FACTORS

English to Metric System (SI) of Measurement

Quantity	English unit	Multiply by	To get metric equivalent
Length	inches (in)or(")	25.40 .02540	millimetres (mmm) metres (m)
	feet (ft)or(')	.3048	metres (m)
	miles (mi)	1.609	kilometres (km)
Area	square inches (in^2)	6.432×10^{-4}	square metres (m^2)
	square feet (ft^2) acres	.09290 .4047	square metres (m^2) hectares (ha)
Volume	gallons (gal)	3.785	litres (l)
	cubic feet (ft^3)	.02832	cubic metres (m^3)
	cubic yards (yd^3)	.7646	cubic metres (m^3)
Volume/Time (Flow)	cubic feet per second (ft^3/s)	28.317	litres per second (l/s)
	gallons per minute (gal/min)	.06309	litres per second (l/s)
Mass	pounds (lb)	.4536	kilograms (kg)
Velocity	miles per hour (mph) feet per second (fps)	.4470 .3048	metres per second (m/s) metres per second (m/s)
Acceleration	feet per second squared (ft/s^2)	.3048	metres per second squared (m/s^2)
	acceleration due to force of gravity (G)	9.807	metres per second squared (m/s^2)
Weight Density	pounds per cubic (lb/ft^3)	16.02	kilograms per cubic metre (kg/m^3)
Force	pounds (lbs) kips (1000 lbs)	4.448 4448	newtons (N) newtons (N)
Thermal Energy	British thermal unit (BTU)	1055	joules (J)
Mechanical Energy	foot-pounds (ft-lb) foot-kips (ft-k)	1.356 1356	joules (J) joules (J)
Bending Moment or Torque	inch-pounds (ft-lbs) foot-pounds (ft-lbs)	.1130 1.356	newton-metres (Nm) newton-metres (Nm)
Pressure	pounds per square inch (psi)	6895	pascals (Pa)
	pounds per square foot (psf)	47.88	pascals (Pa)
Stress Intensity	kips per square inch square root inch (ksi $\sqrt{in}$)	1.0988	mega pascals $\sqrt{metre}$ (MPa $\sqrt{m}$)
	pounds per square inch square root inch (psi $\sqrt{in}$)	1.0988	kilo pascals $\sqrt{metre}$ (KPa $\sqrt{m}$)
Plane Angle	degrees (°)	0.0175	radians (rad)
Temperature	degrees fahrenheit (F)	$\frac{tF - 32}{1.8} = tC$	degrees celsius (°C)



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1. INTRODUCTION

Currently, overhead signs are permanently attached to existing bridge structures by 3/4-inch-diameter threaded rods bonded in 1-inch-diameter drilled holes with either portland cement (PC) grout or epoxy(4,5,6). Occasionally, where design loads are small, mechanical expansion anchors are used(4,6). Often only limited embedment depths and edge distances are available.

Using either of these approved bonding systems in shallow horizontal holes is risky because it is difficult to, 1) fill horizontal holes with such pourable materials, and 2) retain the material in the hole while it is setting. In addition, there are two inherent problems when either PC grout or epoxy are used to anchor threaded rods in drilled holes. Both materials, 1) shrink while hardening -- a definite disadvantage when attempting to develop maximum bond strength -- and 2) require that the components be carefully weighed and mixed to ensure adequate strength.

Current guidelines used by the California Department of Transportation (Caltrans) for installing post-bonded threaded rods with epoxies emphasize to "never use bonding (epoxy) for sustained axial loading because of the plastic flow characteristics of epoxy."(4) This recommendation is based on the known tendency of current Caltrans-approved epoxies to creep under sustained tensile load. Use of portland cement grout (a neat cement paste made from Type II modified portland cement and water) requires that, 1) a curing compound be applied to the exposed grout surface to prevent rapid loss of water, and 2) before loading, the threaded rods be left undisturbed for at least three days to allow the grout to develop adequate strength. Compliance with these requirements can increase the total cost of the installed anchors considerably.

European countries have used prepackaged polyester resin capsule anchors for some time with good success. Recently, three companies, Hilti, Molly, and U.S.E. Diamond, which have typically marketed mechanical expansion anchors, have offered resin capsule anchors manufactured in Europe for use in the United States, and tout them as a superior alternative to bonded systems using epoxy or portland cement grout. Pullout and shear strengths of these resin capsule anchor systems have been determined by these companies. However, creep characteristics have not been fully determined or verified, especially for anchor rods which have been embedded less than the minimum hole depths recommended by the manufacturers, or which have been installed at extremely small edge distances.

A literature search was performed to determine if studies had been done to evaluate the effects of shallow embedment depth and small edge distance on tensile strength and short-term creep of polyester resin capsule anchors. No pertinent information was found.

Since resin capsule anchors appear to be superior for many applications to either of the currently approved bonding systems and mechanical expansion anchors, especially for attaching overhead signs to existing bridge structures, the Caltrans' Office of Structures Design requested that the Transportation Laboratory (TransLab) test commercially available 3/4-inch-diameter resin capsule anchor systems under sustained axial loads of 6300 and 3150 pounds in unreinforced concrete slabs, evaluate short-term creep performance under sustained tensile loads, and provide recommendations concerning their performance where installed at minimum embedment depths and edge distances (see Appendix A).

The 6300-pound tensile load value is based on AASHTO's recommended allowable unit stress for ASTM A-307 fasteners, the tensile stress area, and the allowable 140% stress increase permitted by AASHTO for Group II loads (see References 2 and 3). This 6300-pound load was further reduced by 50% for instances where a minimal embedment depth of 4 inches and small edge distances would be encountered, and the resulting 3150-pound load was also tested.

The purposes of conducting these tests were:

1. To determine, if at the minimum embedment depths specified by Caltrans Office of Structures Design, commercially available 3/4-inch-diameter polyester resin capsule anchor systems could withstand direct tensile loads of 6300 and 3150 pounds with acceptable creep, and

2. To evaluate short-term creep after 100 hours of sustained loading on the above anchor systems.

A total of thirty-six 3/4-inch-diameter threaded rods were installed using prepackaged polyester resin capsules (12 from each of three anchor companies - Hilti, Molly and U.S.E. Diamond) in unreinforced Class A concrete slabs. Creep tests were performed for 100 hours using procedures detailed in California Test 681 (see Appendix B) and following the work plan shown below:

Test Series	No. of Tests	Embedment Depth Inches	Edge Distance[1], Inches	Desired Working Loads, Kips	Actual Sustained Tension Test Loads[2], Kips
1	9	5	4 3/8	6.30	9.450
2	9	4	4 3/8	3.15	4.725
3	9	5	2 3/4	6.30	9.450
4	9	4	2 3/4	3.15	4.725

1 Edge distances shown are the distance from the center of threaded rods to the edge of concrete slabs.

2 For test purposes, a safety factor of 1.5 was applied to both of the desired working loads to obtain actual sustained tension test loads.

Following the creep tests, resin capsule anchors were loaded in direct tension to failure.

Resin capsule anchors were evaluated at two edge distances, 2 3/4 and 4 3/8 inches (five hole diameters), as requested by Caltrans Structures Design, and at two different sustained tensile test load levels. In addition, two embedment depths were used.

The resin capsule anchors positioned at an edge distance of 2 3/4 inches were installed in horizontal holes (see Figure 1) simulating post-bonded anchors embedded in the edge of a bridge deck overhang to attach bridge-mounted signs. The resin capsule anchors installed in vertical holes and tested at an edge distance of 4 3/8 inches (five hole diameters) - the minimum distance specified in California Test 681 - represent those which would be installed away from edges, as in a bridge deck or exterior girder stem (see Figure 2).

Figure 1. Creep test in progress on polyester resin capsule anchors installed in horizontal holes at a 2 3/4-inch edge distance.

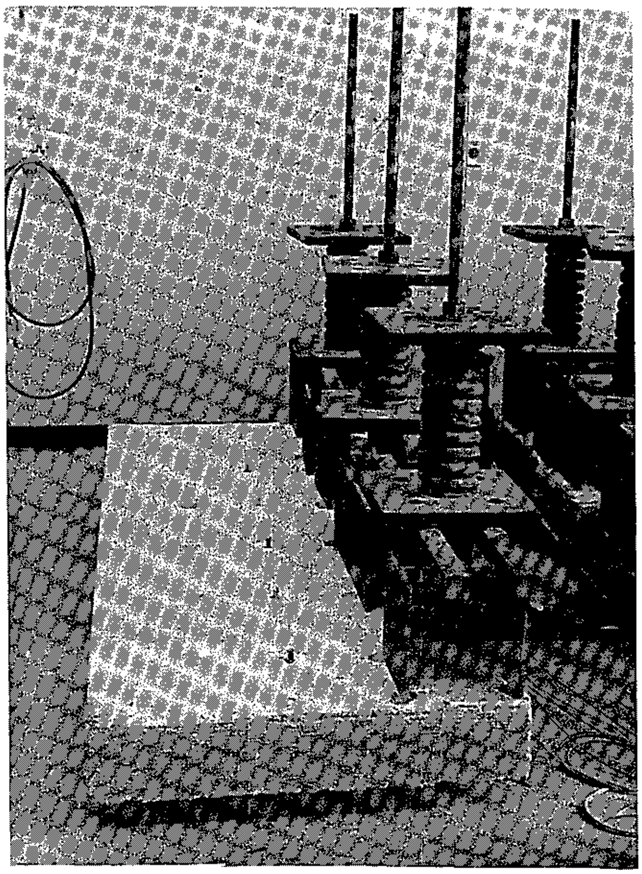

Figure 2. Creep tests on polyester resin capsule anchors installed in vertical holes at a 4 3/8-inch edge distance.

[illegible]GEME[illegible]

[illegible]MEETI[illegible]

2. CONCLUSIONS AND OBSERVATIONS

General Conclusions:

- Test results confirm that the desired static tension loads of 6300 pounds for resin capsule anchors embedded 5 inches, and 3150 pounds for those embedded 4 inches, could consistently be maintained with a safety factor of 1.5.

- All three brands of 3/4-inch-diameter resin capsule anchors evaluated in this research performed well with the limited embedment depths and small edge distances tested. Creep observed during short-term sustained tensile loading was generally less than that found in previous testing of mechanical expansion anchors, and was much less than the maximum creep allowed in Section 75-1.03 of the Caltrans Standard Specifications(6).

- The typical failure modes observed in ultimate tensile tests conducted in this research were either a cone-type failure or a tensile splitting in the unreinforced concrete slabs. Bond strengths of the resins were excellent, and did not appear to limit the ultimate tensile loads applied to the threaded rods.

2.1 Resin Capsule Anchors Embedded 5 Inches and Creep Tested Under a 9450-pound Sustained Axial Tensile Test Load

Resin capsule anchors installed at a 5-inch embedment depth and at two edge distances, 2 3/4 inches and 4 3/8 inches, satisfactorily resisted a sustained axial tensile test load of 9450 pounds for 100 hours with small anchor rod creep displacements varying from 0.009 to 0.025 inch. These values are from one-fifth to one-half of the allowable creep of 0.050 inch previously allowed for mechanical expansion anchors tested for the same 100-hour time period. The ultimate tensile strengths of these capsule anchors, determined after the completion of the creep test varied between 13.4 and 15.3 kips when installed in concrete slabs having compressive strengths from 5300 to 5400 psi. Ultimate strengths of these resin anchor systems varied between 15.3 and 21.1 kips when installed in concrete slabs with compressive strengths ranging from 6000 to 6900 psi.

2.2 Resin Capsule Anchors Embedded 4 Inches and Creep Tested Under a 4725-pound Sustained Axial Tensile Test Load

For resin capsule anchors installed in 4-inch-deep holes at edge disances of both 2 3/4 inches and 4 3/8 inches, a constant axial tensile test load of 4.725 kips was maintained for 100 hours with negligible creep displacements (from zero to 0.004 inch). The ultimate strengths of these resin anchor systems, determined after the completion of the creep tests, varied between 10.7 and 14.1 kips when installed in concrete slabs having compressive strengths ranging from 5000 to 5300 psi. Ultimate strengths of similar resin capsule anchor systems varied between 13.2 and 15.1 kips when installed in concrete slabs with compressive strengths ranging from 5800 to 6000 psi.

2.3 Observations

It was observed that the ultimate strengths of polyester resin anchor systems tested rose and creep was significantly reduced when the compressive strengths of the concrete test slabs were increased. Additionally, it was observed that the anchorage system's ability to resist creep under a sustained axial tensile test load was not reduced at an edge distance as small as 2 3/4 inches.

It should be noted that in the ICBO research reports on two of the resin capsule anchors tested (see Appendix C), resin anchors are not permitted for use in walls (horizontal holes) or for overhead applications. This is because when ambient temperatures of surrounding concrete or rod temperatures become elevated, the bond strength of the resin decreases significantly. Also, long-term direct exposure of the resin to excessive amounts of UV radiation may also cause resin degradation and loss of bond strength.

The minimum specified cure time - 10 minutes - for the mixed polyester resin capsules at the ambient temperature of approximately 70°F present during this research was short. Longer cure times are required for resin anchors installed at lower ambient temperatures; for example, a one-hour cure time is specified for ambient concrete temperatures for between 32°F and 50°F. This range of curing temperature will frequently be encountered when anchor installations must be performed during winter months or at night and lane closures must be made on busy freeways. On such occasions, it is desirable but not always possible with these cool temperatures to preload the resin capsule anchors immediately after installation so as to reduce work time and duration of lane closures.

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3. RECOMMENDATIONS AND IMPLEMENTATION

Based on results of this research, it is recommended that the 3/4-inch-diameter polyester resin capsule anchor systems as tested be considered as alternatives equal to or better than mechanical anchors (see proposed Standard Special Provision in Appendix B) or other currently approved grouted or bonded anchor systems because of the tendency of the mixed resin to stay in the hole and its quick set time. Other brands of resin capsule anchors may be acceptable but must be evaluated by the vendor or contractor using the Revised California Test 681 (Appendix A).

It should be cautioned that certain variables such as concrete compressive strength, the various tools and methods available for drilling, cleaning and installing anchors, and general undesirable conditions experienced in field work may affect the performance of resin capsule anchors and result in lower loads than were obtained in this study. Also, resin capsule anchors should not be used in walls or overhead applications where the temperature of the surrounding concrete will be elevated, or where the resin will be directly exposed to excessive UV radiation, as anchor bond may be significantly reduced (see Appendix C).

It is recommended that:

- Parameters for the installation of 3/4-inch-diameter resin capsule anchors be limited to the following values for conditions similar to those used in this research:

Hole Diameter, inch	Min. Embedment Depth, Inches	Min. Edge Distance, Inches	Max. Tensile Load (no shear), Kips
7/8	5	2 3/4 to 3	6.30*
7/8	4	2 3/4 to 3	3.15

*Maximum design load values recommended are based on allowable loads calculated from AASHTO specifications (References 2 and 3) and have been verified by tests performed in this research study.

- The quality of the concrete in existing bridge structures be assessed prior to using resin capsule anchors, and edge distances and embedment depths be increased when concrete strength is less than that used in this research.

- When both shear and tensile loads are present, the number/spacing of the threaded rods be determined by using an appropriate combined stress ratio formula.

As only 36 creep tests were conducted in this research study on only one size of resin capsule anchor, additional research may be needed to verify satisfactory short-term creep performance for other anchor sizes. In addition, limited data on long-term creep performance of resin anchors under sustained loads are available from manufacturers and verification tests need to be performed to confirm their suitability.

Future Research Recommended

It is recommended that the following additional research be conducted in the future:

- Evaluation of other sizes of resin capsule anchors,
- Development of more complete performance specifications for resin capsule anchors,
- Determination of the limits for allowable shear and combined shear and tension loading on resin capsule anchors,
- Determination of the effect of close spacing of resin capsule anchors having shallow embedment and/or small edge distances, and
- Development of specifications for materials contained in resin capsules to include controls on:

  (a) resin quality
  (b) aggregate size and quality, and
  (c) mix proportions of resin, aggregate, and catalyst.

4. DESCRIPTION OF EXPERIMENTAL PROGRAM

4.1 Testing Program

In this research, four separate test series were performed to determine the effects of limited edge distance and embedment depth on creep behavior of 3/4-inch-diameter threaded rods bonded using special prepackaged capsules containing a polyester resin adhesive, aggregate, and an accelerator. In each test series, nine rods were installed and their creep was monitored simultaneously using an electronic data acquisition system.

4.1.1 Determination of Sustained Tensile Test Loads

The allowable tensile load, 6.30 kips, was determined by multiplying the basic allowable bolt load for a 3/4-inch-diameter fastener, 4.5 kips, by the allowable stress increase of 140%, permitted for Group II loads, as shown in section 1.2.6 - GROUP LOADS(2).

The allowable bolt load was calculated by multiplying the allowable working stress of 13.5 ksi, permitted by AASHTO's "Standard Specifications for Highway Bridges," Table 1.7.41C, page 171(3), by 0.334 inch, the tensile area of the 3/4-inch-diameter threaded rod, as recommended in Section 1.3.4(A) of reference 2.

To account for the negative effects of a minimum embedment depth of 4 inches, the initial 6300 pound tensile load was reduced by 50% and also tested.

For test purposes, a safety factor of 1.5 was applied to both of the above desired design tensile loads. The resulting tensile test loads of 9450 pounds and 4725 pounds were used to evaluate creep and ultimate tensile strength for embedment depths of 5 inches and 4 inches, respectively.

4.1.2 Important Test Parameters

The following parameters were considered important when testing resin capsule anchors in this research project:

- Embedment depth: 4 and 5 inches.

- Edge distance: 2 3/4 and 4 3/8 inches (5 hole diameters).

- Magnitude of sustained tensile test loads: 9450 pounds on resin capsule anchors embedded 5 inches, and 4725 pounds on anchors embedded 4 inches.

- Brand of resin capsule anchor: Three brands were tested in each of the four test series.

- Type of threaded anchor bar: 3/4-inch-diameter threaded anchor bars made of steel conforming to ASTM Specification A-307.

- Hole diameter: 7/8-inch-diameter holes as recommended by vendors of the 3/4-inch-diameter threaded rods.

- Hole orientation: Vertical and horizontal.

4.1.3 Work Plan

A flow chart outlining the various possible testing sequences is shown in Figure 3.

