Special Studies

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• This paper summarizes the detailed discussions of the Special Studies conducted during and following the main road test experiment which are presented in HRB Special Report 61F. Studies undertaken during the main road test included not only those conducted by the Road Test personnel but also those conducted by and for outside agencies primarily for their own benefit and with the cooperation of the Road Test personnel. In most instances existence of the physical plant constructed in a highly controlled condition and subjected to exactly known traffic loadings made it an ideal testing ground for these studies. Reference to the source of publication of most of these studies are noted in the report.

INDEPENDENT STUDIES

Investigations of the nature of special studies began prior to the main traffic study. An extensive instrumentation development program was of utmost importance to the research group and a considerable amount of the development was undertaken on the Road Test site. Of significance was the development of the nuclear testing equipment for measurement of in-place density of the several components of the pavement structure. Commercially available equipment was adapted and extended to produce field equipment; techniques for using the modified equipment were also developed.

Two papers were given by AASHO Road Test personnel describing this program. The first (HRB Special Report 38) describes the development work with a discussion of some of the problems associated with this system of measurement. The second paper, presented at the Symposium for Nuclear Density and Moisture Tests, June 1960 (ASTM), described the technique for evaluating the nuclear equipment. In addition, comparisons between commercial and AASHO Road Test equipment are given.

In general, the study indicated this system of determining density and moisture content has a great potential in the highway industry and properly calibrated equipment very likely is superior to conventional techniques. However, the calibration procedures developed and described were found to be extremely sensitive and required a considerable amount of time.

Other instrumentation developed prior to the start of the traffic testing included a device for determination of the depth of frost penetration. The reasonably simple electrical resistance sensing unit is described in detail in "Frost Depth Determination by Electrical Resistance Measurements," *Highway Research Board Abstracts*, Vol. 27 (April 1957).

An extensive program of dynamic testing of the pavement structure making use of the Shell Road Vibration Machine was conducted during the period November 1958 to May 1959. These tests were conducted during regular traffic operations on selected test sections in each of the traffic loops. The primary objectives of this study were to investigate the seasonal variation in stiffness of pavements, to attempt to relate this stiffness to pavement performance, to measure properties of the layered construction by non-destructive velocity testing, to compare measured stiffness with the stiffness calculated from the properties of the layers, and to compare the properties of the sections subjected to traffic with the sections without traffic.

The analyses of the velocity and stiffness data are described in "Dynamic Testing at the AASHO Road Test" (Bull. WRP 7-59, Shell Oil Company). Some of the conclusions from this study were:

1. The stiffness of the asphalt pavement is greatly influenced by seasonal changes.
2. Seasonal recovery of the pavement structures indicated that the degree of recovery required further investigation.
3. The stiffness of pavement sections with bituminous-treated bases is very high.

Similar dynamic testing equipment developed by the Waterways Experiment Station, U. S. Army Corps of Engineers, was used in a smaller study at the end of the post-traffic program. Personnel from the Waterways Experiment Station, with the assistance of the project staff, made the field tests and analyzed the data. Further information on the tests and results will be available on request to the Director of the Waterways Experiment Station, Vicksburg, Miss.

Personnel from the Ohio Division Laboratories, U. S. Corps of Engineers, demonstrated the method of determining the Westergaard foundation modulus K from the top of the rigid pavement surface. Personnel from the Road

Test conducted a number of such tests on the surviving road test sections. Analysis of the data by the personnel from the Ohio River Division Laboratories had not been completed at the time of the publication of HRB Special Report 61F. The preliminary indications were that *K*-values determined by the volumetric displacement method compare favorably to those obtained by the method normally used by the U. S. Corps of Engineers. Information on the final analyses of the data will be available upon request to the Director of the Laboratory.

A study suggested by the subcommittee on human reactions of the Special Study Panel were conducted by the U. S. Army Personnel Research Office, Office of the Chief of Research and Development, Department of the Army, in cooperation with the Transportation Corps, Department of the Army.

The purpose of this study was to test the alertness of personnel engaged in a fatiguing and monotonous driving task. Alertness was measured on an hour-by-hour basis for one group of drivers in order to observe the level and scope of performance. Another group of drivers were administered a variety of psychological tests and measures in an attempt to predict individual differences in alertness.

The test instrument used to measure alertness was designed by members of the AASHO Road Test staff from a concept furnished by psychologists by the Army Personnel Research Office.

