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Einar Dahl-Jorgensen

STRESS-STRAIN TESTS
OF POLYMER MODIFIED CONCRETE

By

Einar Dahl-Jorgensen

Department of Civil Engineering
Fritz Engineering Laboratory
Lehigh University
Bethlehem, Pennsylvania

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USE OF POLYMERS IN HIGHWAY CONCRETE

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STRESS-STRAIN TESTS OF POLYMER IMPREGNATED CONCRETE

ABSTRACT

In this investigation, Polymer Impregnated Concrete (PIC) was prepared by impregnation with the monomer methyl methacrylate. The polymerization was carried out using the thermal-catalytic method and one of two different catalysts. These were either 3% benzoyl peroxide or 0.5% azobisisobutyronitrile both by weight of the monomer.

When the 3% benzoyl peroxide was used, a central core was left inside the specimen containing unpolymerized monomer. 0.5% azobisisobutyronitrile, however, gave full polymerization.

Polymer cement concrete (PCC) was prepared by adding the monomer diacetone diacrylamide in the fresh concrete mix followed by polymerization. This experiment was unsuccessful, however, as the concrete was left with virtually no strength.

Further experiments with PCC included mixing a prepolymer latex product in the fresh concrete. An approximate 50% increase in strength was found for this concrete.

1. INTRODUCTION

Most previous investigations have shown the preparation and ultimate strength of Polymer Modified Concrete.[1,2,3]

In this investigation the entire stress-strain relationship of 3x6 in. Polymer Modified Concrete specimens was determined. Figure 4 shows the load-strain relationship as recorded from split-tensile tests and Fig. 5 shows the stress-strain relationship in compression.

2. SCOPE

Sand, coarse aggregate, type of cement, water-cement ratio and curing age and conditions were standardized for all the experiments.

The variables were (1) oven drying (2) drying with an open gas flame to simulate a possible field procedure. For the impregnation in the PIC experiments, the monomer was induced in the concrete by using (3) vacuum and pressure and (4) only pressure. The monomer MMA (methyl methacrylate) and the catalyst 3% benzoyl peroxide or 0.5% azobisisobutyronitrile were used.

For the PCC (Polymer Cement Concrete) experiments, three different concentrations, 10%, 8%, and 6% by weight of the monomer diacetone diacrylamide were dissolved in the water and mixed in fresh concrete.

When the latex was used in the PCC experiments, the water was partially or completely substituted by the latex-liquid solution, producing PCC specimens with 25, 15 and 10% solid latex polymer by weight of the cement.

3. PIC SPECIMENS WITH METHYL METHACRYLATE

3.1 Impregnation Vessel

For impregnation of the dried concrete specimens a vessel (Fig. 1) was constructed from an 8x15 in. steel pipe. A bottom and top flange was welded to the pipe and a lid bolted to the top flange. The lid was further equipped with a gage measuring vacuum and pressure, a safety valve, and a valve to induce the monomer after the specimens had been under vacuum for the specified time. The vessel could impregnate eight 3x6 in. specimens simultaneously.

3.2 Materials and Specimens

The cement was a high early strength (Type 1) Portland cement, mixed with natural siliceous sand (fineness modulus = 2.90) and mixed gravel 3/8 in. in size. The mix consisted of water, cement, sand, and gravel in proportion 1:2.2:3.7:3.0 by weight.

The concrete was compacted in 3x6 in. cardboard cylinder molds and removed from the molds after 24 hours and cured in 90-100 percent relative humidity for 28 days and 14 days in 40% relative humidity.

3.3 Impregnation and Polymerization

The specimens referred to as MMA1 were dried over an open gas flame for four hours with the temperature at the concrete surface exceeding 600°F.

The specimens referred to as MMA2, MMA3, and MMA4 were dried at 260°F (125°C) for 24 hours.

