TEXAS TRANSPORTATION INSTITUTE

TEXAS HIGHWAY DEPARTMENT

COOPERATIVE RESEARCH

DYNAMIC DEFLECTIONS USING THE ELECTROMAGNETIC VIBRATOR
2-8-54-1

in cooperation with the
Department of Commerce
Bureau of Public Roads

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DYNAMIC DEFLECTIONS USING THE ELECTROMAGNETIC VIBRATOR

Compiled by
Texas Transportation Institute
March 1964

1. "A guide to the structural design of bituminous-surfaced roads in tropical and sub-tropical countries", Gt. Britain, Dept. of Scientific and Industrial Research, Road Research Laboratory, Road Note 31, March 1962, 16pp.

This note is intended to provide a guide to the engineer in designing bituminous-surfaced roads in the tropics.

In most of the developing countries in the tropics, road traffic is increasing rapidly, in both weight and numbers. Annual increases in traffic flow of the order of 15-20 percent are not uncommon. In some countries the load-carrying capacity of roads and bridges makes it necessary to put special restrictions on vehicle weights; on the other hand there are mounting pressures to extend the mileage of bituminous-surfaced roads capable of carrying vehicles with axle loadings up to the limits accepted in more developed countries.

One of the main tasks of the Road Research Laboratory in their work on road building in the tropics has been to derive methods of design for bituminous-surfaced road pavements. The method of design proposed in this Note makes use of the CBR test as a measure of the strength of the soil. Inquiry has shown that theCBR test is by far the most widely used in pavement design in tropical countries, and there is much to be said for using testing techniques which are already familiar and for which there is a considerable background of experience.

Moisture conditions have an important influence on the strength of a soil and a wide range of moisture conditions is encountered in different climates found in the tropics. The results of studies by the Laboratory to determine the influence of climate on moisture conditions in soil under roads and runways have provided the basis for the simple classification of tropical climatic environments into three categories which is used in this Note.

Road pavements are normally designed and constructed so that they will be adequate to carry the traffic expected over many years. In Great Britain, for instance, a 20-year life is usually assumed, and the roads are designed to carry the increasing traffic expected during that period. Less developed countries where traffic is increasing rapidly, may well expect it to increase 15 times or so over a 20-year period. Often they cannot afford to build roads to meet the traffic intensities predicted 20 years hence; nor is it economically desirable that they should. It will generally be more appropriate to design roads to meet

the traffic intensities predicted 20 years hence; nor is it economically desirable that they should. It will generally be more appropriate to design roads to meet the requirements of traffic for a shorter period, perhaps 10 years, and to use a form of construction that can be readily strengthened as traffic increases. This pattern of stage construction to meet the requirements of rapidly increasing traffic over a wide network of roads forms the basis for the recommendations of this Note.

2. Baum, G., "Dynamische Untersughungen an Strassen", Strasse u Autobahn 10: n 8, Aug 1959, p 277-82.

Dynamic testing of roads; measurements made at about 250 testing points on German roads; use of vibrating instruments in which frequency of vibration is between 10 to 75 cps; amplitude of response, characteristic for various constructions, and conditions of road is shown by geophone stresses measured by millivoltmeter; examples of measurements are given.

3. Benkelman, A.C., "Analysis of flexible pavement deflection and behavior data", Nat'l Research Council--Highway Research Bcard Bul 210, 1958, p 39-48.

In the WASHO Road Test there was a pronounced difference in the performance of the edge and center portions of the bituminous pavement, as well as a great difference in behavior of sections with 2 in. of surfacing and those with 4 in. of surfacing.

This paper presents a series of relations to indicate to what extent the over-all pavement structure thickness and the seasons of the year enter into the differences in behavior of the edge and center portions of the pavement, and into the difference in behavior of the sections with 2-in. and 4-in surfacing.

4. Benkelman, A.C., R.I. Kingham and H.Y. Fang, "Special deflection studies on flexible pavement", Nat'l Research Council--Highway Research Board Spec Rep 73, 1962, p 102-120.

The flexible pavement performance study at the AASHO Road Test indicated that the life of a pavement was related to the level of pavement deflection as measured with the Benkelman beam. It is probable, therefore, that planners of satellite or pavement evaluation programs will include measurements of pavement deflection in their experimental

programs. In order to interpret the measurements of pavement deflection taken in any experimental program, some knowledge of the factors that affect the measurement is required.

