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16. ABSTRACT

Engineers must think about or take into account many different phenomena relating to the behavior of the things they build, and among these is the question of how much movement occurs when a material or structure is under load. Most engineering works are required to sustain loads or resist forces, but in the process of sustaining these loads virtually all structural members yield or deflect slightly. Thus, tall buildings sway or bend under high wind pressures and the floors of buildings and decks of bridges deflect and rebound measurably under heavy axle loads to a greater or lesser degree depending upon several factors or conditions. One common factor is the magnitude of the load, but there is another variable that influences the deflections of pavements that is not involved in bridge decks; namely, the nature of the underlying support. A bridge deck must be strong enough to carry the design loads across the span between piers or abutments, but pavements are not expected to span any appreciable distance or area and therefore the nature of the subgrade support becomes a major consideration when studying the performance of payments under load.

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Deflectometer

Semiautomatic Unit Speeds Surface Deflection Measurement

By F. N. HVEEM, Materials and Research Engineer

ENGINEERS must think about or take into account many different phenomena relating to the behavior of the things they build, and among these is the question of how much movement occurs when a material or structure is under load. Most engineering works are required to sustain loads or resist forces, but in the process of sustaining these loads virtually all structural members yield or deflect slightly. Thus, tall buildings sway or bend under high wind pressures and the floors of buildings and decks of bridges deflect and rebound measurably under moving wheel loads.

Movement under transient vehicle loads is not confined to bridges as it can be shown that all highway pavements deflect under heavy axle loads to a greater or lesser degree depending upon several factors or conditions. One common factor is the magnitude of the load, but there is another variable that influences the deflections of pavements that is not involved in bridge decks; namely, the nature of the underlying support. A bridge deck must be strong enough to carry the design loads across the span between piers or abutments, but pavements are not expected to span any appreciable distance or area and therefore the nature of the subgrade support becomes a major consideration when studying the performance of pavements under load.

Established Procedure

The design of a reinforced concrete or steel beam which will sustain a given load is a well established engineering procedure, and here the strength elements are confined solely within the beam. While many engineers regard a highway pavement as a sort of "beam" actually the pavement itself is no more than the upper layer or "crust" of a "beam" which is of considerable depth but with no clearly defined lower boundary. The

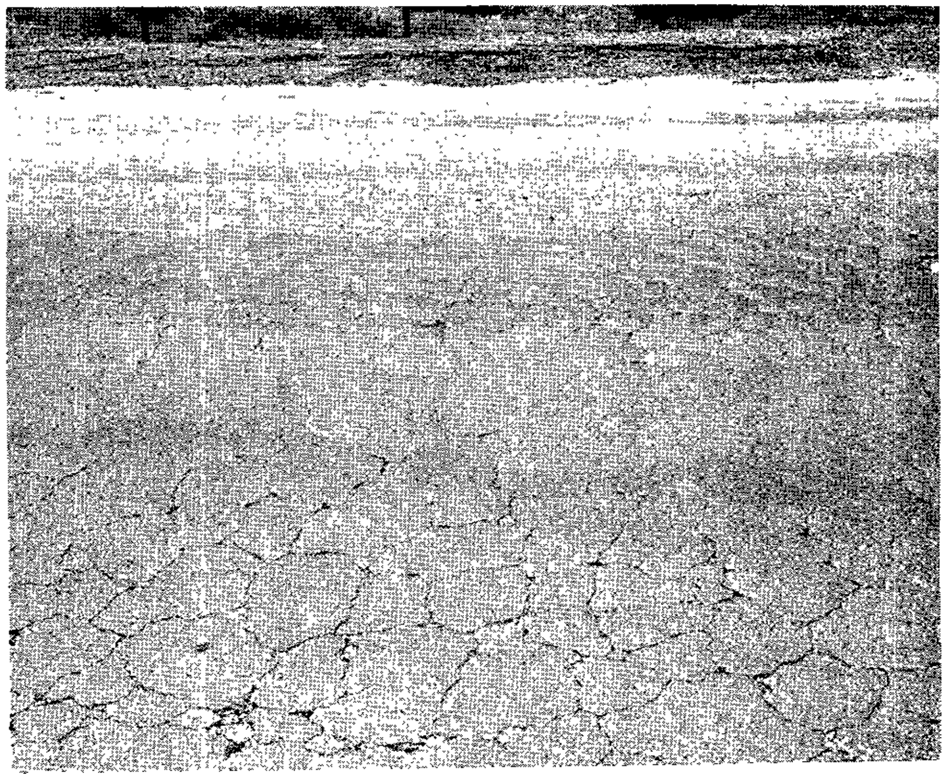

Figure 1. Fatigue cracks, generally known as "alligator" cracks.