Table 1 gives the preparation procedures for the PIC specimens. The catalyst used for the MMA1, MMA2, and MMA4 was the 3% benzoyl peroxide. 0.5% azobisisobutyronitrile was used for the MMA4 specimens. All specimens were polymerized submerged in warm water.[4,5]

Table 1 Impregnation and Polymerization Details

Specimens	Drying Method	Vacuum in. of Mercury	Time of Vacuum Hr.	Pressure psi	Time of Pressure Hr.	Time for Polymeriz. 70-75°C Water Hr.
MMA1	gas flame	10	2	20	2	2
MMA2	oven	20	2	40	2	4
MMA3	oven	0	0	40	2	4
MMA4	oven	20	2	40	2	4

The average polymer loading is given in Table 2, calculated as the weight increase after polymerization, divided by the initial dry weight of the specimens.

Table 2 Polymer Loading

Specimens	Polymer Loading % (Average)	Number of Specimens
MMA1	5.4	4
MMA2	5.9	6
MMA3	4.9	6
MMA4	6.0	2

4. PCC SPECIMENS WITH DIACETONE DIACRYLAMIDE

This solid monomer was first dissolved in the mixing water in the ratio of 10, 8, and 6 weight percent of the specimen. The following amount of catalyst per 100 grams of the monomer was added at the same time; (1) 5.0 mg sodium bisulfite; (2) 5.0 mg potassium persulfate. After 24 hours the specimens were removed from the molds and heated up to 65°C for 2 hrs. to complete the polymerization, followed by moist curing.

The specimens started to crack and crumble after a few hours and the investigation was terminated.

5. PCC SPECIMENS WITH THE LATEX "SARABOND"

In Table 3 are shown the mixture used for these specimens. The latex-cement ratio is the ratio of solid latex material to the cement. The liquid-cement ratio is the ratio of water plus latex to the cement. Four specimens of each concentration were prepared and given the same curing as the PIC specimens.

Table 3 PCC Specimens with Latex

Specimens	Latex-Cement Ratio	Liquid-Cement Ratio	Liquid-Latex lbs	Cement lbs	Fine Aggr. lbs	Coarse Aggr. lbs
L15	0.15	0.45	2.85	9.51	15.99	12.75
L20	0.20	0.45	3.80	9.51	15.99	12.75
L25	0.25	0.50	4.75	9.51	15.99	12.75

6. TEST SET-UP

The split-tensile test (ASTM C496-66) setup is shown in Fig. 2, with an electrical strain gage glued to the plane bottom surface, normal to the expected crack pattern.

The compression test (ASTM C39-66) is shown in Fig. 3. The strain was recorded using two "clip type" extensometers on either sides of the specimen. The setup which was designed for this experiment proved to be accurate, economical and easy to handle.

The load-strain relationship was recorded automatically on a X-Y plotter for both tests.

7. TEST RESULTS

7.1 PIC Specimens

The general mode of failure in both tests was brittle and almost explosive.

For the MMA1, MMA2, and MMA3 the polymerized area penetrated only 1 in. into the specimen, leaving an inner core of 1 in. without polymer. A strong smell of monomer was released when the specimens were broken suggesting full penetration but inadequate polymerization.

One investigator has suggested that benzoyl peroxide is absorbed by the cement and leaves the monomer in the center without sufficient catalyst to promote polymerization.[6]

For the MMA4 specimens the 0.5% azobisisobutyronitrile was used and complete polymerization was achieved.

Figure 4 shows the average tensile load-strain curves and Fig. 5 the average compressive stress-strain curves.

Table 4 Ultimate Strength

Specimens	Tensile Strength ksi	Compressive Strength ksi	E-modulus ksi x 10^3
MMA1	1.27	14.4	5.3
MMA2	1.36	16.0	6.0
MMA3	1.19	15.2	5.3
MMA4	1.51	19.6	6.0
L25	0.83	8.9	4.1
Control	0.62	6.6	3.9

7.2 PCC with Diacetone Diacrylamide

PCC is more convenient to prepare than PIC and a successful PCC would be a major achievement. However, this experiment with diacetone diacrylamide was unseccessful.

7.3 PCC Specimens with Latex

By adding an essential amount of Latex (25% by weight of the cement) the strength of the concrete was increased by 50%. The data for this concentration are shown in Figs. 4, 5, and Table 5.

Only slight improvements were recorded for the 15 and 20 percent latex concentrations, and the results are not mentioned in this report.