At the AASHO Road Test special pavement deflection experiments were conducted to determine the effect of varying the Benkelman beam procedure and to consider an alternative method of measurement using an electronic device. Numerous other special experiments were carried out to determine the relationships of pavement deflection to wheel load, vehicle speed, tire pressure and pavement temperature. In addition, a program of plate load testing made possible a correlation between plate load test data and Benkelman beam data.

Test data are summarized by means of tables, graphs and mathematical equations. The equations express the pavement deflection as functions of wheel load, vehicle speed and pavement temperature.

5. Bode, O. and others, "Comparison of different methods of determining the dynamic wheel load", Deutsche Kraft n 131, 1959, 33pp (German) M.I.R.A. Translation No. 1/63.

Because of the growing importance of the dynamic forces between wheel and road, several German engineering colleges have developed methods of measuring the dynamic wheel loads of motor vehicles. The methods compared in the first part of the present study are those of the Aachen, Brunswick, and Hanover colleges. Aachen determines the wheel loads by measuring the accelerations of axle and superstructure. The Brunswick method uses the tire as a measuring spring. The variations in the distance between axle and road surface resulting from tire deflections are measured by a capacitative technique. With the help of the load/deflection curve of the tire, the wheel loads can be calculated. The Hanover method is based on the relationship between the dynamic wheel loads and the resulting elastic deformations of the axle housing. Details of the test equipment, calibration, and methods of evaluation used by the three institutes are given.

To compare the three methods, wheel-load measurements were made simultaneously on the same vehicle, a 10-ton truck, by the test teams of the three institutes, each using its own method of measurement and evaluation. The test runs were made on a good and a bad road and on a roadway. The results are given in tables and diagrams. A second series of tests was made as above, except that the test data were all evaluated by the same statistical method, and additional measurements were made during travel over sewer covers and transit lines. Potential sources of errors inherent in the test methods are discussed.

Part 2 of the study compares the wheel-load measuring techniques of the Darmstadt, Munich, and Brunswick institutes. Darmstadt measures the bending stresses at two points in the rim base of a special test wheel. As the correct load is indicated only twice per wheel revolution, viz., each time one of the strain gages is vertically above the tire-ground contact center, no continuous wheel-load trace is obtained, and the method is statistical in character. In the Munich method, the transverse bulging of the tire resulting from vertical tire deflection is used as a measure of the wheel load. The bulging is scanned by two mechanical feelers which are so connected that the effects of side forces are largely eliminated. The Brunswick method was as described above.

The results were again statistically evaluated. The inherent sources of error are mentioned, and the advantages and disadvantages of the methods are compared. In Part 3, three methods are compared, all of which use the tire as a measuring spring. These are the Brunswick and Munich methods mentioned above and another method developed at Brunswick which also measures tire bulging, but by means of electric scanners. These tests were evaluated by direct comparison of the traces.

6. Bonse, R.P.H. and S.H. Kuhn, "Dynamic forces exerted by moving vehicles on a road surface", Nat'l Research Council--Highway Research Board Bul 233, 1959, p 9-32.

This paper describes an apparatus for measuring the forces exerted at a point on a road surface by the wheels of moving vehicles. Detailed results are presented of measurements of three force components; vertical force, and longitudinal and transverse horizontal force components. The investigation included a study of the influence on these forces of tire inflation pressure, speed, acceleration, wheel load, height of measuring stud above road surface, etc.

Seven different vehicles were used covering a range of wheel (tire) load from 135 kg to 2,540 kg (300 lb to 5,600 lb), and a speed range of 15 kph to 75 kph (6 mph to 47 mph).

7. Boramisa, T. and L. Gashpar, "Determining the load capacity of road surfacings by the measurement of surface deformation under load", Avtom Dorogi (Moscow, USSR) 25: n 8, 1962 p 28-30 (In Russian).

