CRACK AND SEAT OF PCC-
STATE OF THE ART

DHT-7

**DEPARTMENTAL
INFORMATION
EXCHANGE**

STATE DEPARTMENT OF HIGHWAYS
AND
PUBLIC TRANSPORTATION

RESEARCH SECTION, FILE D10-R, P.O. BOX 5051 AUSTIN, TX 78763-5051, 512-465-7403, STS 241-7403

Technical Report Documentation Page

1. Report No. DHT-7	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Crack and Seat of PCC - State of the Art		5. Report Date April 1988
		6. Performing Organization Code
7. Author(s) Jeff Seiler, Engineering Assistant II Special Projects Coordinator		8. Performing Organization Report No. DHT-7
9. Performing Organization Name and Address State Dept. of Highways and Public Transportation Transportation Planning Division P.O. Box 5051 Austin, Texas 78763		10. Work Unit No. (TRAIS)
		11. Contract or Grant No.
12. Sponsoring Agency Name and Address State Dept. of Highways and Public Transportation 11th and Brazos Austin, Texas 78701		13. Type of Report and Period Covered
		14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

No previous experience of eliminating reflective cracking of both joints and cracks in portland cement concrete pavements through bituminous concrete overlays has been completely successful. This led to the idea of breaking slabs into smaller pieces in order to control movement of the deteriorating PCC pavements under the overlays. In cracking and seating, the existing pavement is broken up into small pieces, approximately 18 inches to 36 inches in size in most cases, and then seated against the subgrade prior to overlaying. Research efforts have been pointed at determining: (1) the nominal size of breakage, (2) the amount of energy (or rolling) required for seating, and (3) the optimum amount of bituminous concrete to be used in the overlay. The answers to each of these will vary from project to project.

17. Key Words Crack and seat Breaking and seating PCC Pavements Reflective Cracking	18. Distribution Statement

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages 12	22. Price

Form DOT F 1700.7 (8-72)

CRACK AND SEAT OF PCC -
STATE OF THE ART

BY

JEFF SEILER
ENGINEERING ASSISTANT II
SPECIAL PROJECTS COORDINATOR

APRIL 1988

TABLE OF CONTENTS

Problem Statement

Rapid advances have recently been made in crack and seat technology. These techniques are widely used throughout the U.S. One state has recently reported success with resonant pavement breakers which "rubble-ize" the pavement. Other states break the pavement into blocks of specified sizes. These blocks vary from about one foot by one foot to four feet by six feet. A recent FHWA study "Crack and Seat Performance - Review Report" reported both successes and failures with this procedure. This report left some questions unanswered such as what performance could be anticipated with thick overlays such as those used in Kentucky, or which procedure is best for pavements with substantial steel, etc. There is an urgent need to determine when, where and how this technology could be used in Texas.

*NOTE: The FHWA study described above is only approximately 30% completed and not available at this time.

Introduction

No previous experience of eliminating reflective cracking of both joints and cracks in portland cement concrete pavements through bituminous concrete overlays has been completely successful. This led to the idea of breaking slabs into smaller pieces in order to control movement of the deteriorating PCC pavements under the overlays. In cracking and seating, the existing pavement is broken up into small pieces, approximately 18 inches to 36 inches in size in most cases, and then seated against the subgrade prior to overlaying. Research efforts have been pointed at determining: (1) the nominal size of breakage, (2) the amount of energy (or rolling) required for seating, and (3) the optimum amount of bituminous concrete to be used in the overlay. The answers to each of these will vary from project to project.

Overview

Vertical movement with differential slab deflection at the joints and temperature related movement in a horizontal direction are both contributing factors in the reflection of the cracking in the existing pavement into and through the overlay of bituminous concrete. Through cracking and seating, there generally is a reduction in the amount of reflective cracks through the overlay during the first few years following the project. However, there have been instances where, after four to five years, the C & S sections exhibited approximately the same amount of reflective cracks as their control sections.

Nevertheless, plain, reinforced and wire mesh PCC have all been treated successfully. For example, it has been found that reflective cracking is reduced in reinforced concrete pavement after C & S and that crack spacing is dependent on the amount and location of reinforced steel as well as slab thickness. Also, reflection cracking is reduced after C & S of non-reinforced concrete pavement, e.g., the reflection cracking in thin overlays was reduced on one project from the expected 40 to 50 percent to about 6 percent after two years.

