# Louisiana Highway Research

## SKID RESISTANCE STUDY

Louisiana Department of Highways – Research & Development Section

# SKID RESISTANCE STUDY

by

HOLLIS B. RUSHING
CONCRETE RESEARCH ENGINEER

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# ABSTRACT

This report describes the design and construction of a two-wheel trailer for measuring skid resistance of roadway surfaces. The trailer was designed to conform to ASTM E274-65T Tentative Method of Test for Skid Resistance of Pavement Using a Two-Wheel Trailer.

The development of the various measuring systems and component parts are discussed in detail in the report along with other general information concerning the tow vehicle and trailer.

As a second phase of this study, some fifty roadway sections throughout the State were tested for skid resistance in order to check out the operation of the trailer and to determine the general range of coefficient of friction that exist on the Louisiana highway system. The tests indicated that most of the surfaces exceeded the requirements for friction levels recommended in NCHRP Report No. 37, "Tentative Skid Resistance Requirements for Main Rural Highways."

# INTRODUCTION

The Louisiana Department of Highways has been conducting limited tests for skid resistance for a number of years. The stopping distance method and the British Pendulum Tester were used for these tests. Due to the expanded emphasis being placed on skid resistance it was decided in early 1966 to construct a two-wheel trailer for performing skid tests in order to provide a means of increasing the number of tests that could be performed and reducing hazards associated with the stopping distance the British Pendulum Methods.

A research project, in cooperation with the Bureau of Public Roads, was initiated to design and construct a two-wheel trailer in accordance with ASTM E-274-65T. This report describes the work performed on this project.

## SELECTION OF EQUIPMENT

The first step in the construction of the system was to obtain as much information as possible from the Highway Departments and agencies that had skid trailers in operation. Since most of the equipment in use at that time did not necessarily conform to ASTM E274-65T, it was necessary to determine which components could be used and which ones would not meet the requirements of the tentative standard established.

At this time it was learned that the Florida Road Department was in the process of constructing a two-wheel trailer to conform to ASTM E274-65T and much of the information used to design the Louisiana Department of Highways system was obtained through correspondence with Florida.

### Towing Vehicle

Many types of towing vehicles were being used by other agencies ranging from pickup trucks to heavy trucks. However, the requirements of E274-65T indicated that a large vehicle would be necessary to provide momentum during tests in order to maintain constant speed. From this consideration, and recommendations of other agencies, a two-ton truck powered by a V-8 engine was selected. Since as a State agency it is necessary to advertise for bids on equipment, it was not possible to select a specific make of vehicle, but rather specifications for the vehicle were written to insure that the performance needed would be met by all bidders. The vehicle received for the prime mover was a Dodge D-500 with stake body.

### Trailer

A set of plans of the trailer designed by the Florida Road Department was used as a guide in designing the trailer. A plan sheet showing the final design of the trailer can be found in the Appendix.

The axle selected for use was a 3000 lbs. capacity, straight axle commercially available from most any dealer that handles parts for trailers. The choice was made to use 12 volt electric brakes on the trailer, so the axle was ordered complete with hubs, brakes and leaf springs. Because of the trailer design, it was necessary to order a 72 inch axle and shorten it to conform to the width needed to meet the requirements of 60±5 inches as specified in ASTM E274-65T. However, this presented no major problem.

The overall design of the trailer was kept as simple as possible to provide for ease of construction and maintenance.

The basic trailer weight including watering system was approximately 1000 lbs. In order to obtain the required load of 1085±25 lbs. per wheel, it was necessary to add ballast. It was decided to use steel weights and bolt them inside the trailer bed to provide a constant non-shifting load that would be for all practical purposes maintenance free. This method proved to be very satisfactory. The Trailer was fabricated in the Department's Central Repair Shop.

Figure 1 shows an overall view of the trailer and tow vehicle.

## Watering System

The watering system for the trailer presented one of the biggest problems associated with the system. In order to provide a supply of water that would vary directly with the speed of the tow vehicle, it was decided to drive pumps directly from the drive shaft of the tow vehicle. The pumps selected were Worthington GA-7, helical gear positive displacement pumps which would provide sufficient water for testing up to 60 m.p.h. Double belt pulleys equipped with magnetic clutches were attached to the pump shaft for driving the pumps. The pumps were mounted underneath the truck chassis as shown in Figure 2.

The first method employed to drive the pumps was by means of belts from the main drive shaft to a jack shaft and then to the pumps so that the right combination of pulley sizes could be obtained to get the necessary r.p.m. needed for the quantity of water required. This was complicated by the limitation of available pulleys with magnetic clutches, which in turn restricted the selection of pulley sizes for the drive shaft and jack shaft. It was necessary to reduce down from 1200 r.p.m. on the drive shaft to 261 r.p.m. on the pump shaft in order to deliver the required amount of water. The main problem associated with this arrangement was vibration in the truck drive shaft due to an unbalanced condition created by driving the pumps. It became obvious that the overall system would never be completely balanced at all speeds to eliminate vibration. Finally it was decided that the vibration which was occurring, mainly at approximately 45 m.p.h., would probably not cause any damage and could be tolerated. However, this proved to be a bad assumption as the drive shaft was lost after approximately 3000 miles of operation.

It was then decided to go to a power take off from the transmission to drive the pumps. This approach was not attempted in the beginning because many equipment suppliers advised that a power take off would not hold up at high speed operations such as 60 m.p.h. However, this approach has performed exceptionally well and