The results of these studies are available as Technical Research Notes 118 and 119 of the Army Personnel Research Office.

It may be of interest that one immediate outcome of the American Association of State Highway Officials' Driver Behavior Studies is the planning of an Army vigilance research laboratory that combines environmental realism with experimental control.

One of the major studies undertaken during the research phase was the investigation of the resistance to skidding of wet and dry flexible and rigid pavements of known design and traffic treatment. The experiment included 80 test sections of different design. Sixteen sections, eight in each traffic lane, were selected from each of the five test loops. Six series of tests were conducted on these sections. The first was completed prior to any traffic operation and the sixth after more than one million loaded axle applications. Details of the experiment and a summary of the test data were given in "Skid Studies at the AASHO Road Test" (HRB Special Report 66, 1961).

The principal findings of this experiment were as follows:

1. The most significant change in the skid resistance properties of the pavement sections observed in the road test experiment was the reduction in the coefficient of friction under wet pavement conditions resulting from an increase in number of truck axle applications for the single- and tandem-axle trucks used in this experiment.

The 1,100,000 axle applications resulted in a 39 percent reduction in the coefficient of friction for the flexible pavements and a 33 percent reduction in the coefficient of friction for the rigid pavements.

2. For the light truck traffic, 2000-lb axle loads, the reduction in the coefficient of friction for the 1,100,000 axle applications was considerably lower than for the heavy truck traffic.

3. A significant reduction in the coefficient of friction was noted as the speed of the General Motors skid test vehicle was increased on all of the test sections. Pavement roughness or serviceability in the range from good to fair did not appreciably influence this relationship.

4. A marked change in the coefficient of friction due to seasonal and/or weathering effects was noted in the results of the skid tests. In general, the coefficients of friction measured during early spring 1960 were 20 to 35 percent higher than the friction values measured in the tests conducted in the summer of 1960.

5. The coefficients of friction for pavements of different structural thicknesses were reasonably uniform over the range of pavement thickness selected for the skid tests. It should be noted, however, that in this respect the tests were limited to the thicker pavement sections which were selected to provide reasonable assurance that the composition of the pavement surface of these sections would not be changed by maintenance operations, such as overlays, required by the test traffic during the two year period in which the road test was in operation.

This concludes a brief review of the independent studies conducted prior to and during the research phase of the road tests.

FORMAL AGREEMENT STUDIES

One of the five objectives of the road test as stated by the working committee was ". . . to conduct special studies dealing with such subjects as paved shoulders, base type, tire size and pressure and heavy military vehicles with the aim of correlating these studies with the results of the basic research."

Results of the studies on paved shoulders and base type are reported in HRB Special Report 61E and will not be discussed at this time. However, the special studies dealing with tire design, tire pressure and heavy military vehicles constitute a major portion of Special Report 61F.

Formal agreements regarding this group of special studies was concluded among the Secretary of the Army, the President of the American Association of State Highway Officials, and the Executive Officer, National Academy of

Sciences—National Research Council, in June and July 1956. It was agreed that the National Academy of Science—Highway Research Board Road Test Staff would assist in the conducting of the special studies both during and after the regular tests, make the necessary analyses and prepare the appropriate reports.

These tests which will be described briefly were conducted primarily to detect trends and to define future research. In addition, it was felt that experience gained would provide a basis for better testing techniques and instrumentation to identify and measure the critical response transmitted to the pavement and to the vehicle. Measurements were made of strain, deflections, embankment pressures and soil and pavement reaction.

Pavement Performance, Loop 2

A pavement performance study on Loop 2, the 2- and 6-kip axle load loop, was recommended by the Special Studies Panel. This study was patterned after the main research program on the road test.

Those sections which survived the over 1,000,000 loaded axle applications were subjected to repetitive applications of 32-kip tandem-axle loads. One group of military tractor, semitrailer units was equipped with low pressure-low silhouette (LPLS) tires at 35 psi and the other with conventional military tires at 70 psi. These units were operated in lanes 1 and 2, respectively. Approximately 16,500 axle applications were applied before completion of the study.

Comparisons of the relative effects of the tire design and pressure, for the flexible sections were made on the basis of serviceability loss, increase in area of cracking and patching, and increase in rut depth. For the rigid sections, these comparisons were on the basis of serviceability loss, increase in cracking and patching, and increase in pumping score.

It should be noted here that the effect of the traffic history on the findings of this study very likely resulted in more favorable results for the LPLS traffic operated on lane 1.

