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# PAVEMENT SURFACES CHARACTERISTICS AND THEIR SKID RESISTANCE VALUES

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BY


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## PREFACE

Many traffic accidents are the results of mechanical failure and human error. However, the pavement surface condition is also an important factor in many accidents. Accidents involving skidding, for instance, frequently occur on slippery surfaces which have low coefficient of friction. With safety as an essential objective, pavement surfaces can be designed, constructed and maintained to save lives, reduce personel injuries and property damage.

The Department of Highways hopes that this report will be a guide for road engineers and road users in our country and other tropical countries which have similar conditions. Nevertheless, more research should be encouraged to further the knowledge in this field.

Chaleo Vajrabukka.

(Chaleo Vajrabukka)

Director - General

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## SYNOPSIS


One important factor which contributes to the road accident is the friction of road surfaces. Friction needs vary with different types of road surfaces and under different circumstances. Three types of pavements constructed with limestone aggregate namely, portland cement concrete, asphaltic concrete and penetration macadam were selected. The criteria used in the selection were that each type of pavement would differ in age and texture depth but have similar traffic volume, environmental conditions and geometric design. A Mu-meter was used to record friction values in both wet and dry conditions and percentage of non carbonate in samples of limestone aggregate were determined. The effects of speed, texture depth, age and water film thickness on skid values were investigated.

In analysis of the data macro and micro principles of approach were applied which revealed that in dry condition all types of pavements under the circumstances investigated exhibited sufficient macro and micro textures which reflected in sufficient coefficient of friction. However, in wet condition, both asphaltic concrete and macadam surfaces with low texture depth and high age exhibited low macro and micro textures resulting in low friction values. Comparisons and relationships between Mu-meter and British Portable Tester were also determined and it was found that there was a good correlation between the two.

INTRODUCTION

The accidents which occur everyday on the roads of Thailand have caused unnecessary loss of lives, time and economy to the country. One important factor involves is the friction of the road surface. The skidding of a moving vehicle on a pavement surface either bituminous or portland cement concrete depends on the frictional resistance between the surface of a pavement and tires of a moving vehicle. Good road surfaces must have sufficient friction for a vehicle travelling at a designated speed to manuver safely in all kinds of weather and geometric conditions. In general any dry pavement surface and essentially any tires, in combination will generate adequat skid reristance to accommodate all but the most extreme of vehicle manuvers. However, when the pavement is wet there is water lubricant between tire-road interface which makes skid resistance to drop significantly. The situation becomes very more noticeable on old pavement surfaces where high traffic volumes cause aggregates to wear and polished especially those constructed with asphalt.

Characteristically, skid resistance properties of a pavement surface depends on macro and micro textures, surface drainage and type of aggregates used. Skid resistance is usually reported as frictional coefficient multiply by 100 and in Thailand it is measured with British portable tester (B.P.T.) and recently, by Mu-meter.

The subject of skid resistance is extremely complex and has been the object of intense research. Variations occur with, among other factors, wet or dry pavement surface, thickness of water film, surface characteristics, age and speed or a moving vehicle. Therefore, in order to gain further knowledge on the topic as how these variation effect skid resistance when subjected to local prevailing conditions, this research was carried out to cover the following objectives.

1. To study some parameters which effect frictional characteristics of pavement surfaces in terms of pavement types.

2. To determine the correlation between skid number obtained by Mu-meter and British portable tester (B.P.T.).

3. To recommend minimum service values of skid resistance for general classes of highway and traffic conditions.

LITERATURE REVIEW

Research in recent years has estabilished that surface roughness and wearing characteristics of both coarse and fine aggregates in both bituminous and portland concrete pavements are critical in developing and maintaining high coefficient of friction. Several researchers have indicated that type and magnitude of texture of the pavement are responsible for such behavior (2, 6, 14). Recently, terms such as macrotexture and microtexture are used to describe the surface roughness of the pavement surfaces. Macroscopic texture refers to a large-scale texture caused by the size and shape of the surface aggregate and micro-texture refers to fine-scale roughness contributed by individual small asperities on the individual aggregate particles. Good macro-texture will allow the water to escape between the tires and the pavement at high speed and good micro--texture will provide sufficient roughness and maintain some level of skidding (6). Therefore, a combination of both is most desirable. (3, 4, 7). Pavement constructed with limestones have proved to be slick when subjected to heavy traffic (16). On the other hand, sandstone and certain granite are better resistance to wear (15). Dahir and Muller (3) reported that generally carbonate aggregates will polish faster than other type of aggregates because of soft carbonate minerals. The more percentage of impurities present the better will be its skid resistance performance. Moreover, the pavements which are constructed with bituminous will "bleed" from excess binder and become extremely slick when wet. Burnett and Gibson (1) reported that the skid resistance of a bituminous surface is governed by larger aggregates in mix, rather than the properties of fine and that hard impurities aggregate are better than soft material. Further, coefficient of friction of wet pavement will vary with speed. High speed on wet pavement will cause hydroplanning which results in "skiing" of vehicle's tires over a pavement.

