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PRELIMINARY EVALUATION OF A TENSION TEST FOR CONCRETE REPAIRS

December 1984

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16. ABSTRACT

A preliminary evaluation was made of using a commercially available hydraulic jack pull-out test device as a method for determining the adequacy of the bond strength of concrete repair materials to concrete. The study indicated that the instrument is useful in evaluating the bond strength of repair materials. The accuracy of the test procedure could be improved by modification of the scale on the test instrument to give a more precise measurement or by increasing the test area of the specimen.

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Concrete and Structural Branch
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Denver, Colorado

SI METRIC

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UNITED STATES DEPARTMENT OF THE INTERIOR ★ BUREAU OF RECLAMATION

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in Island Territories under U.S. Administration.

The research covered by this report was funded under the Bureau of Reclamation Program Related Engineering and Scientific Studies allocation No. DR-380 *Improved Repair Systems for Concrete.*

CONTENTS

TABLES

FIGURES

INTRODUCTION

Since its founding in 1902 the Bureau of Reclamation has built many concrete structures for storing and delivering water. Over the years, some of these structures have deteriorated from abrasion, erosion, freezing and thawing, chemical attack, or a combination of these destructive agents. If not arrested, the deterioration may shorten the service life of the structures.

Over the years, many repair materials have become available. Because some of these materials have better properties than others, an easy, quick method to evaluate them would be useful. Also, it would be advantageous to have equipment that could accurately test the quality of a repair. One type of test that appears promising is a simple tension test,* which can be used to determine:

- The quality of the base concrete,

- The adequacy of surface preparation,

- The quality of the repair material, and

- The strength of the bond between repair material and base concrete.

A commercially available instrument that was developed for a pull-out type of test to determine the strength of concrete after curing for various periods of time appeared to be suitable for testing concrete repairs. This instrument, the Lok-Test device, is a light, portable, hydraulic jack. The instrument appeared suitable as it applies a load at a uniform rate, is easy to operate, and is suitable for both laboratory and field testing.

The test procedure was modified slightly from its intended application by the use of steel plates bonded to the top surface of the cores, rather than pull-out bolts. The first step in the test is to drill part way into the base concrete using a diamond drill core bit, leaving the core intact in the concrete. The steel plate is then glued to the top of the sand-blasted core using an epoxy adhesive. Using the hydraulic jack, a pull-out load is applied to the core until the core fails or pulls out.

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* *Patching of Deteriorated Concrete Surfaces and Edges With Reaction Resin Mortars*, translated from MIB, Forschungs-Gesellschaft Fur Das Strassenwesen, Köln, Germany, 1978.

The test may be used on the base concrete before applying a repair material to determine the quality of the concrete and the adequacy of the surface preparation. The failure in the concrete should equal the expected tensile strength of good quality concrete. A failure at the surface of the concrete may indicate inadequate surface preparation or possibly improper epoxy application.

In testing the repair material, the core is drilled through the repair material into the base concrete. The failure should occur in the concrete. The test is based upon the assumption that the strength of the repair material and the strength of the interface between the repair material and the base concrete should be greater than the strength of the concrete. A failure at the interface indicates insufficient bond strength. A failure in the repair material indicates insufficient strength of the repair material.

CONCLUSIONS

1. The method appears to be suitable basically as a bond strength test for concrete repair materials.

2. The equipment is compact, portable, and easy to operate.

3. Testing is not complicated; it requires time for preparation. Before the test is performed, a core must be drilled, the core surface sand blasted, plates epoxied, and the epoxy cured.

4. The accuracy of data obtained using the 32- and 54-mm-diameter pull-out plates is somewhat questionable as the instrument scale readings at the point of failure are at the low end of the scale on the instrument. The use of plates larger than 54-mm in diameter would shift the scale readings to the mid-part of the instrument range and provide more accuracy. However, the use of the larger plates would require an adapter ring to support the instrument.

5. The instrument should be modified with a lower range instrument scale, or equipped with an adapter ring to permit the use of larger diameter plates.

6. The epoxy concretes, polymer concretes, and polymer modified concretes generally appear to have staisfactory bond strengths although a few instances of bond failures were observed.

TEST INSTRUMENT

The test instrument consists of a hydraulic jack with a gauge, coupling ring, pull-out plates, and bolts. All equipment fits neatly into a briefcase and has a mass of less than 10 kg (fig. 1).