Experience gained in Hungary since 1955 in the use of an instrument similar to the Benkelman beam is reviewed. The application of the method which differs from that used in other countries is explained. An illustrated description is given of the design of the instrument; deflections in a pivoted beam 2.4 m long are recorded by a needle dial. Surface deformations under a 5-ton load were measured to winthin 0.01 mm by two beams each extending from between the double rear wheels of the test lorry. Measurements were made 1.2 m from the edge of flexible surfacing and in the center of concrete slabs at intervals of 200 m. Investions have been carried out on almost all the road network of Hungary. The vehicle is left in position for not more than 1 min and then moved 3 m and another measurement is made; if the specified tolerance is exceeded a third reading is taken. At least 15 km of road can be tested per day. A table of limit deformation values for various surfacings is given. A 1-cm rolled asphalt course was found to be the equivalent of a 3.5-cm course of crushed stone aggregate.

8. Croney, D. and G. F. Salt, "Three full-scale roads experiments and their implication in relation to pavement design", Proc 5th Int Conf on Soil Mech and Found Eng., Paris II: pp 199-206, 1961.

The paper describes three experiments on the design of flexible road pavements carried out in Great Britain on heavily traveled roads since the last war. In each, sections of different thicknesses have been laid on subgrades of known properties. Studies have been made of the relative contributions of various base and surfacing materials to the performance of the pavement.

The results show that sections surfaced with hot rolled asphalt have performed better than similar sections surfaced with bitumen macadam. Where a hot-rolled asphalt wearing course was used, sections thinner than the CBR design thickness performed satisfactorily for periods up to 9 years (the duration of the observations). When bitumen macadam surfacings were used, sections thicker than the CBR needed some maintenance of the surfacing to counteract the deformations that occurred under traffic and to restore

a satisfactory riding surface.
Sections with a bound base (tar-coated stone) deformed less than similar sections using crushed stone and gravel bases.

9. Goodwin, W.A. Chairman, "Symposium on flexible pavement behavior as related to deflection", Proc Assn Asph Pav Techn 31: 1962, p 208-399.

Contains nine papers presented at the symposium. They are:
Method of measurement, F. N. Finn.
Significance of pavement deflections, C. L. Monismith.
Flexible pavement deflections--methods of analysis and interpretation, E. J. Yoder.
Observations of the significance of pavement deflections, J. H. Havens.
Deflection measurements in controlled test sections, R. G. Ahlvin.
Correlation of load deflections with design and performance, R. F. Baker.
A comparison of flexible pavement performance with structure, J. R. Bissett and M. C. Ford.
Pavement deflection and rebound measurements and their application to pavement design and evaluation, G. Y. Sebastyan.
Pavement deflection as related to the ultimate capacity of flexible pavements, W. S. Housel.

10. Harris, H., "Electronics assists in highway construction", Electronics 32: n 51, Dec 18 1959, p 69-71.

Electronic instrumentation for testing highway construction described; instruments measure various effects of highway traffic on test pavements and moisture content and subsurface temperature at test site; instruments speed acquisition of test data, permit rapid engineering and statistical analysis.

11. Heukelom, W., "Analysis of dynamic deflections of soils and pavements", Geotechnique 11: n 3, pp 224-243, September 1961.

The deflections of soils and roads under sustained vibration conditions have been observed. The resistance to deformation is expressed in the dynamic stiffness.
The dynamic stiffness is found to consist of an elastic part, which is considered independent of the frequency, and a part which depends on frequency. The latter is split into a damping and a mass effect.

The magnitude of the elastic stiffness, the damping and the mass is discussed, and special attention is paid to the linearity of the system and to the fact that the mass effect decreased at relatively high frequencies.

Under the shock type of loading by traffic, mass effects are found to be less important than under the conditions of sustained vibrations. It is derived that the traffic stiffness is almost equal to the elastic part of the dynamic stiffness, which can be measured fairly accurately by means of a vibration machine.

12. Heukelom, W., and C. R. Foster, "Dynamic testing of pavements", ASCE Proc 86: (J Soil Mechanics & Foundations Div) n SM1 Feb 1960, pt 1, paper n 2368, p 1-28.

Each time vehicle passes over pavement, surface is deflected and rebounds, creating strain conditions for 0.01 to 0.1 sec; methods used in Netherlands for simulating and studying such dynamic conditions in pavements, base courses and subgrades; use of single frequency monochromatic wave vibrator and of three point bending machine for determination of dynamic Emodulus and strength of asphaltic mixtures.