The following table shows the actual sustained load tests conducted in this research:

Test Series	No. of Sustained Tensile Tests	Embedment Depth, Inches	Edge Distance, Inches	Hole Orientation	Sustained Tensile Test Load, Kips
1	9	5	4 3/8	Vertical	9.450
2	9	4	4 3/8	Vertical	4.725
3	9	5	2 3/4	Horizontal	9.450
4	9	4	2 3/4	Horizontal	4.725

4.2 Materials

4.2.1 Concrete: Mix Design, Compressive Strength, and Dimensions of Test Slabs

A number of unreinforced Class A concrete slabs having dimensions of 3'x8'x7 1/2" and 3'x7 1/2'x 5 1/2" and previously cast for another research project were used for the creep and ultimate strength testing. Compressive strengths of concrete as determined from cores taken from the old slabs or cylinders made while placing the new slabs were as follows:

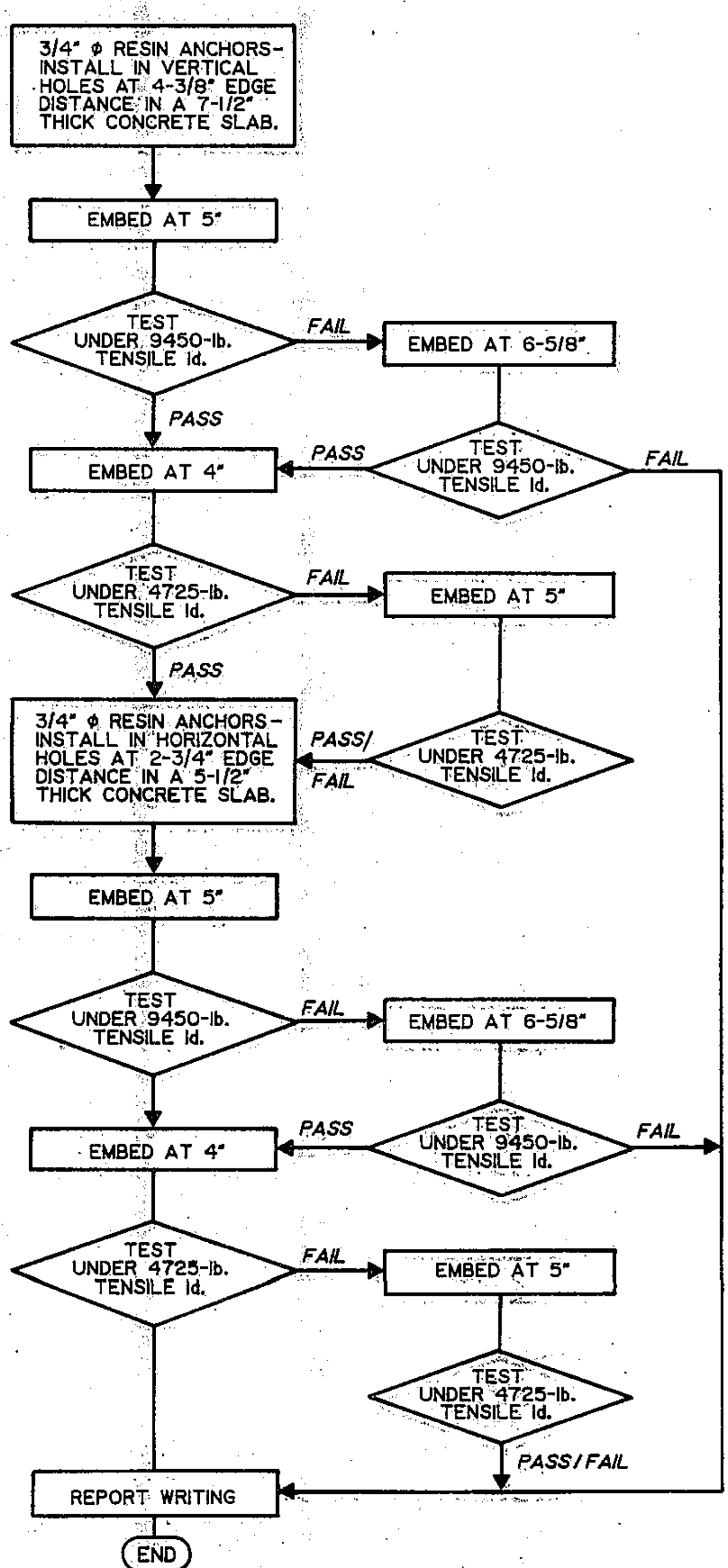


Figure 3. Resin capsule anchor test flow chart.

Test Series	Slabs Cast On	Slabs Used for Creep Testing On	Concrete Compressive Strength (psi) @ Time of Creep Test
1	5-10-84	6-22-84	5300-5400
2	3-20-84	7-9-84	5000-5300
3	3-9-83	7-31-84	6000-6900
4	3-9-83	8-15-84	5800-6050

4.2.2 Types of Resin Capsule Anchors Tested

Each resin capsule anchor system used was composed of a threaded rod and a sealed glass capsule which contained polyester resin, quartz aggregate, and a benzoyl peroxide catalyst. Resin capsule anchors available from three companies - Hilti, Molly, and U.S.E. Diamond (see Figures 4 to 6) - were used for the tests. The 3/4-inch-diameter threaded rods used in this research had a yield strength of 71.4 ksi and a tensile strength of 80.2 ksi. In two of the resin systems evaluated - Molly's Parabond and U.S.E. Diamond's SUP-R-SET - the large outer capsule contains a mixture of premeasured amounts of polyester resin and quartz aggregate. In both of these systems, the benzoyl peroxide catalyst is contained separately in a small glass vial within the main capsule. In the third system tested - Hilti's HVA adhesive anchor - the main capsule contains only the polyester resin, and aggregate coated with the benzoyl peroxide catalyst was contained in a separate inner vial.

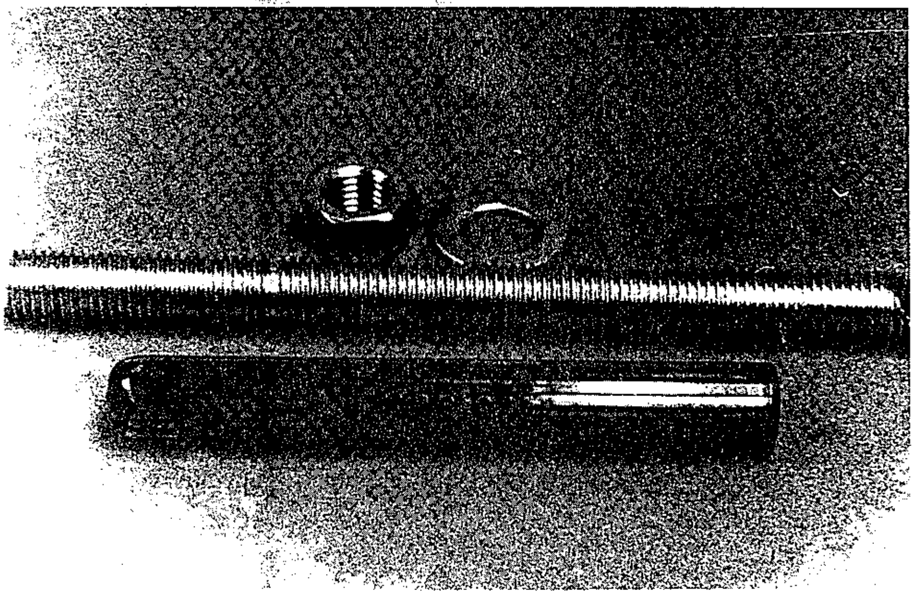


Figure 4. Hilti's HVA resin capsule anchor system (HBP M19-3/4" capsule with HAS threaded rod, washer, and nut).

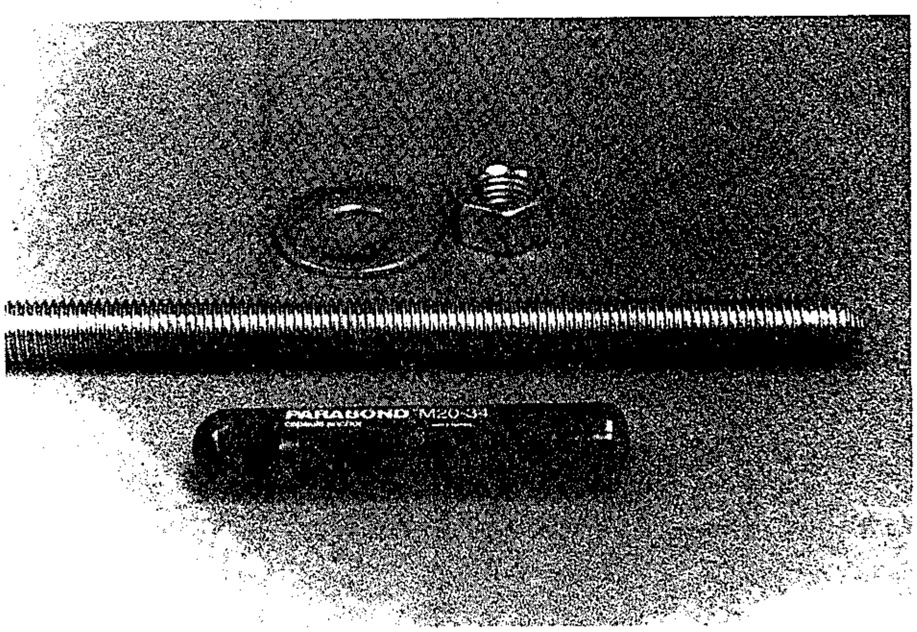


Figure 5. Molly's 'Parabond M20-34' resin capsule with threaded rod, washer, and nut.

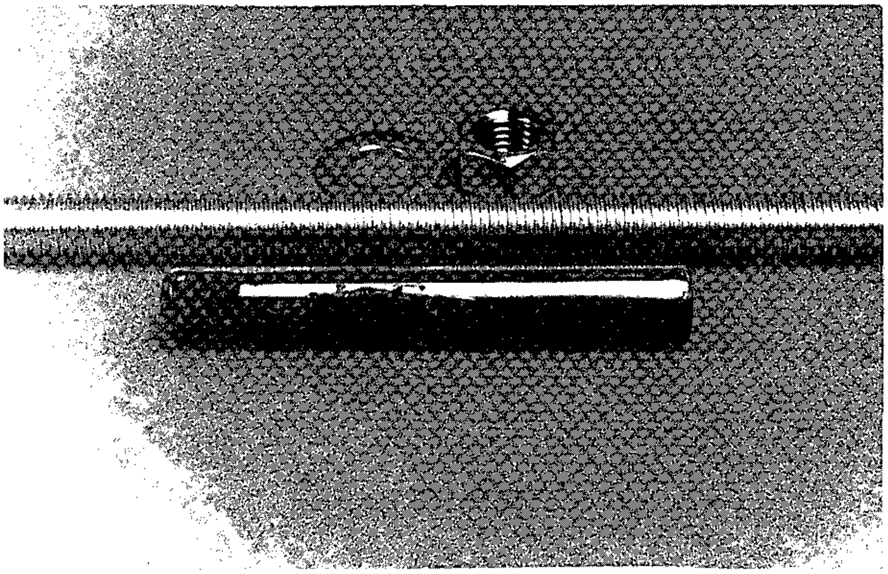


Figure 6. U.S.E. Diamond's 'SUP-R-SET' resin capsule with threaded rod, washer, and nut.

4.3 Test Method and Apparatus

California Test 681 with revisions (see Appendix A) was followed for determining short-term creep behavior of the resin capsule anchors (see Appendix A). Because the creep behavior of the polyester resin under sustained axial load was a major concern in this research, the 48-hour creep period required in Test 681 was extended to 100 hours in all creep tests performed in this study. A suitable creep test apparatus used in this research is shown in Figures 8 and 9. During each test series, nine identical sets of apparatus were used simultaneously.

4.4 Hole Preparation and Installation of Threaded Rods with Resin Capsules

Holes seven-eighth inch in diameter were drilled with a rotary impact drill and carbide tipped bit to specified depths as shown in the work plan (Section 4.1.3). After drilling was completed, dust was blown out using a blow nozzle and compressed air.

Appropriate resin capsules were inserted into each hole (see Figure 7). A threaded rod was installed into the adaptor unit of the rotary impact hammer and then jammed in the hole in order to break the glass capsule. The rotary impact hammer was immediately turned on, and while pressure was applied to seat the rod, the glass capsules and contents were mixed and ground up until the threaded rod bottomed out in the hole. The rotary impact hammer was then immediately turned off. After the installed rod set for 10 minutes, the drive unit was disconnected. The installed threaded rod was then cured for approximately 24 hours prior to testing.

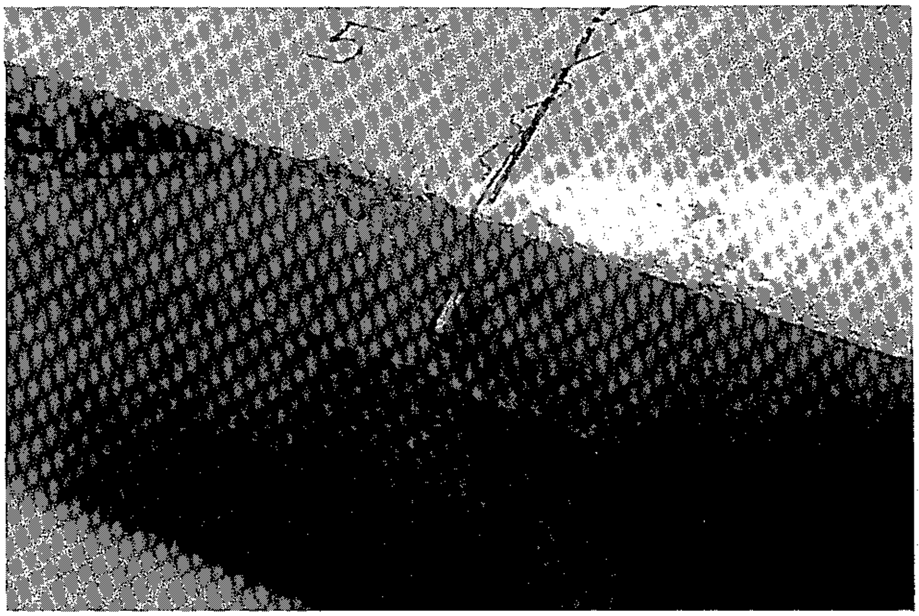


Figure 7. Unbroken glass resin capsule inserted in a drilled hole.

4.5 Test Procedure

For each of the four creep test series performed in this research, nine threaded rods were bonded in drilled holes with three different brands of resin capsules following parameters previously described in Section 4.1.2. All nine creep tests of each series were performed simultaneously using nine sets of testing apparatus previously described.

Each installed threaded rod was readied for creep testing using the following procedure: A base plate, to which a load collar and deflection bracket were welded, was placed over each rod and held securely against the concrete surface using a washer and nut. A torque of 160 ft-lb was applied to each nut. The external test load was applied to the base plate through the load collar.

Prior to applying an external load, an initial displacement reading of each potentiometer was made.

The spring system used to sustain tensile loads was assembled as shown in Figures 8 and 9. The appropriate sustained tensile test load, as specified in the work plan, Section 4.1.3, was applied to each rod by means of a 60-ton jack. The load was measured using a load cell and a transducer/strain indicator. For each anchor rod, creep displacement was recorded on paper tape using an electronic data acquisition system (see Figure 10). Readings were taken immediately after each anchor rod was loaded and subsequently, every two hours until the 100-hour test duration was reached.

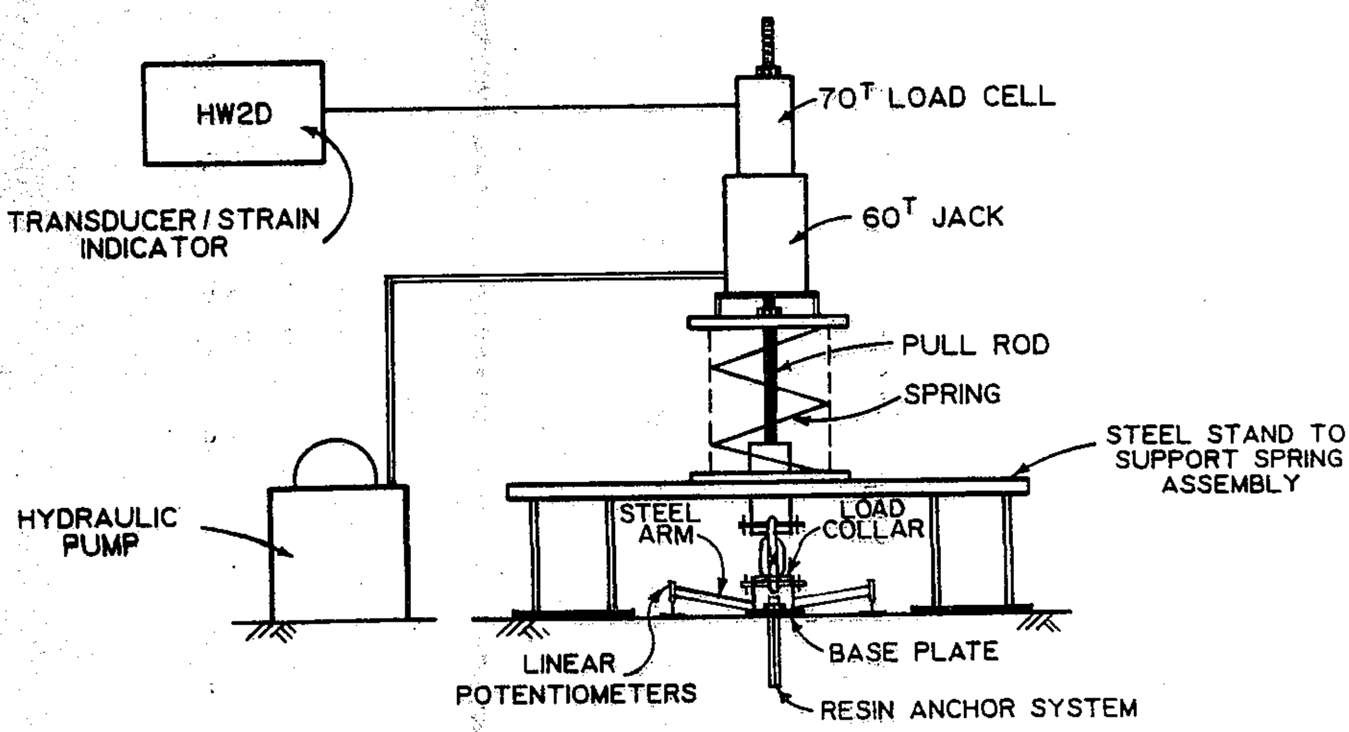


Figure 8. Testing apparatus used to apply sustained loads to resin capsule anchors.

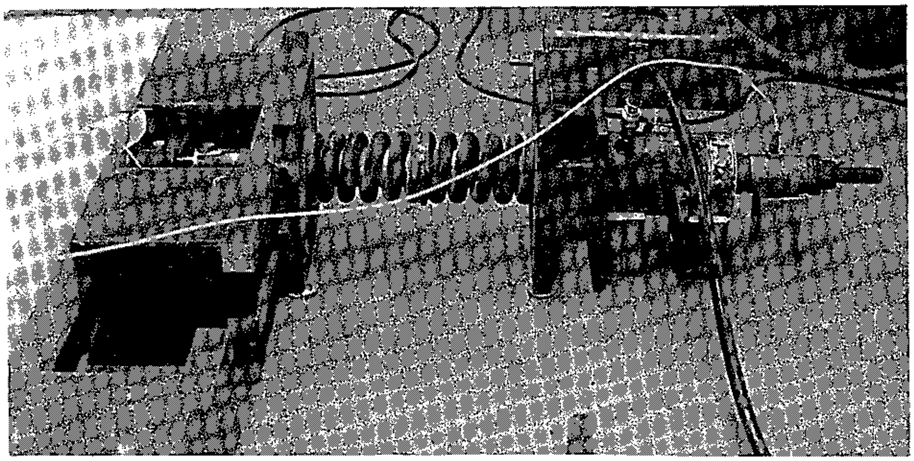


Figure 9. Testing apparatus used to apply sustained loads to resin capsule anchors installed in the edge of a slab in horizontal holes (Test Series 3 and 4).