The hydraulic jack is offset from the load chamber. It has a load capacity of 60 kN and a standard operating range of 10 to 60 kN. A calibrated oil pressure gauge measures the load and is mounted on top of the load chamber. A special precision valve system in the load chamber ensures a continuous load application rate of 30 $\pm$10 kN/min.

The pull-out plates and bolts are made of high strength steel. The pull-out plates were fabricated in two sizes: 32 mm in diameter by 19 mm thick; and 54 mm in diameter by 19 mm thick. The bolts are about 8 mm in diameter and 47 mm long. The diameter of the plates was determined by the diameter of available steel stock.

TEST MATERIALS

To evaluate the usefulness of the test instrument for determining the suitability of material for concrete repair, various repair materials (table 1) were overlaid according to manufacturers' directions on several 300- by 300- by 100-mm concrete slabs. Each repair material was cured under conditions specified by its manufacturer to give the best performance. Mix designs following manufacturer's recommendations and having good workability for these repair materials and base slabs are shown in table 2.

The repair materials tested were divided into four main groups:

1. Epoxy concretes

2. Polymer concretes

3. Polymer modified portland cement concretes

4. Special concretes (portland cement concrete with aluminum and copper sulfate additives, and a magnesium phosphate concrete)

TEST PROCEDURES

After the specimens had been properly cured, standard concrete core drilling equipment and practices were used to drill through the overlay into the concrete slab. Core drills 35 and 60 mm in diameter were used to drill the test specimens. The core drill was set to core through the repair material and into the concrete slab to a depth of 35 mm.

Then, the surfaces of the repair materials were lightly sandblasted to ensure a good bond between the pull-out plate and the repair material. Plates were bonded to the top of the cores with a high-strength bonding epoxy. The epoxy was applied and cured according to manufacturer's directions.

When the bonding epoxy had cured, the pull-out bolt was fitted through the coupling ring and screwed into the pull-out plate on the core. The test instrument then was slipped over the coupling ring and locked in place. Three specimens of each material were tested with both the 32- and 54-mm pull-out plates. The load was applied and increased by cranking the hydraulic jack handle until a tensile break occurred. The load causing this tensile break was read from the gauge and recorded. The pull-out strength was calculated by the following equation:

$$S = \frac{L}{1000\,A}$$

where:

S = pull-out strength, MPa,
L = load, kN, and
A = area of the core, m^2.

In addition to test on specimens of repair materials, tests were conducted on conventional portland cement concrete slabs and vinyl ester polymer concrete slabs. Mix design data for the vinyl ester polymer concretes are shown in table 2.

Direct tensile strength tests were conducted on the repair materials and special concretes as a control study. Direct tension tests were performed on 75- by 150-mm cylinders which were epoxied to steel end plates. Results are shown in table 3.

OBSERVATIONS

The pull-out test results showed fairly good consistency within the accuracy of the scale readings of the test instrument. Most repair materials had higher strength and higher bond strength to the base concrete than the strength of the base concrete. Figure 2 shows a typical pull-out test break, with the fracture occurring below the repair material in the base concrete. A comparison of pull-out strengths and direct tensile strengths for the repair materials is given in table 3.

The pull-out strengths obtained using the 55-mm plates were lower than those for the 32-mm pull-out plates. All of the failure loads in the tests were on the low end of the instrument scale; therefore, a pull-out plate larger than 54 mm would be needed to reach the middle range of the scale. The pull-out tests indicatd higher tensile strengths for portland cement concrete than direct tensile strength tests of 75- by 150-mm cylinders. The average pull-out test strengths for the portland cement concrete base slabs were 5.0 MPa with the 32-mm plate, and 3.9 MPa with the 54-mm plate; whereas the direct tensile strength of the cylinders was 3.4 MPa.

The accuracy of the test results is somewhat questionable due to the lack of precision in reading the low end of the instrument scale. The accuracy would be improved by using larger diameter plates, by modifying the instrument scale to give more precise measurements, and by testing a statistically significant number of specimens. However, it is noted that the main points of the test are to ascertain if the base concrete is sound, and if the failure occurs in the repair material, at the interface between the repair material and the base concrete, or in the base concrete.