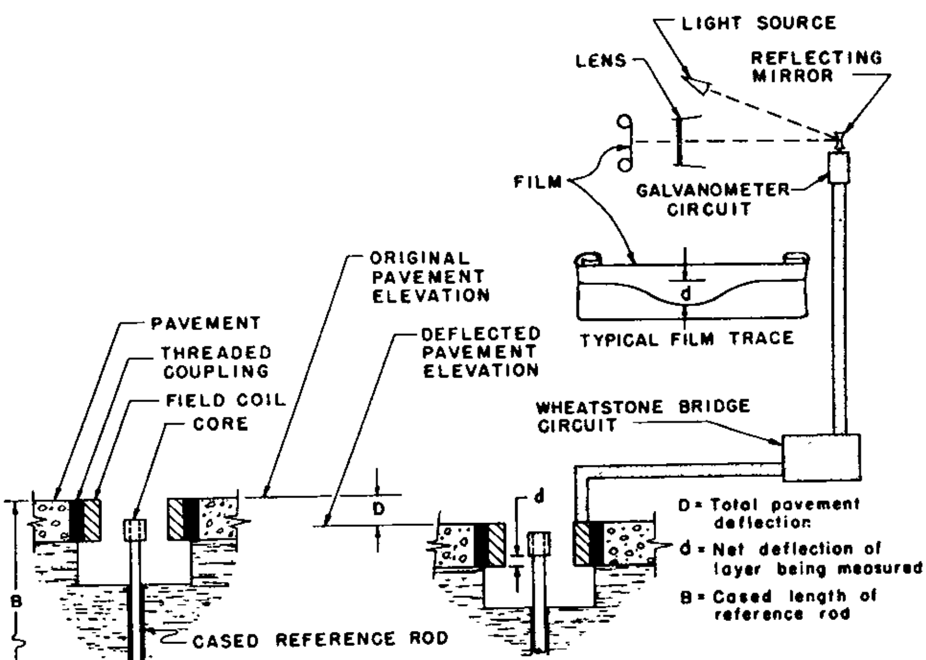

Figure 2. Travel Gage in use since 1938.

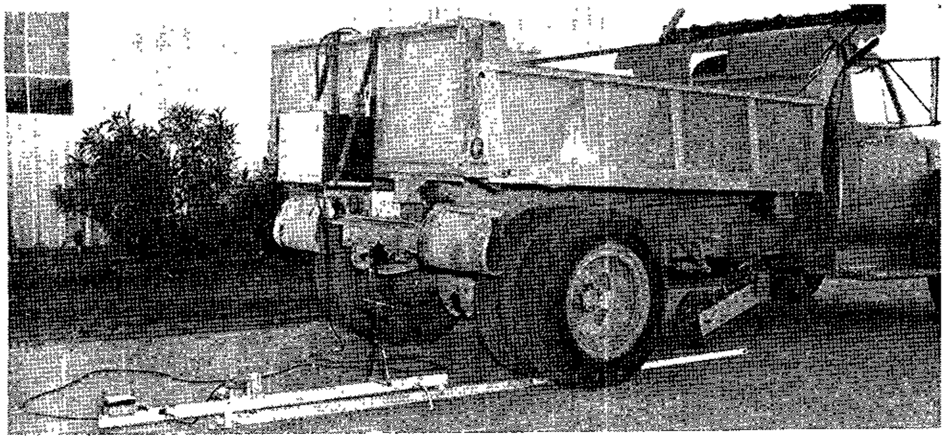

Figure 3. Benke'man Beam used under a loaded truck wheel. The recorder and odometer wheel were added by California.

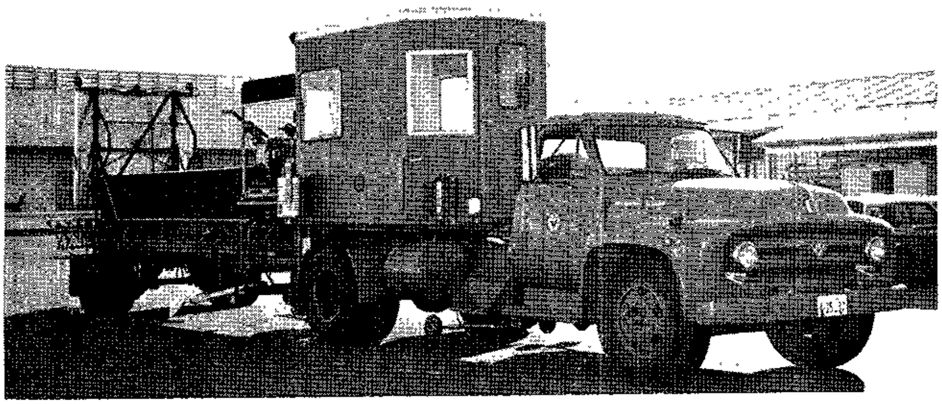

Figure 4. Traveling Deflectometer.