Rules and Guides

Cracking and seating does not mean reducing the PCC to a rubble. Destructive techniques such as the use of a headache ball, chisel-nose pile driver, and other inappropriately designed impact faces, as well as excessive energy, will lead to undesirable spalling and excessive loss of structural strength. The type of impact equipment, energy of impact, slab temperature, inherent stresses in the slab, and subgrade condition can all affect the crack pattern achieved. The proper cracking techniques result in fine cracks that run throughout the complete depth of the slab. When the proper procedures are used, the cracks are usually so fine that water may have to be sprayed on the surface to render them visible to the eye. Spacing of impacts and energy of impacts must be adjusted to avoid spalling. It is customary to establish the proper procedure on a 100-foot test section before beginning work. In addition, frequent checks of the pattern are needed to assure that the procedure is effective. Checking the pattern is a very important aspect of the technique, demanding vigilance on the part of contractor and agency alike. Coring and deflection analyses before and after C & S can be used to verify that proper cracking has occurred. Coring the PCC through a visible surface crack has also been used to verify that full depth cracking has been achieved. However, visual observation with surface water is easier and less costly although this method is not a guarantee that approximately vertical cracks have been obtained.

Care should be taken concerning cracking and cracking locations. Impacting close to the edge of the slab can induce longitudinal cracking. Longitudinal cracks are undesirable because they tend to reflect through bituminous overlays. Direct cracking over culverts, underground ducts, and drainage pipes also should be avoided to prevent damage to these systems.

In order for the C & S process to be fully effective, drainage problems must be eliminated and the pavement must sit on a good subbase. Non-reinforced pavements that are cracked and sit on a poor base/subbase are susceptible to rocking or vertical movement of some of the pavement pieces. If a history of frost heaving or other base and/or subgrade deficiencies exist, cracking, seating, and overlaying will not improve the condition.

Caltrans' criteria for crack and seat projects is an unacceptable ride and extensive structural problems with multiple cracking of over ten percent of slabs in the truck lane. Other guidelines used by Caltrans in determining the extent of cracking and seating are:

(1) Use in all lanes expected to carry an appreciable amount of truck traffic. On facilities with six or more lanes, this would generally include the outer two lanes. On four-lane facilities, it would often include all lanes, especially in urban areas.

(2) On lanes expected to carry primarily auto traffic: Where there is 1/8 inch or more average faulting with or without slab breakage, cracking and seating is recommended. Where there is less than 1/8 inch average faulting and no slab breakage, cracking and seating is <u>not</u> recommended.

<u>Equipment</u>

There are several types of cracking equipment on the market and most of them are modified pavement breakers. Six types of equipment used are listed and briefly described below.

CMI Dynapulse Concrete Breaker: This type of equipment, while capable of high production, requires a special head in order to ensure the correct cracking pattern. Initial use in Michigan was not completely successful due to the uncertainty of production rates and success in obtaining the desired cracking pattern.

Hydraulic Concrete Breaker: This equipment, while suitable for small projects, is not capable of high production rates and requires fitting with a special head, as the normal breaking head is designed to break the pavement for removal. It is difficult to establish the correct cracking pattern due to the almost uncontrollable amount of impact.

Diesel Pile Hammer: The diesel pile hammer must be adapted to a concrete cracker. On some projects, the hammer was outfitted with a special shoe which was a steel plate with a 45.72 cm (18 inch) square protruding from the bottom of the plate. The solid steel square received the impact from the diesel hammer and produced the desired cracking pattern. This equipment is capable of very high production rates on large open road projects. However, the hammer is noisy, dirty, and creates the perception that it is not only cracking the pavement but doing damage to surrounding buildings and other structures.

The diesel pile hammer can be mounted in the bowl of a small scraper for large volume projects. This modification provides for higher production rates and lower unit costs. The one drawback of this method, however, is that it is difficult for the operator to control the forces that are transmitted by the hammer to the concrete being cracked.