Epoxy Concretes

Epoxy concretes had the highest direct tensile strengths of the materials investigated. The epoxy concrete direct tensile strengths (7.2 to 11.3 MPa) were higher than the tensile strength of portland cement concrete (3.4 MPa). All breaks for the pull-out tests with the 32-mm plate occurred in the base concrete slabs. The strengths of these slabs ranged from 4.7 to 5.0 MPa. It was observed that one epoxy concrete specimen showed an adhesion failure at the bond line and a low pull-out strength of 2.9 MPa. This particular epoxy concrete also had the lowest direct tensile strength of the group of epoxy concretes. It is not known at this time if the failure is an inherent weakness of the system or only represents a poor job of bonding the epoxy concrete to the base concrete.

Polymer Concretes

Five polymer concrete materials having a wide range of direct tensile strengths (2.7 to 8.3 MPa) were tested. Two of these five materials showed adhesion failure. These failures occurred at pull-out strengths near the strength of the base concrete.

Polymer Modified Concretes

Tensile strengths and pull-out strengths were nearly the same for the polymer modified concretes using the 32-mm plates. Pull-out and direct tensile strength test results indicated that there was little difference between the various materials. The average tensile strength for the five materials was 4.6 MPa — with a high of 5.3 and a low of 3.9 MPa. In the pull-out tests with the 32-mm plate, strengths ranged from 3.8 to 5.5 MPa — with an average of 4.8 MPa. With the 54-mm plates, the strengths from the tests were lower and ranged from 3.7 to 4.2 MPa — with an average of 3.9 MPa. Two materials (Acryl Set and Synthemul) showed bond failure using the 32-mm plates. These bond failures occurred near the 5.0-MPa pull-out strength of the base concrete. Bond failures did not occur in the tests with the 54-mm plates.

Special Concretes

Magnesium phosphate concrete and the concrete with aluminum and copper sulfate additives showed low direct tensile strength. They both failed in adhesion at the joint in pull-out tests with each size plate.

Table 1. – Concrete repair materials tested.

Epoxy concrete	*Acrylic polymer concrete*
Flexocrete III	Concresive 2020
Flexocrete	Degadur 330
Pro Bond ET 150G	Crylcon
Hultscrete	Silikal
	Degadur 410
Polymer modified concrete	***Special concretes***
Rhoplex E-330	Set 45 (magnesium phosphate cement)
Tylac	Ali/Cite (aluminum and copper sulfate cement)
Acryl Set	Portland cement concrete
Dylex Latex	
Synthemul	

Table 2. – Mix design of concrete repair materials.

EPOXY CONCRETES

Epoxy — Flexocrete III

U.S.A. Standard series sieve size-fraction range, mm	*Aggregate System* Material	Percent by weight
4.75 — 9.5	Natural siliceous aggregate	24.9
2.36 — 4.75	Natural siliceous sand	18.0
1.18 — 2.36	Natural siliceous sand	13.7
0.60 — 1.18	Natural siliceous sand	8.6
0.30 — 0.60	Natural siliceous sand	6.0
0.15 — 0.30	Natural siliceous sand	3.4
pan	Natural siliceous sand	11.1

Resin System

Material	Amount, percent
Part A	9.9
Part B	4.4

Epoxy — Flexocrete

U.S.A. Standard series sieve size-fraction range, mm	*Aggregate System* Material	Percent by weight
4.75 — 9.5	Natural siliceous aggregate	24.9
2.36 — 4.75	Natural siliceous sand	18.0
1.18 — 3.36	Natural siliceous sand	13.7
0.60 — 1.18	Natural siliceous sand	8.6
0.30 — 0.60	Natural siliceous sand	6.0
0.15 — 0.30	Natural siliceous sand	3.4
pan	Natural siliceous sand	11.1

Resin System

Material	Amount, percent
Part A	9.9
Part B	4.4

Epoxy — Pro Bond ET 150G

U.S.A Standard series sieve Size-fraction range, mm	*Aggregate System* Material	Percent by weight
9.5 — 19.0	Natural siliceous aggregate	23.3
4.75 — 9.5	Natural siliceous aggregate	17.4
2.36 — 4.75	Natural siliceous sand	12.6
1.18 — 3.36	Natural siliceous sand	9.6
0.60 — 1.18	Natural siliceous sand	6.0
0.30 — 0.60	Natural siliceous sand	4.2
0.15 — 0.30	Natural siliceous sand	2.4
pan	Natural siliceous sand	7.8