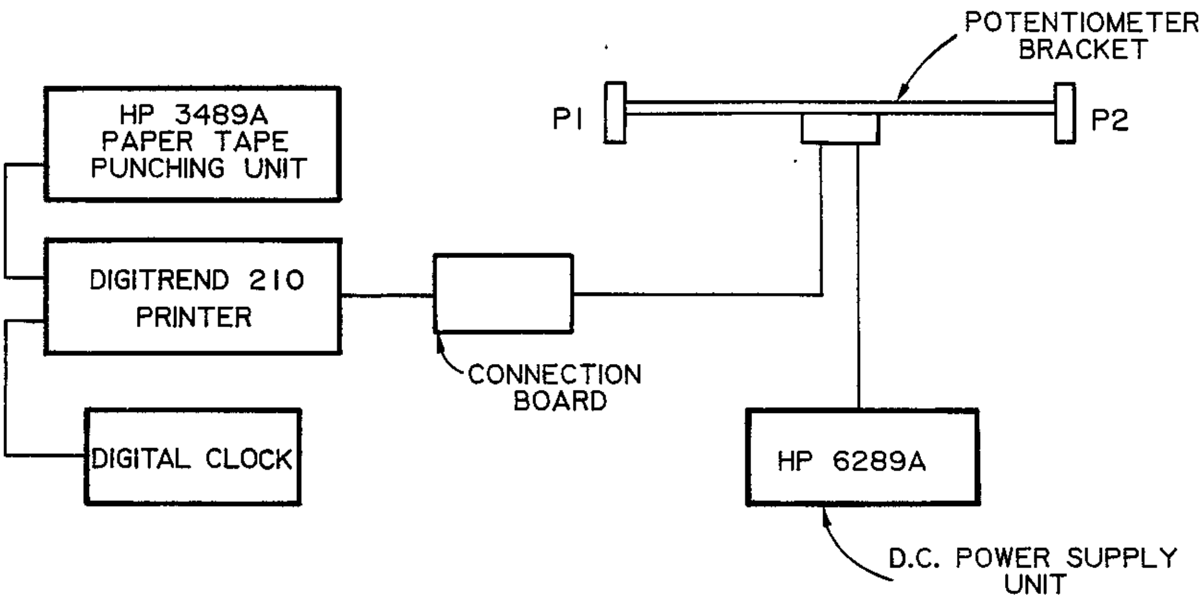


Figure 10. Displacement recording system.

After the 100-hour creep tests were completed, the sustained load was released and the spring apparatus was removed. Using the pull bar, hydraulic jack and support system (shown in Figure 15), the resin capsule anchors were subjected to short-term tensile loading to failure.

5. SUMMARY OF TEST RESULTS

General Summary:

All three brands of 3/4-inch-diameter resin capsule anchors evaluated in this research performed satisfactorily as tested. For all short-term creep tests, displacements measured after 100 hours of sustained loading were less than the maximum allowed for mechanical expansion anchors as specified in Section 75-1.03 of the Caltrans Standard Specifications.

In all pullout tests performed to determine the ultimate strengths of the resin anchorage systems, peak loads were limited by the strength of the concrete. Where threaded rods were installed in vertical holes, failure of the systems typically occurred when the concrete surrounding the rods spalled in a classical conical shape. Where rods were tested in vertical holes, the tensile cracks formed below the embedment depth and extended through the entire thickness of the unreinforced concrete slabs.

The bond strengths of all three of the polyester resins tested were excellent. No ultimate failures resulted from either low resin bond strength or tensile failure of the threaded steel rods.

Values of maximum creep/displacement of the resin capsule anchors tested are presented in Tables 1 to 4. Creep data of displacement versus time for these anchors are presented in Tables 5 to 8, and are graphically shown in Figures 16 through 27 .

The following sections are summaries of the four test series performed in this research project.

5.1 <u>Test Series 1</u>. In this series, resin capsule anchors were embedded 5 inches in vertical holes at a 4 3/8-inch edge distance and were creep tested under a sustained axial tensile load of 9450 pounds.

From test results shown in Figures 16, 17, and 18 (see pages 41 to 43), it was observed that, with the exception of one U.S.E. Diamond resin capsule anchor which failed prematurely, all capsule anchors performed satisfactorily. As shown in Table 5, displacement values after 100 hours of sustained loading for the eight remaining resin capsule anchors ranged from 0.009 to 0.025 inch. These displacement values are one-third to one-half of the 0.050-inch displacement limit previously specified for mechanical expansion anchors tested for a similar 100-hour sustained loading period.

Anchor No. 3, bonded with a U.S.E. Diamond resin capsule experienced gross slip and failed sometime between 21 and 23 hours after the initial test load had been applied. The sudden failure generated an impact load which fractured the concrete test slab (see Figure 12). The resulting crack passed through holes No. 7 (bonded with a Hilti capsule) and No. 9 (bonded with a Molly capsule). This impact loading and resulting crack caused both of these adjacent dowels to fail.

The specific locations of test specimens in the concrete test slab are shown in Figure 11.

It was observed that dowel No. 3 was fully bonded for only one-half of the desired 5-inch embedment depth. The cause of the lack of full bond is unknown.

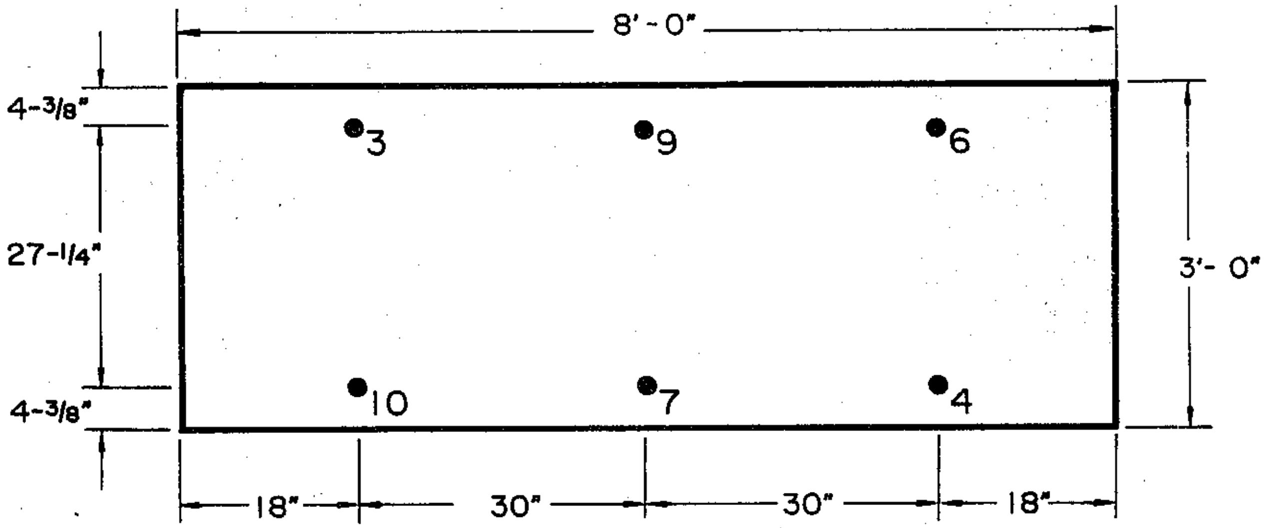


Figure 11. Plan view of slab used for Test Series 1 showing anchor locations.

After creep tests, resin capsule anchors were subjected to short-term tensile tests until failure occurred. As shown in Table 1, page 33 ultimate strengths varied between 13.4 and 15.3 kips. A typical failure mode is shown in Figure 13.

5.2 <u>Test Series 2</u>. In this series, resin capsule anchors were embedded 4 inches in vertical holes at a 4 3/8-inch edge distance, and were creep tested under a sustained axial tensile load of 4725 pounds.

Because the potentiometers used for the Test Anchor No. 2 were faulty, the data collected for that test were deemed invalid. Creep displacements of the remaining eight resin capsule anchors subjected to a 100-hour sustained axial

Figure 12. Fractured concrete slab used in Test Series 1.

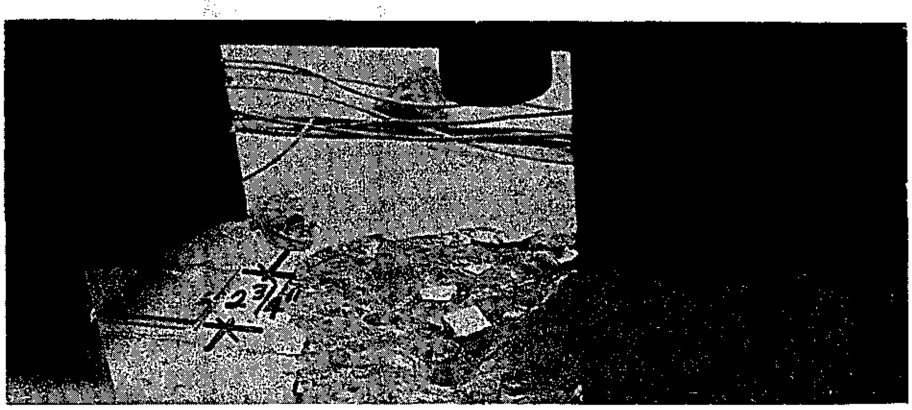


Figure 13. Typical cone failure in concrete slab after an ultimate load test on a resin capsule anchor bonded in a 5-inch-deep hole and installed at a 4 3/8-inch edge distance.

tensile test load were very small and varied between zero and 0.004 inch. Data and plots of creep-versus-time for these resin capsule anchors are presented in Table 6 and Figures 19 through 21.

After creep tests, resin capsule anchors were subjected to short-term tensile load tests until failure occurred. As shown in Table 2, their ultimate strengths varied between 10.7 and 14.1 kips.

5.3 Test Series 3. In this series, resin capsule anchors were embedded 5 inches in horizontal holes at a 2 3/4-inch edge distance, and were creep tested under a sustained axial tensile load of 9450 pounds.

As shown in Figure 14, resin capsule anchors in this test series were installed horizontally at a 2 3/4-inch edge distance to simulate anchors located in the edge of a 6 to 7-inch-thick bridge deck overhang and used for attaching overhead signs. Results of Test No. 7 were deemed invalid as the nut was threaded only half way onto anchor rod No. 7 and could not withstand the above mentioned sustained load. The nut threads stripped sometime between four and seven hours of sustained load testing.

From test results shown in Table 7 and Figures 22, 23, and 24 (see pages 39 and 47 to 49), it was observed that, with the exception of test anchor No. 7 which failed prematurely, all resin capsule anchors performed satisfactorily. Creep values for those remaining resin capsule anchors tested for 100 hours ranged from 0.005 to 0.009 inch. These are very small and are considered negligible when compared to the 0.050-inch displacement limit previously permitted for mechanical expansion anchors.

Ultimate strengths of the resin capsule anchor systems determined following the creep tests varied from 15.3 to 21.1 kips.

The slabs used in this test series were cast on March 9, 1983 and exhibited a 28-day compressive strength of from 5090 to 5110 psi. At the time creep testing was performed, the compressive strength of the well-aged concrete slabs had increased to between 6000 and 6900 psi. This was much higher than that of the slabs used in Test Series 1. Despite the smaller 2 3/4-inch edge distance, creep values determined in Test Series 3 were significantly lower and ultimate strengths, limited only by the tensile strength of the concrete, were higher than those found in the first test series. Evidently, higher concrete strength caused a significant increase in the tensile capacity of the concrete and also a reduction in creep of these anchors.

5.4 Test Series 4. In this series, resin capsule anchors were installed in 4-inch-deep horizontal holes at a 2 3/4-inch edge distance, and were creep tested under a sustained axial tensile test load of 4725 pounds.

Displacements due to creep were very small and varied between zero and 0.004 inch. Data and plots of creep-versus-time for the test anchors are presented in Table 8 and Figures 25 through 27.

After creep tests, resin capsule anchors were subjected to short-term tensile loading until failure occurred. As shown in Table 4, ultimate strengths varied between 13.2 and 15.1 kips.

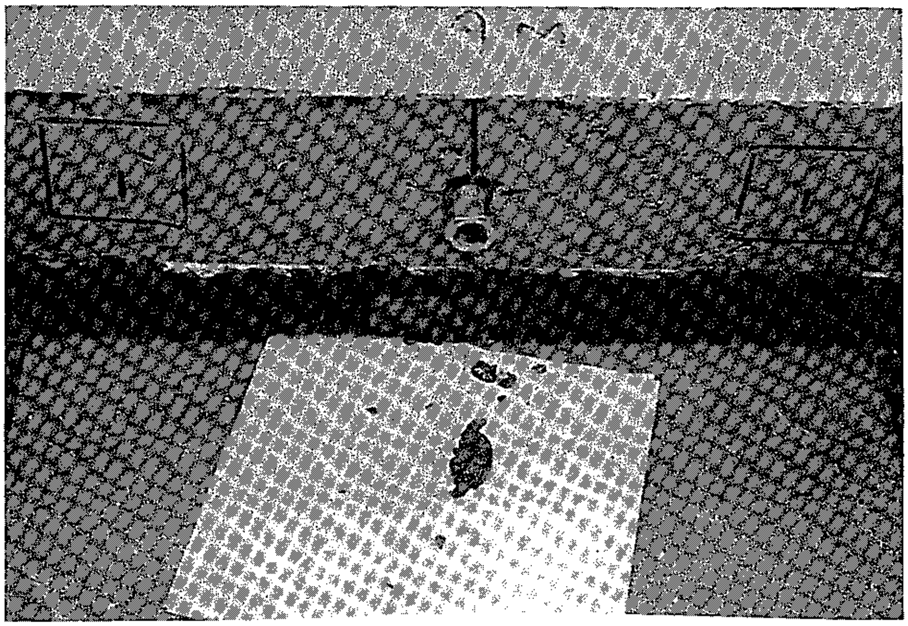


Figure 14. Resin capsule anchor installed in a horizontal hole at a 2 3/4-inch edge distance (Test Series 3).

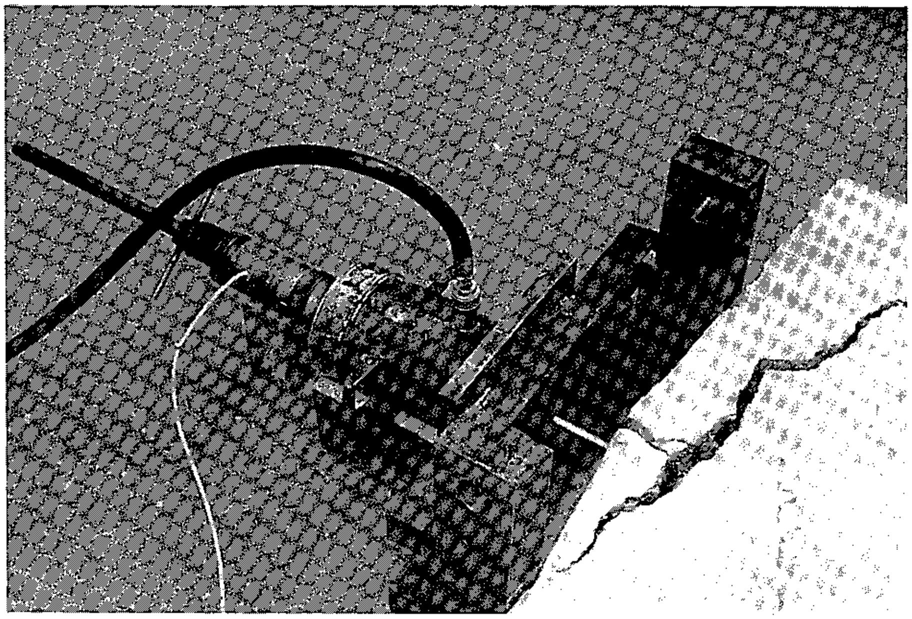


Figure 15. Typical failure in concrete slab after ultimate tensile load test on resin capsule anchor bonded in a 5-inch-deep horizontal hole and installed at a 2 3/4-inch edge distance (Test Series 3).

As discussed previously, the well aged concrete slabs used in this test series (compressive strength of 5800 to 6000 psi) were stronger than those used in Test Series 2 (compressive strength of 5100 to 5300 psi). Since the tensile strength of concrete appears to govern the ultimate strength of these shallowly embedded resin anchor systems, resin capsule anchors tested in Test Series 4, even though installed at a smaller edge distance of only 2 3/4 inches, could resist higher ultimate loads than those in Series 2, installed at a 4 3/8-inch edge distance.

REFERENCES

1. Dusel, J. P. and Andersen, D. H., "Evaluation of 1 1/4-Inch-Diameter Resin Capsule Anchors for Securing Lateral Earthquake Motion Restrainers to Concrete Bridge Piers," January 14, 1985 "Memo to File," Caltrans Transportation Laboratory.

2. AASHTO Technical Committee for Structural Supports for Signs, Luminaires, and Traffic Signals, "Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals Draft No. 2, February 1, 1984.

3. "Standard Specifications for Highway Bridges," AASHTO, 1977, with interim specification changes to 1981.

4. "Memo to Designers 21-41," Cast-in-place, Epoxied and Grouted Anchorages, pp. 3 and 4, Caltrans Office of Structures Design, December 1982.

5. Standard Special Provision B51.60, "Drill and Bond Dowels," California Department of Transportation, 7-2-84.

6. "Standard Specifications," Sections 51-1.13, Bonding, and 75-1.03, Miscellaneous Bridge Metal, pp. 51-24 and 75-2 through 75-4, California Department of Transportation, July 1984.

Table 1. Displacement/Creep of Resin Capsule Anchors Evaluated in a 100-Hour Creep Test, Test Series 1.

Test Date: 6-22-84

Magnitude of Sustained Load: 9450 pounds

Slab Thickness: 7 1/2 inches
Concrete Compressive Strength at Creep Test: 5300 - 5400 psi

Rod Diameter: 3/4 inch
Hole Diameter: 7/8 inch
Hole Orientation: Vertical
Embedment Depth: 5 inches
Edge Distance: 4 3/8 inches
Installation Torque: 160 ft-lb

Anchor No.	Test No.	Brand of Resin Capsule Anchor	Resin Cure Time (hours)	Displacement/Creep (inch) After 100-Hour Creep Test	Ultimate Strength of System (kips)	Failure Mode
2	1	U.S.E. Diamond	24	0.016	13.4	Concrete Cone
3	2	U.S.E. Diamond	24	Invalid Test		
4	3	U.S.E. Diamond	24	0.013	14.3	Concrete Cone
5	4	Hilti	24	0.021	15.3	Concrete Cone
6	5	Hilti	24	0.015	15.1	Concrete Cone
7	6	Hilti	24	Invalid Test		
8	7	Molly	24	0.009	15.0	Concrete splitting in tension
9	8	Molly	24	Invalid Test		
10	9	Molly	24	0.025	13.8	Concrete Cone

Table 2. Displacement/Creep of Resin Capsule Anchors Evaluated in a 100-Hour Creep Test, Test Series 2.