Modified Pile Driver: The modified pile driver, like the diesel pile hammer, is fitted with a shoe. The hammer is frequently mounted on a trailer which is tractor-drawn. The rate of impact can be varied by changing the fuel input into the hammer. The rate of forward motion of the towing vehicle can also be varied to give different impacts on the pavements.

Resonant Pavement Breaker: Experimental work was conducted in California to determine the usability of the resonant breaker. The breaker employed a 13 inch by 7 inch pad on the end of a 12.5 feet long steel beam which was vibrated at 44 cycles per second. Attempts to induce transverse cracking by impacting the paving between longitudinal cracks were not successful. However, on a similar project, the resonant breaker was used to induce longitudinal cracks with better results.

Wirtgen "Guillotine" Cracking Machine: Used extensively in Germany, the guillotine hammer has been successful in the cracking, breaking, and removal of pavements. This equipment utilizes a large steel-edged breaking head (or blade) that is approximately 36 inches wide, 5-7 tons, and moves up and down on vertical guides. The amount of impact can be varied by changing the drop height. Some models are capable of varying drop heights ranging from 12 inches to 9 feet 8 inches, but the usual height is about 18 inches.

This machine is self-propelled and can be carefully monitored by the operator walking or riding it with good visual access to the pavement being cracked. The operator, thus, can control the speed of the machine which in turn determines the distance between impacts.

This type of machine lends itself to producing transverse cracks, and it is the current thinking that these are the most important types of cracks in the cracking and seating process. In fact, consistent longitudinal cracking is avoided. It, the machine, accomplishes its purpose very well with high rates of production and good mobility.

Whiphammer Breaker: In the whiphammer machine, the impact hammer is attached to the end of a leaf-spring arm, approximately 6 feet long, which can be controlled in a horizontal as well as a vertical direction, enabling it to do lane widths of pavement as it travels down the road. The breaker is mounted on the rear of a conventional truck with the operator at the rear with a direct view of the area being subjected to the breaking head. The operator controls the hammer and, as only one operator is required, is able to drive the truck from the rear position or drive the truck away when the job is completed.

The breaking head can be easily removed to adjust to the correct shape for establishing the desired cracking pattern. From the controller's position, it is very easy to control the impact and spacing of the impact points.

Once cracked, the pavement (concrete) pieces must be firmly seated against the subgrade. Without proper seating, the pieces may rock and cause reflection cracking in the bituminous concrete overlay. Seating can be accomplished using a rubber-tired roller or pneumatic-tired roller. In general, the most effective seating is accomplished with a heavy pneumatic-tired roller. Two passes with a 50-ton pneumatic-tired roller has given good results. Success has also been obtained with a fully ballasted 35-ton multi-wheeled pneumatic-tired roller.

Some seating has been tried with steel drum rollers and vibratory rollers but with little success. These types of rollers tend to bridge over the cracked pieces, thus they are not generally satisfactory for seating purposes.

(*See illustrations at end of report*)

<u>Costs and Benefits</u>

Cracking and seating is the first effective, economic method to prevent or delay the onset of reflective cracking. In the beginning, the average cost ranged from $1.00 to about $1.50 per square yard. Now, in areas where there is a regular program of projects, costs have stabilized in the $0.25 to $0.50 per square yard region. Projects costs will, of course, vary according to experience and volume of work. Costs are higher for experimental work or projects requiring special treatments to joints, etc.

Many times, cracking and seating is cost justified compared to crack filling, undersealing, patching, maintenance, etc. In instances of excessive pumping, rocking slabs, and similar distresses, it would probably be more economical to crack and seat rather than undersealing. Another example is a project on Highway 81 in northeastern Pennsylvania. The project was scheduled for patching with portland cement concrete and an overlay of 3.5 inches of hot-mix asphalt at a cost of $999,087. A proposal was submitted by State Aggregates, Inc. to crack and seat 55,700 square yards on the northbound lanes and to increase the asphalt overlay to 4.5 inches. The total cost of this alternate proposal was $438,133 -- A savings of $552,954.