13. Hudson, W.R., "Comparison of strain measurements on AASHO Road Test and existing theories for rigid pavements", Paper presented at the 43rd annual meeting of the Highway Research Board, January 1963.

Existing rigid pavement design equations primarily spring from the theory of H. M. Westergaard in the 1925 Highway Research Board Proceedings. Some of these design equations are based on empirical modifications of the original theory, others are merely simplifications. These empirical modifications have been developed in several instances from strain measurements taken under static loads. Recent developments in the field of electronics made dynamic strain measurements much more accurate and feasible than they were formerly. Using such new equipment, approximately 100,000 individual strain gage readings were made under dynamic loads in conjunction with the AASHO Road Test.

This paper discusses these strain measurements and compares them with the static measurements used to develop existing empirical design equations. They are also compared

with the original Westergaard theory. The results of such comparisons could form the basis for modifying empirical design equations to more nearly account for the dynamic load effect.

14. Hveem, F. N., "Pavement deflections and fatigue failures", Nat'l Research Council--Highway Research Board Bul 114, 1955, p 43-87.

This is a continuation of the paper entitled "The Factors Underlying the Rational Design of Pavement" appearing in the 1948 Proceedings of the Highway Research Board. The original work indicated the importance of fatigue failures caused by resilience in the supporting soils. This paper describes the initial work of measuring deflections over a wide variety of pavements. Examples are shown illustrating the load-deflection curves where pavements are showing signs of failure and on other sections where conditions are good or excellent. In general, the deflections are directly proportional to load, although not in all cases. The deflections were measured under both single-axle and tandem-axle loads and the relationship between these two types of loading are established for several types of pavement.

Laboratory methods are discussed including the design of a resiliometer for measuring the resilient characteristics of soil samples and the design of a fatigue testing machine for measuring the relative flexibility of pavements. The study indicates that a comprehensive design procedure must provide a pavement structure that will either be capable of surviving the fatigue resulting from continuous flexing or have sufficient "stiffness" to reduce the flexing to an acceptable value.

15. "Information bulletin on dynamic testing of roads and runways, No. 1", Shell Internationale Research Maatschappij N.V., Koninklijke/Shell-Laboratorium, Amsterdam, 1961, 13p.

This is the first of a series of bulletins whose publication was decided upon at the Symposium on Vibration Testing of Roads and Runways held in 1959. It contains the following brief communications on new results obtained since the 1959 symposium: Dynamic test method according to Baum used in fatigue tests on bituminous road surfacings; Dynamic influences on measurements with soil pressure cells; The interpretation of surface wave propagation data and Investigation of roads with forced vibrations.

16. "Investigation of pressures and deflections for flexible pavements; development of representative soil strengths from laboratory tests,"U.S. Army Engineer Waterways Experiment Station, Corps of Engineers Tech Memo No. 3-323, Report 5, December 1960, 43pp.

One of the most important features of the comprehensive study of the distribution of stress, deflection, and strain in soil masses, of which the triaxial tests are a part, is the determination by measurement of the stress-strain relations existing within large soil masses subjected to surface loading. In two earlier phases of the comprehensive investigation, stress-strain curves were developed, for a vertical orientation, that are representative of the actual stress-strain relations existing within a large homogeneous clayey silt and a large homogeneous sand test section during application of surface loads. The triaxial test program had as its objective the establishment of a test method or procedure whereby stress-strain curves developed from laboratory tests on small, laboratory samples would duplicate the field data curves.

By trial and error it was found that curves developed in variable-confining-pressure triaxial tests on undisturbed samples from the homogeneous clayey silt test section yielded stress-strain curves duplicating the field data so closely as to be identical for practical purposes. Similar results were obtained from prepared samples of sand from the homogeneous sand test section.

It is believed that a theoretical loading curve can be used with the variable-confining-pressure triaxial test to develop stress-strain relations for soils of the type used in the tests reported, and perhaps for other types as well. It is recommended that in future work the test methods developed in the triaxial study be used to determine moduli of deformation, and that the probable validity of these moduli be considered in order that the test methods developed in the study may be further substantiated.

17. Janes, R.L., "PCA mobile transportation laboratory", Portland Cement Assn--Research & Development Laboratories--J 2: n 1, Jan 1960, p 15-18.