In Thailand, the materials and Research Division of the Royal Thai Highway Department has been interested in the subject since 1971. Two publications (10, 17) about the subject have been published and currently, an inventory of coefficient of friction is being conducted through out the highway system.

THE COMPONENT OF FRICTIONAL FORCE BETWEEN TIRE AND PAVEMENT AND THEIR RELATIONSHIP TO PAVEMENT TEXTURE.

The forces between a tire and a pavement are produced by two principle factors, adhesion and hysteresis; as shown in Fig. 1. Adhesion is a force which developed by the interaction of the rubber and the microtextures of the pavement. Hysteresis is the other component of force generated by absorbed energy when the tire is deformed and projected on the pavements aggregate. This forces is introduced by the macrotexture of the pavement.

Generally, these two components of forces will be efficiently developed on a dry pavement. However, when a pavement is covered with a film of water, the following events must occur in order for hysteresis and adhesion to exist.

The layer of water must be expelled from the tire-pavement interface in order for the tire to be deformed by pavement macrotexture. The paths for this water to escape are formed by the channels of the pavement macrotexture and by the openings in the tire treads. The water which still covered the microtexture would then be allowed to squeeze aside. With a good microtexture, the sharpness of aggregate projections will help in penetrating this film of water to develop the adhesion force between rubber and a pavement surface. As the speed of a vehicle increases, the time available to expel this layer of water decreases. When there is no longer enough time for water to squeeze out a pressure between the tire and the pavement surface begins to develop and the value of skid resistance begins to drop. When this pressure becomes large and reaches the value equal to the pressure exerted by the tires over a pavement surface, dynamic hydroplaning occurs and the tire "rides" on water surface.

There fore, a high level of macrotexture will provide a pavement with a good drainage at high speed where as microtexture is the main texture which sustains a given friction level. For a good anti-skid road in all types of weather, both macro and micro textures must be both presented at the same time.

SCOPE OF THE TESTS

For the studies, three types of pavement surfaces, namely portland cement concrete, asphaltic concrete and penetration macadam at various ages and texture depth were chosen. In the selection of the sites, considerations concerning the traffic volume, character of traffic, environmental conditions geometric design and gradation were taken to be as close as possible so that their influences on the values of skid resistance would be minimized. The measurements of coefficient of friction were taken with the Mu-meter making a series of three passes over each site at a speed of 50, 60 and 80 k.p.h. over a length of 5 kilometers. The average from these individual readings were recorded and used in the study analysis. Texture depth measurements were conducted by sand patch method at each location under the investigation. To similate wet condition, a watering system calibrated to supply sufficient water to create a surface film thickness of 0.254 m.m., 0.508 m.m., and 0.762 m.m. representing just wet, wet and very wet conditions was used. Water was sprayed through the nozzles in front of the Mu-meter's two frictional-measuring pneumatic tires.

Tests for percentage of non carbonate in limestone and Los Angeles Abrasion test were conducted on the samples of aggregate from two quarries commonly used as aggregate supplying sources.

The tests were conducted during the months of June 1974 to February 1975. Testing temperature was in the 30 degree C range. No seasonal nor temperature corrections were applied to the skid coefficient values.

The summary of test results will be found in appendix 1 and the details of the instruments, method of tests and sample of calculation will be found in appendix 2.

DISCUSSION OF RESULTS

For the purposes of this report, four parameters which influence skid resistance values on different types of surface pavement were chosen and their effects investigated individually. The four chosen parameters were water film thickness, texture depth, age and speed. It was felt that the effect of each parameter on the friction values should be separately discussed to give a clear understanding view of the subject.

Effect of water film thickness

The effects of water film thickness on the skid resistance values of asphaltic concrete pavement was presented in Fig. 2

In this figure, the friction values versus the water film thickness on the different ages and surfaces texture depth were plotted. The friction values were the average values recorded by Mu-meter travelling at constant speed of 60 k.p.h. over the test section for three times. The curves indicate that as the water film thickness on the pavement surface increases the friction values decreases accordingly. This characteristic is caused by the hydrodynamic pressure which built up between the tire-pavement interface since it decreases a tire gripping capability and traction. However, the dip of curve 1, 2 and 3 which represent water film thickness in just wet, wet and very wet zone of water conditions seems to indicate the ability of the pavement's texture to drain the water. For the young age pavement surfaces with high texture depth and hence, better micro and macro texture to penetrate and drain water, it shows a slower decrease in skid values compared to that of the older one because lesser fluid pressure is being built up between tire-pavement interface.

Effect of surface texture depth

The effect of surface texture depth on friction values has been furthur investigated on various type of pavement usually constructed in Thailand. The average texture depths of this investigations were found to be in the range of 0.254 to 0.752 mm. The friction values in both dry and wet conditions were recorded by Mu-meter travelling at constant speed of 60 k.p.h. It was found that the dry friction values on all types of surface pavement increase with the texture depth. This is due to the result of the improvement of hysteresis component of the friction force between tire and the pavement. In the lower range of texture depth, asphalt surface which involves bleeding show a lower level of friction than that of portland cement concrete. However, in the case of dry penetration macadam (curve 6), the friction obtained seems to be low for this texture depth. this may be due to larger size aggregates in the mix protruding out from the surface resulting in lesser contact area between the tire-pavement surface, plus the bleeding of the pavement. In wet condition; it was found that the values of skid resistance on all surfaces pavement under investigation increased as the macrotexture of the surfaces improved. Further, it was found that the asphaltic concrete surface which possess the lowest texture depth showed the highest improvement in wet skid resistance values (curve 3). This characteristic introduces the need of specifying the minimum texture depth of this type of pavement.