The benefits of cracking and seating, followed with bituminous concrete overlays, are many. Reflection cracking is prevented or delayed, thus extending the service life of the overlay. Maintenance costs are reduced and disruption of traffic is minimized compared with other alternative treatments such as removing the old pavement structure and replacing it. In addition, the overlay, coupled with C & S, improves riding smoothness and restores skid resistance. Finally, old overlays on PCC can be reclaimed and recycled, thus conserving materials and energy as well as saving costs.

Example Projects

One example is a project conducted/contracted by the Ohio DOT in 1984. The DOT cracked and seated 2.5 miles of four-lane, divided U.S. Route 23 in Wyandot County prior to overlaying with hot-mix asphalt. A pavement breaker was rented for the cracking procedure and it utilized a diesel powered hammer, mounted in a frame, which is capable of producing up to 30,000 foot-pounds of energy. Three passes for each 12 ft. lane were made with the breaker and it delivered 80 to 90 blows per minute. A dozer pulled the machine at a speed that allowed the hammer to hit approximately 40 blows per 60 ft. slab. When the breaker was pulled across a slab with extreme deterioration or a soft subgrade, the tow vehicle would increase speed, eliminating undue damage and spalling to a already deteriorated pavement.

After cracking, a roller was loaded with concrete slabs to a weight just over 50 tons. Two passes were made over the cracked surface, seating the cracked rigid pavement into the subgrade. The pavement was then swept with a power broom.

After cracking, seating, and cleaning, a tack coat was applied then a 3 inch asphalt base course of 301 was laid, followed by a 1.75 inch asphalt concrete leveling coarse of 402. Finally, a 1.25 inch surface coarse of 404 was laid, completing the 6 inch overlay.

More example projects can be found in references 1 through 5.

Summary

Cracking and seating should be approached with caution. Agencies contemplating the use of C & S should do a thorough project-by-project analysis to determine if it is the most cost-effective rehabilitation technique to employ. Although the idea of breaking PCC pavements prior to overlaying is not new, it is only relatively recently that the cracking concept has become popular, with the development of suitable equipment to apply the correct techniques.

In summary, the general procedure is:

1) Remove any existing overlay and stockpile the reclaimed material for recycling. Some work has been done without removing the overlay but it is difficult to determine the extent of the cracking procedure.

2) Determine if there is a need for edge drains. If there is, install edge drains before the cracking procedure commences.

3) Inspect the joints. Special treatment may be required. Also note joint locations, culvert and drainage pipe locations, etc., so these areas can be avoided if necessary.

4) Determine the cracking technique and pattern by means of a 100-foot test section, then proceed with cracking.

5) Seat the cracked portions firmly onto the subgrade by means of one or two passes of a heavy pneumatic-tired compactor (roller).

6) Where necessary, remove soft or failed areas (punch-throughs, etc.) and reinstate with full depth patches.

7) Sweep off any loose material.

8) Tack coat the surface and lay the leveling coarse.

9) Place and compact the overlay to the design thickness.

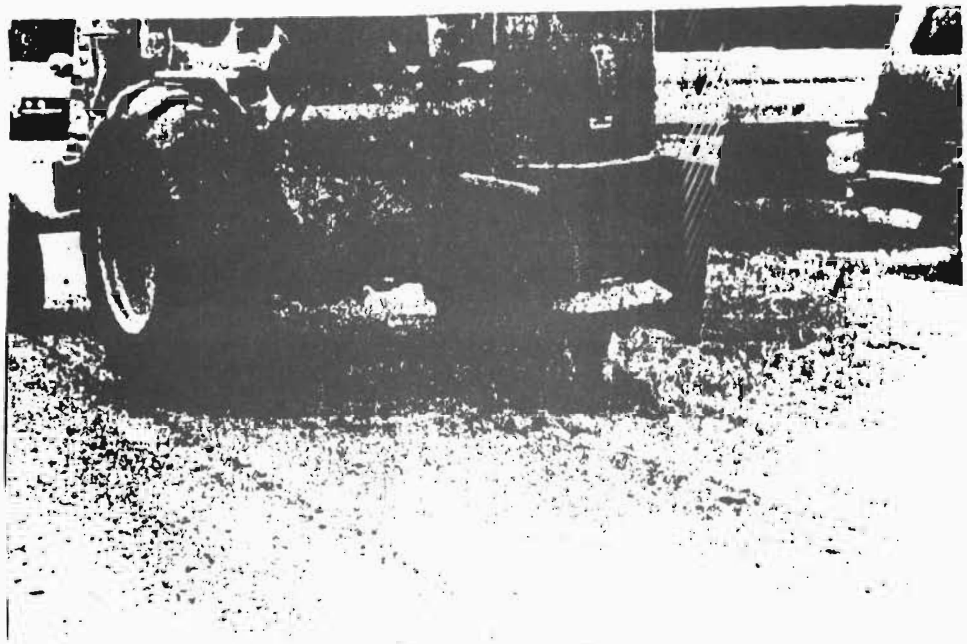
The optimum size of cracked pieces has yet to be established. Success has been obtained with various sizes, but 18 inches to 36 inches appears to be the popular range selected. Good experience has also been obtained by inducing transverse cracks at intervals of 2 feet to 4 feet in slabs, thus effectively reducing the length of slabs. Overlay thickness will depend on the expected traffic and the modulus of the cracked and seated pavement section.