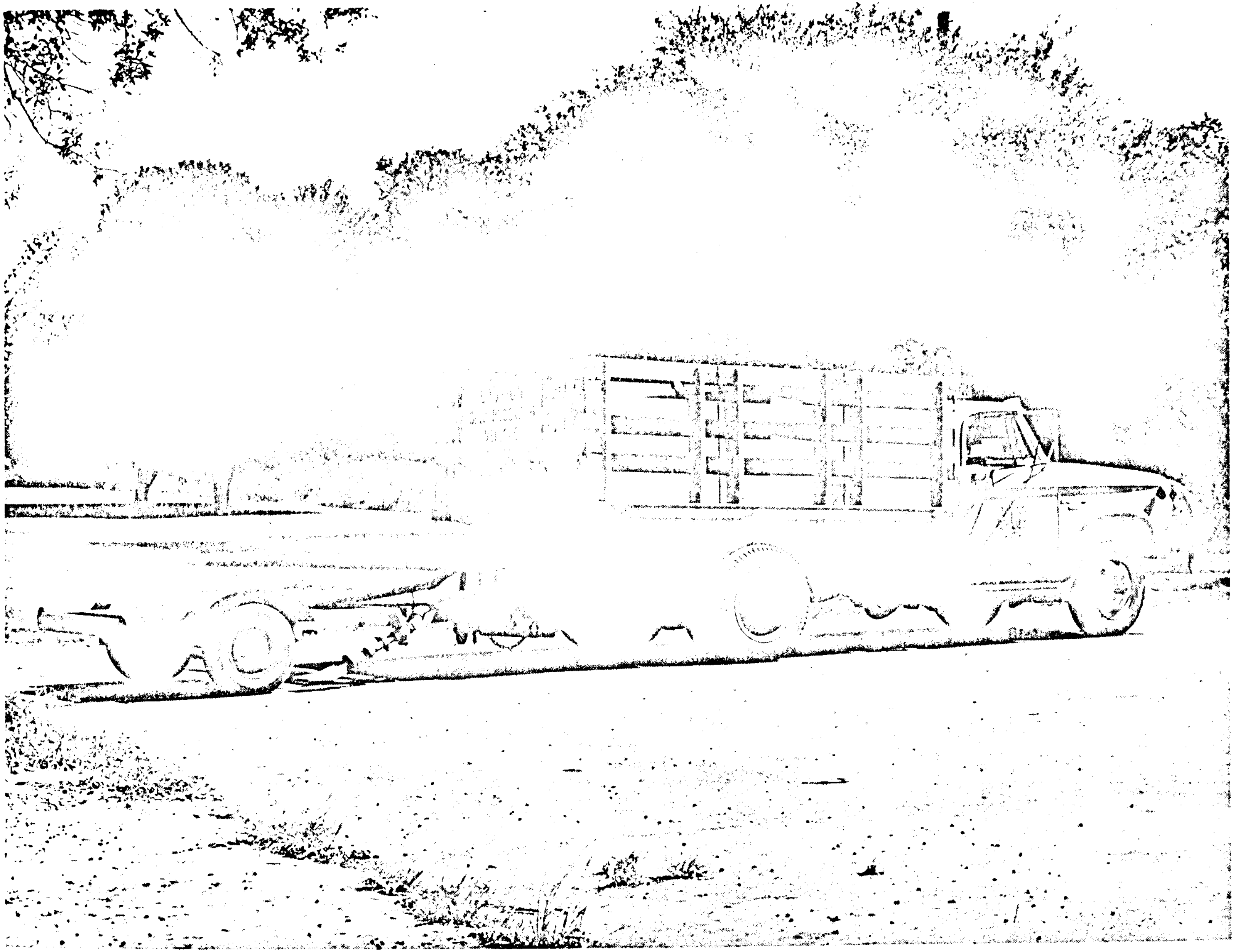


Figure 1

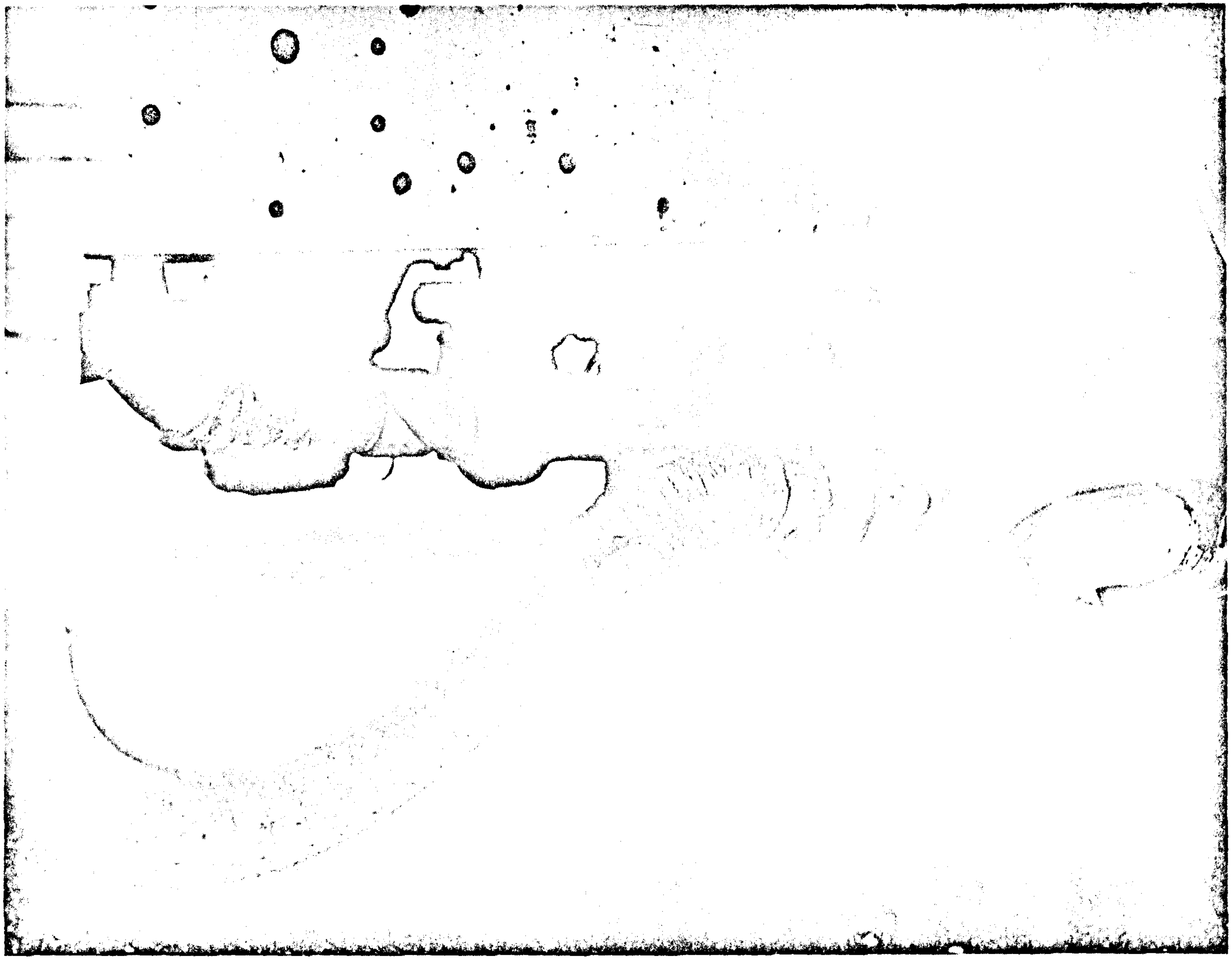


Figure 2

after some nine months of operation no trouble has been experienced. The real benefit from this system, is that the power take off can be disengaged while traveling to test sites and only engaged when actual testing is in operation.

In addition to the pumps, the water system consists of two inch pipe for the supply and a two inch, electric operated solenoid valve for each wheel. Figure 3 shows the solenoid valve and water nozzle on the trailer.

Water is supplied from a 1000 gallon tank located on the bed of the truck. A large opening is provided at the top for quick filling from a fire hydrant.

## Force Measuring System

The ASTM requirement for measuring the frictional force at the tire-pavement contact is to measure wheel torque. Two approaches are given as to how this can be accomplished. The brake anchor pin method was chosen. This method requires the fabrication of special anchor pins on which strain gauges can be mounted to measure bending when the brakes are applied. After approximately six months of constant trouble, this system was abandoned and strain gauges were mounted directly on the axle housing to measure torque. This is a very simple method and believed to be reliable.

The problem associated with the brake anchor pin in our opinion was due to the short moment arm and the inability to insure that the brake shoe contacted the anchor pin in the same position each time. A small movement in the brake shoe that would allow the contact point to shift a minute amount would cause considerable error in the strain gauge reading. Therefore, it was decided to abandon this approach and use a pure torque measurement from the axle housing between the backing plate of the brake system and the U-bolt anchor for the leaf springs. The only critical part of this method is to insure that torque only is being measured and not torque and bending. This is done by positioning the strain gauges exactly 180 degrees apart on the top and bottom of the axle housing. The plan sheet in the Appendix shows the positioning of the gauges. A full bridge is used in this configuration, with all four arms active. The only disadvantage is the reduction in sensitivity, but if the recording system is provided with amplifiers this is no problem.

