Load Test Results on the Maryland Test Road

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It is a rather startling reflection, but the last investigation of the nature I will describe was made nearly 30 years ago by the Illinois Division of Highways on the project known as the Bates Road Test. Great changes have taken place since then in the field of highway transportation, but research on the effect of truck axle loads on pavements continued to lag behind that of the rapidly growing trucking industry.

Sir Isaac Newton once said that in the case of a disagreement about facts, the matter "is to be decided not by discourse but by new trial of the experiment."

Road Test One-MD, "the new trial of the experiment" was conceived to provide some of the much needed information. For six months the Highway Research Board subjected a 1.1-mile section of concrete pavement to continuous, around the clock, seven days a week traffic using four single rear axle trucks loaded to 18,000 and 22,400 lb. per axle and four tandem rear axle trucks loaded to 32,000 and 44,800 lb. per tandem. In the six months the eight trucks have traveled approximately 400,000 miles. The principal object of the test is to determine the relative effects, on a particular concrete pavement, of the four different axle loadings on two vehicle types.

Information, such as is being secured from this experiment, is greatly needed for use in appraising the load carrying capacities of existing concrete pavements, for use in designing new pavements and to provide fundamental data that may be useful in framing equitable legislation to govern highway transportation operations. This research project was proposed by the Interregional Council on Highway Transportation which was formed at Columbus, Ohio, on December 5 and 6, 1949. A special Committee of the Council met in Baltimore, Maryland, on January 9 and 10, 1950. This Committee decided that the project, as suggested, was feasible and recommended that the tests be conducted at the joint expense of the participating state highway departments with the Highway Research Board assuming direction of the project.

As finally organized the following highway departments executed contracts with the National Academy of Sciences, agreeing to participate financially in this cooperative project: Connecticut, Delaware, Illinois, Kentucky, Maryland, Michigan, New Jersey, Ohio, Pennsylvania, Virginia, Wisconsin and the District of Columbia.

The project is being administered and supervised by the Highway Research Board of the National Academy of Sciences through a small Project Executive Committee and an Advisory Committee, both under the chairmanship of the Associate Director of the Board, Fred Burggraf. The Project Executive Committee includes also H. S. Fairbank, T. J. Kauer, and A. S. Gordon. The Advisory Committee includes one representative from each participating state, one representative from the Bureau of Public Roads, one representative from the Automobile Manufacturers Association, one from the American Trucking Association and one representative from the Department of the Army. Other members appointed by the Highway Research Board are the Chairman of the Highway Research Board's Department of Economics, Finance and Administration, and of the Department of Design. The field staff assigned to the Highway Research Board by the Bureau of Public Roads consisted of A. Taragin as Project Engineer and three Assistant Engineers—Theodore Dec, Jack R. Hutchins and Sydney W. Smith.

The cost of this project is shared by the participating states in monetary contributions; by the Bureau of Public Roads in providing personnel and instruments for measurements of surface roughness, slab strains and deflections caused by the test loads, for soil surveys and other necessary instrumentation and testing services, and in providing the services of the project engineer and three assistants; by the petroleum industry in providing gasoline, oil and grease; and by truck manufacturers of the Automobile Manufacturers Association in providing the test vehicles. Vehicles were furnished by The Ford Motor Company, Reo Motors, Inc., General Motors Corporation, Autocar Company, White Motor Company, International Harvester Company and Mack International Motor Truck Company. Gasoline, oil and grease were supplied by the following 14 companies: American, Atlantic, Cities Service, Esso Standard of New Jersey, Gulf, Ohio, Phillips, Pure, Shell, Sinclair, Socony Vacuum, Sun, Texas and Tidewater.

I should like to mention briefly one aspect of this job that is especially noteworthy from an overall view—that is the demonstration given by this project of the benefits of cooperation by a number of diverse agencies in research on a problem of great mutual importance, by pooling their support under the direction of an independent institution which can have no possible interests in the matter other than the development of facts and acquisition of new knowledge.