Resin System

Material	Amount, percent
Part A	11.0
Part B	5.7

Epoxy — Hultscrete

Aggregate System Material	Percent by weight
Manufacturer furnished sand	82.1

Resin System

Material	Amount, percent
Part A	12.8
Part B	5.1

ACRYLIC POLYMER CONCRETES

Polymer Concrete — Concresive 2020

U.S.A. Standard series sieve size-fraction range, mm	*Aggregate System* Material	Percent by weight
4.75 — 9.5	Natural siliceous aggregate	28.5
2.36 — 4.75	Natural siliceous sand	9.5
	Polymer powder	56.0
	Liquid polymer	6.0

Polymer Concrete — Degadur 330

U.S.A. Standard series sieve size-fraction range, mm	*Aggregate System* Material	Percent by weight
4.75 — 9.5	Natural siliceous aggregate	30.9
2.36 — 4.75	Natural siliceous sand	14.1
1.18 — 3.36	Natural siliceous sand	10.8
0.60 — 1.18	Natural siliceous sand	7.9
0.30 — 0.60	Natural siliceous sand	6.2
	F-95 Ottawa sand	7.9
	Silica flour	10.4
	Liquid polymer	11.6
	Benzoyl peroxide	0.2

Polymer Concrete — Crylcon

U.S.A. Standard series sieve size-fraction range, mm	*Aggregate System* Material	Percent by weight
4.75 — 9.5	Natural siliceous aggregate	28.3
2.36 — 4.75	Natural siliceous sand	9.4
	Polymer powder	56.7
	Liquid polymer	5.6

Polymer Concrete — Silikal

U.S.A. Standard series sieve size-fraction range, mm	*Aggregate system* Material	Percent by weight
4.75 — 9.5	Natural siliceous aggregate	28.3
2.36 — 4.75	Natural siliceous sand	9.4
	Polymer powder	56.7
	Liquid polymer	5.6

Polymer Concrete — Degadur 410

U.S.A. Standard series sieve size-fraction range, mm	*Aggregate System* Material	Percent by weight
4.75 — 9.5	Natural siliceous aggregate	30.9
2.36 — 4.75	Natural siliceous sand	14.1
1.18 — 3.36	Natural siliceous sand	10.8
0.60 — 1.18	Natural siliceous sand	7.9
0.30 — 0.60	Natural siliceous sand	6.2
	F-95 Ottawa sand	7.9
	Silica flour	10.3
	Liquid polymer	11.7
	Benzoyl peroxide	0.2

Table 2. - Mix design of concrete repair materials.-Continued

POLYMER MODIFIED CONCRETES

Emulsion — Rhoplex E-330

U.S.A. Standard series sieve size-fraction range, mm	*Aggregate System* Material	Percent by weight
0.60 — 1.18	Natural siliceous sand	27.1
0.30 — 0.60	Natural siliceous sand	27.1
0.15 — 0.30	Natural siliceous sand	5.7
pan	Natural siliceous sand	2.9
	Portland cement, type I	24.6
	Acrylic emulsion	7.3
	Water	5.2
	Defoaming agent	0.04

W/C ratio 0.40

Emulsion — Tylac

U.S.A. Standard series sieve size-fraction range, mm	*Aggregate System* Material	Percent by weight
4.75 — 9.5	Natural siliceous aggregate	33.1
2.36 — 4.75	Natural siliceous sand	6.0
1.18 — 3.36	Natural siliceous sand	6.2
0.60 — 1.18	Natural siliceous sand	10.3
0.30 — 0.60	Natural siliceous sand	10.3
0.15 — 0.30	Natural siliceous sand	6.4
pan	Natural siliceous sand	2.1
	Portland cement, type I	16.5
	Acrylic emulsion	5.2
	Water	3.9

W/C ratio 0.44

Emulsion — Acryl Set

U.S.A. Standard series sieve size-fraction range, mm	*Aggregate System* Material	Percent by weight
4.75 — 9.5	Natural siliceous aggregate	33.7
2.36 — 4.75	Natural siliceous sand	5.1
1.18 — 3.36	Natural siliceous sand	5.1
0.60 — 1.18	Natural siliceous sand	8.4
0.30 — 0.60	Natural siliceous sand	8.4
0.15 — 0.30	Natural siliceous sand	5.1
pan	Natural siliceous sand	1.7
	Portland cement, type I	22.6
	Acrylic emulsion	6.6
	Water	3.3