## Recording System

The recording system selected for use was a Honeywell 1508 Visicorder Oscillograph. This particular recorder was selected because of quick response time, and

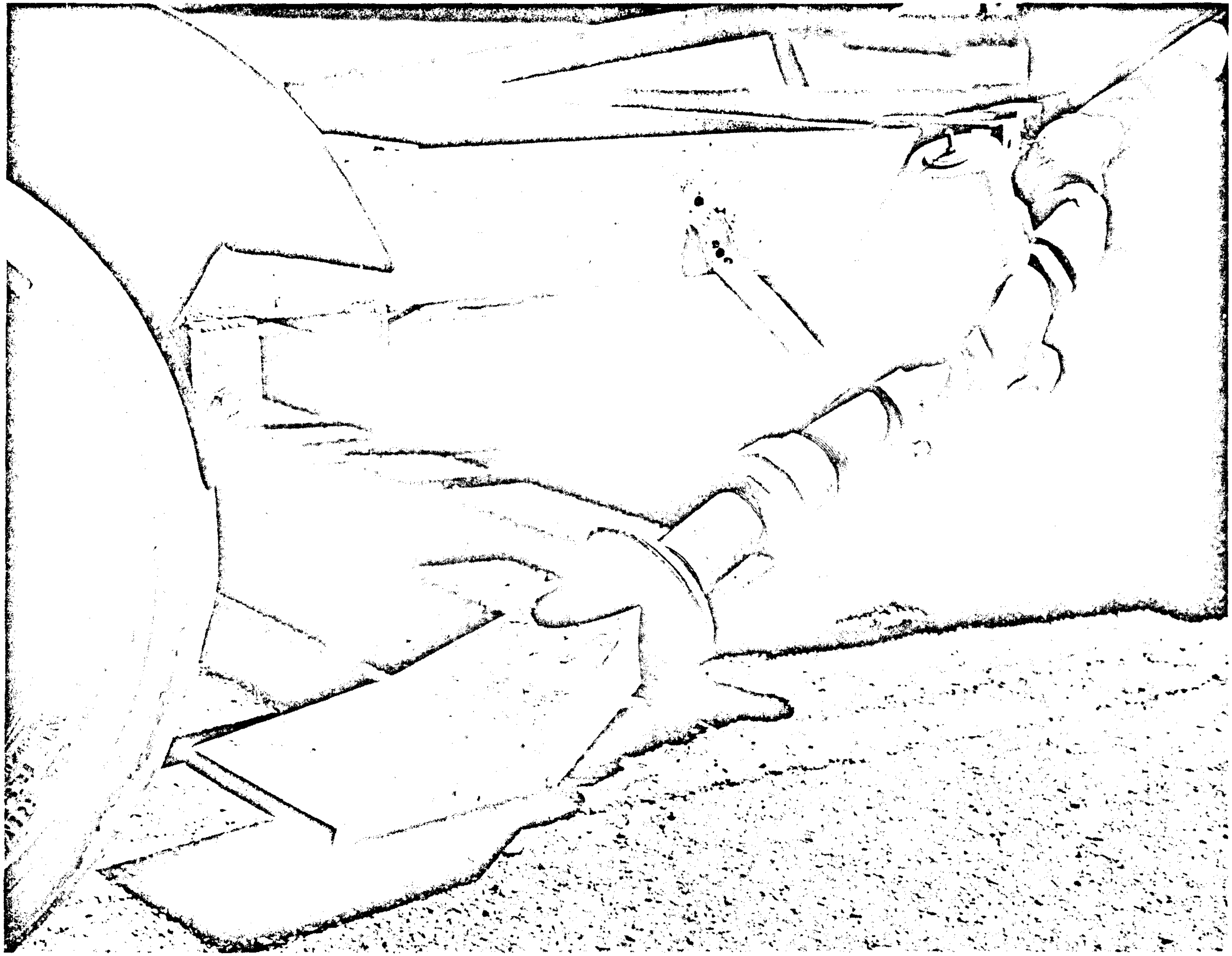


Figure 3

Figure 4

sensitivity. The 1508 is a 24 channel recorder, but it was approximately the same price as a four channel, so it was felt that perhaps other uses could be obtained for the instrument when it was not in use with the skid trailer. The strain gauge signal is recorded by the Visicorder on light sensitive paper. The chart speed can be selected at any of twelve different speeds from 80 inches per second to 0.1 inch per second. It was found that a speed of 0.4 inch per second gave excellent readout and yet did not consume a great deal of paper. Figure 4 shows an overall view of the recorder mounted in the instrument panel.

## Control Panel

Figure 5 is a close up view of the control panel showing all the function switches, timer, and recorder.

The controls for the operation of the skid trailer were fabricated by the Research and Development Section.

The sequence of operations is controlled by a Cramer Timer. The timer is shown in the center of the control panel. The timer has a four second cycle and the events occur in the following order. When the operator presses the start button, the timer is actuated and the chart drive on the recorder is started. The next event is the energizing of the magnetic clutches on the water pumps. Next, the solenoid valves on the trailer are opened and water is discharged ahead of the tire. The electric brakes are then locked for two and one-fourth seconds and then released. The solenoid valves are closed, the magnetic clutches deenergized and the chart drive stopped. This completes the cycles and the process can be repeated immediately.

The control panel gives the operator a choice of operating modes from both wheels locked, to either left or right wheel locked individually. The main switches, shown to the left of the timer, control all functions for left wheel or right wheel. In addition, the individual switches located to the right of the timer control each separate function so that any mode can be selected with either wheel.

On the back of the control unit are located the balancing and sensitivity controls for the strain gauge circuits. The power supply for the strain gauges is a 12 volt wet cell battery. The operator has to make calibration checks prior to each days run and normally several times during the day. This is a very quick procedure which requires the flipping of a switch to throw in a calibrated resistor and reading the deflection on the galvanometer in the Visicorder. If the standard deflection is obtained, then the power supply is good and the strain gauge circuit