8. CONCLUSION

(1) The magnitude of the applied vacuum and pressure appears to be less important than choosing the proper catalyst for the PIC. The results suggested that the azobisisobutyronitrile is a more effective catalyst than the benzoyl peroxide when used in PIC.

(2) The effect of drying the specimens with a gas flame proved to be as effective as oven drying, apparently without damaging the specimens.

(3) The test setup for the compression test was found to be reliable, inexpensive and simple to use.

(4) The mode of failure for the PIC specimens was brittle and explosive.

(5) For PCC, addition of the monomer diacetone diacrylamide and subsequent polymerization produces a concrete of much inferior quality than ordinary concrete.

(6) Addition of preformed polymer latex produces only a modest increase in strength in the PCC.

9. ACKNOWLEDGMENTS

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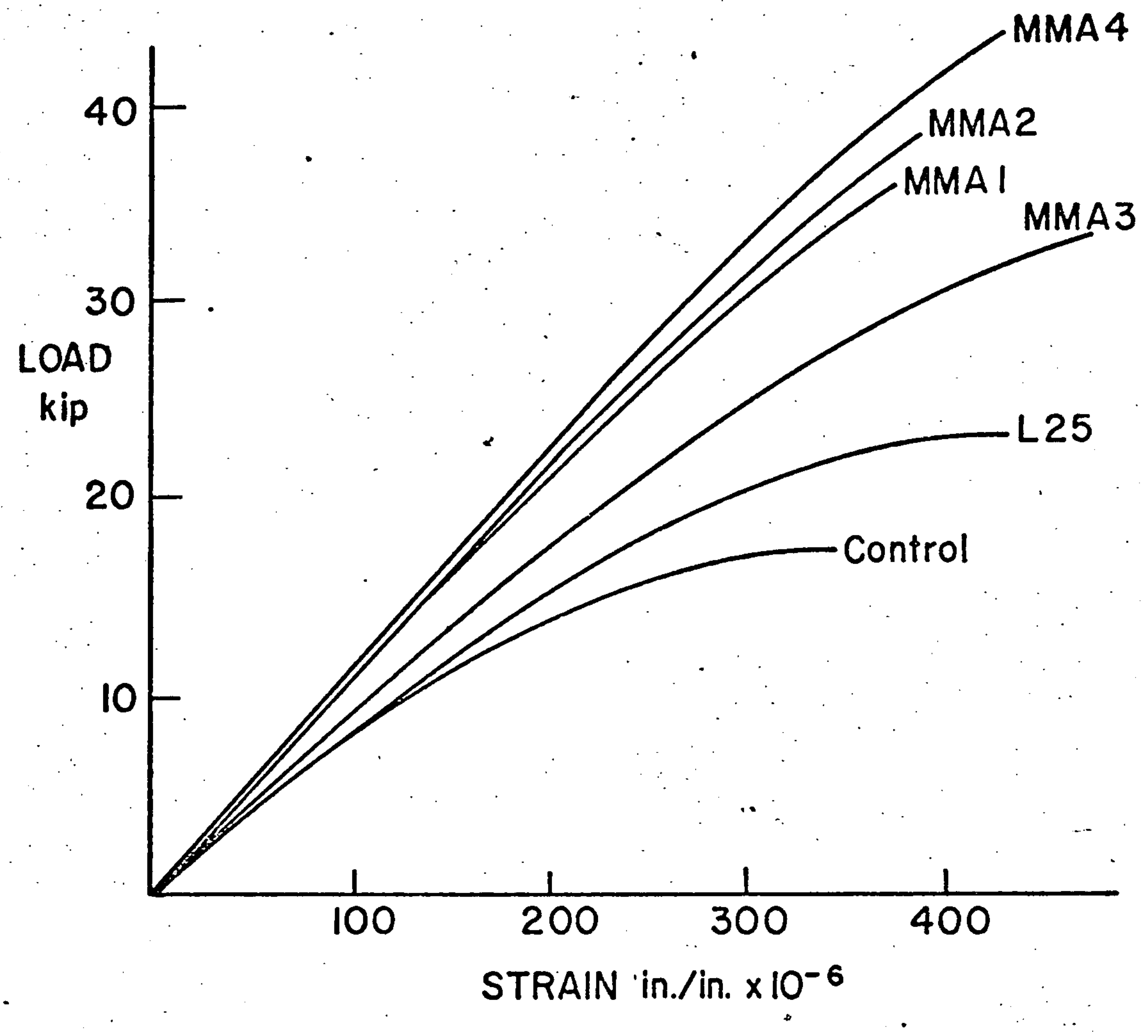