Test Date: 7-9-84

Magnitude of Sustained Load: 4725 pounds

Slab Thickness: 7 1/2 inches
Concrete Compressive Strength: 5000 - 5300 psi
at Creep Test

Rod Diameter: 3/4 inch
Hole Diameter: 7/8 inch
Hole Orientation: Vertical
Embedment Depth: 4 inches
Edge Distance: 4 3/8 inches
Installation Torque: 160 ft-lb

Anchor No.	Test No.	Brand of Resin Capsule Anchor	Resin Cure Time (hours)	Displacement/Creep (inch) After 100-Hour Creep Test	Ultimate Strength of System (kips)	Failure Mode
5	1	U.S.E. Diamond	24	0.001	13.8	Concrete Cone
6	2	U.S.E. Diamond	24	0.003	11.2	Concrete Cone
7	3	U.S.E. Diamond	24	0.000	12.7	Concrete Cone
2	4	Hilti	24	0.032	13.5	Concrete Cracked
3	5	Hilti	24	0.004	14.1	Concrete Cracked
4	6	Hilti	24	-0.001	11.1	Concrete Cracked
8	7	Molly	24	0.003	11.2	Concrete Cone
9	8	Molly	24	0.000	11.0	Concrete splitting in tension
10	9	Molly	24	0.002	10.7	Concrete splitting in tension

Table 3. Displacement/Creep of Resin Capsule Anchors Evaluated in a 100-Hour Creep Test, Test Series 3.

Test Date: 7-31-84

Magnitude of Sustained Load: 9450 pounds

Slab Thickness: 5 1/2 inches
Concrete Compressive Strength at Creep Test: 6000 - 6900 psi

Rod Diameter: 3/4 inch
Hole Diameter: 7/8 inch
Hole Orientation: Horizontal
Embedment Depth: 5 inches
Edge Distance: 2 3/4 inches
Installation Torque: 160 ft-lb

Anchor No.	Test No.	Brand of Resin Capsule Anchor	Resin Cure Time (hours)	Displacement/Creep (inch) After 100-Hour Creep Test	Ultimate Strength of System (kips)	Failure Mode
2	1	U.S.E. Diamond	24	0.005	*	Slab Cracked
3	2	U.S.E. Diamond	24	0.002	15.3	Concrete Cracked
4	3	U.S.E. Diamond	24	0.003	21.1	Concrete splitting in tension
5	4	Hilti	24	0.004	17.3	Concrete splitting in tension
6	5	Hilti	24	0.007	17.0	-
7	6	Hilti	24	Invalid Test	Invalid Test	Nut Stripped
8	7	Molly	24	0.009	18.0	Concrete splitting in tension
9	8	Molly	24	0.005	17.7	Concrete splitting in tension
10	9	Molly	24	0.004	19.0	Concrete Cracked

*Slab cracked through anchor #10 causing anchor #2 to fail prematurely.

Table 4. Displacement/Creep of Resin Capsule Anchors Evaluated in a 100-Hour Creep Test, Test Series 4.

Test Date: 8-15-84

Magnitude of Sustained Load: 4725 pounds

Slab Thickness: 5 1/2 inches
Concrete Compressive Strength: 5800 - 6050 psi
at Creep Test

Rod Diameter: 3/4 inch
Hole Diameter: 7/8 inch
Hole Orientation: Horizontal
Embedment Depth: 4 inches
Edge Distance: 2 3/4 inches
Installation Torque: 160 ft-lb

Anchor No.	Test No.	Brand of Resin Capsule Anchor	Resin Cure Time (hours)	Displacement/Creep (inch) After 100-Hour Creep Test	Ultimate Strength of System (kips)	Failure Mode
8	1	U.S.E. Diamond	24	0.004	13.3	Concrete splitting in tension
9	2	U.S.E. Diamond	24	0.001	14.5	Concrete splitting in tension
10	3	U.S.E. Diamond	24	0.002	14.2	Concrete splitting in tension
2	4	Hilti	24	0.000	13.7	Concrete splitting in tension
3	5	Hilti	24	0.003	15.1	Concrete splitting in tension
4	6	Hilti	24	0.005	14.4	Concrete splitting in tension
5	7	Molly	24	0.001	14.0	Concrete splitting in tension
6	8	Molly	24	0.002	13.2	Concrete splitting in tension
7	9	Molly	24	0.003	14.2	Concrete splitting in tension

Table 5. Displacement/Creep versus Time of Resin Capsule Anchors During 100-Hour Creep Test, Test Series No. 1

Test Date: 6-22-84

Magnitude of Sustained Load: 9450 pounds
Slab Thickness : 7 1/2 inches
Concrete Compressive Strength @ Creep Test : 5300-5400 psi
Installation Torque : 160 ft-lb

Rod Diameter : 3/4 inch
Hole Diameter : 7/8 inch
Hole Orientation: Vertical
Embedment Depth : 5 inches
Edge Distance : 4 3/8 inches

1	2		3		4		5	
	U.S.E. Diamond		U.S.E. Diamond		U.S.E. Diamond		Hilti	
	Time	Move	Time	Move	Time	Move	Time	Move
	0	0.000	0	0.000	0	0.000	0	0.000
	0	0.007	0	0.005	0	0.004	0	0.010
	11	0.010	1	0.008	16	0.007	2	0.013
	15	0.011	5	0.012	32	0.009	16	0.016
	31	0.013	11	0.017	48	0.010	32	0.018
	47	0.014	15	0.021	64	0.012	48	0.019
	63	0.014	19	0.027	80	0.013	64	0.020
	79	0.016	21	0.033	98	0.013	80	0.021
	97	0.016	23	0.458			98	0.021
				Invalid				

6		7		8		9		10	
Hilti		Hilti		Molly		Molly		Molly	
Time	Move	Time	Move	Time	Move	Time	Move	Time	Move
0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
0	0.005	0	0.006	0	0.004	0	0.004	0	0.014
12	0.009	0	0.010	17	0.007	2	0.007	4	0.017
16	0.009	13	0.014	33	0.007	9	0.010	16	0.019
32	0.011	17	0.014	49	0.008	15	0.011	32	0.022
48	0.012	25	0.493	65	0.009	25	0.504	48	0.023
64	0.014		Invalid	81	0.009		Invalid	64	0.024
80	0.014			99	0.009			80	0.024
98	0.015							96	0.025
								112	0.025

NOTE: Cumulative displacement/creep is shown in inches. Time is shown in hours.

Table 6. Displacement/Creep versus Time of Resin Capsule Anchors During 100-Hour Creep Test, Test Series No. 2

Test Date: 7-9-84

Magnitude of Sustained Load: 4725 pounds
Slab Thickness : 7 1/2 inches
Concrete Compressive
Strength @ Creep Test : 5000-5300 psi
Installation Torque : 160 ft-lb

Rod Diameter : 3/4 inch
Hole Diameter : 7/8 inch
Hole Orientation: Vertical
Embedment Depth : 4 inches
Edge Distance : 4 3/8 inches

1	2		3		4		5	
	Hilti		Hilti		Hilti		U.S.E. Diamond	
	Time	Move	Time	Move	Time	Move	Time	Move
	0	0.000	0	0.000	0	0.000	0	0.000
	0	0.009	10	0.003	16	-.000	16	0.000
	4	0.028	16	0.003	32	-.001	32	0.000
	16	0.027	32	0.003	48	-.001	48	0.001
	20	0.034	48	0.003	66	-.001	66	0.001
	30	0.029	66	0.003	82	-.001	82	0.001
	32	0.028	82	0.004	98	-.001	98	0.001
	44	0.033	98	0.004	114	-.001	114	0.001
	48	0.032	114	0.003				
	56	0.029						
	66	0.030						
	68	0.033						
	82	0.031						
	94	0.035						
	98	0.034						
	108	0.030						
	114	0.033						

6		7		8		9		10	
U.S.E. Diamond		U.S.E. Diamond		Molly		Molly		Molly	
Time	Move	Time	Move	Time	Move	Time	Move	Time	Move
0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
16	0.002	16	-.001	16	0.002	17	-.000	17	0.000
32	0.002	32	-.001	32	0.002	33	0.000	33	0.000
48	0.002	48	-.001	48	0.002	49	0.000	49	0.000
66	0.003	66	-.000	66	0.002	67	0.000	67	0.000
82	0.003	82	-.000	82	0.002	83	-.000	83	0.001
98	0.002	98	-.000	98	0.003	99	0.000	99	0.001
114	0.003	114	0.000	114	0.002	115	-.000	115	0.001

NOTE: Cumulative displacement/creep is shown in inches. Time is shown in hours.

Table 7. Displacement/Creep versus Time of Resin Capsule Anchors During 100-Hour Creep Test, Test Series No. 3

Test Date: 7-31-84

Magnitude of Sustained Load: 9450 pounds
Slab Thickness: 5 1/2 inches
Concrete Compressive Strength @ Creep Test: 6000-6900 psi
Installation Torque: 160 ft-lb

Rod Diameter: 3/4 inch
Hole Diameter: 7/8 inch
Hole Orientation: Horizontal
Embedment Depth: 5 inches
Edge Distance: 2 3/4 inch

1	2		3		4		5	
	U.S.E. Diamond		U.S.E. Diamond		U.S.E. Diamond		Hilti	
	Time	Move	Time	Move	Time	Move	Time	Move
	0	0.000	0	0.000	0	0.000	0	0.000
	0	0.003	15	0.002	2	0.003	0	0.003
	15	0.003	42	0.002	16	0.003	16	0.003
	42	0.003	59	0.002	35	0.003	35	0.004
	59	0.004	75	0.002	52	0.004	52	0.004
	75	0.004	91	0.002	68	0.003	68	0.004
	91	0.004	107	0.002	84	0.003	84	0.004
	107	0.005	123	0.003	100	0.003	100	0.004
	123	0.005	139	0.003	118	0.004	118	0.004
	139	0.005	155	0.004	134	0.004	134	0.004
	155	0.005			150	0.004	150	0.004

6		7		8		9		10	
Hilti		Hilti		Molly		Molly		Molly	
Time	Move	Time	Move	Time	Move	Time	Move	Time	Move
0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
0	0.004	0	0.006	0	0.006	0	0.004	19	0.003
16	0.006	4	0.009	18	0.008	19	0.005	40	0.003
37	0.006	7	0.523	39	0.008	40	0.005	57	0.003
54	0.006		Invalid	56	0.009	56	0.005	73	0.004
70	0.007			72	0.009	72	0.005	89	0.004
86	0.007			88	0.009	88	0.005	105	0.004
102	0.007			104	0.009	104	0.005	123	0.004
120	0.008			122	0.009	122	0.005	139	0.004
136	0.008			138	0.010	138	0.006	155	0.004
152	0.008			154	0.010	154	0.006		

NOTE: Cumulative displacement/creep is shown in inches. Time is shown in hours.

Table 8. Displacement/Creep versus Time of Resin Capsule Anchors During 100-Hour Creep Test, Test Series No. 4

Test Date: 8-15-84

Magnitude of Sustained Load: 4725 pounds
Slab Thickness: : 5 1/2 inches
Concrete Compressive
Strength @ Creep Test : 5800-6050 psi
Installation Torque : 160 ft-lb

Rod Diameter : 3/4 inch
Hole Diameter : 7/8 inch
Hole Orientation: Horizontal
Embedment Depth : 4 inches
Edge Distance : 2 3/4 inches

1	2		3		4		5	
	Hilti		Hilti		Hilti		Molly	
	Time	Move	Time	Move	Time	Move	Time	Move
	0	0.000	0	0.000	0	0.000	0	0.000
	16	-.001	16	0.002	17	0.003	17	0.000
	40	-.000	40	0.003	41	0.004	41	0.001
	56	-.000	56	0.003	57	0.004	57	0.001
	72	-.000	72	0.003	73	0.004	73	0.001
	88	-.000	88	0.003	89	0.005	89	0.001
	104	-.000	104	0.003	105	0.005	105	0.001

6		7		8		9		10	
Molly		Molly		U.S.E. Diamond		U.S.E. Diamond		U.S.E. Diamond	
Time	Move	Time	Move	Time	Move	Time	Move	Time	Move
0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
15	0.001	15	0.002	16	0.003	16	0.000	16	0.001
31	0.001	31	0.002	32	0.003	32	0.001	32	0.001
47	0.001	47	0.002	48	0.003	48	0.001	48	0.002
63	0.002	63	0.002	64	0.004	64	0.001	64	0.002
79	0.002	79	0.003	80	0.004	80	0.001	80	0.002
97	0.002	97	0.003	98	0.004	98	0.001	98	0.002

NOTE: Cumulative displacement/creep is shown in inches. Time is shown in hours.

FIGURE 16. CREEP vs. TIME PLOT FOR U.S.E. DIAMOND RESIN CAPSULE ANCHORS

DATA SUMMARY

Test series: 1   Anchor No.: 2,3,4.
Test date: 6-22-84
Magnitude of sustained load: 9.4 kips
Creep: 0.016 (max) in. @ 100 hrs

Brand of resin anchor: U.S.E. DIAMOND
Resin cure time: 24 hrs
Concrete's compressive strength: 5300-5400 psi

Rod diameter: 3/4 in.
Hole diameter: 7/8 in.
Slab thickness: 7-1/2 in.
embedment depth: 5 in.
edge distance: 4-3/8"

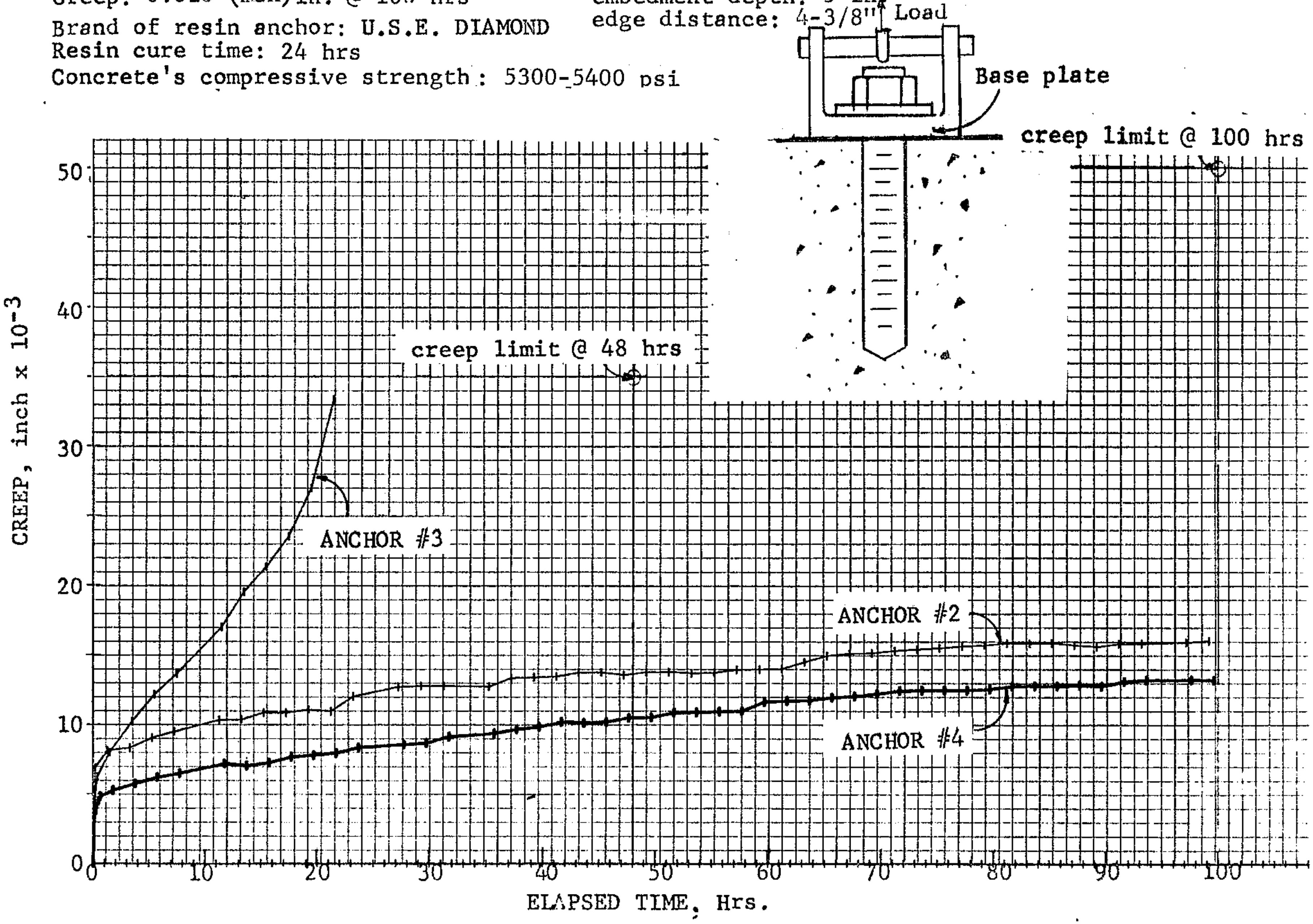


FIGURE 17. CREEP vs. TIME PLOT FOR HILTI RESIN CAPSULE ANCHORS

DATA SUMMARY

Test series: 1 Anchor No.: 5,6,7.
Test date: 6-22-84
Magnitude of sustained load: 9.4kips
Creep: 0.021 (max) in. @ 100 hrs
Brand of resin anchor: HILTI
Resin cure time: 100 hrs
Concrete's compressive strength: 5300-5400 psi

Rod diameter: 3/4 in.
Hole diameter: 7/8 in.
Slab thickness: 7-1/2 in.
embedment depth: 5 in.
edge distance: 4-3/8"