There are a number of different types of pavement crackers and compactors on the market. The arrival of these various types of equipment has generally led to a reduction in costs for the process. Reflective cracking can be reduced or at least delayed, thus saving pavement costs and extending the service life of the pavement structure.

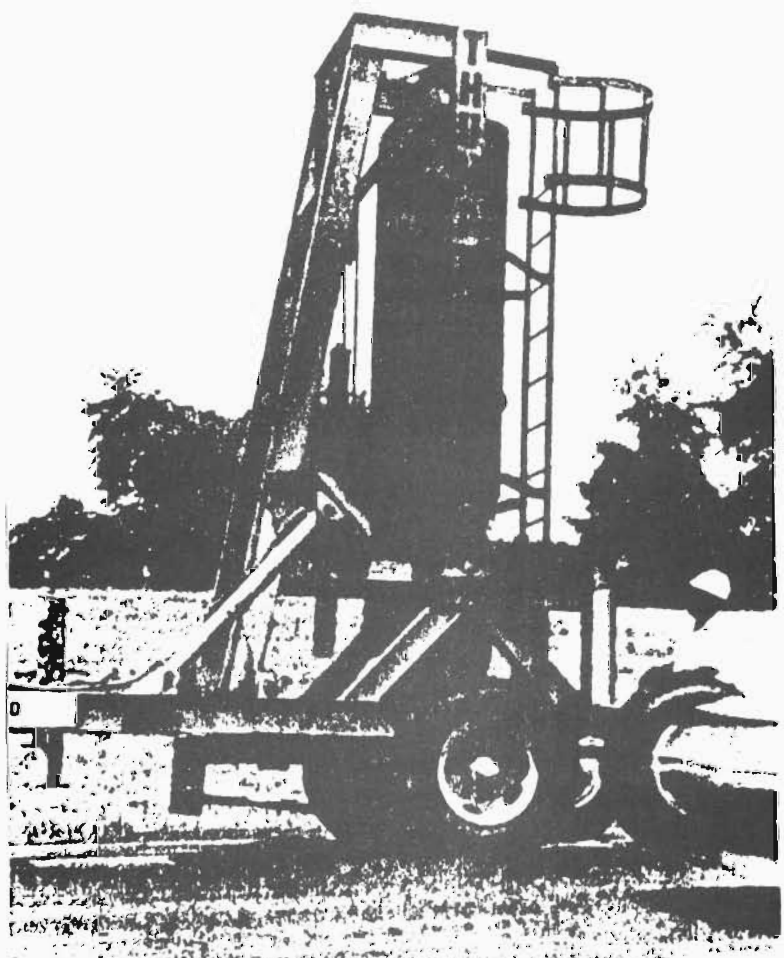
EQUIPMENT

ILLUSTRATIONS

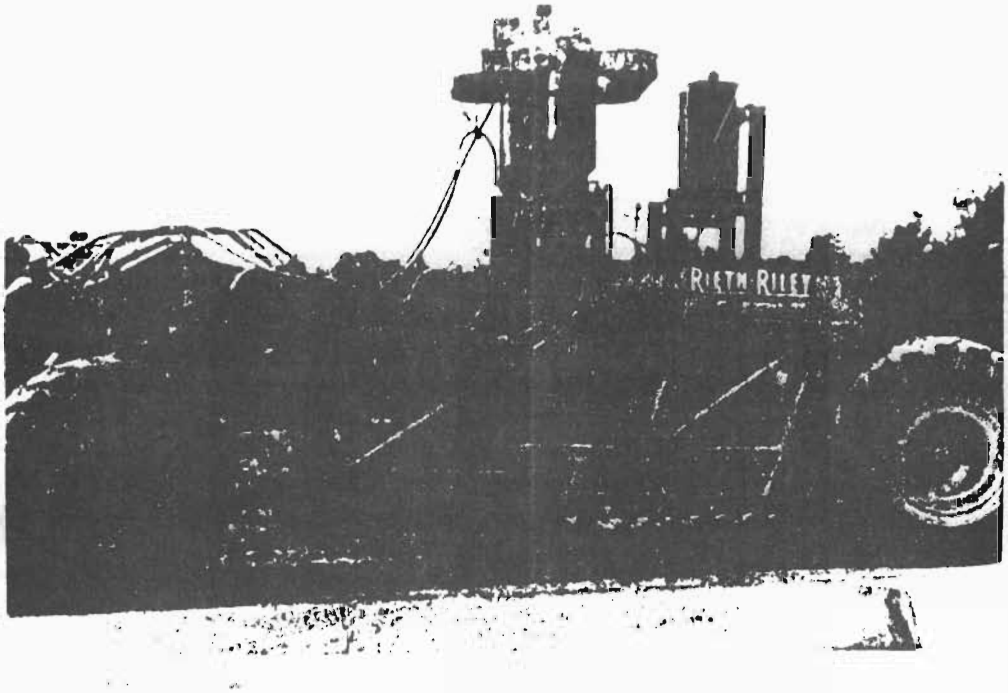
(Original pictures are available through Reference #11.)



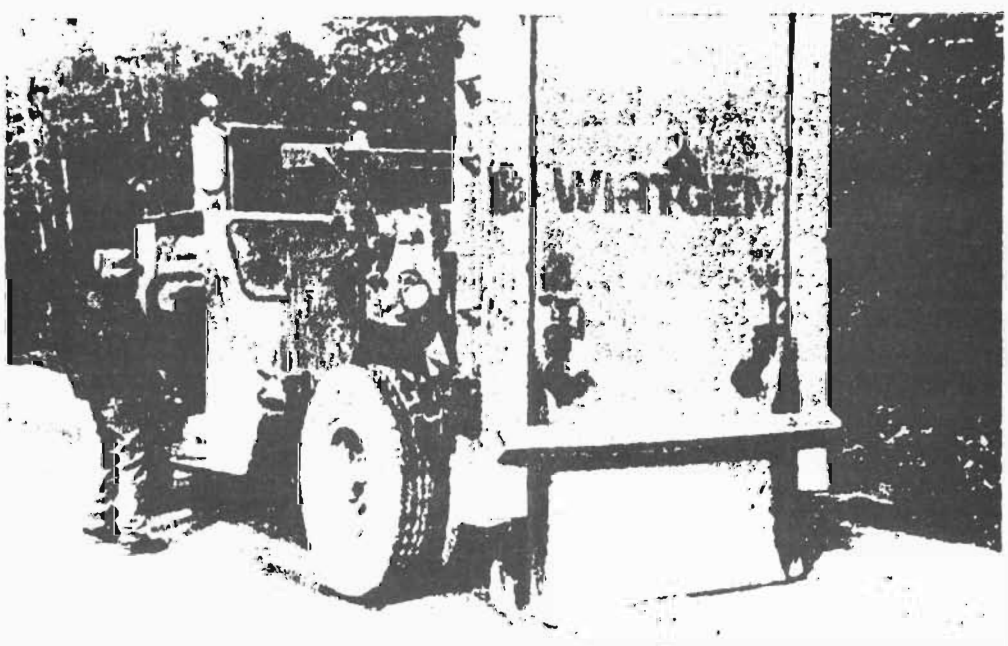
CMI Dynapulse Breaker.