The total estimated cost of the project is $245,000. Toward this amount $150,000 has been contributed by the 12 highway departments previously mentioned; the balance has been in contributions of personnel, services, equipment and material valued approximately as follows:

Bureau of Public Roads	
Personnel and service	$40,000
Truck Manufacturers	
Test Vehicles	27,500
Petroleum Industry	
Grease, oil and gasoline	20,000
Department of Defense	
Aerial Photography	3,100
Highway Research Board	
Personnel	4,400
	$95,000

Estimated distributions of the cash expenditures are:

Testing operations	$52,450
By-pass road and turnarounds	50,900
Administration	9,050
Maintenance of test road	2,000
Final repair of test road	29,000
Reports	2,600
	$146,000

Test Section—The tests are being conducted on a 1.1-mi. section of Concrete Road on U. S. 301, located approximately nine miles south of La Plata in Southern Maryland. The pavement was constructed in 1941 and was in excellent condition at the start of the tests. The pavement is reinforced, is 24-ft. wide, and is divided at the center with a longitudinal joint. The cross section is of the double parabolic type thickened at both the outside and center longitudinal joint edges. The depth of the cross section of each 12-ft. lane is 9-7-9 in. Expansion joints ¾-in. wide are spaced at intervals of 120-ft. with two intermediate contraction joints at 40-ft. spacing.

Load transfer devices of a cantilever, plain dowel type were placed in all of the transverse joints. The dowel bars are ¾-in. in diameter and placed at 15-inch spacing. The longitudinal joint is a straight butt construction type with 4-ft. long tie bars spaced at intervals of 4-ft. The welded wire fabric reinforcement is approximately 3-in. from the surface and contains No. 2 wires spaced 6-in. c-c. in the longitudinal direction and No. 2 wires 12-in. c-c. in

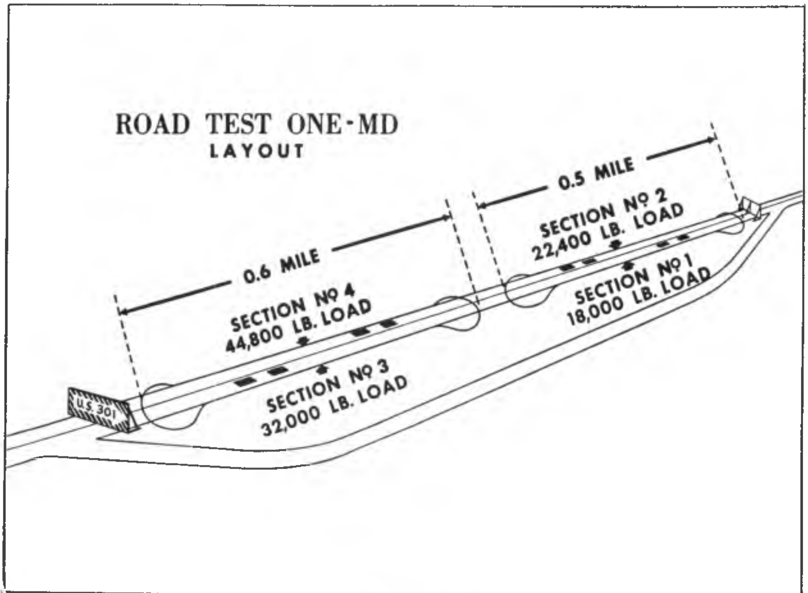


Figure 1

the transverse direction. The weight of the fabric is 59.4 lb. per 100 sq. ft.

The 1.1-mi. test road has been divided into two sections; the south section being 0.5-mi. long, and the north section 0.6-mi. long. At each end of each section, turnarounds of 50-ft. outside radius with 20-ft. bituminous roadways, have been constructed to allow the test trucks to operate back and forth on the same lane. The vehicles negotiate these turnarounds at approximately 6 mph. (See Fig. 1).

On the west lane of the south section two single unit, two-axle trucks with rear axle loads of 18,000-lb. are operated. The Ford

Motor Company and Reo Motors, Incorporated, supplied these vehicles. On the east lane of the south section two single unit, two-axle trucks with rear axle loads of 22,400-lb. are operated. These vehicles were supplied by the General Motors Corporation and the Autocar Company. On the west lane of the north section two single unit, tandem-axle trucks with tandem loads of 32,000-lb. are operated. The White Motor Company and the International Harvester Company supplied these vehicles. On the east lane of the north section two single-unit, tandem-axle trucks with tandem loads of 44,800-lb. are operated. These vehicles were supplied by the General Motors Corporation and the Mack International Motor Truck Company.