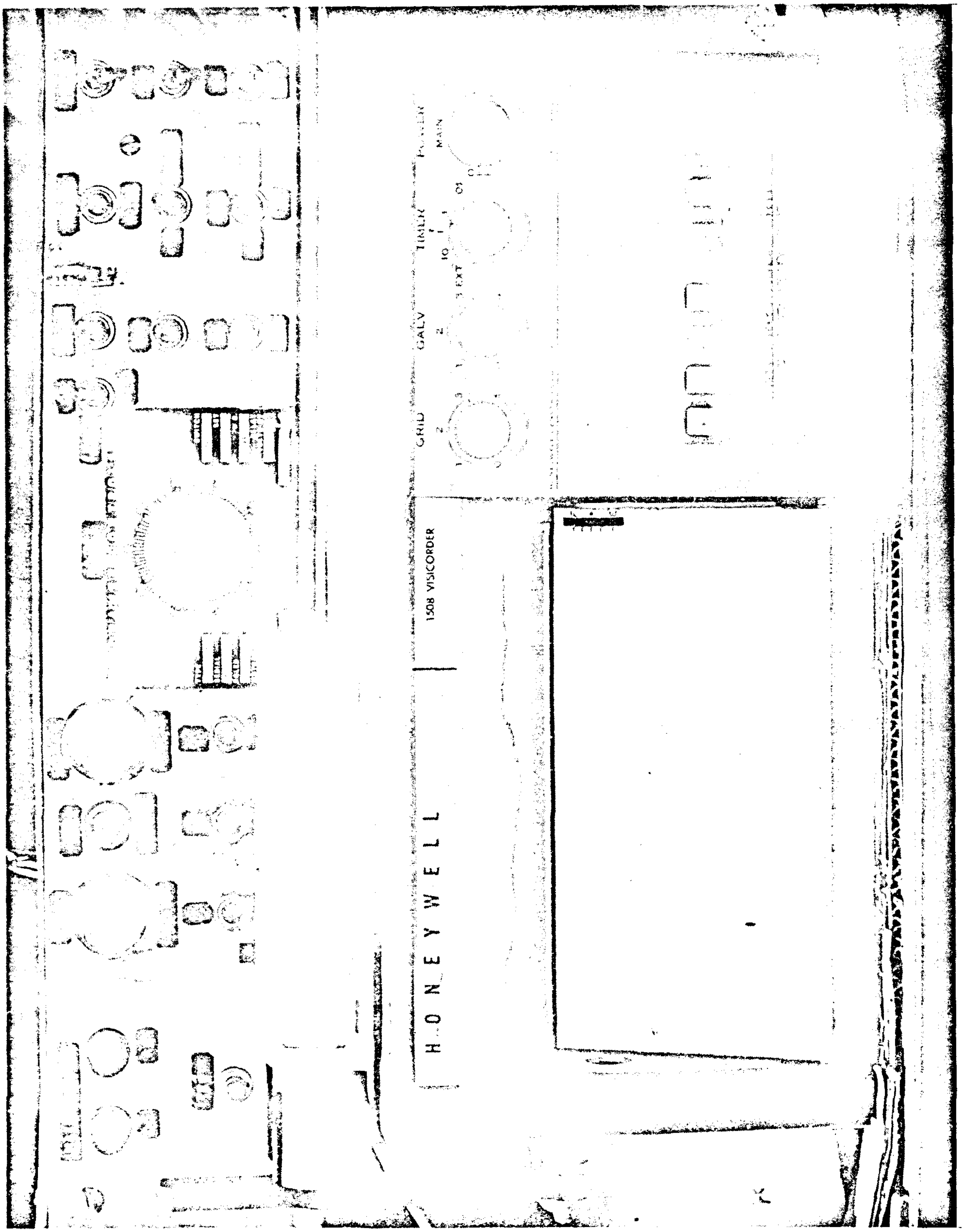

HONEYWELL
1508 VISICORDER
GRID
GALV
TIMER
EXT
POWER
MAIN
OFF

Figure 5

is functioning properly. However, if the voltage from the batteries gets low, then a smaller deflection will result on the galvanometer and the voltage must be brought back by adjusting the sensitivity control or new batteries are needed. A fresh set of batteries are kept in the truck at all times for replacement and as needed the ones taken from the truck are recharged.

### Power Requirements

With the exception of the Visicorder, and solenoid valves, all equipment is operated on 12 volt direct current from the truck electrical system. However, due to the power needed for the recorder (approximately 750 watts) it was necessary to provide an AC generator.

Figure 6 shows the generator mounted on the bed of the truck behind the water tank. The generator has an electric starter, so the operator doesn't have to climb in and out of the truck each time to start the generator.

## CALIBRATION

### Water

The water calibration consisted of measuring the width of the water trace on the pavement by means of photographs and using the formula given in ASTM E274-65T to compute the quantity required to produce a film thickness of 0.02± 0.005 inch. The truck was then jacked up and while in a stationary position, the truck was operated at various speeds to drive the water pumps and the quantity of water being discharged was measured.

Once the quantity of water required was established and the right pulley configuration was obtained, no problems have been experienced in maintaining the correct output.

### Force Measuring System

When the conversion from brake anchor pins to torque measurements on the axle was made, a change in calibrating the system was also made. Initially a device to calibrate the trailer as outlined in ASTM E274-65T was built. However, this required a considerable amount of time to calibrate and was not portable. Therefore, a lever arm device was fabricated that attaches to the hub and by applying a fifty pound weight at two foot intervals from the center line of the axle, torque forces of known quantities are applied and the strain gauge readings are recorded. A calibration curve is then drawn and used to compute skid numbers in accordance with ASTM E274-65T. There is some error in using this procedure, since the small displacement that occurs due to the sliding on the roadway surface is not obtained. However, the magnitude of this error is not of such proportion that the lever arm method cannot be used successfully.

The lever arm method was checked against the pull method recommended by ASTM E274-65T, and no difference was observed in the calibration.

Figure 6

# EVALUATION OF ROADWAY SURFACES

After construction of the skid trailer was completed, a general evaluation of 44 roadway sections was made to determine the range of skid numbers existing and to determine a speed gradient for each type surface, if possible.

The determination of the number of tests required for a particular section was made in the following manner. A five mile section of roadway, surfaced with asphaltic concrete, that had been subjected to approximately six months of traffic was tested. Tests were performed at three different intervals. The first series of tests were performed at one mile intervals. The second series of tests were performed at one-half mile intervals, and the third series were performed at one-fourth mile intervals. All tests were performed at a speed of 40 m.p.h. using the left wheel only. Table 1 shows the results of these tests. As can be seen from the results, the average value for each series varied by only one skid number. The largest variation at any particular spot for the three series was four skid numbers at the one mile location. In all other locations where duplicate or triplicate results were obtained, the largest variation was three skid numbers with the majority being two skid numbers or less. Therefore, it was decided to perform all field tests at one-half mile intervals unless the section was less than two miles in length, and one-fourth mile intervals for these shorter jobs.

The reason only the left wheel was used for testing, was due to the unsafe condition encountered at higher speeds due to side slip of the trailer when both wheels are locked. In addition, it is believed that the side slip experienced affects the results received. Therefore, the conclusion was reached to perform all tests, where possible, with the left wheel, and if not possible then the right wheel would be used.

The 44 sections were selected at random throughout the State. Portland cement concrete, asphalt cement concrete, and bituminous surface treatments were represented with the ages of the sections ranging from one year to thirteen years. Table 2 lists the sections with the surface types, age and skid numbers (SN) at 20, 40 and 60 m.p.h. In some cases the 60 m.p.h. reading was not taken due to the geometry of the section which made it impossible to drive the truck at this high speed.

Figure 7 shows typical speed gradient curves for Portland cement concrete surfaces. The speed gradient was generally consistant for all ages of surface with an average change of 14 skid numbers between 20 and 40 m.p.h. and 10 skid numbers between 40 and 60 m.p.h. The average SN for all concrete surfaces was 62 at 20 m.p.h., 46 at 40 m.p.h. and 36 at 60 m.p.h.