Fig. 4 Compressive Stress-Strain Curves

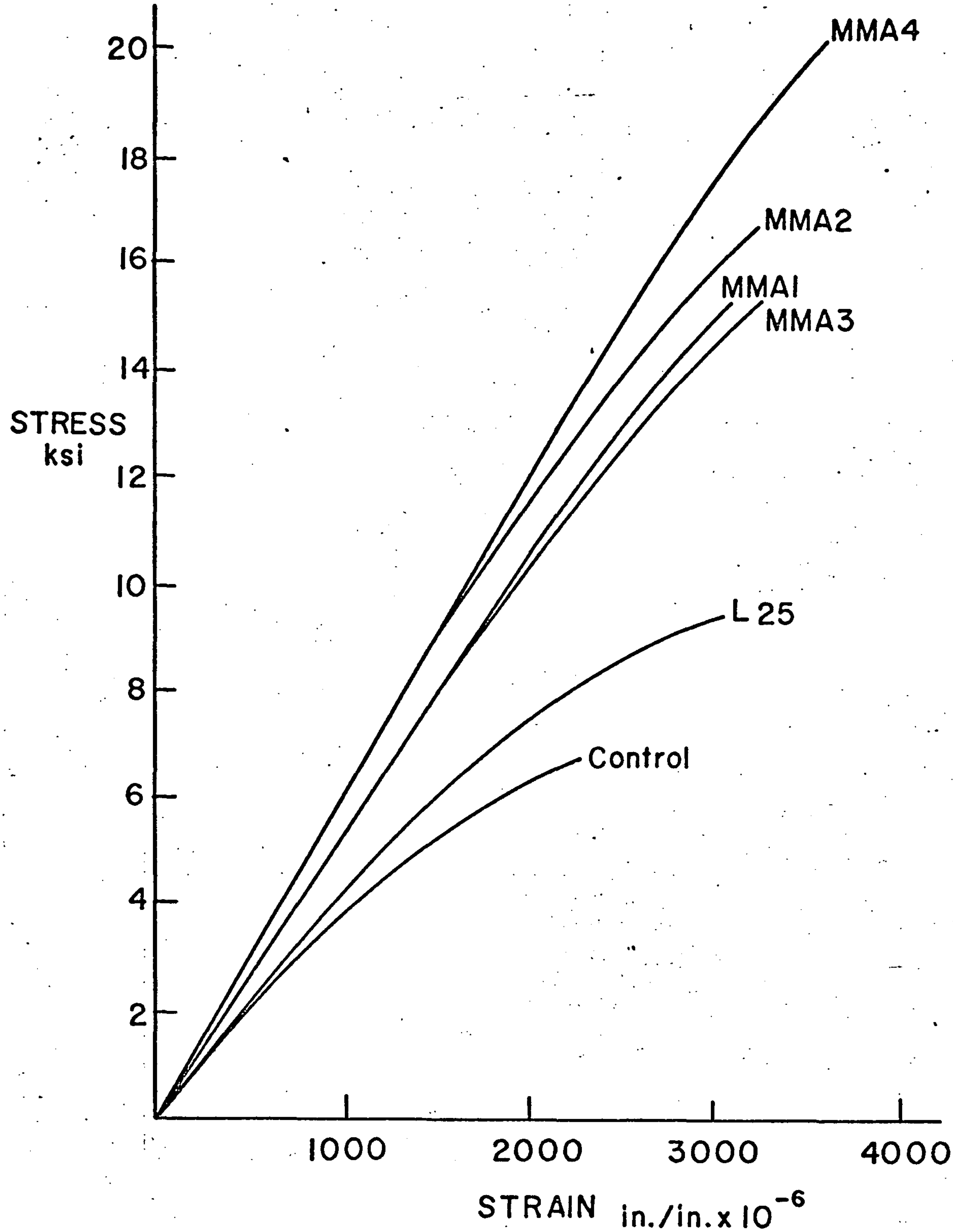


Fig.5 Tensile Load-Strain Curves