W/C ratio 0.34

Emulsion — Dylex Latex

U.S.A. Standard series sieve size-fraction range, mm	*Aggregate System* Material	Percent by weight
9.5 — 19.0	Natural siliceous aggregate	16.6
4.75 — 9.5	Natural siliceous aggregate	16.7
2.36 — 4.75	Natural siliceous sand	6.2
1.18 — 3.36	Natural siliceous sand	6.2
0.60 — 1.18	Natural siliceous sand	10.4
0.30 — 0.60	Natural siliceous sand	10.4
0.15 — 0.30	Natural siliceous sand	6.2
pan	Natural siliceous sand	2.1
	Portland cement, type I	16.8
	Acrylic emulsion	4.6
	Water	3.8

W/C ratio 0.40

Table 2. - Mix design of concrete repair materials.-Continued

Emulsion — Synthemul

U.S.A. Standard series sieve size-fraction range, mm	*Aggregate System* Material	Percent by weight
4.75 — 9.5	Natural siliceous aggregate	27.0
2.36 — 4.75	Natural siliceous sand	5.8
1.18 — 3.36	Natural siliceous sand	5.9
0.60 — 1.18	Natural siliceous sand	9.7
0.30 — 0.60	Natural siliceous sand	9.7
0.15 — 0.30	Natural siliceous sand	6.0
pan	Natural siliceous sand	2.0
	Portland cement, type I	21.8
	Acylic emulsion	7.2
	Water	4.7
	Defoaming agent	0.2

W/C ratio 0.43

SPECIAL CONCRETES

Set 45–Magnesium Phosphate Cement

U.S.A. Standard series sieve size-fraction range, mm	*Aggregate System* Material	Percent by weight
4.75 — 9.5	Natural siliceous aggregate	31.5
	Water	5.2
	Magnesium phosphate and fine aggregate	63.3

Ali/Cite–Aluminum and Copper Sulfate Cement

U.S.A. Standard series sieve size-fraction range, mm	*Aggregate System* Material	Percent by weight
9.5 — 19.0	Natural siliceous aggregate	21.9
4.75 — 9.5	Natural siliceous aggregate	21.9
2.36 — 4.75	Natural siliceous sand	4.7
1.18 — 3.36	Natural siliceous sand	4.8
0.60 — 1.18	Natural siliceous sand	7.9
0.30 — 0.60	Natural siliceous sand	7.9
0.15 — 0.30	Natural siliceous sand	4.9
pan	Natural siliceous sand	1.6
	Portland cement, type I	16.3
	Water	8.1
	Compound 62EC	

PORTLAND CEMENT CONCRETE

U.S.A. Standard series sieve size-fraction range, mm	*Aggregate System* Material	Percent by weight
9.5 — 19.0	Natural siliceous aggregate	25.8
4.75 — 9.5	Natural siliceous aggregate	17.2
2.36 — 4.75	Natural siliceous sand	4.8
1.18 — 3.36	Natural siliceous sand	4.8
0.60 — 1.18	Natural siliceous sand	7.9
0.30 — 0.60	Natural siliceous sand	7.6
0.15 — 0.30	Natural siliceous sand	5.2
pan	Natural siliceous sand	1.4
	Portland cement, Type II	17.6
	Water	7.7
	Air entraining agent	*

W/C ratio 0.44

*143 mL of air entraining agent for 132 kg mix.

Table 3. – Comparison of direct tensile test instrument pull-out strengths.[1]