## TABLE 1

## RESULTS OF SKID TESTS AT VARYING INTERVALS

| Distance in Section Miles | Skid Numbers (SN) at 40 m.p.h. Series 1 | Series 2 | Series 3 |
|---|---|---|---|
| 1/4 | | | 47 |
| 1/2 | | 44 | 45 |
| 3/4 | | | 48 |
| 1 | 48 | 44 | 47 |
| 1 1/4 | | | 50 |
| 1 1/2 | | 46 | 45 |
| 1 3/4 | | | 47 |
| 2 | 48 | 48 | 48 |
| 2 1/4 | | | 48 |
| 2 1/2 | | 48 | 48 |
| 2 3/4 | | | 47 |
| 3 | 50 | 47 | 47 |
| 3 1/4 | | | 45 |
| 3 1/2 | | 47 | 45 |
| 3 3/4 | | | 48 |
| 4 | 47 | 47 | 48 |
| 4 1/4 | | | 52 |
| 4 1/2 | | 50 | 52 |
| 4 3/4 | | | 50 |
| 5 | 48 | 47 | 50 |
| Average | 48 | 47 | 48 |

Figure 8 shows four typical speed gradient curves for asphaltic concrete surfaces. These sections ranged in age from 2 years to 11 years and 8 months. As can be noted the curves are very similar with an average skid number change of 12 between 20 and 40 m.p.h. and 8 between 40 and 60 m.p.h. The average change for all jobs was 11 skid numbers between 20 and 40 m.p.h. and 8 skid numbers between 40 and 60 m.p.h. The average SN for all asphaltic concrete jobs were 54 at 20 m.p.h., 43 at 40 m.p.h. and 35 at 60 m.p.h.

Figure 9 shows four typical speed gradient curves for bituminous surface treatment sections. There is some doubt as to the accuracy of the ages of these sections since they are normally resealed within three to five years. The average change in skid numbers for the four jobs shown in Figure 9 was 11 numbers between 20 and 40 m.p.h., but only 3 numbers between 40 and 60 m.p.h. These were very typical results as the average change for all jobs tested was 8 skid numbers between 20 and 40 m.p.h. and 3 skid numbers between 40 and 60 m.p.h.

Figures 7,8 and 9 are shown for the purpose of illustrating the speed gradients of the various surfaces, at various ages. It is not intended to be used as a guide in determining the effect of age on skid resistance. It was not felt that sufficient data was gathered during this study to determine the relationship between age and skid resistance.

Figure 10 shows the average speed gradient for all jobs tested. The Portland cement concrete surfaces gave higher values at all speeds. Asphaltic concrete surfaces produced higher results than bituminous surface treatment at 20 and 40 m.p.h., but gave identical results at 60 m.p.h. The difference in skid numbers at 60 m.p.h. for all surfaces averaged only one skid number, with Portland cement concrete yielding an SN of 36, and asphaltic concrete and bituminous surface treatment an SN of 35.

The results at 60 m.p.h. were particularly interesting. Although as noted previously sufficient data was not obtained to reach definite conclusions, the trend of the results would indicate that at high speeds the difference in skid values for the three types of surfaces is insignificant.

## TABLE 2

## SKID NUMBERS FOR TEST SECTIONS

| Type of Surface | Age | Average Skid Numbers | | |
|---|---|---|---|---|
| | | 20 m.p.h. | 40 m.p.h. | 60 m.p.h. |
| Concrete | 4 yrs. - 10 mos. | 66 | 53 | 41 |
| Concrete | 5 yrs. - 0 mos. | 55 | 41 | 32 |
| Concrete | 5 yrs. - 2 mos. | 68 | 52 | 39 |
| Concrete | 5 yrs. - 5 mos. | 68 | 52 | 40 |
| Concrete | 5 yrs. - 6 mos. | 55 | 44 | 35 |
| Concrete | 5 yrs. - 10 mos. | 65 | 50 | 38 |
| Concrete | 5 yrs. - 11 mos. | 58 | 45 | 33 |
| Concrete | 6 yrs. - 1 mo. | 54 | 43 | 36 |
| Concrete | 6 yrs. - 11 mos. | 56 | 40 | 31 |
| Concrete | 7 yrs. - 1 mo. | 57 | 45 | 36 |
| Concrete | 7 yrs. - 1 mo. | 58 | 44 | 35 |
| Concrete | 7 yrs. - 7 mos. | 64 | 50 | 38 |
| Concrete | 7 yrs. - 11 mos. | 60 | 46 | 34 |
| Concrete | 9 yrs. - 0 mos. | 60 | 44 | 36 |
| Concrete | 9 yrs. - 6 mos. | 57 | 46 | 36 |
| Concrete | 9 yrs. - 6 mos. | 61 | 47 | 41 |
| Concrete | 11 yrs. - 7 mos. | 55 | 41 | - |
| Average | | 62 | 46 | 36 |
| Asphaltic Concrete | 2 yrs. - 0 mos. | 66 | 52 | - |
| Asphaltic Concrete | 4 yrs. - 1 mo. | 56 | 42 | 34 |
| Asphaltic Concrete | 4 yrs. - 11mos. | 60 | 45 | 36 |
| Asphaltic Concrete | 5 yrs. - 0 mos. | 46 | 37 | - |
| Asphaltic Concrete | 5 yrs. - 2 mos. | 57 | 44 | 35 |
| Asphaltic Concrete | 5 yrs. - 7 mos. | 51 | 37 | 30 |
| Asphaltic Concrete | 5 yrs. - 10 mos. | 55 | 45 | 38 |
| Asphaltic Concrete | 6 yrs. - 6 mos. | 52 | 42 | 32 |
| Asphaltic Concrete | 7 yrs. - 6 mos. | 54 | 45 | 39 |
| Asphaltic Concrete | 9 yrs. - 6 mos. | 46 | 38 | 31 |
| Asphaltic Concrete | 9 yrs. - 8 mos. | 52 | 42 | 37 |
| Asphaltic Concrete | 10 yrs. - 0 mos. | 52 | 42 | 34 |
| Asphaltic Concrete | 10 yrs. - 6 mos. | 52 | 44 | 39 |
| Asphaltic Concrete | 11 yrs. - 8 mos. | 53 | 42 | 34 |
| Average | | 54 | 43 | 35 |