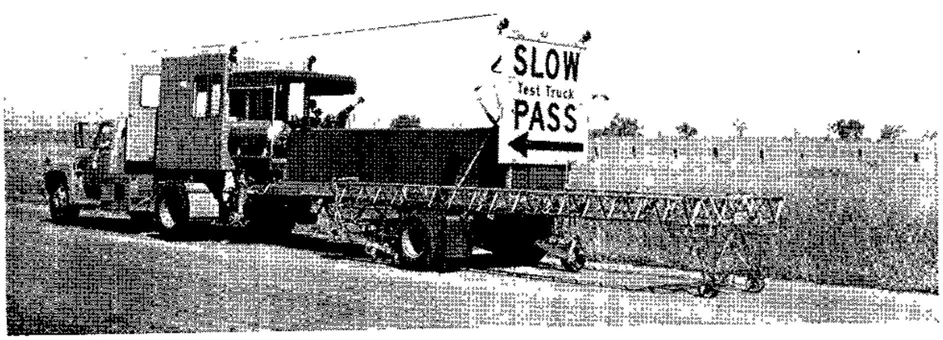

Figure 5. Traveling Deflectometer: In the recording cycle the probes and their traverse assembly remain stationary on the road while the truck moves forward.

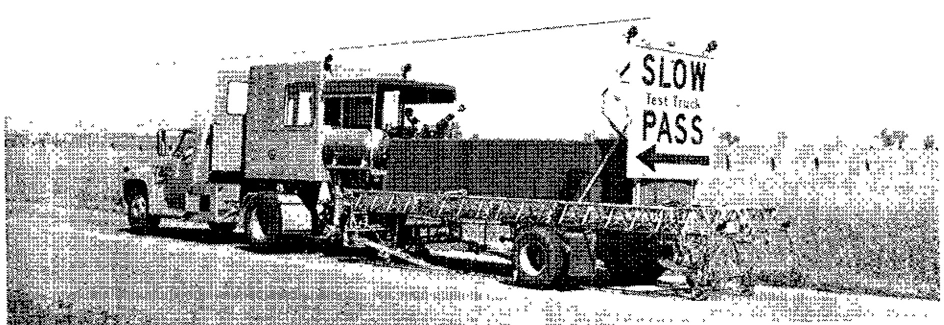

Figure 6. Traveling Deflectometer: The traverse assembly is picked up by a pneumatic operated track and carried ahead and dropped on the road to repeat the cycle.

amount of deflection which the more or less hard and brittle upper layer must undergo as the underlying soil is compressed with each passing wheel load is a matter for concern as sufficient alternate bending and flexing will ultimately lead to cracking of the pavement surface. These cracks are of the type known as fatigue cracks, Figure 1.

The measurement of pavement deflections has been carried on in California for a number of years. In 1938, the laboratory secured a General Electric travel gage which was used in investigations both on state highways and on airfield pavements during the war years. In 1951, an organized study of California pavements was undertaken and results reported.* This instrument still remains one of the most accurate methods for measuring pavement deflections, Figure 2. It has the disadvantage, however, of requiring considerable time and expense for the installation of units as five-inch diameter holes must be drilled in the pavement, and cased reference rods driven to the desired depth.