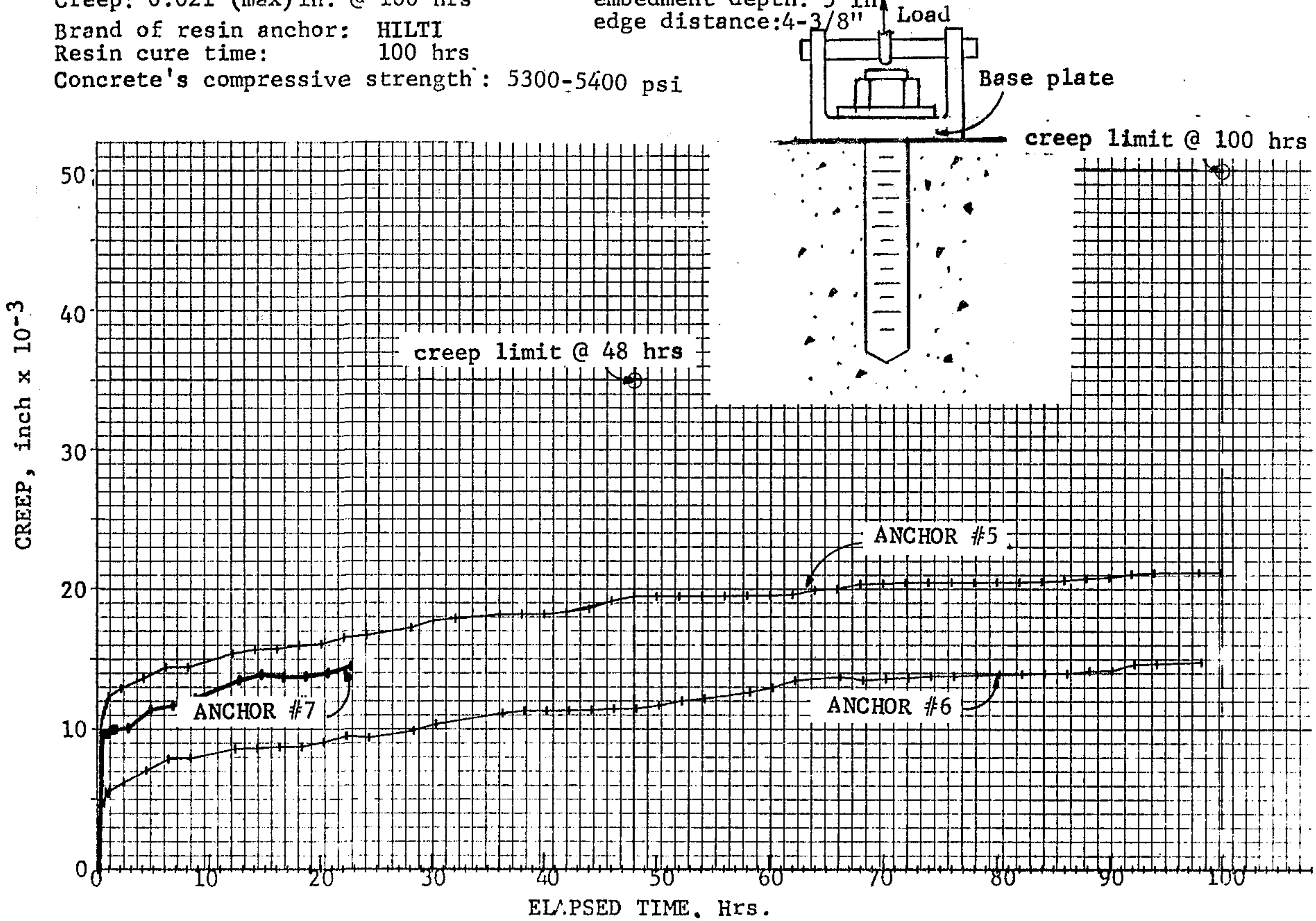


FIGURE 18. CREEP vs. TIME PLOT FOR MOLLY RESIN CAPSULE ANCHORS

DATA SUMMARY

Test series: 1 Anchor No.: 8,9,10.
Test date: 6-22-84
Magnitude of sustained load: 9.4kips
Creep: 0.025 (min) in. @ 100 hrs
Brand of resin anchor: MOLLY
Resin cure time: 100 hrs
Cor[illegible] compressive strength: 5300-5400 psi

Rod diameter: 3/4 in.
Hole diameter: 7/8 in.
Slab thickness: 7-1/2 in.
embedment depth: 5 in.
edge distance: 4-3/8"

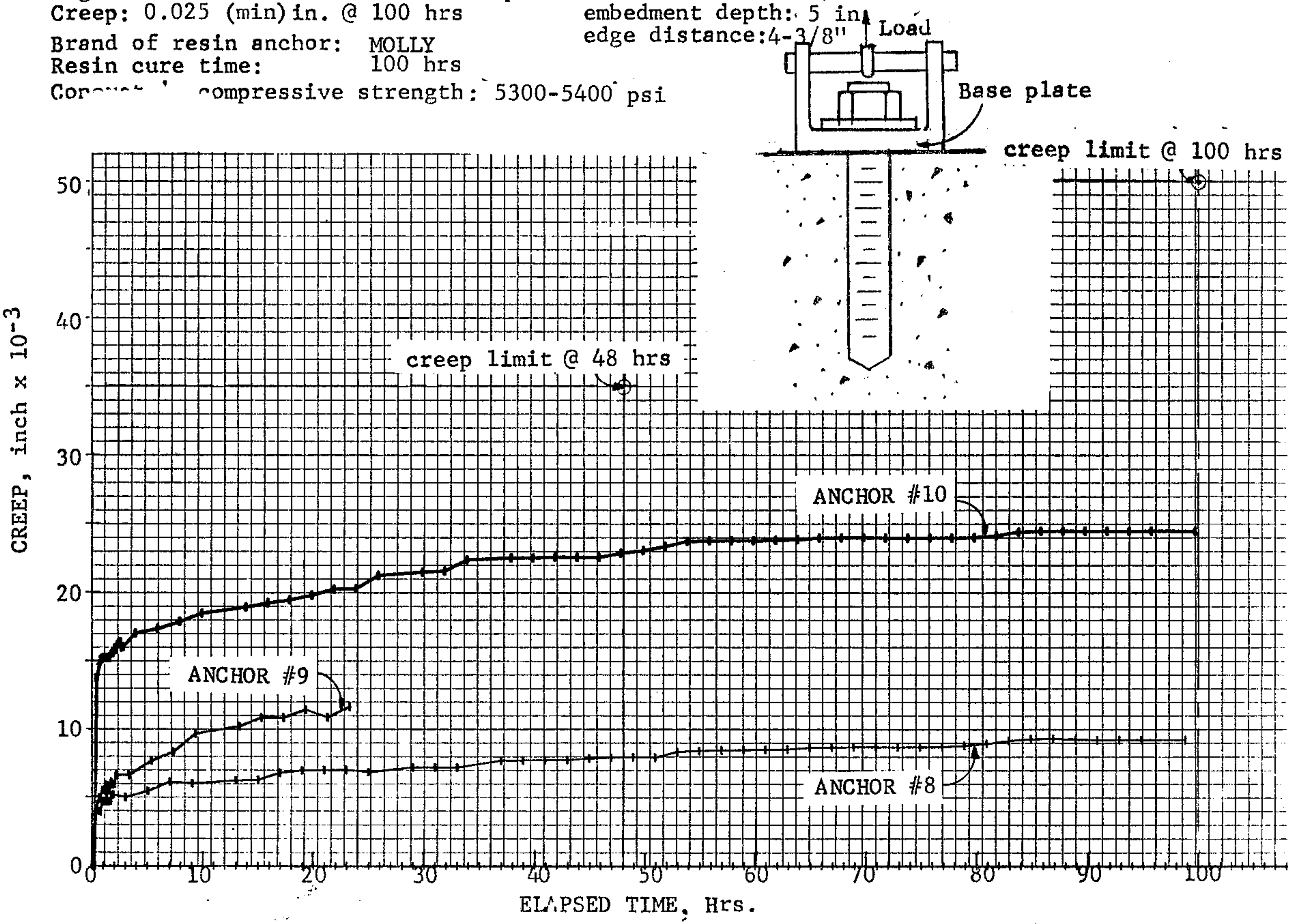


FIGURE 19. CREEP vs. TIME PLOT FOR U.S.E. DIAMOND RESIN CAPSULE ANCHORS

DATA SUMMARY

Test series: 2   Anchor No.: 5,6,7.
Test date: 7-9-84
Magnitude of sustained load: 4.73 kips
Creep: 0.003 (max) in. @ 100 hrs
Brand of resin anchor: U.S.E. DIAMOND
Resin cure time: 24 hrs
Concrete's compressive strength : 5000-5300 psi

Rod diameter: 3/4 in.
Hole diameter: 7/8 in.
Slab thickness: 7-1/2 in.
embedment depth: 4 in.
edge distance: 4-3/8"

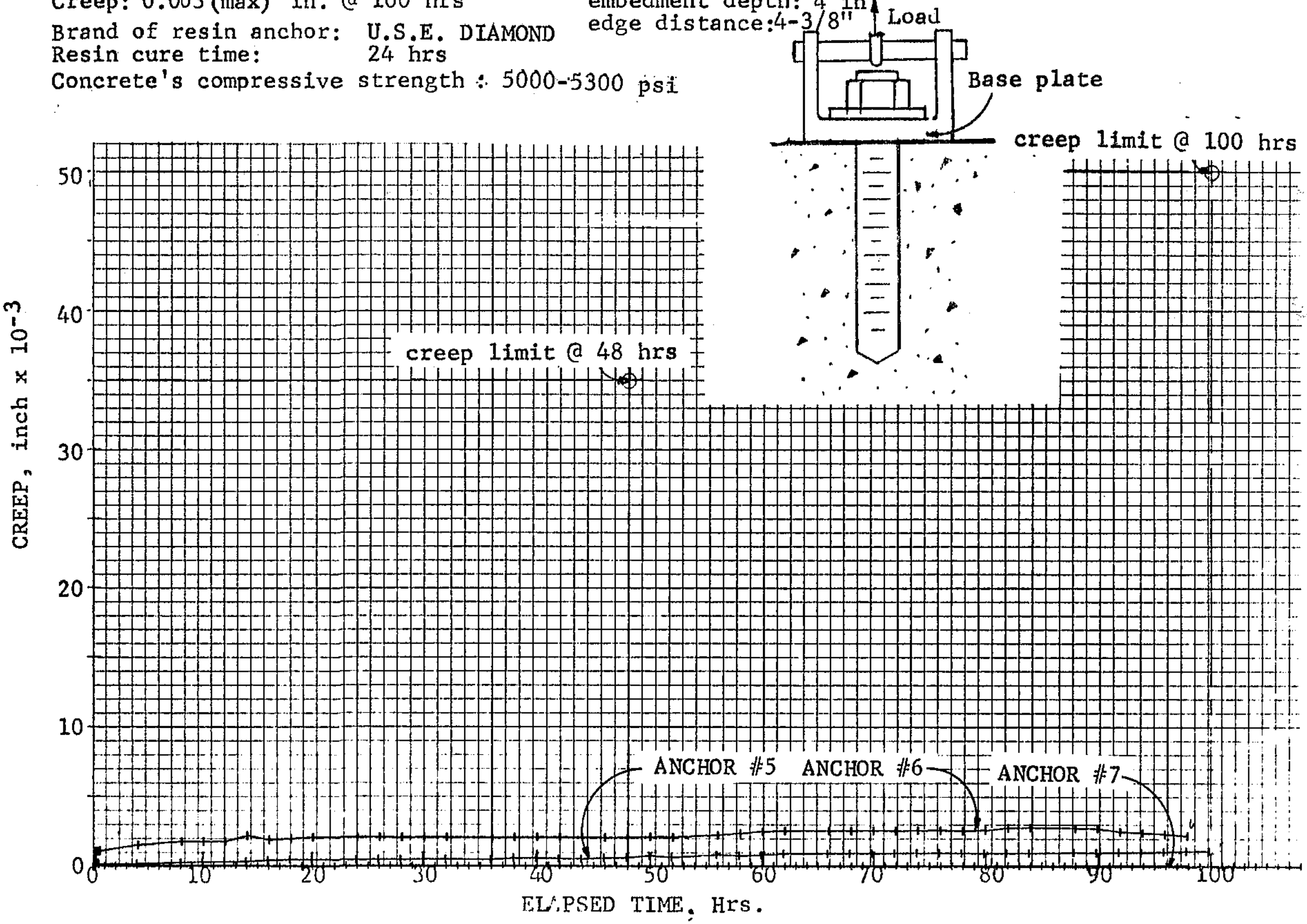


FIGURE 20. CREEP vs. TIME PLOT FOR <u>HILTI</u> RESIN CAPSULE ANCHORS

DATA SUMMARY

Test series: 2 Anchor No.: 3 and 4
Test date: 7-9-84
Magnitude of sustained load: 4.73kips
Creep: 0.004 (max) in. @ 100 hrs
Brand of resin anchor: HILTI
Resin cure time: 24 hrs.
Concrete's compressive strength : 5000-5300 psi

Rod diameter: 3/4 in.
Hole diameter: 7/8 in.
Slab thickness: 7-1/2 in.
embedment depth: 4 in.
edge distance: 4-3/8"

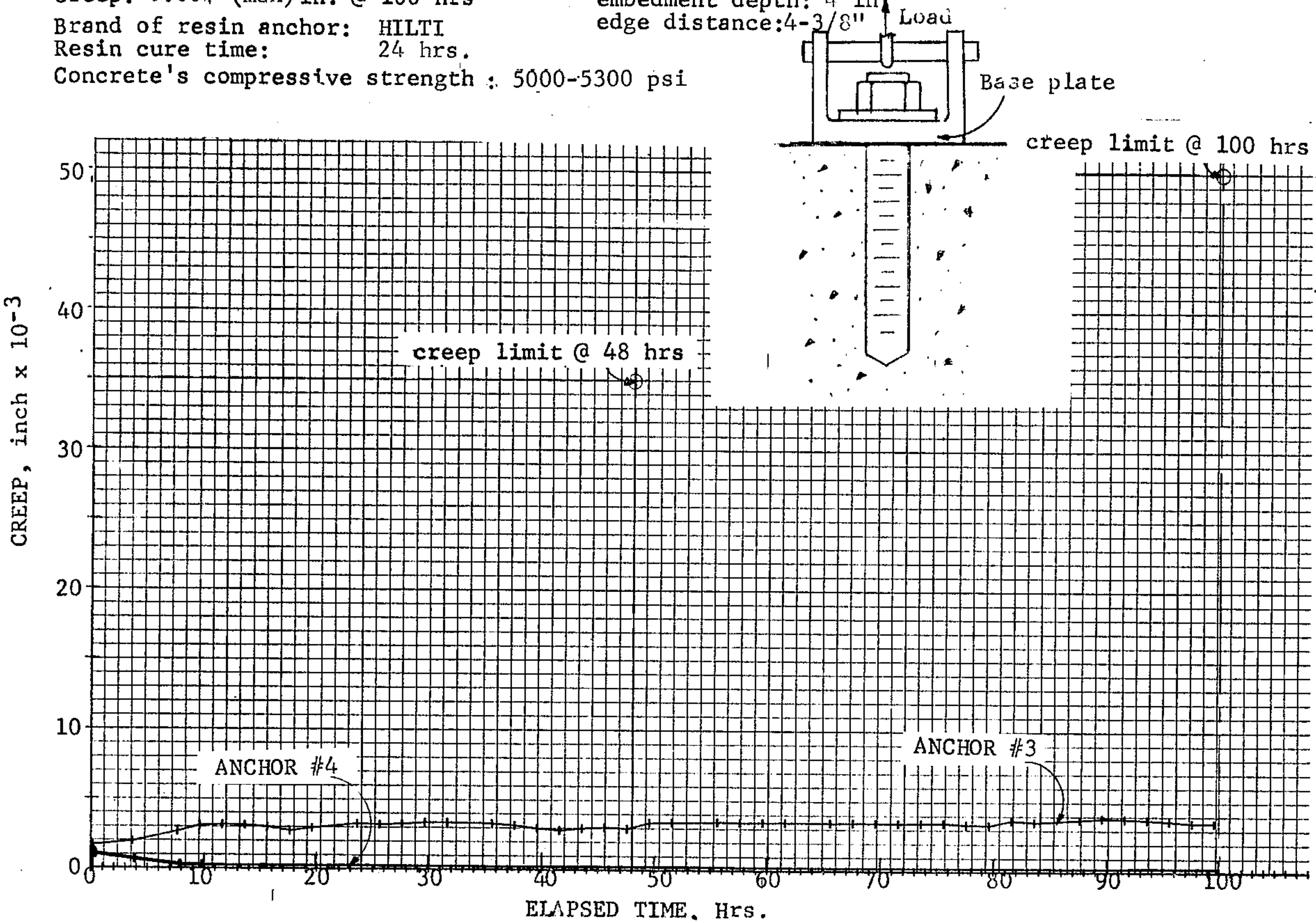


FIGURE 21. CREEP vs. TIME PLOT FOR MOLLY RESIN CAPSULE ANCHORS

DATA SUMMARY

Test series: 2 Anchor No.: 8,9,10
Test date: 7-9-84
Magnitude of sustained load: 4.73kips
Creep: 0.003 (max) in. @ 100 hrs
Brand of resin anchor: MOLLY
Resin cure time: 24 hrs
Concrete's compressive strength : 5000-5300 psi

Rod diameter: 3/4 in.
Hole diameter: 7/8 in.
Slab thickness: 7-1/2 in.
embedment depth: 4 in.
edge distance: 4-3/8"

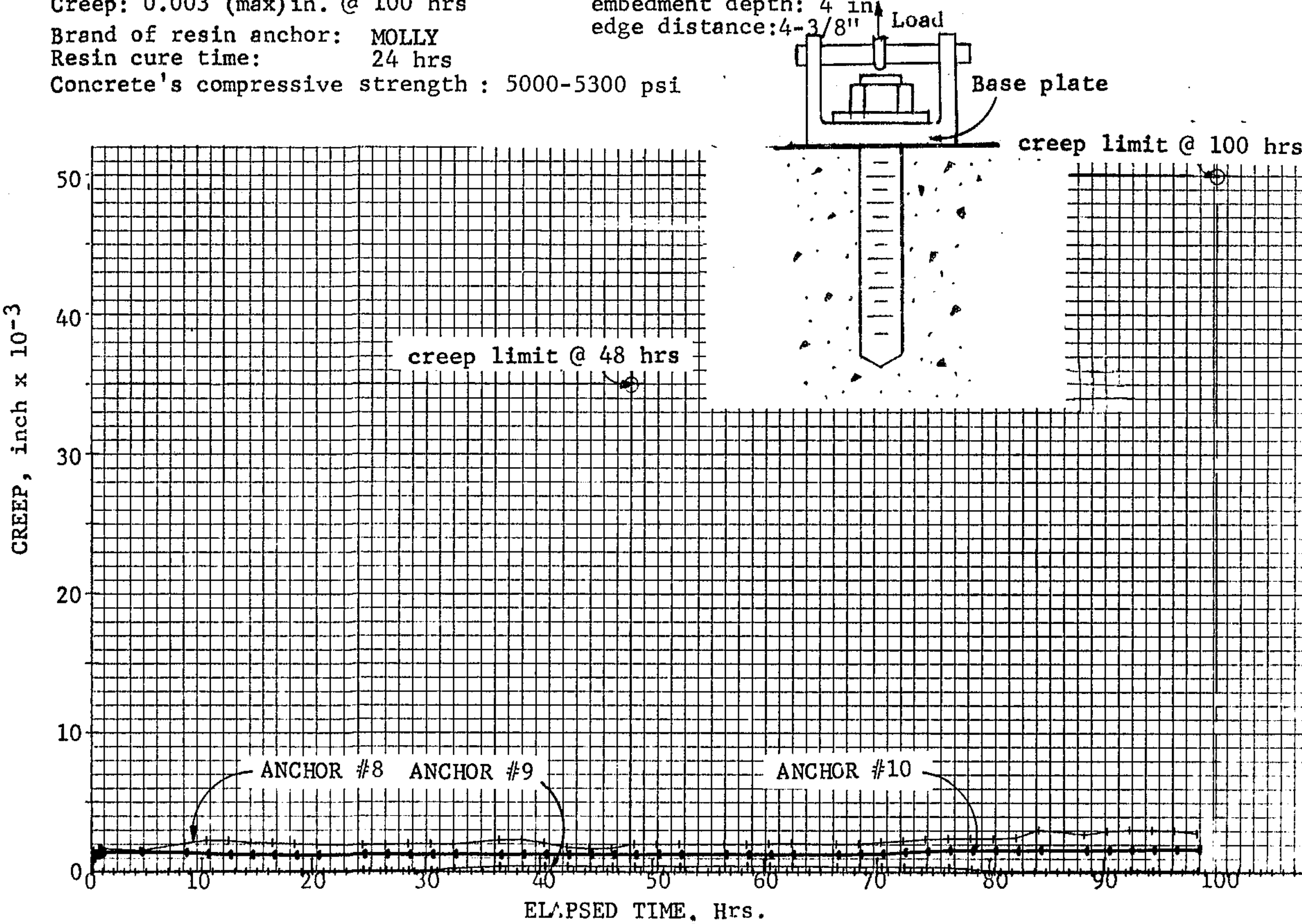


FIGURE 22. CREEP vs. TIME PLOT FOR U.S.E. DIAMOND RESIN CAPSULE ANCHORS

DATA SUMMARY

Test series: 3 Anchor No.: 2,3,4.
Test date: 7-31-84
Magnitude of sustained load: 9.45 kips
Creep: 0.005 (max) in. @ 100 hrs
Brand of resin anchor: U.S.E. Diamond
Resin cure time: 24 hours
Concrete's compressive strength: 6000-6900 psi