From the physical measurements and observations made during the traffic operations of this special study, the following conclusions can be drawn:

For flexible pavement sections:

1. The loss in serviceability of the sections subjected to the LPLS tires was generally less than for the comparable sections subjected to the conventional tires.

2. When related at a common level of actual load applications, the sections subjected to the conventional tires showed a greater increase in area of cracking and patching than did the sections subjected to the LPLS tires. However, only the lane 2 (conventional tires) sections had shown any distress in the form of cracking and patching during the main Road Test.

3. The increase in depth of rut was greater for the lane 1 (LPLS) sections than for the lane 2 (conventional) sections, and the before-traffic rut depths were less for lane 1 than for lane 2; however, as indicated in Special Report 61E, the rate of increase of rutting decreases after a certain depth of rut develops.

4. The relative performance of replicate sections subjected to both the LPLS and conventional tires on the basis of serviceability loss, increase in cracking and patching and increase in rut depth indicated a beneficial but not highly significant effect of the LPLS tires.

For rigid pavement sections:

1. The loss in serviceability for the sections subjected to the LPLS tires was generally less than for the sections subjected to the conventional tires. In most comparisons however, the loss in serviceability amounted to only a few tenths of a point.

2. The increase in linear feet of cracking in lane 1 (LPLS) was greater than the increase in lane 2 (conventional). The formation of minor cracking apparently occurred under a few applications but did not develop into the class of cracking which detracts from the serviceability of the section. The lane 1 sections in this study had no previous history of crack development.

3. Pumping had developed only in the lane 2 sections during the main Road Test and continued to progress more rapidly during this study than pumping in the lane 1 sections. This relationship was found to exist for the main Road Test as well.

4. The loss in serviceability for the four replicate sections was not significant and thus, the comparison of the performance of these sections must be made on the basis of the increases in pumping score and lane cracking. In general, the differences in the increase in these two measurements was so slight that no valid comparisons could be made.

5. Investigation of the physical properties of both the rigid and flexible pavements sections failed to indicate any significant effect of the different traffic loadings.

In addition to the performance study on the original remaining sections, an investigation of the effectiveness of an asphaltic concrete overlay of variable thicknesses on both pavement types was incorporated into this study. Difficulty was encountered in the construction of satisfactory overlays as short as one flexible test section (100 ft). Thus, observation of the performance of these sections beyond a few thousand applications was difficult since the ramps up and down from the full thickness of overlay showed distress in the form of shoving and cracking soon after traffic started. This necessitated the addition of more surfacing material which produced a major change in the serviceability index. For these reasons, an analysis of the performance of the flexible sections that had been overlayed was not practical.

However, the overlayed rigid sections (length 120 ft and 240 ft) performed very satisfactorily with only a slight loss in serviceability accompanied by the development of rutting in the overlay of about 0.1 in. In only one instance did the ramp effect necessitate discontinuing observations of the section.

Because many of the test sections in Loop 2 had failed prior to this study, a balanced factorial experiment design could not be used. However, the performance equations developed in the main Road Test were applied to the conditions of this study. The results indicated that the sections would have survived in most cases, as much as ten times the applications they did survive.

It should be noted, however, that the actual performance of similar sections in Loop 4 which were subjected to the 32-kip tandem-axle loads agreed very well with the performance predicted from the equations. Therefore, it can be assumed that the conditions that were obtained during this study were severe compared to those during the main Road Test.

Although some trends were shown in this study, it was clear that additional research is needed before the relative effects on pavement performance of the vehicles equipped with the two types of tires can be evaluated. The additional work may well take the form of that reported here except that the different tire designs and pressures should be operated over test pavements that are either new or have identical traffic histories, and provision should be made for a much greater number of test load applications and for more instrumentation for obtaining measurements relating to performance or serviceability than were available at the time of this study at the Road Test. As a result of these findings, the Army intends to continue research based on these recommendations.

Tire Pressure and Design Study

The objective of the second major investigation included in the post-traffic study program was to determine the possible effect of changes in tire pressure and design on the dynamic measurements associated with pavement structures and bridges.

Eighteen test vehicles loaded to four different axle loads were equipped with wire and nylon cord tires of several sizes and inflation pressures. The range of tire pressures was from 60 to 130 psi and tire sizes included 8.25 × 20 to 12.00 × 20.