Laboratory at Skokie, Ill, uses pavement testing mobile unit composed of tractor trailer which can be variously loaded and of mobile laboratory trailer with equipment for recording eight separate pieces of information including strains anddeflections in pavement surface, temperatures, pressures, accelerations or velocities, or other physical phenomena; separate skid trailer is used to determine function characteristics of concrete pavements.

18. Jones, R. and A. C. Whiffin, "A survey of dynamic methods of testing roads and runways", Nat'l Research Council--Highway Research Board Bulletin 277, 1960, p 1-7.

The object of this paper is to indicate how far dynamic methods of testing roads have developed in the various countries and to summarize the present state of the work.

The vibrational method of testing roads originated in Germany where, before World War II, mechanical vibrators were used to investigate the mechanical properties of different types of soil. During and after World War II, further developments of the technique were made by the Royal Dutch Shell Co.'s Laboratory at Amsterdam, and the method was applied to testing roads and runways. The dynamic stiffness of the construction was deduced from the applied vibratory force and the resultant amplitude of vibration. Tests on a variety of roads indicated that high values of the stiffness were associated with strong forms of construction, and low values with weak ones. The ultimate objectives of this form of nondestructive test are to predict the performance of roads under traffic and to determine where and when failure of the construction is beginning. Testing techniques to these ends have been developed recently in Germany.

The British Road Research Laboratory has been studying the velocity of propagation of vibrations in layered constructions using electro-mechanical vibrators covering a much wider frequency range than is possible with the rotary machines normally employed. The relations obtained between velocity and frequency are being studied to deduce the elasticities and thicknesses of the layers partly to assess the quality of the construction and partly to obtain data which might be later employed for pavement design. The application of vibrational testing to pavement design is still in its infancy and it is too early yet to decide whether or not such a design technique will ultimately be possible.

19. Jones, R., "Following changes in the properties of road bases and subbases by the surface wave propagation method", Civ Eng & Pub Works Rev (London) 58: n 682, pp 613-617, May 1963, n 683, pp 777-780, June 1963.

The surface wave propagation method has been developed at the Road Research Laboratory for obtaining the elastic properties and, where possible, the thicknesses of the constituent layers of a road. By this method, measurements are made of the wavelength and velocity of the vibrations at the surface of the road at frequencies in the range of 30 to 30,000 cycles per second and the relation between velocity and wavelength is analyzed theoretically to yield the required information. Repetitive tests on experimental roads over a period of about five years have emphasized the particular usefulness of the method as a nondestructive method of following the changes in the properties of the base materials caused by time and traffic.

Examples are given which show that: (1) under favorable conditions, considerable increases (threefold or more) can be obtained in the elastic modulus of a sand subbase or a wet-mix-slag base material because of compaction by traffic. These increases lead to improvements in the load-spreading properties of these materials. (2) Cement-bound bases usually have extremely high elastic moduli in their uncracked condition. The development of cracks in these bases can be detected by the surface wave propagation method and it has been found that when weak or thin cement-bound bases become extensively cracked their effective elastic moduli become comparable with those of a well-compacted crushed-stone or wet-mix base. (3) The surface wave propagation method has detected stripping in bituminous materials which also leads to a decrease in the effective elastic modulus and load-spreading properties of the base.

20. Jones, R., "Measurement and interpretation of surface vibrations on soil and roads", Nat'l Research Council--Highway Research Board Bulletin 277, 1960, p 8-29.

The Road Research Laboratory is developing nondestructive techniques for measuring the dynamic mechanical characteristics and thicknesses of the layers forming a road. The mathematical theory for computing stresses and deformations requires knowledge of these data and the development of these testing techniques is a necessary step towards a system of pavement design based on the stresses encountered in the road and the mechanical properties of the materials.

Apart from this, the techniques are already able to provide information of immediate value in that they provide data of assistance in appraising the performance of experimental and other roads under traffic, they can be used to locate areas where variations of mechanical properties or thickness occur, and they can be used to study the changes produced by traffic and weather.