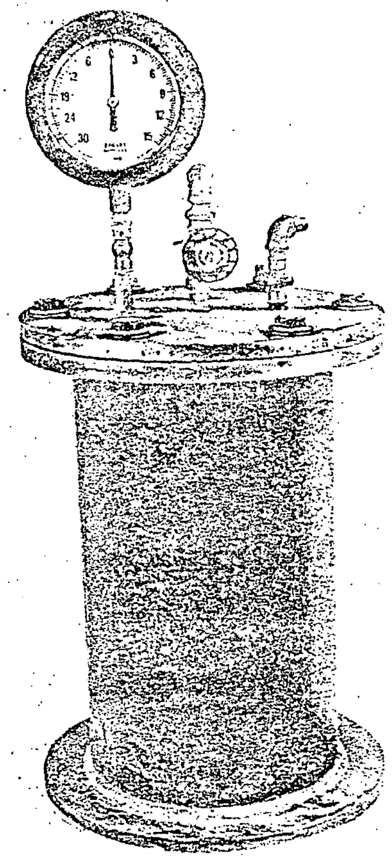


Fig. 1 Impregnation Vessel

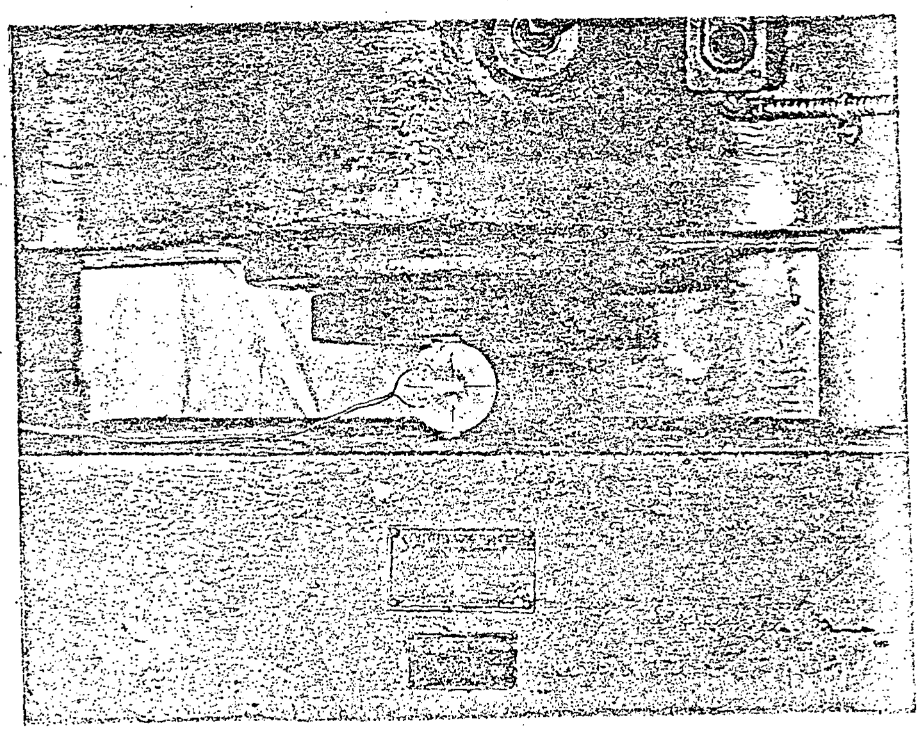
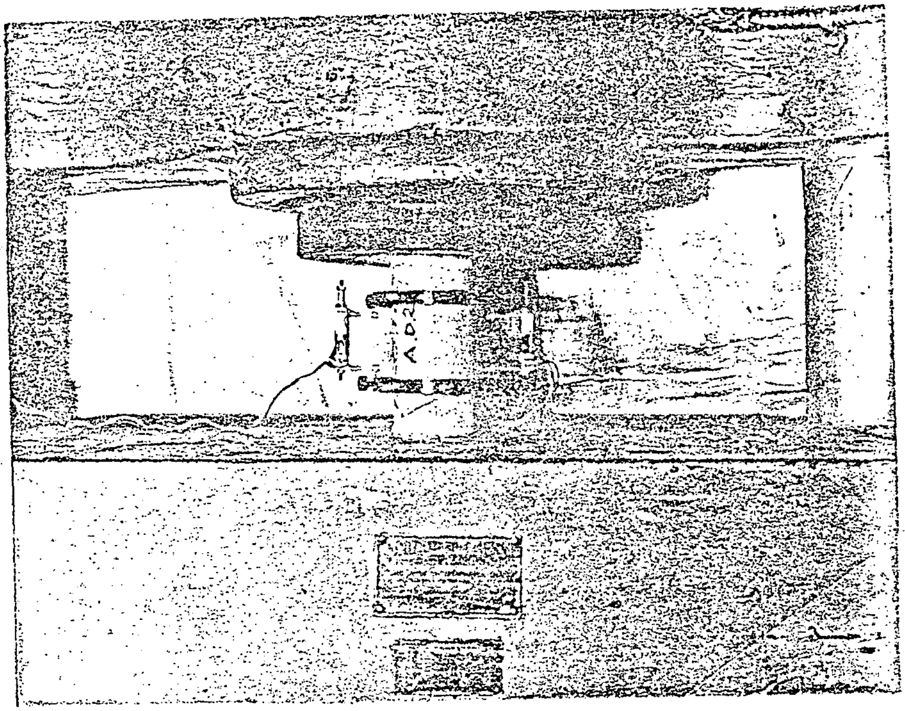