Material	Tensile strength[2] MPa	Lok-Test pull-out test			
		32-mm plate		54-mm plate	
		Strength[3] MPa	Type failure	Strength[3] MPa	Type failure
Epoxy concrete					
Flexocrete III	11.2	5.0	Concrete	3.5	Adhesion
Flexocrete	11.3	5.0	Concrete	3.8	Concrete
Pro Bond	9.2	5.0	Concrete	4.0	Concrete
Hultscrete	7.2	4.7	Concrete	2.9	Adhesion
Polymer concrete					
Concresive	6.3	4.4	Adhesion	2.9	Adhesion
Crylcon	8.3	4.8	Concrete	4.0	Concrete
Silikal	7.1	4.5	Adhesion	3.5	Adhesion
Degadur 330	2.7	4.6	Concrete	3.6	Concrete
Degadur 410	6.6	5.3	Concrete	4.4	Concrete
Polymer modified concrete					
Rhoplex	4.3	5.2	Concrete	4.0	Concrete
Tylac	5.1	5.5	Concrete	3.7	Concrete
AcrylSet	5.3	3.8	Adhesion	4.2	Concrete
Dylex Latex	4.5	5.1	Concrete	3.8	Concrete
Synthemul	3.9	4.5	Adhesion	3.8	Concrete
Special concrete					
Set 45 Magnesium phosphate	0.3	4.1	Adhesion	2.6	Adhesion
Ali/Cite Aluminum and copper sulfates	0.7	3.6	Adhesion	2.4	Adhesion
Portland cement concrete					
Control mix	3.4	5.0	Concrete	--	--

[1] Materials were tested after 28 days' age.
[2] Average of three test specimens.
[3] Average of three to five test specimens.

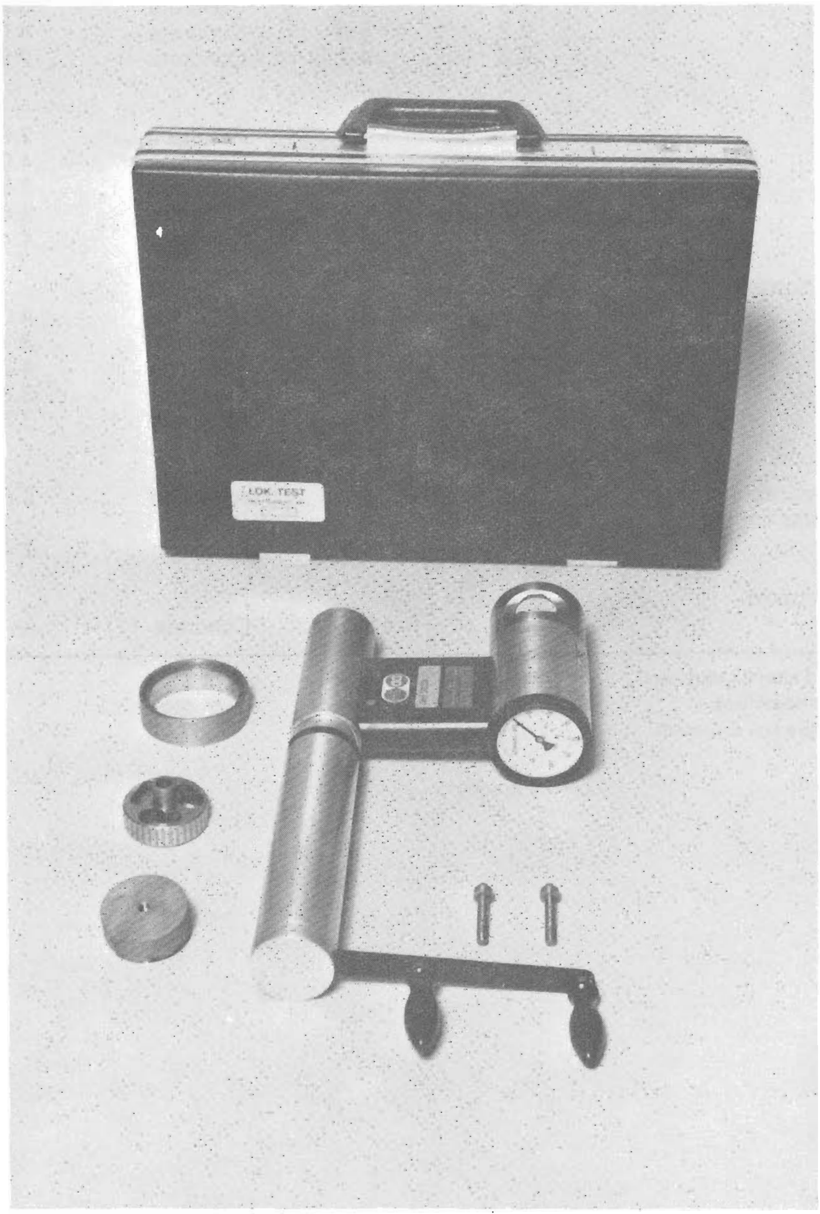

Figure 1. – Test device. The parts are (clockwise from the top) the Lok-test instrument, two coupling bolts, steel plate which is epoxied to the concrete core test specimen, coupling, and adapter ring. Photo P801-D-80925