Each slab (12 by 40 ft.) is identified by a number painted on the slab. Ten spots are painted in each slab for reference points for precise level observations of variation in elevations. The Coast and Geodetic Survey placed 15 concrete Bench Markers along the project and determined their elevation. These are used as reference points to determine the settlement of the slabs. The average settlement for all the slabs at the free edge of the transverse joints as of October 2 was: Section 1 (18,000-lb. single axle)—0.17 in.; Section 2 (22,400-lb. single axle load)—0.40 in.; Section 3 (32,000-lb. tandem axle)—0.27 in.; and Section 4 (44,800-lb. tandem axle)—0.88 in.

The trucks in each of the series have been selected so as to obtain the highest practicable rate of acceleration between 10 and 40 mph. In order to provide the necessary test load, 215 1,000-lb. concrete blocks and ten 750-lb. concrete blocks were made at the Maryland State Roads Commission Garage in La Plata where the trucks were loaded. Approximate loads were obtained at the garage with loadometers. The trucks, loaded by a crane, were then driven to a Virginia Highway Department weighing station located five miles south of the test section. All axle and gross loads were then adjusted to within 200-lb. of the loads specified for each vehicle.

SCHEDULE OF TRAFFIC OPERATIONS

Each lane is marked with longitudinal stripes as follows: White stripes along the outside edge of the pavement and 8-ft. from the outside edge of the pavement; yellow stripes 2-ft. and 10-ft. from the outside edge of the pavement. These stripes are used as guides for the trucks so that the following pattern of lateral placements of the outside rear-axle tires is maintained: one application with the outside tire at the edge of the pavement; one application with the outside tire 2-ft. in from the edge; three applications with the outside tire between the two positions. This pattern of truck operation represents the average operation of trucks on similar type highways as determined from lateral placement studies made by the Bureau of Public Roads.

Operations of all test vehicles are continuous on a 24 hour a day, seven day a week basis, except as necessary for maintenance of the vehicles, meals and rest stops for the drivers and except as interrupted by special tests. Drivers work three eight-hour shifts and are allowed 30 minutes for a meal and a 10 minute rest period each hour. Applications of load are indicated and counted by means of electric counters actuated by the passage of the test vehicles and checked by odometer readings in the trucks.

TEST PROCEDURES

Crack Survey—A detailed survey was made of the cracks in each slab prior to the beginning of operation with the test trucks. A solid, black line approximately one inch wide was painted adjacent to each existing crack along its full length. As new cracks or extensions of old cracks developed, they were painted with contrasting lines one inch wide as follows:

Solid yellow line for the first six weeks of operation.
Solid white line for the second six weeks of operation.
Solid red line for the third six weeks of operation
Broken yellow line for the last six weeks of operation.

Each slab is checked for cracks each day and the exact position of each crack as it develops is recorded on a card with the date and number of applications when the crack was first noticed.

Road Surface Roughness—The Bureau of Public Roads road surface roughness indicator was used to obtain surface roughness data on June 12 before the tests started and on August 8 and September 20. These measurements were made in both directions along each normal wheel path. The average of all the sections show an increase in roughness during the first eight weeks of truck traffic of only 3.6 units but during the next six weeks an additional increase in roughness of 11.6 units was recorded.

Concrete Quality—Nineteen beams, approximately seven inches wide, were sawed from the four concrete specimens removed from the pavement for this purpose by the Maryland State Roads Commission. The average flexural strength was 708 psi. The average flexural strength of 28 beams made during the construction of the pavement included in this test section was 485 psi. at seven days. The average compressive strength of 12 six-inch diameter cores drilled in June from portions of the roadway not subjected to traffic was 6944 psi. after being immersed in water for 28 days. The average compressive strength of 20 cores drilled from the pavement included in this test section, two months after it was constructed and tested at an age of approximately four months was 4838 psi.