Fig. 2 Split-Tensile Test



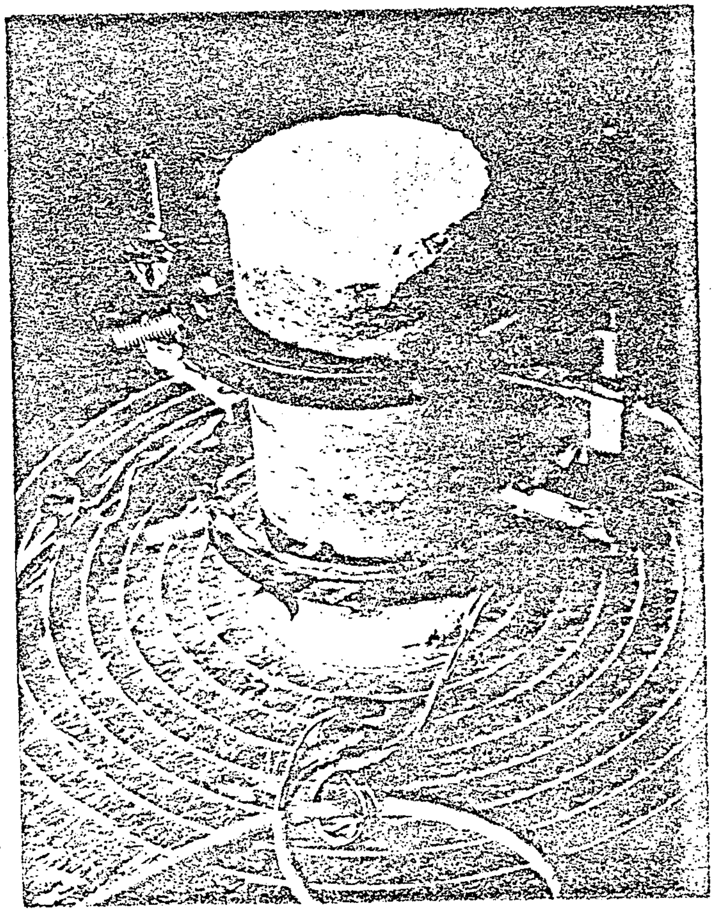


Fig. 3 Compression Test and Strain Measuring Device