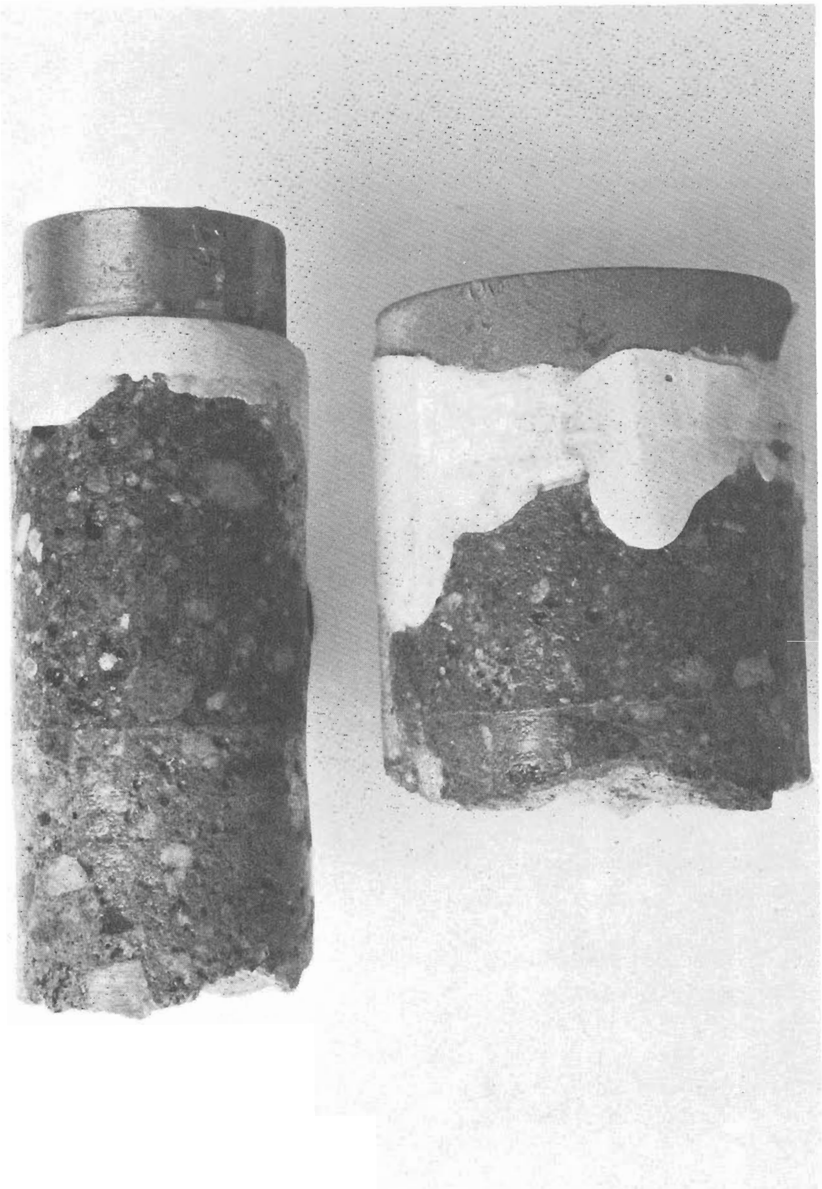

Figure 2. – A typical break in the concrete using the pull-out test to evaluate the quality of concrete repair materials. Photo P801-D-80926

GPO 848-725

Mission of the Bureau of Reclamation

The Bureau of Reclamation of the U.S. Department of the Interior is responsible for the development and conservation of the Nation's water resources in the Western United States.

The Bureau's original purpose "to provide for the reclamation of arid and semiarid lands in the West" today covers a wide range of interrelated functions. These include providing municipal and industrial water supplies; hydroelectric power generation; irrigation water for agriculture; water quality improvement; flood control; river navigation; river regulation and control; fish and wildlife enhancement; outdoor recreation; and research on water-related design, construction, materials, atmospheric management, and wind and solar power.

Bureau programs most frequently are the result of close cooperation with the U.S. Congress, other Federal agencies, States, local governments, academic institutions, water-user organizations, and other concerned groups.