The average height of these cores showed the pavement to be of the designed thickness as the required thickness for the areas from which the cores were taken was 7.5-in. and the actual thickness for the same areas was 7.6-in. The average modulus of elasticity value of the cores was 4,800,000 psi. for the wet condition. All of these

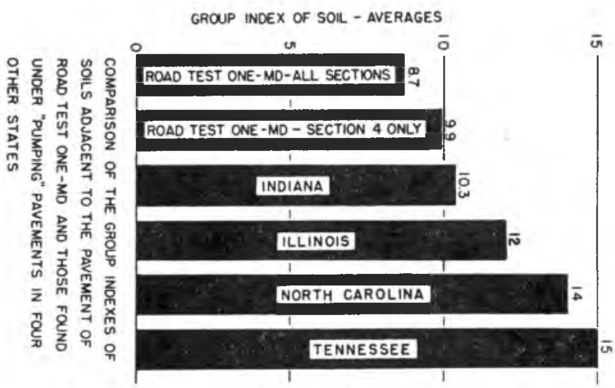


Figure 2

tests show that the concrete is of good quality and the pavement has the designed thickness. At the conclusion of the traffic tests, many more slabs and cores will be removed from the road and tested.

Preliminary Report on Soil Survey—Soil test data have been obtained from 50 auger borings made adjacent to the concrete pavement to a depth of approximately 30 inches, spaced uniformly from end to end of each test lane. These data indicate that approximately 15 per cent of the subgrade soils have granular characteristics and that the remainder are fine-grained plastic soils. These fine-grained soils have been compared, by group index ratings, with the average types of soils found under "pumping" pavements in Illinois, Indiana, North Carolina and Tennessee. This comparison shows that the loam and silty loam soils on this project are better than the averages of the soils that have been found conducive to pumping in three of the states and is about the same as the average of such soils in the fourth state. (See Figure 2)

Also a comparison on a grain size basis shows the average of the soils adjacent to the pavement on the project to be slightly better than the average of soils for the entire State of Maryland.

Regardless of the variation in the soils along the edge of the pavement, Sections 3 and 4 (tandem axle loadings) can be compared directly with each other as the subgrade across the grade is uniform. Sections 1 and 2 (single axle loadings) can also be compared for the same reason. But before the behaviors of the test pavements under tandem axle loading can be compared with those of single axle loads, the characteristics of the subgrade soils under each pavement slab and other variables such as rate of application of load must be studied in detail.

Maintenance—The Executive and Advisory Committees for this project have defined maintenance as follows: "To maintain shoulders reasonably flush with the edge of the pavement, to seal joints, and to correct profile deficiencies to insure safe operating conditions as necessary in the opinion of the Project Engineer with the advice of the State Resident Maintenance Engineer and others. Maintenance is not to include undersealing to correct for pumping." Table 1 shows

TABLE 1

SHOULDER AND JOINT MAINTENANCE ON ROAD TEST ONE-MD.

(NUMBER OF TIMES EACH ITEM OF MAINTENANCE WAS PERFORMED DURING EACH MONTH)

Type of Maintenance	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Shoulders							
Dragged	3	2	1	2	1		9
Bladed			2	1	1	1	5
Gravel Added	2	2	1				5
Maintained by Hand Labor		2	1				3
Rolled and Calcium Chlorided	1						1
Total Number of Times Shoulders were Maintained	6	6	5	3	2	1	23
Joints Resealed	2	2	2	1	3	1	11

the extent of maintenance given to the test sections. For the six-month period of operation the shoulders were maintained 23 times and the joints were resealed 11 times.

Strains and Deflections—Between September 5 and September 14 the deflections at various joints caused by the trucks traveling at creep speed over the pavement were measured. The deflection readings were made at intervals varying from four to six hours throughout a full 24-hour cycle, by personnel loaned by the State Highway Departments of Maryland, Pennsylvania and Virginia, at two expansion and two contraction joints in each of the four sections and at the center of the slab edge at two points in Section 4. Joints were selected for study at which no pumping and varying degrees of pumping had occurred in each of the four sections.