The vehicles were operated at several speeds on both the flexible and rigid test sections in Loops 4 and 6 which were equipped with instrumentation to measure dynamic strain and deflection, dynamic load (making use of a tire pressure-differential load device developed at the Road Test) and transmitted embankment pressures. In addition, midspan strain and deflection were taken on the remaining test bridges.

Selection of the test sections for study was limited to the thicker designs, thus reducing the scope of the study to some extent. Pilot studies conducted previously on the Road Test helped to define a range of vehicles and loads tested; and the findings of these studies predicted to a certain degree the findings of the study described.

Bearing in mind that the tests were conducted on pavement sections which had survived over one million applications of either 18-kip or 30-kip single-axle loads and on bridges that had been subjected to over 500,000 vehicle passages, a summary of the findings of the study is as follows:

For flexible pavement sections:

1. Tire inflation pressure changes of the order of 40 to 50 psi accompanied by a limited tire design change had little effect on the dynamic deflections.
2. Relationships similar to those found in the side studies of the main Road Test existed between wheel load and deflection indicating that the data accumulated were rational.
3. Changes in tire design or pressure had little or no effect on the pressure transmitted to the embankment soil. Such changes may or may not affect transmitted pressures within the pavement structure. However, no instruments were available to measure such phenomena.
4. The area of maximum transmitted pressure appeared to increase with an increase in tire inflation pressure which is normally associated with a decrease in tire contact area.

For rigid pavement sections:

1. Changes in tire pressure or tire design produced no noticeable effect on the dynamic edge strains or deflections. However, had instrumentation been available to measure strain or deflection in the pavement surface at points other than the edge, effects may have been found.
2. Relationships found between wheel load and deflection and strain and between vehicle speed and deflection and strain agree with those presented in Special Report 61E.
3. The dynamic load effect as determined by the tire pressure differential-load device was clearly related to vehicle speed and pavement serviceability. However, the effects of changes in tire pressure or design were not consistent within the range included in this study.
4. The possible effects of the different tire pressures and designs on the bridge responses

must be considered only as trends since the characteristics of the vehicles and the vehicle load patterns were not uniform.

For the bridge study:

In general, the strain and deflection amplification factors (dynamic strain or deflection as a ratio of static strain or deflection) relationships found in this study agree with those given in the Special Report 61D. That is, an increase in speed was associated with larger amplification factors; and the amplification factors for single-axle vehicles were generally greater than those for the tandem-axle vehicles.

Although some conclusive trends were shown by this study, it was not clearly established that changes in tire pressure and design had any consistent effect on the dynamic measurements of the pavement structure.

Further research should include a greater range of tire pressure and designs than were available for this study. Also, the selection of the pavement sections should include designs below the thickness of those that were available on the Road Test at the time of this study.

In addition, further research to detect these effects might well include performance studies patterned after the experiment design of the main Road Test and the performance study on Loop 2.

Commercial Construction Equipment Study

The objective of the third major investigation included in the post-traffic study program was to determine the dynamic effect on bridges and pavements of commercial construction equipment and, insofar as possible, to relate the dynamic effects of these vehicles to those observed for conventional dual-tire units.

One medium and one small two-axle tractor-scraper units were operated over pavement sections on which dynamic measurements were made of strain, deflection, transmitted embankment pressure and dynamic load effect. Maximum strain and deflection measurements were taken on the test structures.

These units were operated on the instrumented sections and bridges in Loops 4 and 6 at several levels of axle loads, vehicle speed and tire inflation pressure. Conventional dual-tire units were operated simultaneously to provide for the comparison specified in the program objective.

The past history of the instrumented pavement sections and the limits imposed on the study because of this history should be considered in reviewing the findings.

For flexible pavement sections:

1. Relationships between deflection and wheel load for the two scraper units agreed with the relationships for the conventional units. The rate of increase of deflection with wheel load for the small scraper was essentially equal to that of the conventional units; whereas, the rate for the medium scraper was considerably lower than the rate for the conventional units.

2. For both units, deflection decreased as vehicle speed increased. However, the effect of the vehicle speed was more pronounced for the small than for the medium scraper. In addition, the speed effect was greater at the higher wheel loads.

3. The study of the effect of the change in tire pressure on the pavement deflection failed to indicate any trends at any wheel load or inflation pressure.

4. As vehicle speed increased, there was a decrease in pressure transmitted to the embankment by both scrapers at all levels of wheel load and tire inflation pressure tested. However, changes in inflation pressure did not noticeably affect the transmitted pressure.