The first part of this paper deals with the experimental technique for measuring the wave length and phase velocity of mechanical vibrations propagated along the surface of soil or road constructions. The vibrations are produced electro-mechanically by apparatus working within the frequency range from 40 to 60,000 c/s and have wave lengths ranging from a few inches to several feet. The results are normally expressed graphically as the relation between phase velocity and the wave length obtained at selected frequencies. This curve has a number of characteristics which depend on the elastic properties and the thicknesses of different parts of theconstruction: the second part of the paper discusses theoretical analyses to calculate these parameters. So far, most of the work has been limited to experimental constructions and all the relevant data concerning thicknesses and type of material have been known, while vibratory experiments have also been made, where necessary, on laboratory specimens of the materials to determine their elastic properties. These data have enabled checks to be made of the validity of predictions from the vibrational experiments.

21. Jones, R., "Surface wave technique for measuring the elastic properties and thickness of roads: theoretical development", Brit J Appl Phys 13: n 1, 1962, p 21-9.

The theoretical development of the expetimental technique for measuring the elastic properties of the layers which make up a road is described. A knowledge of these properties is required in the development of a fundamental method of pavement design. The elastic properties are deduced from measurements of the wavelength and velocity of vibrations of known frequency along the surface of the road, and this paper develops the theory of the method of analysis of the relation between velocity and wave-length for pavements with one and two superficial layers. The paper was prepared at the Road Research Laboratory, Harmondsworth.

22. Knight, William R. and Jong Ping Chen, "Two-sample method for pavement deflection survey", ASCE Proc 88: J of the Highway Div No. HW2, Sept 1962, p 37-45, n 3280.

A method of taking deflection measurements on pavements in two stages described. First stage determines number of observations required in second stage.

23. Kriz, L.B. and O. A. Kurvits, "Deformation measurements for structural testing", Portland Cement Assn - (Research and Development Laboratories--J) 1: n 3, Sept 1959, p 35-41.

Instrumentation and methods commonly used in PCA Structural Laboratory; deflections are measured by micrometer dial gages, precision leveling or precision triangulation; installation of "SR-4" strain gages on concrete and reinforcement; electronic instruments for strain measurement.

24. Ormerod, A., "The deflexion of an elastic structure", Structural Engineer (GB) 40: n 6, June 1962.

Basic concepts; relationship between cross-flexibilities; derivation of general relationship; use of relationships; note on form of relationship; applied moments; response; derivation of general relationship.

25. Partridge, G.R., J. W. Dunkin, K. L. Anderson and R. C. Geldmacher, "14-channel displacement measuring device utilizing magnetic and paper tape recording", Am Inst Elec Engrs Trans 76: pt 1 (Communication & Electronics) n 32, Sept 1957, p 461-7.

Instrument designed for evaluation of subgrade construction methods by determination of relationship between stresses, strains, damping and elastic constants and deflection of pavement surface of different types of highways; instrument meets stringent requirements of linearity, stability, sensitivity, and dependability. Paper 57-662.

26. Preus, C.K. and L. A. Tomes, "Frost action and load-carrying capacity evaluation by deflection profiles", Nat'l Research Council--Highway Research Board Bul 218, 1959, p 1-10.

This report describes the experimental use of a Benkelman beam with a Helmer recorder attached as a means of measuring the changes inload-carrying capacity of flexible pavements that occur as a result of frost action. An

attempt also has been made to correlate the values of load-carrying capacity as determined by the use of the well established plate bearing test with similar load-carrying capacities as determined by the use of the Benkelman beam with the Helmer recorder attached.
About 1956 a Benkelman beam was made available to the Highway Research Board's Committee on Soils Calcium Chloride Roads. With this apparatus considerable data were collected in Alabama, Virginia, and particularly in Minnesota, on maximum deflections and residual deflections of flexible pavements under comparatively realistic loading.

27. "Remotely-controlled measuring devices", Concrete and Contructional Engineering 54: n 11, pp 390-391, November 1959.