The data indicate that the deflections caused by the loads are (1) normally much greater at night when the pavement edges are warped upward than during the daytime when they are warped downward; (2) two or three times greater at pumping joints than at nonpumping joints; (3) larger at pumping expansion joints than at pumping contraction joints of the dummy type; and (4) larger during the period when pumping is receding than at any other time.

Additional information, which will be of great value to designers of future pavements and to those charged with evaluating the load carrying ability of existing pavements, is being obtained by means of strain measurements of the pavements under various loads and by measurements of strains induced by warping of the slabs due to temperature differentials between the top and bottom of the concrete. These tests have not been completed so no definite results can be given at this time. Mr. E. C. Sutherland and H. D. Cashell of the Bureau of Public Roads have been assigned to the Project and are supervising the stress and deflection test program agreed to by the Advisory Committee.

SUMMARIZING

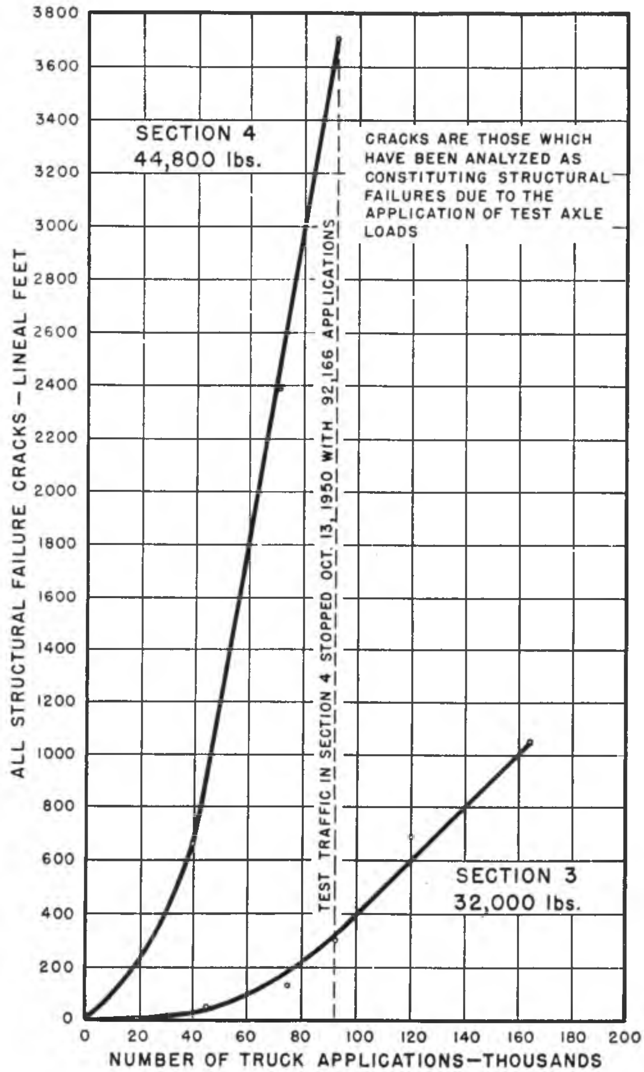
As stated by the Advisory Committee: "All pertinent data must be carefully analyzed and considered before the final report, however, certain facts relative to the behavior of the pavement under test have already been established.

"The more significant observations which may be made from the test results to December 23 (after six months of continuous operation) are as follows:

1. Soil tests made on samples obtained throughout the length of the pavement adjacent to the pavement edges and under certain

sections of the pavement indicate that there is reasonable uniformity in the soils on the two sides of the pavement.