For rigid pavement sections:

1. Compressive edge strains increased with wheel load for both scrapers but were affected very little by vehicle speed or tire inflation pressure. Tensile strains measured at the pavement edge were not noticeably affected by the wheel load, vehicle speed or inflation pressure.

2. Corner deflection measurements increased with an increase in wheel load for both scrapers at a lower rate than for the conventional units but the effect of inflation pressure was neither uniform nor large for either scraper.

3. The percent of increase in dynamic axle load over static load was comparable to that found for conventional units. Of the two sections of pavements tested, the dynamic load effect was appreciably greater for the pavement with the lower serviceability and also increased appreciably with vehicle speed and inflation pressure.

For the bridge study:

1. Although the trend was not consistent for all bridges tested, mean strain and deflection amplification factors for both scraper units were lower than for those for the single-axle vehicles but greater than those with the tandem-axle vehicles.

2. The mean strain amplification factors for the small scraper was slightly higher than for the medium. However, the relationship was not consistent for the deflection amplification factor.

The findings and trends established in this study were generally conclusive but the restrictions on vehicle speed, pavement design and instrument locations make further research desirable.

Dynamic measurements of strain and deflection in rigid pavement sections should be made at locations other than the edge or corner of the pavement surface. Transmitted pressure instrumentation at other levels within the flexible pavement structure may indicate greater effects of vehicle speed and/or tire inflation pressure.

If an expansion of the dynamic load-tire pressure study were to include both axles of the units, impact and acceleration tests might establish trends not detected in this program.

Based on the findings of the main Road Test, a performance study of these units versus equivalent axle loads on conventional units would be desirable.

Special Suspension System Study

The objective of the fourth major investigation in the special study program was to determine the dynamic effects on pavements and bridges of vehicles equipped with special suspension systems and to compare these to the dynamic effects of conventional vehicles with similar axle loads and tire pressures.

As in the previous studies, these special suspension vehicles were operated on the instrumented sections and bridges at several levels of vehicle speed and transverse placement.

Three tractors and two semitrailers equipped with special suspension systems were made available to the Road Test by the manufacturers through the efforts of the Department of Army, the Automobile Manufacturers Association and the Truck Trailer Manufacturers Association.

The types of suspensions made available were LPLS tires with conventional suspension systems; a tandem-axle semitrailer equipped with a combination fluid and air suspension system; a semitrailer equipped with unique staggered-wheel suspension system of which no axle is common to any two wheels; a tandem tractor equipped with a variable single leaf suspension system with rear-axle drive; a tandem tractor equipped with the standard Hendrickson walking beam type suspension with rubber load cushions; and a tandem tractor equipped with a standard Hendrickson walking beam type suspension with steel leaf springs.

The variation in the design of the several suspension systems caused a certain amount of difficulty in determining the exact transverse location of the vehicles at the instrument locations which in turn necessitated the reporting of general trends rather than conclusive findings. However, the trends reported do indicate the direction of further research.

For flexible pavement sections:

1. The changes in deflection for the several designs of suspension systems within the limits of this study, were less than the differences attributed to experimental error. An increase in vehicle speed caused a comparable decrease in pavement deflection for all suspension systems and conventional vehicles.

2. The pressure transmitted to embankment soil was generally lower for the special suspension vehicles than for the conventional units with little variation apparent among the several units. The effect on the transmitted pressure of the vehicle speed was uniform for all suspension systems and conventional units and the transverse or longitudinal distribution of the transmitted pressure showed no effect of the design of the suspension systems.

For rigid pavement sections:

1. The decrease in edge strain and corner deflection caused by an increase in vehicle speed, was reasonably uniform for all the suspension systems. Similar relationships for the conventional units showed no appreciable differences which could be associated with changes in the suspension systems.

2. For the dynamic load study on the two sections of pavement tested, the dynamic load effect for all units was greater for the pavement with lower serviceability and also increased with increase in vehicle speed. The relative dynamic load effect of the several suspension systems indicated some variation subject to vehicle speed and pavement serviceability.

For the bridge study:

1. The non-uniform loading of the test vehicles coupled with other vehicle characteristics not determined in this study negate the findings in the bridge study to some degree.

2. In general, however, the mean amplification factors for the conventional single-axle vehicles were higher than those for the tandem-axle vehicles, both conventional and special. This finding agrees with those given in Special Report 61D.