Rod diameter: 3/4 in.
Hole diameter: 7/8 in.
Slab thickness: 5-1/2 in.
embedment depth: 5 in
edge distance: 2-3/4"

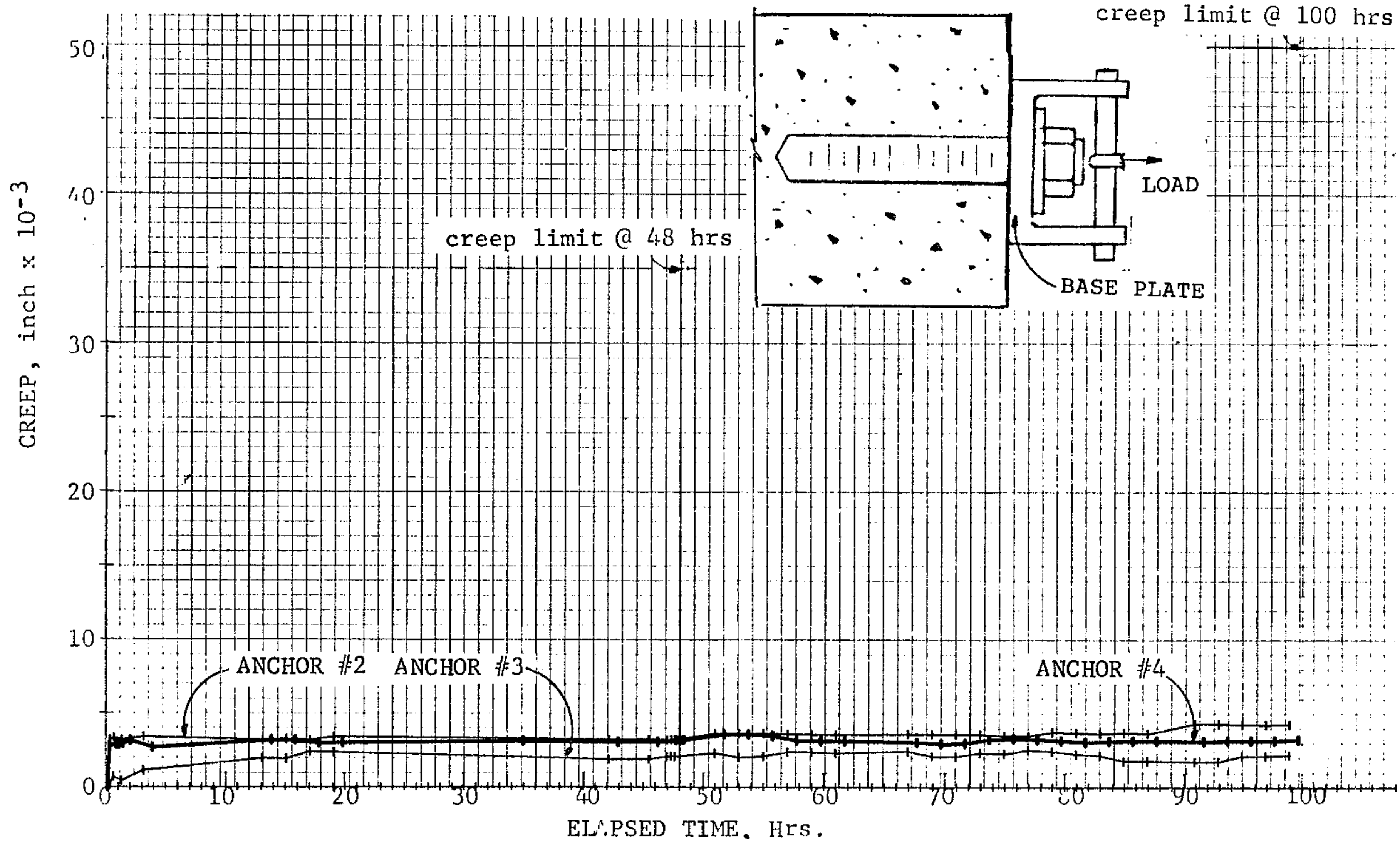


FIGURE 23. CREEP vs. TIME PLOT FOR HILTI RESIN CAPSULE ANCHORS

DATA SUMMARY

Test series: 3 Anchor No.: 5,6,7.
Test date: 7-31-84
Magnitude of sustained load: 9.45 kips
Creep: 0.007 (max) in. @ 100 hrs
Brand of resin anchor: HILTI
Resin cure time: 24 hrs
Concrete's compressive strength: 6000-6900 psi

Rod diameter: 3/4 in.
Hole diameter: 7/8 in.
Slab thickness: 5-1/2 in.
embedment depth: 5 in
edge distance: 2-3/4"

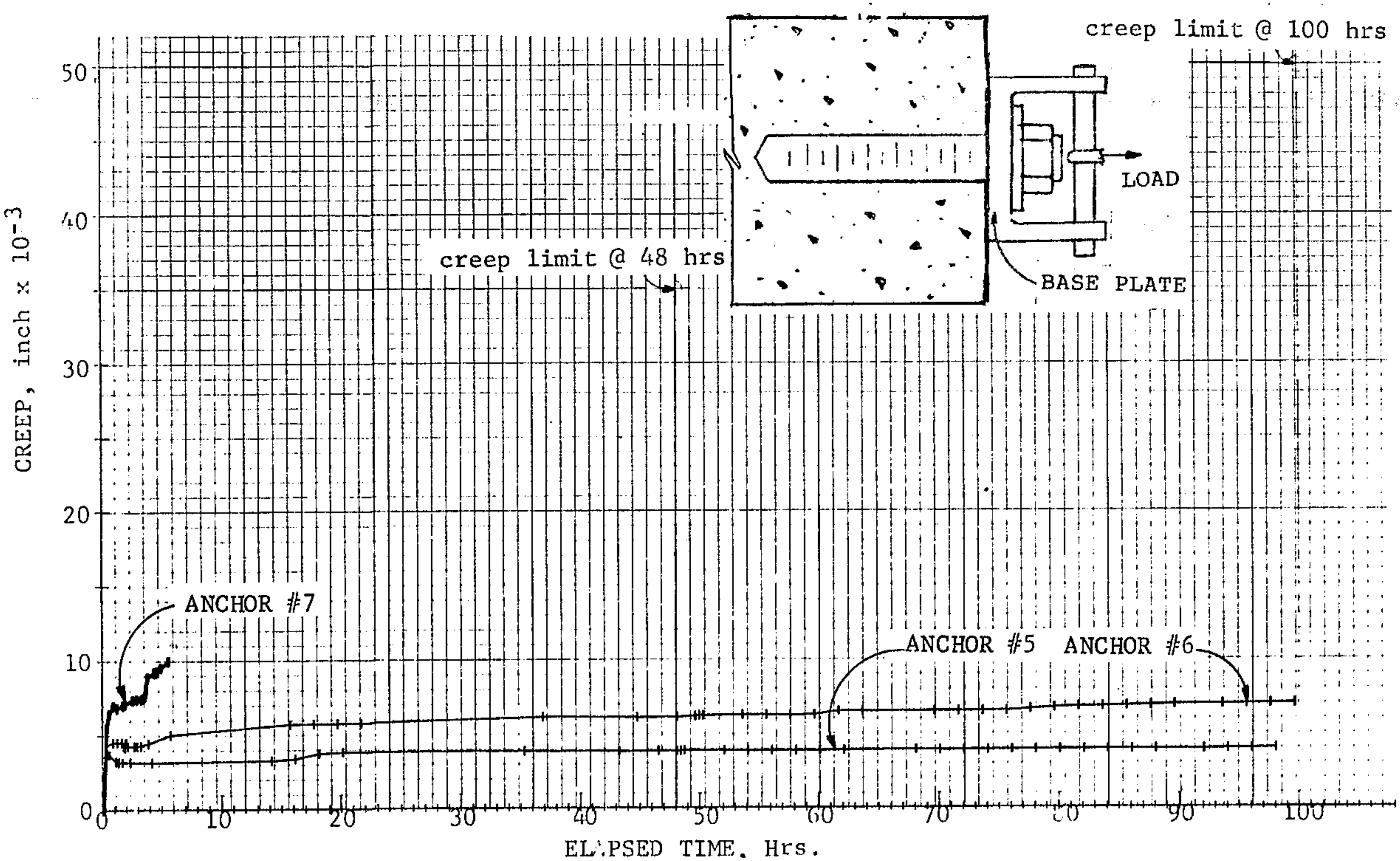


FIGURE 24. CREEP vs. TIME PLOT FOR MOLLY RESIN CAPSULE ANCHORS

DATA SUMMARY

Test series: 3 Anchor No.: 8,9,10.
Test date: 7-31-84
Magnitude of sustained load: 9.45 kips
Creep: 0.009 (max) in. @ 100 hrs
Brand of resin anchor: MOLLY
Resin cure time: 24 hrs
Concrete's compressive strength: 6000-6900 psi

Rod diameter: 3/4 in.
Hole diameter: 7/8 in.
Slab thickness: 5-1/2 in.
embedment depth: 5 in
edge distance: 2-3/4"

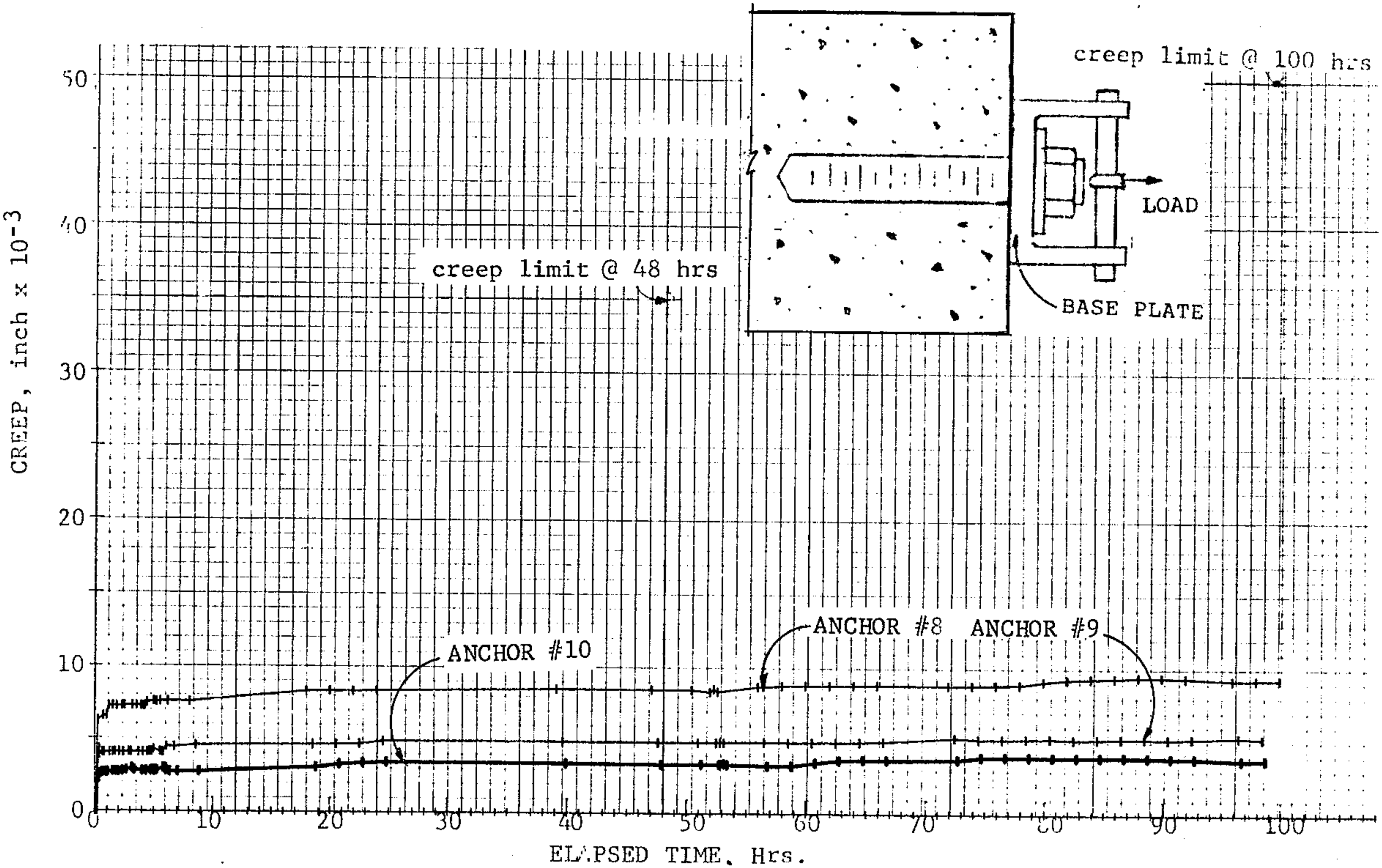


FIGURE 25. CREEP vs. TIME PLOT FOR U.S.E. DIAMOND RESIN CAPSULE ANCHORS

DATA SUMMARY

Test series: 4 Anchor No.: 2,3,4.
Test date: 8-15-84
Magnitude of sustained load: 4.73 kips
Creep: 0.004 (max) in. @ 100 hrs
Brand of resin anchor: U.S.E. DIAMOND
Resin cure time: 24 hrs.
Concrete's compressive strength: 5800-6050 psi.

Rod diameter: 3/4 in.
Hole diameter: 7/8 in.
Slab thickness: 5-1/2 in.
embedment depth: 4 in
edge distance: 2-3/4"

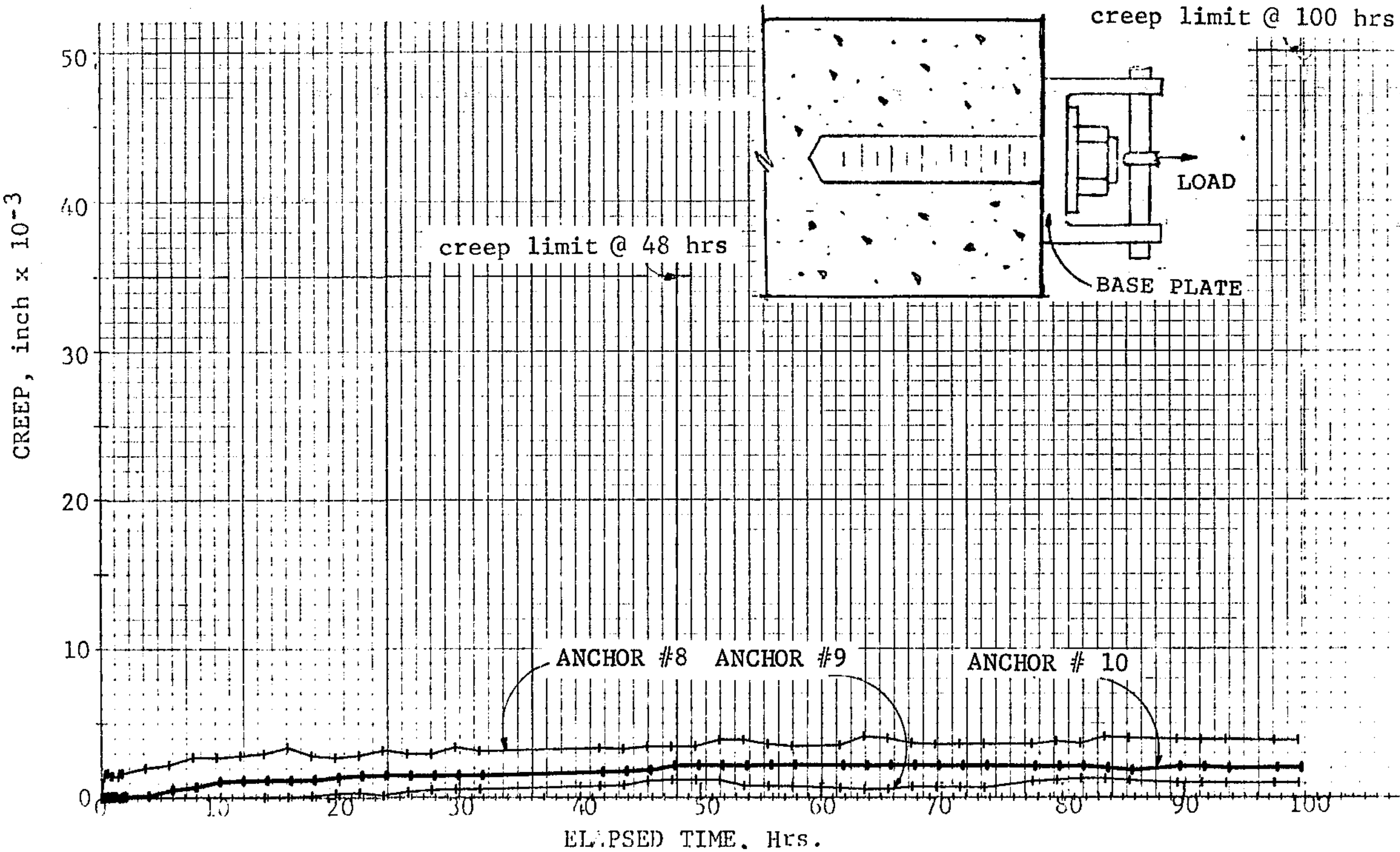


FIGURE 26. CREEP vs. TIME PLOT FOR HILTI RESIN CAPSULE ANCHORS

DATA SUMMARY

Test series: 4 Anchor No.: 5,6,7.
Test date: 8-15-84
Magnitude of sustained load: 4.73kips
Creep: 0.005 (max) in. @ 100 hrs

Brand of resin anchor: HILTI
Resin cure time: 28 hrs.

Concrete's compressive strength: 5800-6050 psi.