2. Based on these same soil tests, there is found to be a definite correlation between soil type and pavement behavior. The higher the granular content and the lower the plasticity of the soil, the better the performance. The sub-grade soils on this project are typical

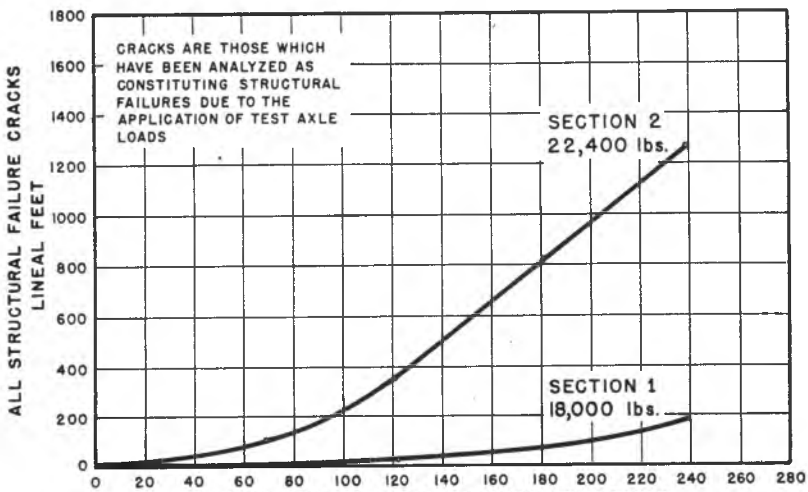


RATE OF CRACK DEVELOPMENT UNDER LOADS OF TANDEM AXLES

Figure 3

of the soils underlying a very extensive mileage of concrete pavement throughout the country.

3. The progress of cracking and depression of joints in the test sections has a definite relationship to the occurrence of pumping. Previous research and observation have shown that four basic conditions must be present simultaneously to create a pumping slab. They are: (1) frequent heavy axle loads; (2) subgrade soils of such a nature that they may pump through open joints or cracks or at pavement edges; (3) free water under pavement; and (4) joints



RATE OF CRACK DEVELOPMENT
UNDER LOADS OF SINGLE AXLES

Fgiure 4

or cracks in the pavement. These conditions were present on this project and pumping resulted.

4. Based on both quality tests and dimension measurements, the concrete in the test sections is of good strength and of the designed thickness.

5. All four sections were damaged as follows by the loads applied:

(a) The 44,800-lb. tandem axle loads caused approximately 11 times as much cracking (lineal feet) as the 32,000-lb. tandem axle loads. This relationship held true over a period of almost four months, that is from 20,000 to 92,000 truck passes in each lane. (See Figure 3 and Table 2).

(b) The 22,400-lb. single axle loads caused approximately six times as much cracking (lineal feet) as the 18,000-lb. single axle loads. This relationship held true over a period of almost five months, that is from 35,000 to 238,000 truck passes in each lane. (See Figure 4 and Table 2).

(c) After 84,000 truck passes, 80 per cent of the joints in the section carrying 44,800-lb. tandem axle loads were depressed, whereas, with the same number of truck passes, only 10 per cent of the joints in the section carrying 32,000-lb. tandem axle loads were depressed.

TABLE 2

PAVEMENT CRACKING ON ROAD TEST ONE-MD.
(PRELIMINARY FIGURES)

Section Number	Number of Truck Passes	Cracks Analyzed to be Structural Failures Due to Load	Cracks Analyzed to be NOT Structural Failures Due to Load	**Total Cracks**
		Feet	Feet	Feet
1—18,000-lb. single axle	238,275	189	52	241
2—22,400-lb. single axle	238,263	1,153	57	1,210
Ratio 2 to 1	1.0	6.1	1.1	5.0
3—32,000-lb. tandem axles	92,000	280	27	307
4—44,800-lb. tandem axles	92,166	3,283	20	3,303
Ratio 4 to 3	1.0	11.7	0.7	10.8
3—32,000-lb. tandem axles	164,523	992	27	1,019

(Depressed joints are defined as those joints at which a marked localized settlement of the pavement has occurred accompanied by cracking of the pavement in the vicinity of the joint.)

(d) After 137,000 truck passes, 22 per cent of the joints in the section carrying 22,400-lb. single axle loads were depressed, whereas, with the same number of truck passes, only two per cent of the joints in the section carrying 18,000-lb. single axle loads were depressed.

6. (a) After 238,000 truck passes, 28 per cent of the slabs in the section under 18,000-lb. single axle loads and 64 per cent of the slabs under 22,400-lb. axle loads contained cracks which have been analyzed as constituting structural failures due to the application of the test axle loads. Conversely, 72 per cent of the slabs in the 18,000-lb. section and 36 per cent of the slabs in the 22,400-lb. section show no such structural failures.