3. The mean strain amplification factors for all special vehicles were appreciably higher than the factors for the conventional units at 30 mph. At speeds of 15 mph, this was not true for either the strain or deflection amplification factors.

Because the instrumentation available at the Road Test was primarily designed to detect variations caused by axle load, vehicle speed and transverse placement and, thus, was not capable of detecting the characteristics or differences associated with changes in vehicle suspension systems, and because the amplification factors used in comparing the effects of the various units on the bridges are dependent upon gross vehicle loads and other vehicle characteristics such as spring and tire constants, further research should be directed so that the study would include more detailed analyses of both the vehicle and of the pavement and the bridge. Furthermore, a more detailed study of the dynamic load effect and vehicle and cargo accelerations may or may not indicate trends of the effect of the different suspension system design.

Military Vehicle Study

The objective of this study was to investigate the dynamic effect on pavements and bridges of specialized units of military highway and off-highway equipment and to compare these effects, where possible, with those conventional units at several axle loads and vehicle speeds.

The equipment furnished by the Office of the Chief of Transportation, Department of the Army, included M–52 tractor semitrailers (with LPLS and conventional tires), a heavy-duty tank transporter (HETAG), a double-ender tank transporter, two units of off-road train cargo trailers, two units of the rolling fluid transporter, a self-propelled cargo-fluid transporter (GOER), a M–47 tank and a T–113 personnel carrier.

The restrictions on axle load and speed on the various vehicles limited the study of these units to individual comparisons of the effects on pavements and bridges with conventional units.

The determination of the characteristics of the individual units were beyond the scope and ability of the instrumentation available at the Road Test. Thus, the measurements of strain, deflection embankment pressure and dynamic wheel load failed to produce any conclusive variations caused by the special units.

In general, the relationships between deflections and strain and axle load and vehicle speed for the military tire units were similar to those for the conventional units, and the relationship of dynamic wheel load to vehicle speed and pavement serviceability for those units tested was as previously reported except for the GOER. For this unit, an increase in vehicle speed and a decrease in pavement serviceability resulted in a decrease in dynamic wheel load which is a reversal of that found for the other units. This phenomenon could not be fully investigated because of the length of time the GOER was available for study.

The lack of conclusive findings was somewhat discouraging but the general trends did indicate possible directions for further research.

Further investigation should be designed so that detailed study at several axle loads, vehicle speeds and transverse placements might be conducted. Instrumentation for detecting strains, deflections and transmitted pressures should be located at points on or about the pavement structure different from those on the Road Test and modifications of the dynamic load-tire pressure instrumentation might make it adaptable to some of the other axle configurations.

For the heavy-duty tank transporters designed as either on or off-highway use, a performance study comparing these units with conventional vehicles might be desirable.

The results of the military track vehicle study indicated that direct comparisons between conventional tire units and track-laying equipment on the basis of dynamic edge strains, deflections or embankment pressures was not of any great value.

Therefore, further research is indicated in which studies should be made on the types of dynamic measurement (and necessary instrumentation) that will prove effective for comparisons of track-laying and conventional equipment.

Braking, Impact and Acceleration Study

A limited investigation of the dynamic effects on pavement, bridges and cargoes of a selected group of vehicles subjected to external accelerations was conducted following the five major investigations of the post-traffic program.

Each of these studies, braking forces, impact and vehicle accelerations, must be considered only as pilot in nature. The location and design of the instrumentation available was such that only slight trends could be effected.

Further research of this type should be directed along the lines of investigation of the vehicle rather than the pavement or bridge. In addition, a performance study for comparison of the various special vehicles with the conventional units would be desirable.

This presentation has been a very brief review of the investigations conducted by the Special Assignments Branch for and with the several cooperating agencies.

As has been pointed out, these studies should not be considered conclusive or final in that the Road Test plant and instrumentation was not designed to detect the minute differences which apparently did exist.

The need for further research is apparent and has been indicated in detail for each separate investigation.

ACKNOWLEDGMENT

The assistance and cooperation of the Department of Defense, the Automobile Manufacturers Association, the Truck-Trailer Manufacturers Association, the Bureau of Public Roads, the Tire Industry, General Motors Corporation, the Caterpillar Tractor Company, the Corps of Engineers, Department of the Army, the Shell Oil Company and the Illinois Department of Highways are gratefully acknowledged.