Device Is Developed

During the operation of the WASHO test road in Idaho, A. C. Benkelman developed a device, Figure 3, now known as the Benkelman Beam, which makes it possible to measure the surface deflections of pavements without the necessity for cutting holes and installing gaging units. The use of the Benkelman Beam has speeded up the process of measuring pavement deflections. However, the measurement of deflections over a long stretch of road is still a relatively slow process, and in order to obtain a greater amount of data for a given expenditure of time the Materials and Research Department has developed a semiautomatic device called the traveling deflectometer. This instrument is shown in Figures 4, 5, and 6. The principle is illustrated by the sketch, Figure 7. The deflectometer combines a truck trailer unit which carries the test load on the rear wheels of the trailer with means for measuring the pavement deflections under both

* "Pavement Deflections and Fatigue Failures," Highway Research Board Bulletin 114 (1955) By F. N. Hveem.

wheels simultaneously. Essentially, this is an electromechanical device capable of measuring pavement deflections under a single axle wheel load at 12½-foot intervals uniformly and continuously as the vehicle moves steadily along the roadway at one-half mile per hour. The deflections are measured to the nearest 1/1000 inch by means of a probe arm resting on the pavement, Figure 8, and permanently recorded on chart paper. (To visualize the sensitivity of this instrument, an ordinary cigarette paper is 1/1000 of an inch thick.) The load on the semitrailer may be readily shifted from front to rear, thus making it possible to vary the axle load from 12,000-lb. to 16,000-lb. simply by means of a switch in the control cab. The great advantage of this deflectometer is that it can be used to quickly scan random spots on long stretches of roadway or make measurements at close intervals where desired.

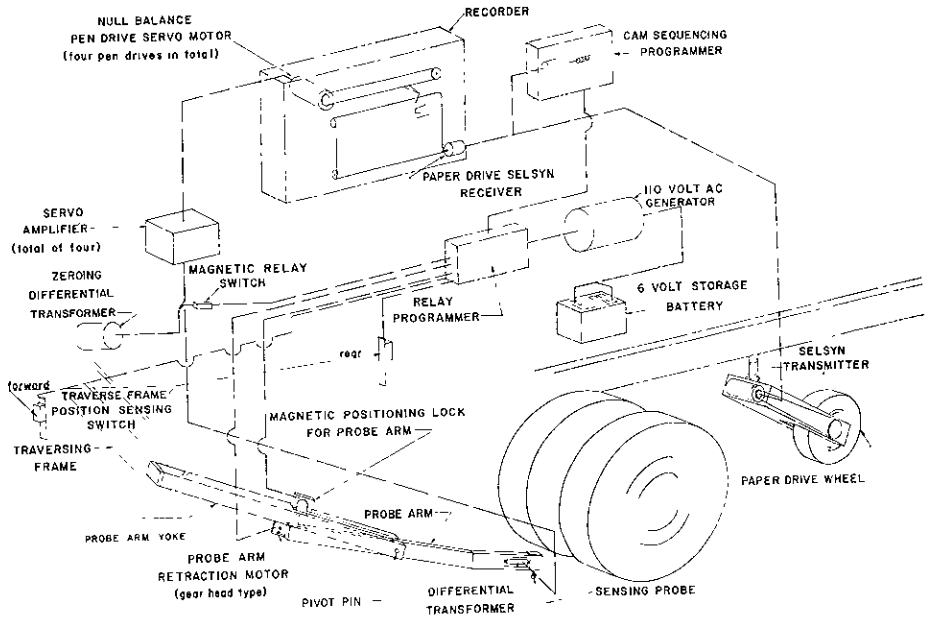

Figure 7. Schematic arrangement of the deflection sensing and recording system.

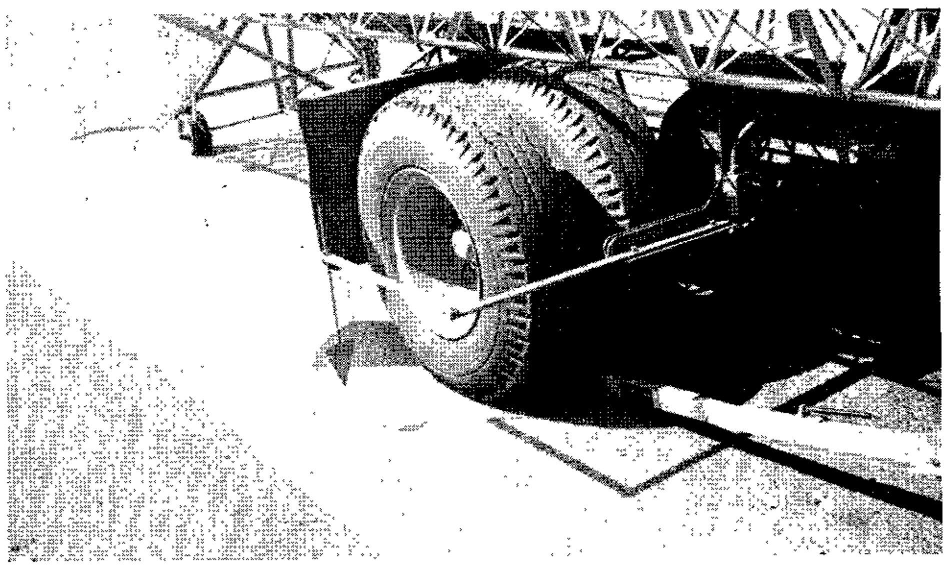

Figure 8. Sensing probe being straddled by dual tires. The truck drives at a constant speed near ½ mile per hour. After being passed by the wheel the probe is automatically lifted and traversed forward to take readings at 12-foot intervals.