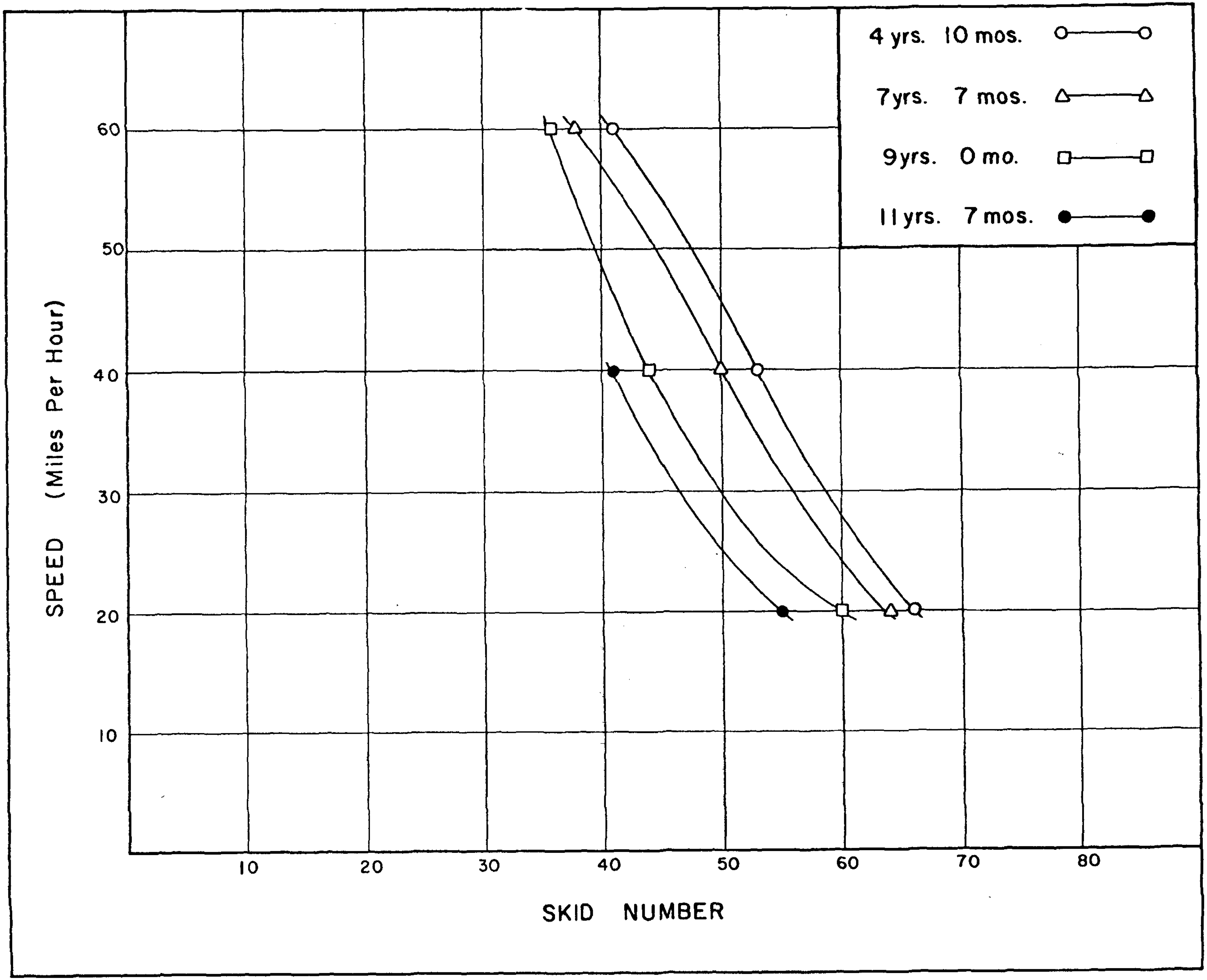


Figure 7 - Typical Speed Gradients for Portland Cement Concrete Surfaces

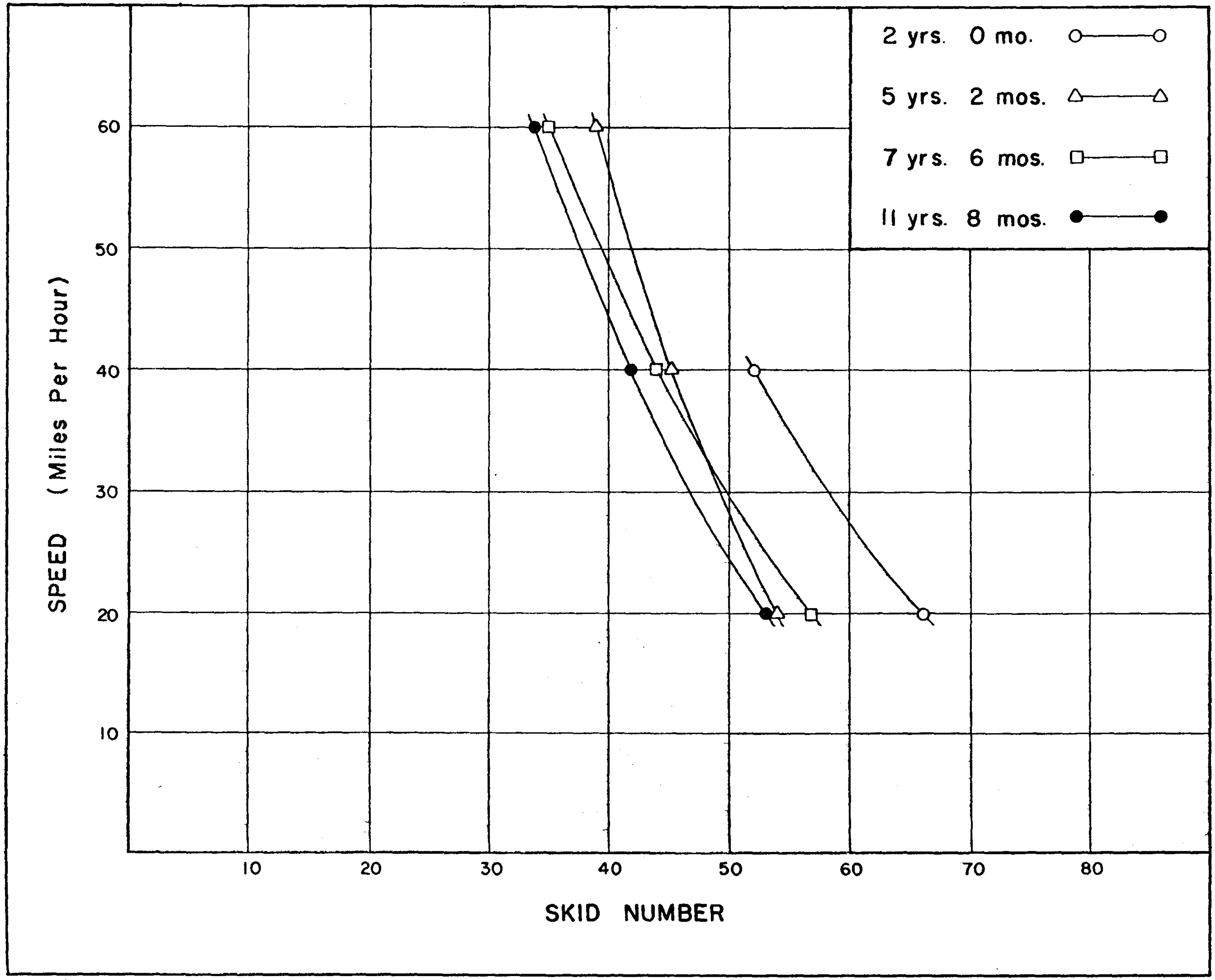


Figure 8 - Typical Speed Gradients for Asphaltic Concrete Surfaces

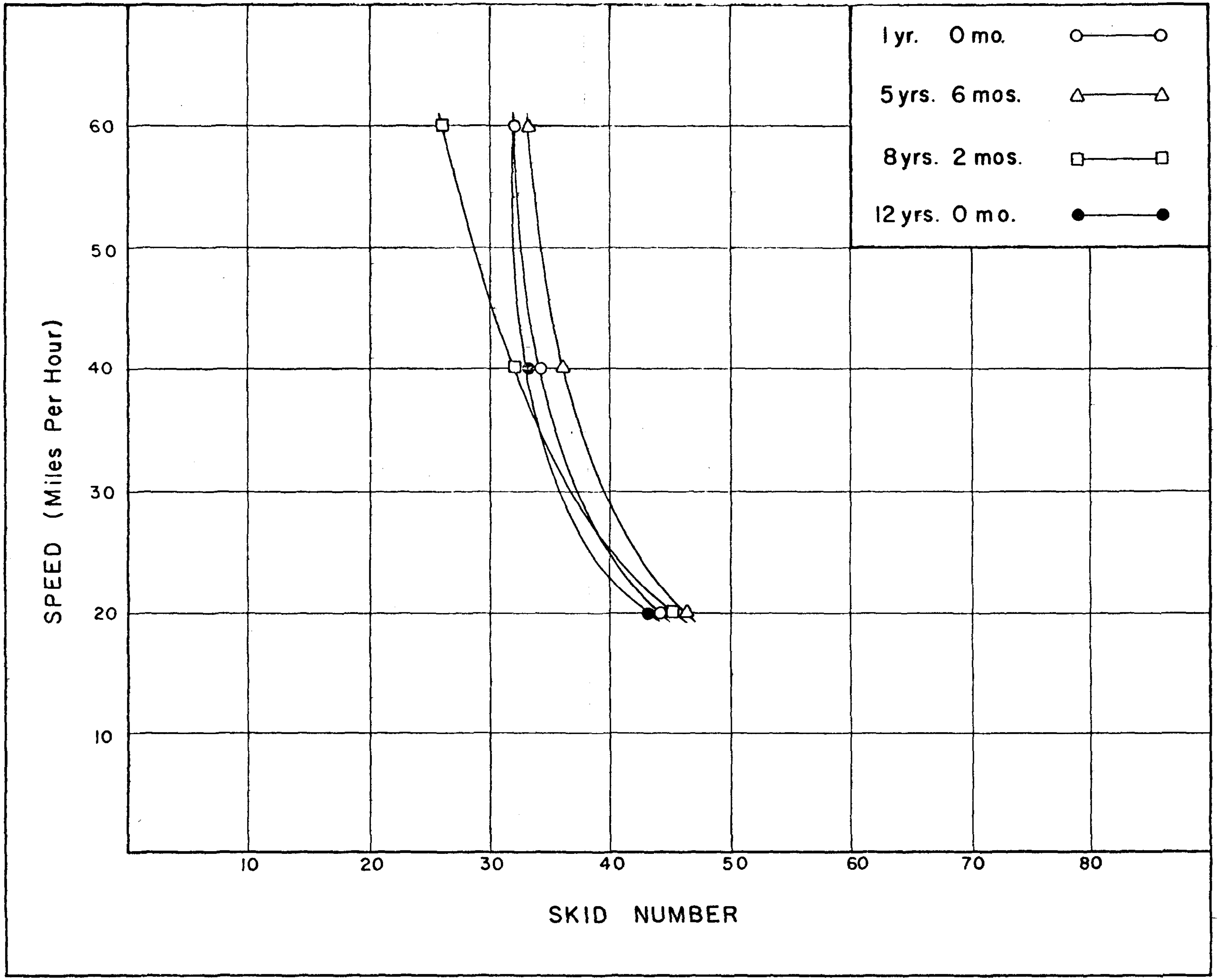


Figure 9 - Typical Speed Gradients for Bituminous Surface Treatment

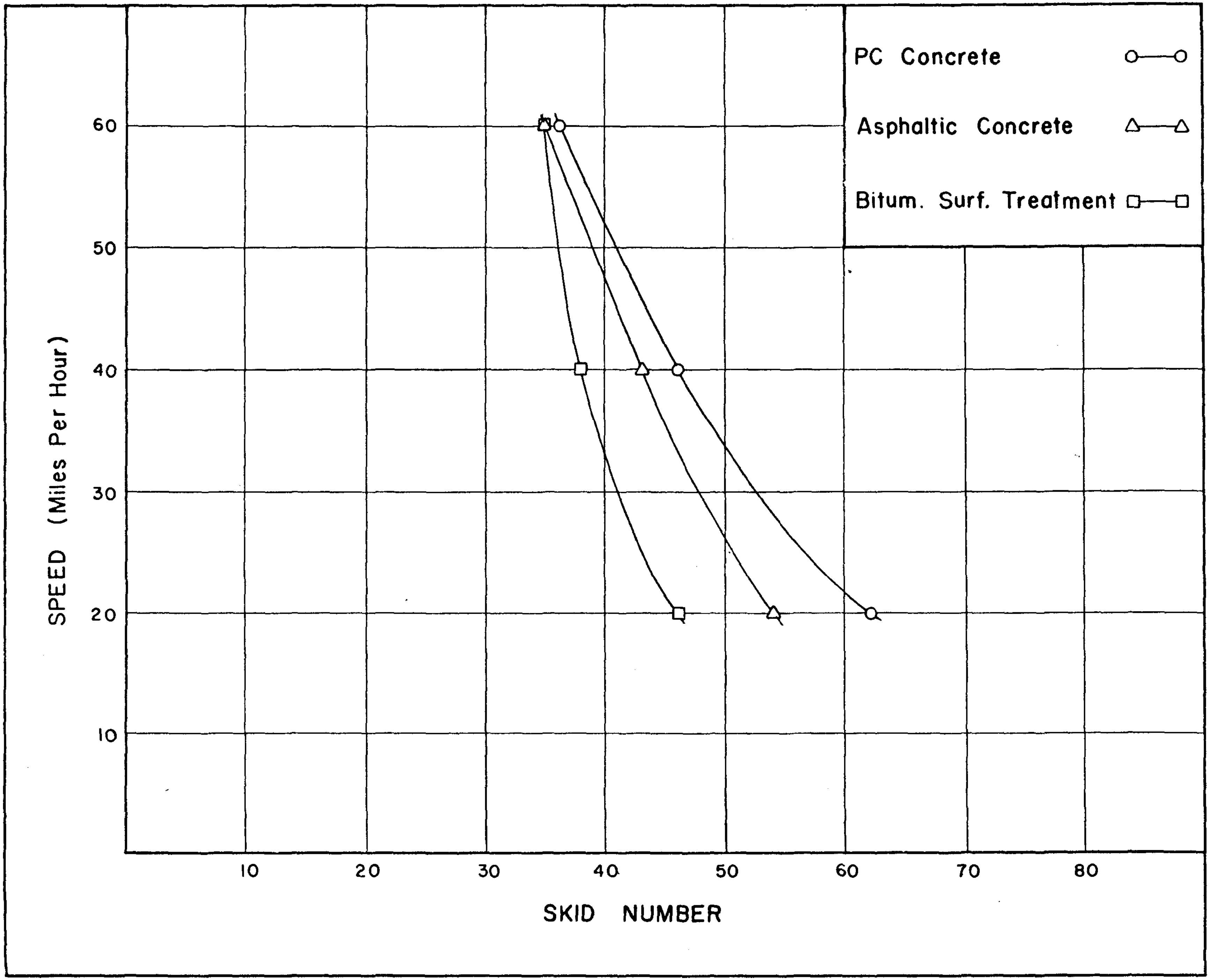


Figure 10 - Average SN vs Speed for All Surfaces Tested

# SUMMARY

The Louisiana Department of Highways, has successfully fabricated a workable two-wheel skid trailer. The approximate cost of this equipment, excluding labor by Department forces was, $1,235.00 for the trailer, $10,860.00 for the control unit and recorder and $8,000.00 for the tow vehicle including water pumps, generator and all modifications and fabrication cost to install the water system.

The limited results received from the 44 sections tested indicate that generally the roadway surfaces are above the minimum values of skid numbers recommended in NCHRP Report No. 37. In addition the change in SN with speed conforms within reason to the results given in NCHRP Report No 37 for Portland cement concrete and asphaltic concrete surfaces. However, the speed gradient for bituminous surface treatment is greatly different between the 40 and 60 m.p.h. speeds.