An electronic device is now available for measuring strains, deflections, pressures, forces, and temperatures, and it is stated that the measurements are accurate within 1 percent. The apparatus comprises a transmitter and a receiver. The transmitter contains a wire that can be made to oscillate by excitation from the receiver. The damped natural vibration of the wire varies with the quantity to be measured, and is transmitted to the receiver that contains a wire whose frequency may be tuned to that of the transmitter. The vibrations of the wire in the transmitter are indicated on a cathode-ray tube as a vertical line, and those of the wire in the receiver as a horizontal line. The frequency of the wire in the receiver is adjusted until a circular or elliptical figure is obtained on the screen, indicating that the vibrations are synchronized. The adjustment necessary of the transmitter multiplied by a constant is the required measurement.
The transmitters made from a variety of types of measurement. These apparatus are made in Hamburg.

28. Schnitter, G. and F. Muller, "The deflection of road pavements under a wheel load", Strasse u. Verkehr 48: n 2, 1962, p 51-64 (In German)

A method used by the Eidgenossische Technische Hochschule, Zurich, for optical measurement of pavement deflection by means of a precision leveling instrument is described, and results of measurements are given. The following aspects of the method are discussed; (1) measurement on existing heavily-trafficked roads; (2) factors affecting test results;

(3) evaluation of different types of road design; (4) observations and comparisons of airfield pavements constructed on a weak subgrade; (5) control of construction work; (6) evaluation of the stress on a pavement caused by specially heavy vehicles.

29. Taragin, A., "Evaluation of performance of an existing concrete pavement under accelerated load application", Nat'l Research Council--Highway Research Board Bul 187, 1958, p 67-68.

This discussion is based exclusively on the experience gained from the load testing, through an accelerated program, of an existing concrete pavement on a section of road which 7 years ago attained national prominence. It is, of course, the research project known as Road Test One-MD. The results of this research were published in 1952 by the Highway Research Board as Special Report 4. It is not intended to present all the results of the test, but to discuss briefly the several methods used to evaluate the performance of the pavement under applied load. The project was conducted under the direction of the Highway Research Board according to a plan of accelerated loading an testing unanimously agreed upon by all the participating states, the Bureau of Public Roads, the Automobile Manufacturers Association, the petroleum industry, the American trucking associations, and the Department of Defense.

The principal prupose of the test was to determine the relative effects on a particular concrete pavement of four different axle loadings--two single axles and two tandem axles. The word "relative" in the objective is stressed because the methods of rating the performance were identical in all test sections under as nearly as possible identical conditions. The only variable was the axle loading. Therefore, any difference in the pavement performance of two parallel test sections was due primarily to the relative effects of the two different axle loadings.

30. Trollope, D.H., I.K. Lee and J. Morris, "Stresses and deformation in two layer pavement structures under slow repeated loading", Proc Australian Road Research Board Paper No. 38 1: pt 2, pp 693-721, 1962.

Successful performance of a pavement structure depends on elastic behavior of the constituent materials under repeated loading.

A laboratory examination of the behavior of sand and a sand-bitumen mix suggests that these granular materials can be conditioned to behave quasi-elastically provided they are proof-loaded to a stress level higher than that required in service. The stress strain characteristics of these materials under slow repeated loading are such that the "true" elastic modulus is that measured on the unloading cycle in a compression test (the rebound modulus) not, as has been assumed previously, the value obtained from a single loading cycle.

Tests on model pavements in the laboratory have indicated that the stresses in two layered systems follow the predictions of the linear elastic theory closely with respect to mode of distribution but the evaluation of the effective modulus still presents a serious problem. It is likely that the behavior is non-linearly elastic. It can also be shown therefore that, in the absence of proof-loading, elastic theory cannot predict adequately the total deformation of a pavement surface.

31. Williams, Stuart and Allan Lee, "Load-deflection study of selected high-type flexible pavement in Maryland", Nat'l Research Council--Highway Research Board Bul 177, 1958, p 1-20.

A cooperative program of load-deflection tests of several high-type flexible pavements in Maryland was inaugurated in the spring of 1955. A single test consisted of the application of a slowly moving 11, 200-lb wheel load of a single-axle truck to an arbitrarily selected point on the pavement and the measurement of the resulting pavement deflection and rebound. Measurements were made at a point between the dual tires by means of the pavement-deflection indicator known as the Benkelman Beam. Tests were made in the spring and in the fall at approximately 1,000 marked locations over a distance of about 85 lane miles. The pavements tested range in age from two to eleven years and are in excellent condition.

This report contains a description of the pavements studied, the test procedure used, and the results of the tests conducted to date.