Purposes Outlined

It is expected that the traveling deflectometer will be useful for the following purposes:

1. To check the condition of lightly constructed highways during the spring wet period or "spring breakup" in order to judge whether load restrictions should be imposed during the time when the pavements are susceptible to damage. (Many highway departments in the northern states have been forced to ban heavy traffic during the critical period to protect the public investment, but the problem of producing test data to prove that a given pave-

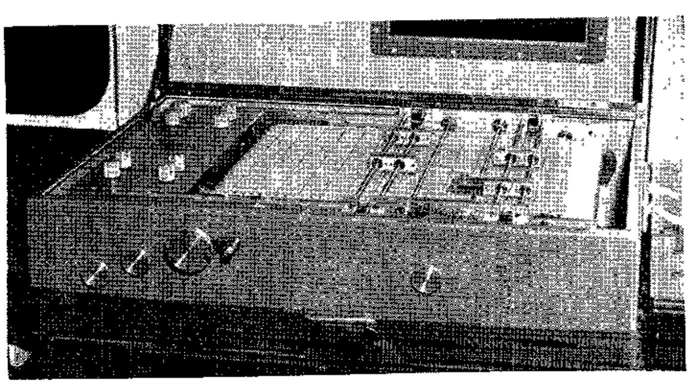

Figure 9. Chart recorder constructed for the Deflectometer. Space for four recording pens on the right. Manual controls on left of console.

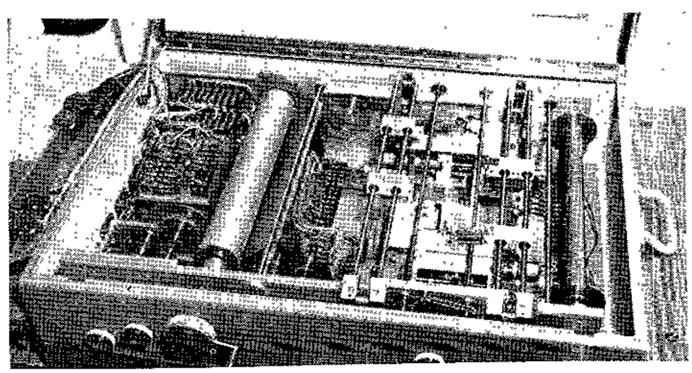

Figure 10. The working parts of the recorder exposed. This unit can record four sets of deflector measurements in one operation.