# RECOMMENDATIONS

The following recommendations concerning the construction and operation of a two-wheel skid trailer are offered based on our experience.

(1) The tow vehicle used should be as small as possible to provide maneuverability. It is believed that a 3/4 ton pickup with a large V-8 engine is sufficient for towing the skid trailer. The large trucks are very difficult to handle in traffic, slow at reaching high testing speeds and requires a skilled driver to operate. It is not often that an operator can be found who possesses both skill in operating a large vehicle and ability to operate properly the complex system of a skid trailer. It is fortunate that the Department has such a man. However, it is intended to change the tow vehicle from the D-500 Dodge, to a 3/4 ton pickup as quickly as possible.

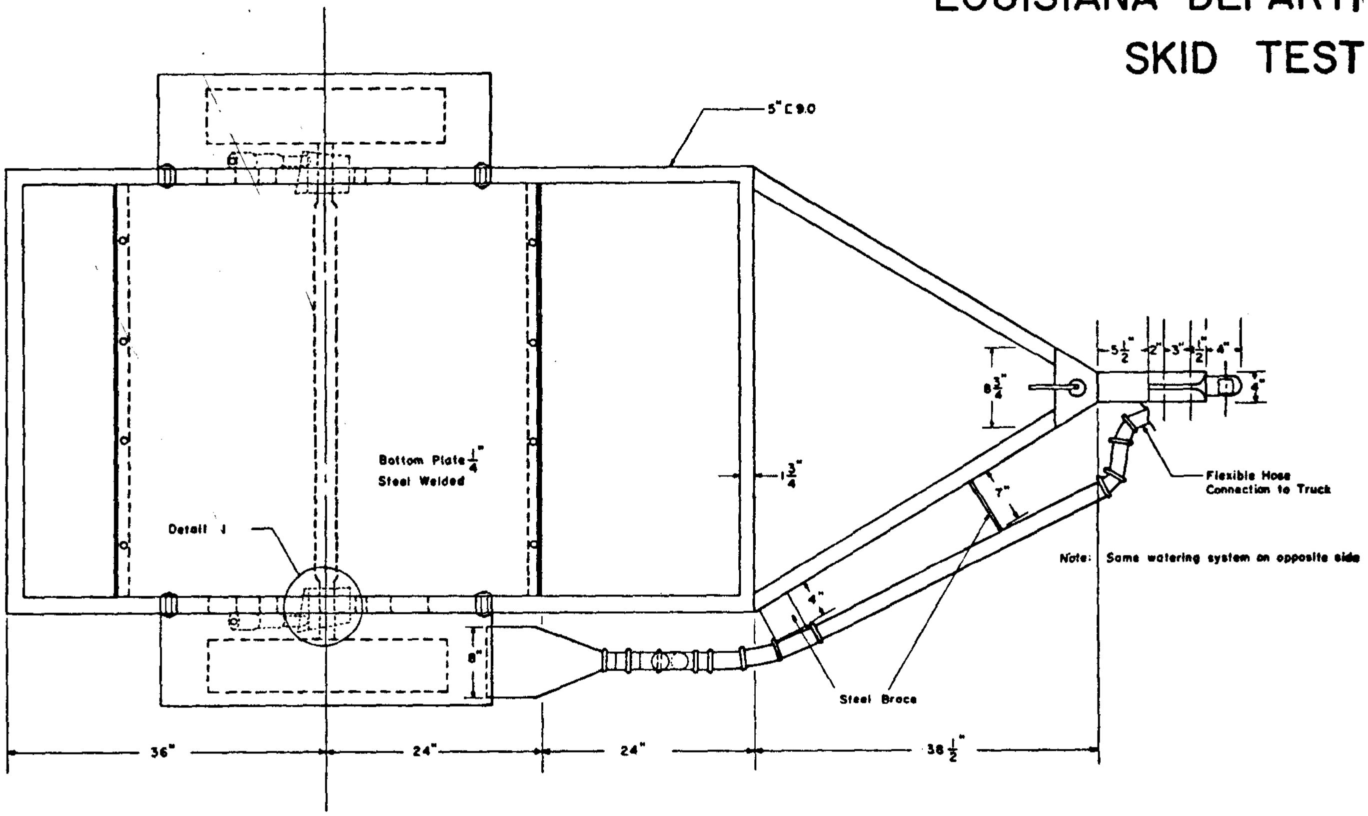
(2) There seems to be no benefit in designing a trailer capable of performing tests with both wheels locked simultaneously. This mode of operation is usually hazardous due to side slip, particularly at higher speeds, and the results received would have to be questionable due to this side motion. It is believed that a trailer designed for operation of either wheel independently can be used to test any situation needed and will be more economical since the same watering system can be used for either wheel.

(3) The ASTM Standard should be revised to allow the torque measuring system on the axle, instead of limiting the option to the two methods currently required.

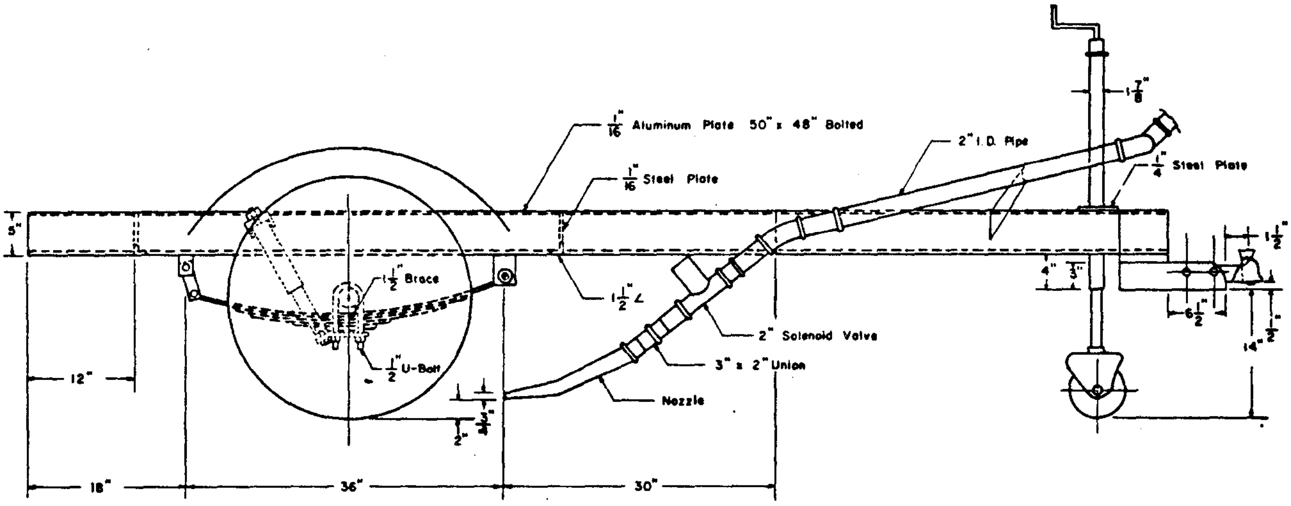
# APPENDIX

# LOUISIANA DEPART

# SKID TEST



Note: Same watering system on opposite side



# RTMENT OF HIGHWAYS
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