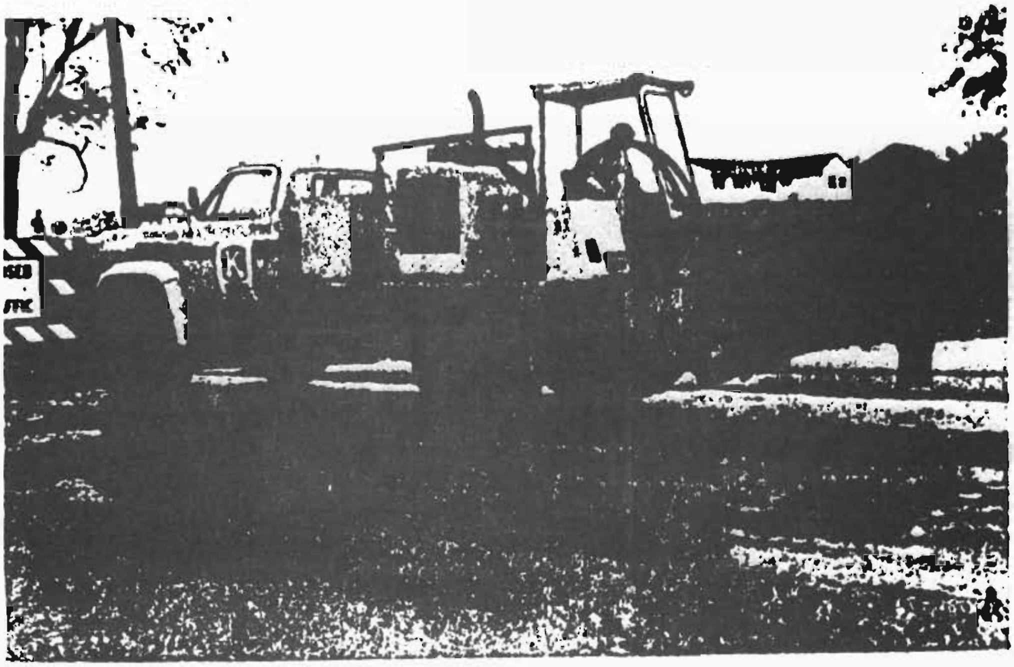
Diesel Hammer.



Diesel Hammer Mounted in Bowl of Scraper.



Wirtgen "Guillotine" Cracking Machine.



Whiphammer Cracking Machine.

A 27,216 to 45,359 kg (30 to 50 Ton) Proof Roller
Is Used for Seating.

REFERENCES

1. "Crack and Seat Performance", Federal Highway Administration, April 1987.

2. Craven, Bob. "Cracking and Seating Tested in Ohio Project" Roads & Bridges, (May 1985).

3. Crawford, Campbell. "Cracking and Seating of PCC Pavements Prior to Overlaying with Hot Mix Asphalt, State of the Art", National Asphalt Paving Association, Information Series 98, 1987.

4. Drake, E. B. "Breaking-Seating and Bituminous Concrete Overlays of Existing Portland Cement Concrete Pavements in Kentucky", Kentucky Department of Highways.

5. Green, Roger. Ohio DOT. Phone conversation, March 1988.

6. Lukanen, Erland O., P.E. "Structural Evaluation of Crack and Seat Overlay Pavements" Midwest Pavement Management, Inc., Commission No. 86-254, September 1986.

7. Lukanen, Erland O., P.E. "Structural Evaluation of Cracked and Seated PCC Pavements for Overlaying with Hot Mix Asphalt" National Asphalt Pavement Association, Information Series 100, 1987.

8. Poston, Bill. Donahue and Associates Engineers. Phone conversation, March 1988.

9. Shrum, Gary. "Cracking and Seating PCC Pavement Prior to Resurfacing to Retard Reflective Cracking" Iowa Department of Transportation, Project HR-277 & HR-279, April 1987.

10. Smith, Roger, P.E. "Cracking and Seating of PCC Pavement: A Pre-Treatment to AC Overlaying" FHWA, TS-84-224, 1984.

11. Welke, Robert A., et al. "Cracking and Seating of Jointed Portland Cement Concrete Pavements in Michigan" Asphalt Paving Technology, Volume 53, (1984).