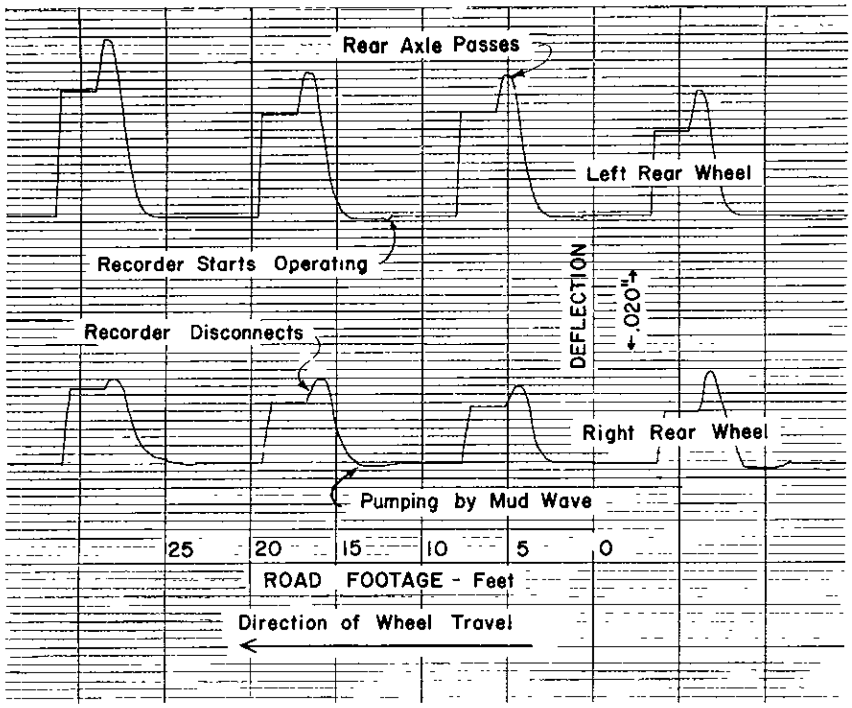

Figure 11. Trace produced by the Deflectometer recorder showing action under both wheels of the loaded trailer. The chart paper feeds from the right. Thus, compared to most graphs, this chart is read backwards. The operational cycle starts about five feet ahead of the axle and, as the dual wheels approach and straddle the sensing probes, a slight plastic heave may precede the downward deflection of the pavement. The deflection continues due to visco-elastic effects until the tire lifts from the pavement, at which time elastic rebound occurs. The right angle "step portion" of the curve is produced by the automatic zero reset and does not represent any movement of the pavement.

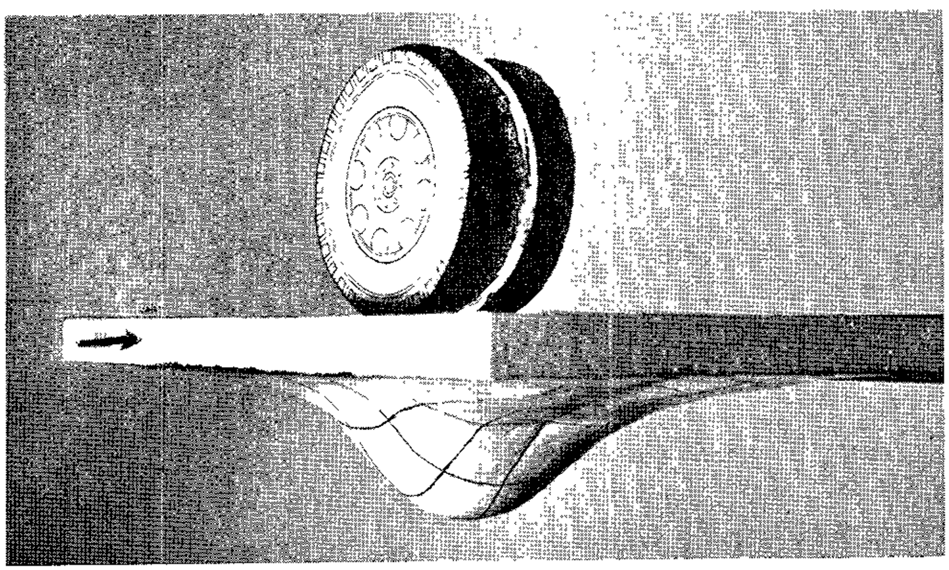

Figure 12. Model showing typical deflection of a flexible pavement under a heavy wheel load. Deflection is about 0.020". The vertical scale is greatly exaggerated on this model.

ment is vulnerable has always been most difficult.)

2. Evaluate existing roadways, both pavements and shoulders, to determine whether reinforcing or overlays are necessary and, if so, what thickness of surfacing may be required. The use of deflection measurements will enable engineers to plan maintenance and reconstruction work more precisely.

3. Permit a periodic checkup on existing pavements so that potential distress may be anticipated. A careful analysis of roadway deflections will make it possible to predict whether or not distress is imminent unless remedial action is taken.

Can Determine Length

Figures 9 and 10 are pictures of the chart recorder. Figure 11 shows some of the deflection records obtained with this instrument. It will be noted that it is possible to determine the length of pavement which is involved in the "deflection area." Figure 12 is a photograph of a model constructed to illustrate the shape of a typical depression under a wheel load on an asphaltic pavement. The length and depth of this depression varies with local conditions and the deflectometer trace indicates both the length of the axis of the oval-shaped area and the maximum depth of the depression.

The deflectometer was designed, developed and constructed jointly by the Materials and Research Department and the Headquarters Equipment Department. The trailer, load-shifting device, cab, etc., were constructed in the equipment shop. The sensing elements, electronic units and circuits were designed by laboratory personnel and constructed in the laboratory shop. Many individuals have been associated with the design and construction among whom are L. S. Hannibal, Senior Mechanical Engineer, and J. C. Eagan, Assistant Physical Testing Engineer. R. E. Wilhelmy supervised all of the machine shop work.

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