Rod diameter: 3/4 in.
Hole diameter: 7/8 in.
Slab thickness: 5-1/2 in.
embedment depth: 4 in
edge distance: 2-3/4"

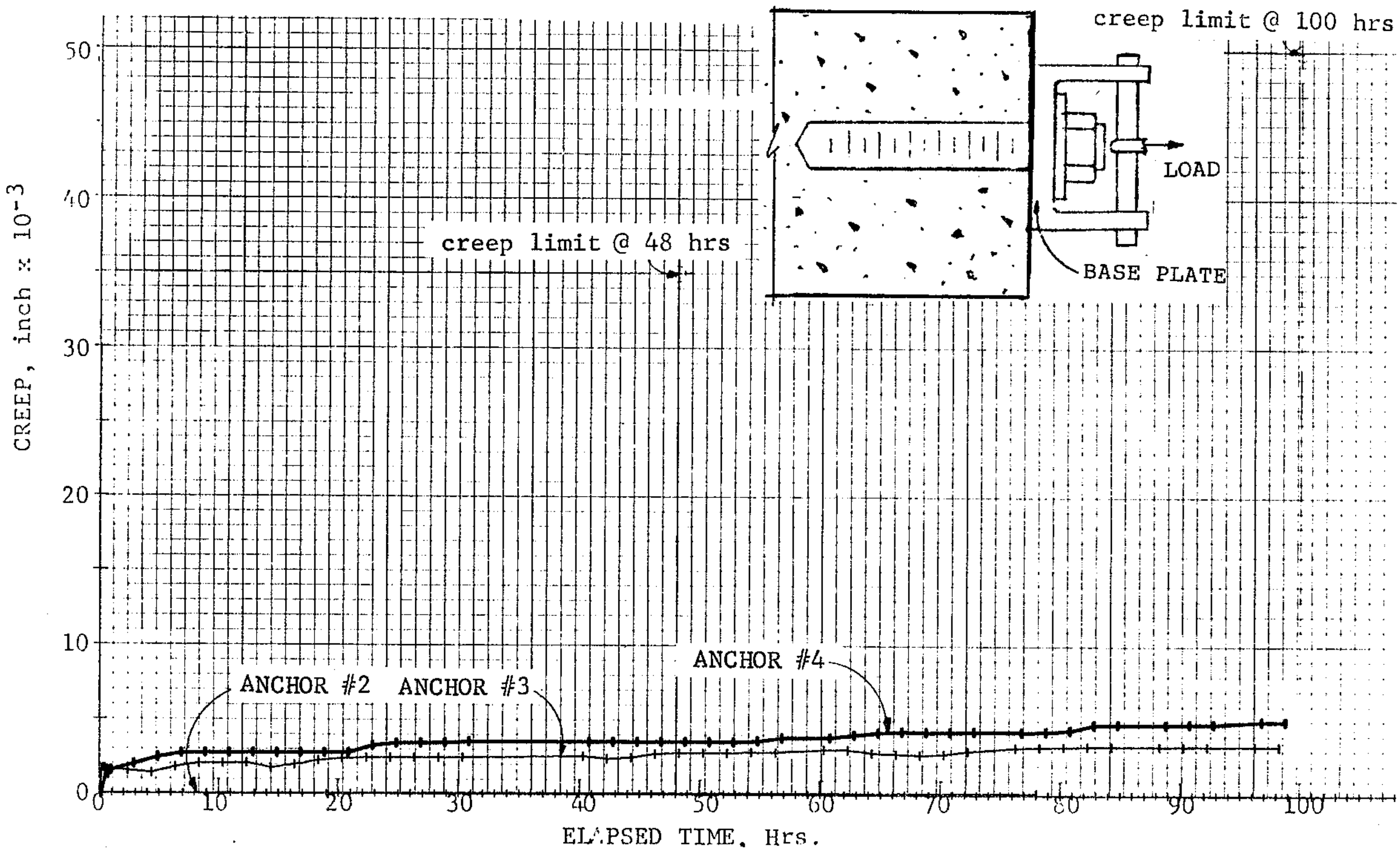
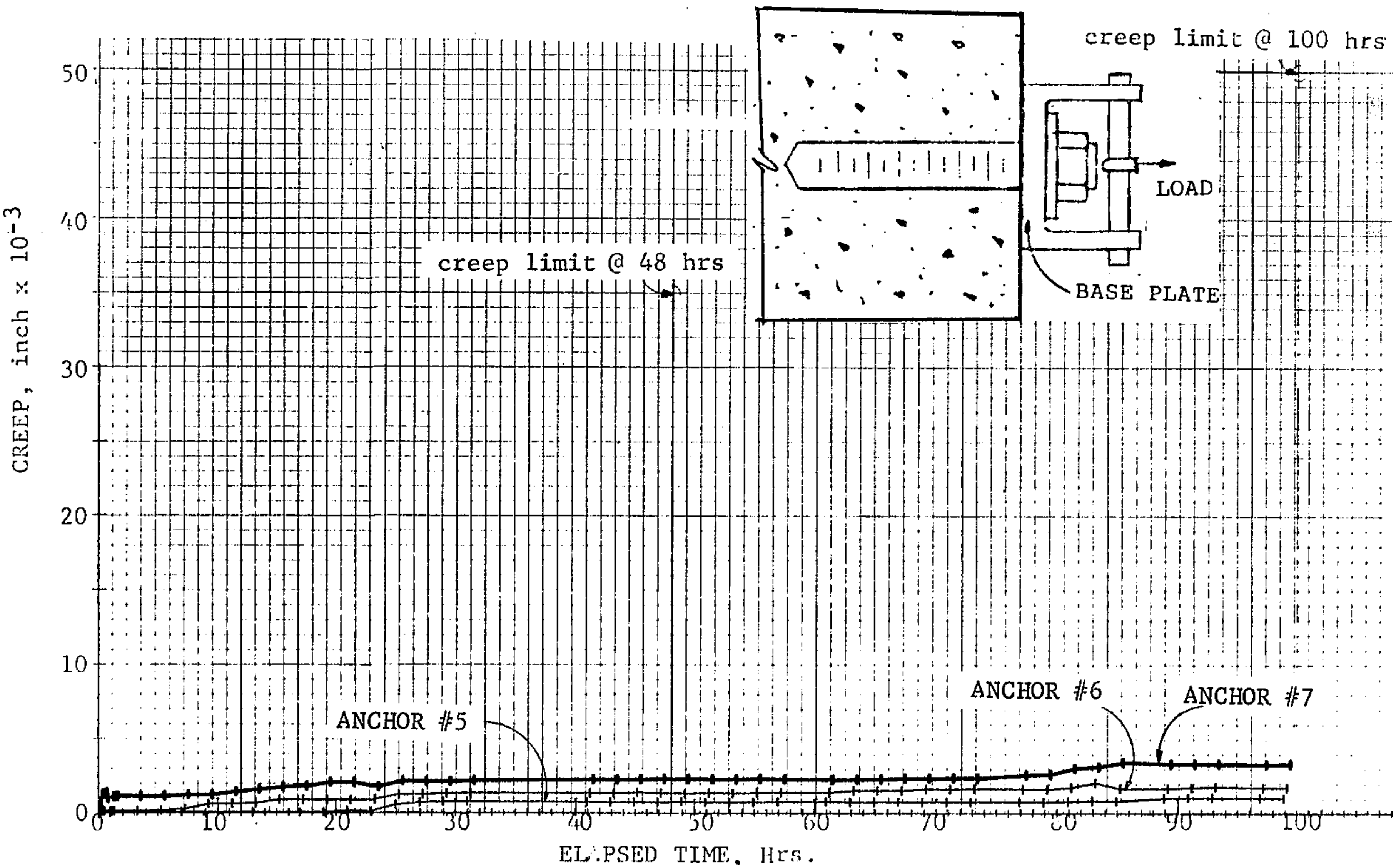


FIGURE 27. CREEP vs. TIME PLOT FOR MOLLY RESIN CAPSULE ANCHORS

DATA SUMMARY

Test series: 4 Anchor No.: 8,9,10.
Test date: 8-15-84
Magnitude of sustained load: 4.73 kips
Creep: 0.003 (max) in. @ 100 hrs
Brand of resin anchor: MOLLY
Resin cure time: 24 hrs.
Concrete's compressive strength: 5800-6050 psi

Rod diameter: 3/4 in.
Hole diameter: 7/8 in.
Slab thickness: 5-1/2 in.
embedment depth: 4 in
edge distance: 2-3/4"



State of California
Department of Transportation
Division of Engineering Services
Office of Transportation Laboratory
P.O. Box 19128
Sacramento, California, 95819

March 1985

CALIFORNIA TEST 681

METHOD FOR TESTING CREEP PERFORMANCE OF CONCRETE ANCHORAGE DEVICES

A. SCOPE

This method describes the test procedure to be used for determining the creep performance of various concrete anchorage devices, including bonded dowels or threaded bars, cast-in-place concrete inserts, polyester resin capsule anchors and mechanical expansion anchors.

B. DESCRIPTION OF TERMS

Creep -- includes all movement associated with the installed concrete anchorage device that occurs while loading and during the sustained loading periods, including short-term slip and creep. Elastic deformations are considered small and are also included in overall creep measurements.

C. TESTING APPARATUS

The following testing apparatus is required for evaluating creep:

1. A suitable hammer and setting tool, if required, for mechanical expansion anchors being tested.

2. A testing apparatus, similar or equivalent to that shown in Figure 1, designed so that the anchorage device is loaded through a base plate beneath the nut on the threaded shaft of the device. The clear distance between the supports of the testing apparatus in contact with the concrete test slab and the expansion anchor stud shall be 3-1/2 times the embedment depth for depths less than or equal to 6-1/2 inches, and 2 times the embedment depth for depths greater than 6-1/2 inches. The load collar with base plate attached and arms on which indicators are mounted shall be designed and built sufficiently rigid to minimize elastic deflections.

3. A pin or swivel connector near the base of the pull bar linkage to eliminate transfer of bending moment to the anchorage device.

4. A load cell or load monitoring device capable of measuring the external tensile force applied to the pull bar of the testing apparatus to within ±1% of the actual applied load.

5. Two dial indicators, linear potentiometers, or other suitable gages per testing apparatus, capable of measuring linear movement to within an accuracy of ±0.001 inch.

6. A suitable torque wrench.

D. PREPARATION OF TEST SPECIMENS

1. Concrete Test Specimen
   a. Fabricate an unreinforced concrete test specimen having sufficient size to provide adequate edge distance and spacing between anchors, as outlined in D.2.a., and to accommodate anchorage devices being tested. Minimum slab depth shall be the minimum required hole depth (see D.2.b.(3)) plus 4 hole diameters.
   b. Concrete used for the test slab shall contain 564 pounds of "Type II Modified" portland cement per cubic yard, and conform to requirements in Section 90-2.01 of the Caltrans Standard Specifications. The aggregate used shall be rounded or crushed gravel or crushed rock and conform to the 1-inch maximum grading in Section 90-3.04, "Combined Aggregate Gradings". Admixtures shall not be used. The maximum slump shall be 4 inches. Concrete shall be cured by either the water or curing compound method in accordance with the provisions in Sections 90-7.03, "Curing Structures". At the beginning of each sustained direct tension test, the concrete shall have an age of not less than 21 days and a compressive strength of not more than 5000 psi.

2. Installation of Anchorage Devices
   a. Locate the hole positions on the concrete test specimen so as to provided a minimum edge distance of 5 hole diameters and a minimum spacing between holes (center to center) of 10 hole diameters.
   b. Drill holes to conform to the following requirements:
      (1) Use an impact rotary hammer drill with a carbide-tipped bit for drilling holes. Use the appropriate drill bit diameter as recommended by the anchor manufacturer. Dimensions of the carbide tip on the drill bit shall conform to ANSI Specification B94.12.
      (2) Drill holes so that their axes are normal to the plane of the concrete surface.
      (3) The required hole depth shall be as follows:
          ..for mechanical expansion anchors;
            - internally threaded drop-in style anchors, the minimum required hole depth is 1/2 inch plus the anchor body length.
            - integral stud-type anchors, the required hole depth is the minimum depth recommended by the manufacturer.
          ..for resin capsule anchors; minimum hole depths shall conform to those recommended by the manufacturer.

c. After drilling the hole, remove dust and residue in the hole by blowing out with compressed air, using an OSHA-approved nozzle. Use of a brush or other instrument to loosen dust particles or water to wash out residual dust in hole is not permitted.
d. Install the anchor using the manufacturer's recommended instructions. For mechanical anchorage devices, the top of internally threaded drop-in type anchor body shall be installed between 1/2 inch and 1 inch below the concrete surface.
e. Bond two small flat metal bearing plates to the surface of the concrete at an appropriate distance from the anchorage device so as to provide smooth surfaces for the contacts of the dial indicators or potentiometers.
f. Position the load collar with dial indicators over the protruding stud, and install the appropriate washer and nut. Apply torque to the nut using an appropriate torque wrench. In the absence of installation torque values recommended by the manufacturer, the following values will be used:

REQUIRED INSTALLATION TORQUE FOR CONCRETE ANCHORAGE DEVICES, FOOT POUNDS

ANCHOR STUD SIZE	Drop-in Type Mechanical Expansion Anchors	Concrete Inserts, Resin Capsule Anchors, Bonded Threaded Bars, or Integral Stud-Type Mechanical Expansion Anchors
3/4"dia.	80	125
5/8"dia.	50	90
1/2"dia.	30	60
3/8"dia.	20	35
1/4"dia.	10	10

E. TEST PROCEDURE

1. Install two indicators (linear potentiometers or dial gages), one on each end of a rigid arm securely fastened near the base plate of the testing apparatus, and position them so as to measure displacements normal to the concrete surface. Tips of the indicators shall rest on bearing plates previously bonded to the concrete surface. Mount these indicators so that their shafts are equidistant from and along lines perpendicular to the axis of the concrete anchorage device at a distance not less than 10 hole diameters apart from one another.

2. Immediately after the required installation torque has been applied to set/preload the anchorage device being tested and indicators have been properly oriented, read and record each indicator before the application of the external tensile test load. Average the two readings to obtain the initial mean indicator measurement.

3. Except for concrete inserts installed in fresh concrete, apply the appropriate sustained axial tension test load shown in the specifications within 48 hours of installation of the concrete anchorage device. This load shall be applied to the base plate of the test fixure so as to indirectly load the stud of the anchorage device through the previously torqued stud nut. The tension test load shall be applied at a uniform rate which does not exceed 1000 pounds per minute.Concrete inserts shall be similarily loaded after concrete has cured for 21 days.

4. Read and record each indicator again immediately after the tension test load has been applied.

5. Maintain the specified tension test load to within ±5% of the required value for the duration of the creep test.

6. Monitor creep for at least 48 hours after applying the full test load. Read and record a minimum of 5 additional sets of indicator values at 2 hour intervals during the last 10 hours of testing. One of the readings shall be made at 48 hours. Determine the mean value for each set of readings taken.

7. Subtract the mean indicator value of the 48-hour reading (E.6) from the initial mean indicator measurement (E.2) to determine the mean creep value for the anchorage device.

F. SAMPLING

1. In order to qualify an anchorage device, three identical tests per diameter must be performed. For anchorage devices of a given diameter and design, a satisfactory performance for the particular embedment length tested will constitute acceptance of that length as well as all longer manufactured lengths. A satisfactory performance is obtained when all three anchorage devices pass.

2. Any future changes in anchor design or materials will require retesting.

G. REPORTING OF RESULTS

The report of creep test results shall include the following minimum information:

1. Test sponsor and test agency.

2. Dates of testing and report preparation.

3. Identification of the anchorage device including manufacturer, type and model number, type of steel used in anchor parts, thickness and type of corrosion protective coating, dimensions, and other pertinent infomation.

4. Description and photograph of the testing apparatus.

5. Photographs of the test specimen.

6. Mean indicator values as required per E.2, E.4, and E.6 with their respective elapsed test times.

7. The concrete mix design, type of aggregates used in the concrete, and slump of the fresh concrete.

8. A physical description of the test slab including dimensions and method of curing used.

9. The compressive strength of the concrete and age, in days, of the test slab on the date creep testing was begun.

10. The length of time, in hours, from the installation of the anchorage devices to the application of the sustained tension test load.

11. The diameter of the carbide tip on the drill bit used, if required.

12. The depth of the drilled hole, when drilling is required.

13. The depth of embedment of the anchorage device.

14. A description of the procedure and materials used to install the anchorage devices, including installation torque.

15. A description of the procedure used to apply the sustained tensile test load and actual rate of loading used.

16. The number of specimens tested.

17. A listing of observers of the qualification tests with the signature and title of the person responsible for testing.

End of Text (5 pages) of Test 681

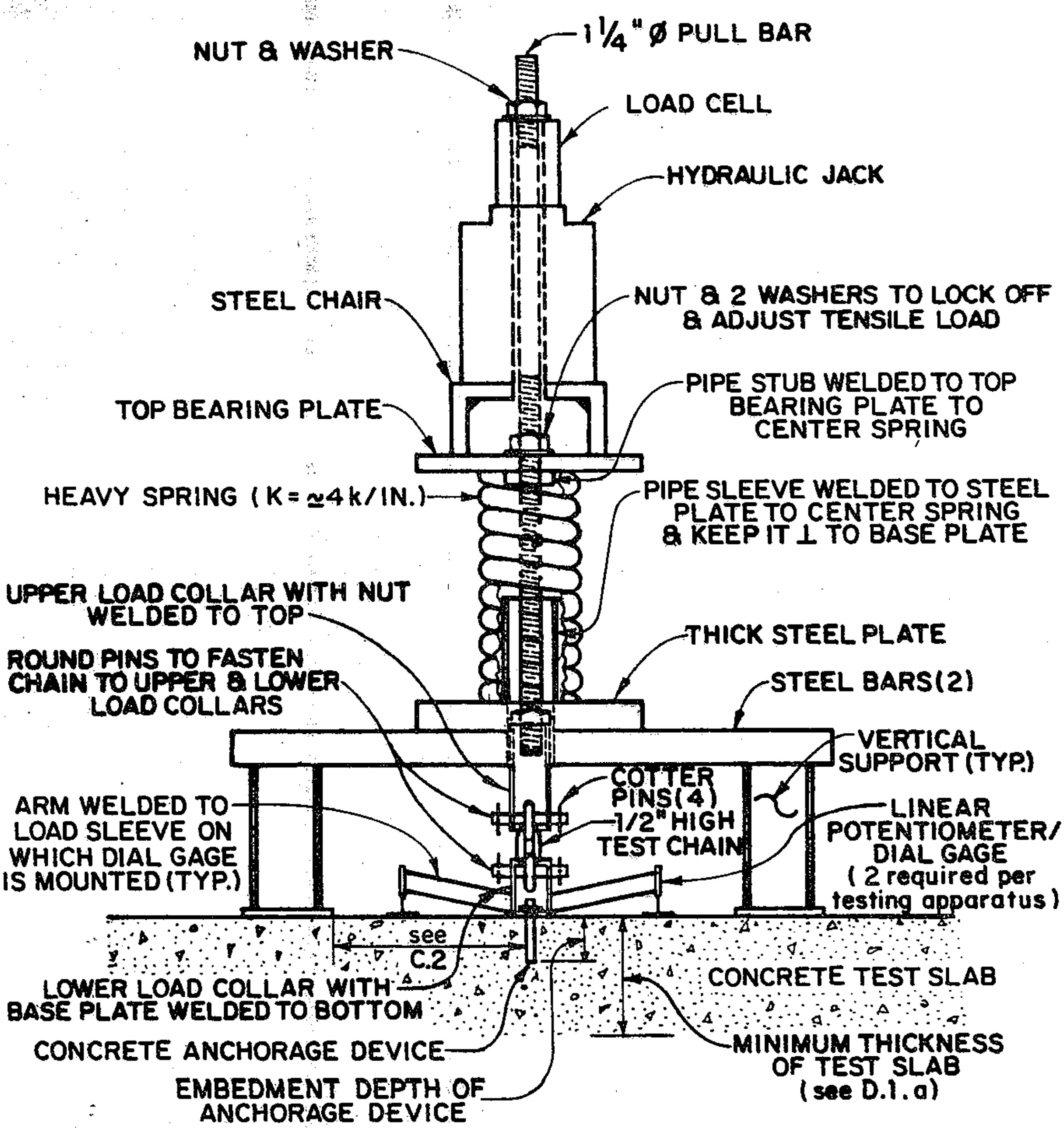


FIG. 1. EXAMPLE OF A SUITABLE CREEP TESTING APPARATUS

APPENDIX B

PROPOSED STANDARD SPECIAL PROVISION

10-1. MISCELLANEOUS BRIDGE METAL

The twelfth, thirteenth and seventeenth paragraphs of Section 75-1.03 "Miscellaneous Bridge Metal" of the Standard Specifications are amended to read:

Concrete anchorage devices shall be mechanical expansion or resin capsule types installed in drilled holes, or cast-in-place types. The anchorage devices shall be complete with threaded studs, hex nuts and cut washers.