(b) After 92,000 truck passes, 27 per cent of the slabs in the section under 32,000-lb. tandem axle loads and 96 per cent of the slabs under 44,800-lb. tandem axle loads contained cracks which have been analyzed as constituting structural failures due to the application of the test axle loads. Conversely, 73 per cent of the slabs in the 32,000-lb. section and four per cent of the slabs in the 44,800-lb. section show no such structural failures.

Broadly speaking, the three main results of this investigation are: (1) it has furnished highway administrators and engineers with quantitative facts regarding the effect of axle loads of different intensity on a concrete road; (2) it has increased and to a certain extent verified our knowledge of the interrelationship between loads, pavements and subgrades and; (3) it has acted as a stimulus for further research.

The following resolution passed at the Annual Meeting of the American Association of State Highway Officials in December 1950, sums up tersely the opinion of the highway administrators about this research project.

> "WHEREAS, a research project consisting of tests under the sponsorship of several states is now being carried on to ascertain the effect on highway pavements of the repeated applications of heavy loads and
>
> WHEREAS, this project is producing information of great value to highway officials responsible for the construction and maintenance of the highway system. Now, therefore, be it
>
> RESOLVED, that the American Association of State Highway Officials in convention assembled in Miami, Florida, December 4-7, 1950, urges the promotion and encouragement of further studies by the states or groups thereof to obtain more specific information on this problem."

The Transport Committee of the American Association of State Highway Officials has been very active in promoting additional research projects and three of the regional Associations of State

Highway Officials have this matter under consideration. In general the tentative plans are for the Southeastern Association of State Highway Officials and the Western Association of State Highway Officials each to finance a research project on a bituminous type pavement and the Mississippi Valley Association of State Highway Officials to finance a research project on another concrete pavement.

These additional tests under other conditions including a different type of pavement are necessary to obtain more complete answers to the questions of highway engineers, administrators and transportation officials.

Now to outline the future tests planned on Road Test One-MD.

First, we plan to make simultaneous measurements of strain and corner deflection at four more joints with four single axle loadings of 14,000, 18,000, 20,000 and 22,400-pounds and four tandem axle loadings of 28,000, 32,000, 36,000 and 44,800-pounds. Two sets of these tests using all eight loadings will be made on pavement sections located on granular subgrades and on which there has been no evidence of pumping. The other two tests will be on joints showing medium and high deflection.

There will also be some strain and corner deflection measurements made under tandem axle loadings of 14,000, 18,000 and 22,400-pounds to determine the relation of the stress to these total loads on rear axles over a range which will permit a direct comparison of stress with the similar single axle loads. It is also planned to make some miscellaneous strain and deflection tests with tractor-semi-trailer combinations.

A detailed soil survey will be made and in this connection plans are underway to dig a trench the full length of the project along both edges of the pavement. This will afford an opportunity to locate definitely the transition points between soils of different types, to observe any changes in the vertical profile, to take representative samples, and to obtain a photographic record of this important component of the road structure. These observations will also determine the location of the cores to be drilled from the pavement to obtain additional soil samples of the subgrade.

To supplement the few preliminary quality tests made on the concrete, several 3 x 4 foot sections will be taken from the pavement and sawed into suitable size specimens for transverse tests. A large number of cores will also be cut from the pavement for compressive strength tests and to check the pavement thickness.

Recently the Commanding Officer of the 18th Tactical Reconnaissance Squadron of Shaw Air Force Base, South Carolina, assured us that they would make another colored aerial strip photograph of the project. The aerial colored photographic record of the final condition of the project will be of great value as it will show the cracks present prior to the test and the rate and extent in which the additional cracks occurred under the various truck axle loads. The one they made of the project this summer at an altitude of 100 feet revealed the cracking patterns in great detail.

In conclusion I wish to say that this research project was truly a cooperative one both in its conception and in its operation. Therefore everyone connected with the project deserves credit for his contribution to this investigation.