Concrete anchorage devices shall be the internally threaded type with independent stud, the integral stud anchor type or the resin anchor type. All metal parts of the anchorage devices shall be fabricated from steel, which shall either be corrosion resistant stainless steel or be protected with a corrosion-resistant coating. The coating shall not have an adverse chemical reaction with concrete.

If the manufacturer's instructions do not include specific torque requirements, nuts used to attach equipment or fixtures shall be torqued to the following installation torque values:

Installation Torque

Anchorage Device Stud Size	Internally Threaded (foot pounds)	Integral Stud and Resin Capsule (foot pounds)
3/4"	80	125
5/8"	50	90
1/2"	30	60
3/8"	20	35
1/4"	10	10

Para. 6. When in a corrosive environment, the anchorage devices and exposed hardware which are not fabricated from stainless steel shall be either hot-dip or mechanically galvanized.

International Conference of Building Officials

RESEARCH REPORT

Report No. 3910
December, 1983

Filing Category: FASTENERS—Concrete and Masonry Anchors

PARABOND CAPSULE ANCHORS
MOLLY DIVISION OF EMHART CORPORATION
504 MOUNT LAUREL AVENUE
TEMPLE, PENNSYLVANIA 19560

I. **Subject:** Parabond Capsule Anchors.

II. **Description: General:** Parabond is a two-part system composed of a threaded rod stud and a sealed glass capsule containing premeasured amounts of a polyester resin, quartz sand aggregate and a hardener contained in a separate vial within the capsule. The threaded rods are manufactured from either C-1018 or C-1020 steel. The ⅜-inch diameter through ¾-inch-diameter rods have a minimum yield stress of 60,000 psi and a minimum tensile strength of 74,000 psi. The ⅞-inch, 1-inch and 1¼-inch threaded rods have a minimum yield stress of 50,000 psi and a minimum tensile strength of 60,000 psi.

Installation: The anchors are installed in a predrilled hole in the concrete. The size and depth of the hole and the minimum spacing, edge and end distances shall conform to the requirements set forth in Table No. I. A rotary percussion hammer drill is to be used. The dust must be removed from the hole. Special inspection is required as noted in Section 306 of the code. The capsule is inserted into the hole with the rounded end facing out of the opening. The threaded rod is installed half way into the nut, and the screw drive unit is installed onto the nut and secured into the chuck of the rotary percussion hammer drill. The capsule is broken with the bevel end of the rod using the rotary hammer drill. After the stud is driven to the bottom of the hole, the drill must be immediately turned off. The chuck may be released and the rotary hammer disengaged. Care must be taken to ensure that the anchor bond is not disturbed for an initial cure period of 10 minutes. The adapter should be removed after the initial cure period without disturbing the bond. The resin must be allowed to cure at the temperature and for the time period noted in Table No. II.

The anchor cannot be used to resist pullout forces when installed in a ceiling or wall since the anchor values for this loading condition are affected by elevated temperature conditions.

Allowable tension and shear values are tabulated for the various size threaded rods as indicated in Table No. I. Allowable load values are influenced by the environment in which the anchor is used. The allowable values given in Table No. I must be adjusted in accordance with Figure No. 2 when the anchors are installed in locations where the ambient temperature may exceed 68°F.

Identification: The Parabond Capsule Anchors are identified in the field as noted in Figure No. 1. The anchor stud is identified with a triangle (△) located on top of the flat portion of the stud.

III. **Evidence Submitted:** Descriptive data and results of tension and shear tests have been submitted.

Findings

IV. **Findings: That the Parabond Capsule Anchors described in this report are alternate types of connectors to that specified in the 1982 Uniform Building Code, subject to the following conditions:**

1. **Allowable shear and tension loads shall not exceed the values set forth in Table No. I.**
2. **The anchor sizes, minimum embedment depths, minimum spacing, edge and end distances shall conform to the requirements set forth in Table No. I.**
3. **Allowable loads for anchors subjected to combined shear and tension forces shall be determined by the ratio of the actual shear to the allowable shear plus the ratio of the actual tension to the allowable tension not exceeding 1.00.**
4. **Special inspection in accordance with Section 306 (a) 12 of the code must be provided for all anchor installations.**
5. **Calculations and details showing that the anchors comply with this report must be submitted to the local building official for approval.**
6. **The anchors cannot be used to support fire-resistive construction.**
7. **The anchors cannot be used to resist pullout forces in overhead or vertical installations.**

This report is subject to re-examination in one year.

TABLE NO. I—ALLOWABLE SHEAR AND TENSION VALUES FOR ANCHORS INSTALLED IN MINIMUM f'_c = 4000 PSI STONE AGGREGATE CONCRETE[1 2 3 5]

CATALOG NUMBER	THREADED ROD DIAMETER (Inches)	DRILL DIAMETER (Inches)	MINIMUM EMBEDMENT (Inches)	TENSION VALUE[4] (Pounds)	SHEAR VALUE (Pounds)
M10-38	⅜	7/16	3½	1,265	770
M12-12	½	9/16	4¼	2,305	1,290
M16-58	⅝	¾	5	3,480	2,345
M20-34	¾	⅞	6⅝	5,070	3,335
M20-78	⅞	1	6⅝	6,400	4,525
M24-1	1	1¼	8¼	7,720	5,710
M30-114	1¼	1½	10¼	13,515	9,840

[1]The tabulated shear and tensile values are for anchors installed in concrete having the designated ultimate compressive strength at the time of installation.

[2]The tabulated values are for anchors installed a minimum of 12 diameters on center and a minimum edge distance of six diameters for 100 percent anchor efficiency. Spacing and edge distance may be reduced to six-diameter spacing and three-diameter edge distance, provided the values are reduced 50 percent. Linear interpolation may be used for intermediate spacings and edge margins.

[3]The allowable tension capacities shown reflect the higher short-term test values obtained reduced by 25 percent to account for the long-term load-carrying capabilities characteristic of adhesive anchors; therefore, the allowable values noted above do not have to be reduced for long-term conditions.

[4]The anchors cannot be used to resist tension forces in overhead or vertical installations.

[5]Allowable loads may be increased 33⅓ percent for duration of loading such as wind or seismic forces.

TABLE NO. II—RECOMMENDED HARDENING TIME FOR THE RESIN (DEPENDING ON AMBIENT TEMPERATURE)

CONCRETE TEMPERATURE	MINIMUM CURE TIME
68°F. and over	10 minutes
50°F. to 68°F.	20 minutes
32°F. to 50°F.	1 hour
23°F. to 32°F.	5 hours

MOLLY®
PARABOND M24-1
capsule anchor
made in Germany

FIGURE NO. 1—TYPICAL IDENTIFICATION MARKING

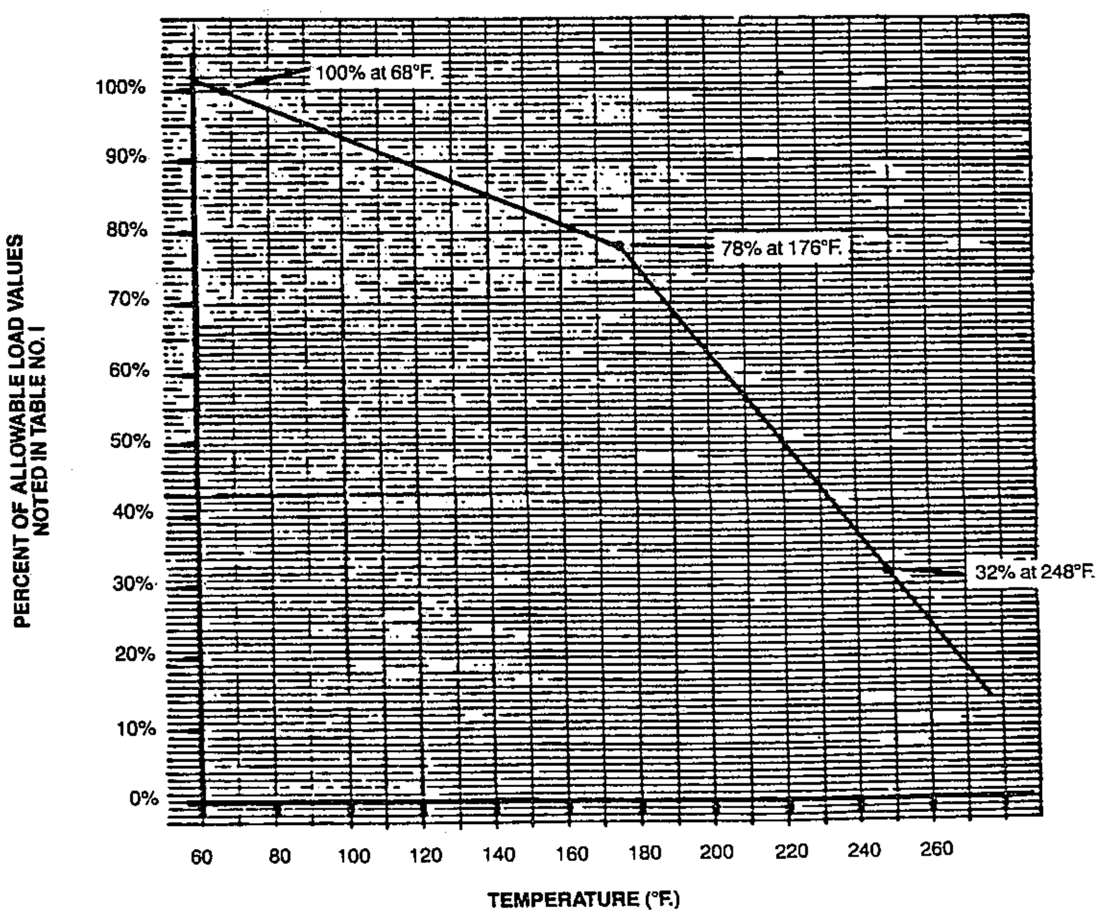


FIGURE NO. 2
PARABOND ANCHOR AMBIENT TEMPERATURE SENSITIVITY LOAD FACTOR

International Conference of Building Officials

EVALUATION REPORT

Report No. 4016
September, 1984

Filing Category: FASTENERS—Concrete and Masonry Anchors

HILTI HVA ADHESIVE CONCRETE ANCHORS
HILTI FASTENING SYSTEMS, INC.
POST OFFICE BOX 45400
TULSA, OKLAHOMA 74145

I. **Subject:** Hilti HVA Adhesive Concrete Anchors.

II. **Description:** The Hilti concrete anchors are stud-type adhesive anchors for use in regular-weight concrete having a minimum compressive strength of 2000 psi or structural lightweight concrete having a minimum compressive strength of 3000 psi. The anchors consist of a threaded rod of zinc-plated SAE 1018 steel, a nut, washer and sealed glass tube containing an unsaturated polyester resin. Inside the tube of resin there is a smaller tube containing quartz sand which has been coated with a hardening agent. The threaded rod is identified as "HAS" and the tube of resin as "HBP." The anchor is available in ⅜-, ½-, ⅝-, ¾-, ⅞- and 1-inch threaded rod sizes.

Installation: The anchor is installed into a predrilled hole in concrete that has been cleaned, using either a brush and a stream of water, or a brush and compressed air. The hole diameter is slightly larger than the HBP. The depth of the hole should be sufficient to allow the HBP to be inserted flush with the surface of the concrete. The HAS is then inserted into a rod adapter which is attached to a rotary hammer by means of a connecting shaft. The beveled end of the HAS rod is placed on top of the HBP and the combination of the rotation and the hammering action pulverizes and mixes the contents of the HBP. After the stud is driven to the bottom of the hole, the drill should be immediately stopped.

The chuck may be released and the rotary hammer disengaged. Care should be taken to ensure that the anchor bond is not disturbed for an initial cure period of ten minutes. The resin must be allowed to cure, before applying a load, at the temperature and for the time periods noted in Table No. I. The resin and the quartz sand combine to form an adhesive mixture which bonds the rod to the wall of the hole. The HAS rod must be embedded up to the minimum embedment ring, which is marked on the rod.

Dimensions and installation criteria are noted in Table No. II.

The anchor cannot be used to resist pullout forces when installed in a ceiling or wall, since the anchor values for this loading condition are affected by elevated temperature conditions. Allowable tension and shear values are tabulated in Table No. III. Allowable load values are influenced by the environment in which the anchor is used. The allowable values given in Tables Nos. III and IV must be adjusted in accordance with Figure No. 1 when the anchors are installed in locations where the concrete temperature may exceed 68°F.

Identification: The anchors are identified in the field by labels on the packaging indicating the manufacturer's name, product name and the anchor size. The HBP cartridges are marked individually as to size and the threaded rod has an "H" stamped on top.

III. **Evidence Submitted:** Descriptive data, results of tension and shear tests and results of dynamic tests.

Findings

IV. Findings: That the HVA adhesive concrete anchors described in this report are alternate types of connectors to that specified in the 1982 Uniform Building Code, subject to the following conditions:

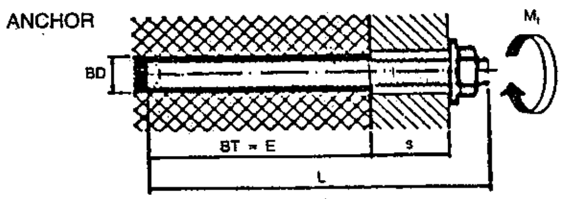
1. **Allowable shear and tension load do not exceed the values set forth in Tables Nos. III and IV.**
2. **The anchor sizes, minimum embedment depths, minimum spacing, edge and end distances conform to Table No. II.**
3. **Allowable loads for anchors subjected to combined shear and tension forces are determined by the ratio of the actual shear to the allowable shear plus the ratio of the actual tension to the allowable tension not exceeding 1.00.**
4. **Calculations and details showing that the anchors comply with this report must be submitted to the local building official for approval.**
5. **Special inspection in accordance with Section 306 (a) 12 of the code must be provided for all anchor installations.**
6. **The anchors cannot be used to support fire-resistive construction.**
7. **The anchors cannot be used to resist pullout forces in overhead and wall installations.**

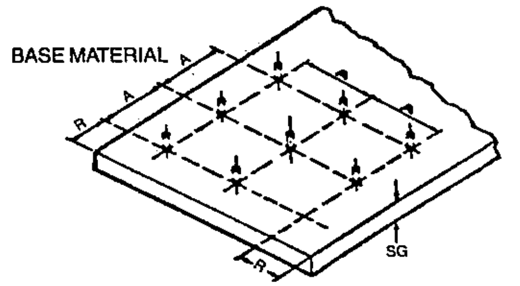
This report is subject to re-examination in one year.

TABLE NO. I

RECOMMENDED HARDENING TIME FOR THE RESIN (DEPENDENT ON AMBIENT TEMPERATURE)	
Above 68°F.	10 min.
50°F. to 68°F.	20 min.
32°F. to 50°F.	1 hr.
Below 32°F.	5 hr.

TABLE NO. II
HVA SPECIFICATIONS AND INSTALLATION DETAILS





DETAILS	ANCHOR SIZE	HVA ⅜"	HVA ½"	HVA ⅝"	HVA ¾"	HVA ⅞"	HVA 1"
BD	Bit diameter (inches)[1]	15/32	9/16	11/16	⅞	1	1⅛
BT = E	Min. hole depth = required depth embed. (inches)	3½ (3¼-LT. WT.)	4¼	5	6⅝	6⅝	8¼
s	max. thickness of material fastened (inches)	1	1½	1¾	2	2¼	2½
L	anchor length (inches)	5⅛	6½	7⅝	9⅝	10	12
M_t	max. tightening torque (ft. lbs.)	18	35	80	160	200	330
	Drill bit size[1]	TE-C-15/32-12	TE-C-9/16-12	TE-C-11/16-12	TE-F-⅞-13	TE-F-1-13	TE-F-1⅛-17
	Rotary hammer drill	TE17/22/52	TE17/22/52	TE17/22/52	TE52	TE52	TE52
SG	Min. base material thickness (inches)*	5½	6¼	7⅛	8½	8½	10½

DISTANCE BETWEEN ANCHORS A AND DISTANCE FROM EDGE R (Inches)[2]

Anchor Type \ A,R,f				LOAD DIRECTED TOWARD EDGE			LOAD NOT DIRECTED TOWARD EDGE		
	A	A min.	fA	R	R min.	fR	R	R min.	fR
HVA	1E	0.5 E	0.7	1.5 E	0.5 E	0.5	1.5 E	0.5 E	0.6

*Base material: Concrete with a minimum nominal compressive strength as noted in this report.

A = spacing to obtain max. load

$A_{min.}$ = shortest distance between anchors when both anchors influence the failure load in tension or shear.

R = distance from edge to obtain max. load

R_{min} = shortest distance from edge when there is an influence on the failure load in tension or shear

fA, fR = load factor of safe working load (or failure load) when using R_{min} and A_{min}

E = recommended min. depth of embedment

[1]The nominal hole diameter is equivalent to the nominal Hilti carbide tip drill bit diameters.

[2]**Example:** HVA ⅝ anchors spaced 3 inches apart (loaded in tension) required spacing for full design load (stone aggregate concrete)

A = 1.0E = 1.0 × 5 inches = 5 inches

minimum required spacing and corresponding load factor

A_{min} = 0.5E = .5 × 5 inches = 2.5 inches

which corresponds to a load factor fA = .7 × 3900 = 2730 lbs.

Interpolating 5 inches—3900 lbs., 2.5 inches—2730 lbs. } 3 inches—2965 lbs.

The application of load factors is cumulative

Example: Load factor for Anchor No. 1:

$f = fR_1 \times fR_2 \times fA_1 \times fA_2 \times fA_3$