## Effect of Speed

Asphaltic concrete and portland cement concrete surfaces which possess the minimum texture depth (0.254 mm.) were selected in the study of the effect which speed has on the values of skid resistance. On dry condition, it was found that the value of skid resistance has dropped fig. 4

2 and 4 percents on portland cement concrete and asphaltic concrete with the increasing of speed from 50 to 80 k.p.h. respectively. The decrease in skid values is believed to be the result of shorter contact time between the tires and the pavement surface as the speed increases. However, it was found that in spite of the losses, the skid values were still warranted for safe travelling on both types of surfaces. In wet concition, asphaltic concrete surface shows a drop of 4 percents on the same range of speed change, but, the values obtained were lower than the accepted standard for safe driving even at 50 k.p.h. The same slope of curves for wet and dry conditions on asphaltic concrete pavement surface seems to indicate insufficient drainage ability of the pavement's textures. Since the performance of the textures on wet surface condition is dependent on the drainage time hence the rate of decreasing friction as the speed increases should be steeper than that of the dry surface.

## Effect of age

The study of the effect of aging on skid resistance values was carried out on asphaltic concrete and macadam surfaces. In fig. 5, a set of curves indicate significant drop in friction values as age increases. The polishing of limestone aggregate which contain 3 to 14 percent noncarbonate, (as shown in Table 1), under traffic decreases the texture depth of the pavement and the angularity of the aggregates. The decrease in friction values of dry pavement fig. 5-a seems to be caused by the reduction of both hysteresis and adhesion components of friction force which are related to macro and micro textures of the surface. The drop of friction on wet pavement (fig. 5-b) is the result of decreasing workability of pavement textures. In addition, the rate of decreasing value of friction on dry pavement is higher than that of wet pavement which seems to be the result of bleeding effect. Fig. 6 shows the effects of bleeding of an asphaltic concrete and polishing of limestone aggregate.

Table 1. Laboratory Test Results of Percentage of Non-carbonate in Limestone aggregates.

| Source and Size | | Mean Percentage of Non-Carbonate |
|---|---|---|
| Ratchaburi | 1" | 7.3 |
| " | ½" | 14.0 |
| Nakhon Sawan | ½" | 3.3 |
| Lopburi | ⅜" | 7.5 |
| Saraburi | ⅜" | 3.7 |

Correlation of the Mu-meter with the British Portable Tester

Correlation tests were run between the Mu-meter and the British Portable Tester (BPT). The tests were made at 14 different locations. The locations were selected so that a range of values would be covered. The Mu-meter ranged from 17 to 77 and the BPT from 38.4 to 103. After measurements with the BPT, the Mu-meter was run over the same section and wheel track. The test speed for the Mu-meter was 60 Kph. The water film thickness for both tests was 0.508 mm. The results of the test are summarized and the regression line shown in Fig. 7.

The relationship obtained in this study gives the regression line as $Y = 1.09x + 17.45$ with a coefficient $r = 0.987$.

CONCLUSION

1. Increases in water film thickness on asphaltic concrete surfaces decreases the friction values.

2. Wet and dry frictional values on all types of pavement tested increase as the texture depth increase.

3. Asphaltic concrete surface shows lesser skid resistance than portland concrete surface in the lower range of texture depth,

4. The overall friction values decrease as speed increases.

5. For all types of pavement surface tested, friction values decrease as ages increase in both wet and dry conditions.

6. The frictional resistance in dry condition decreases more than in wet condition as ages increase.

7. In dry condition, the coefficient of friction is found to be above the minimum requirement with either increasing of speed or age of pavements.

8. For heavy travelled asphaltic concrete pavement which has been in used for about 24 months shows very low texture depth and insufficient wet skid resistance.

9. The percentage of noncarbonate composition in limestone aggregate used in all types of pavement investigated is lower than 15 percent.

10. Good correlation was found to exist between the Mu-meter and British portable tests.

RECOMMENDATIONS

In views of safety and economy, the following recommendations, based on the findings are put forward in order to serve as useful guide lines for the future pavement surfaces construction. They are as follows.

1. The recommended skid resistance values for different types of road are shown in Table 2.

Table 2. Guidelines for Minimum SR Values, Wet Condition.

| Site | British Portable Number | Mu-meter Number 60 KPH |
|---|---|---|
| Difficult Sites such as bends, roundabouts, gradients, approaches to traffic lights and high accident locations. | 50 | 30 |
| Primary, Secondary highways and Feeder roads with easy sites and ADT 1500. | 45 | 25 |

2. The criteria for pavement surfaces with 7 years economic life and traffic count of more than 1500 average vehicles daily are

a. Use blending of polish-resistance aggregates such as granite or basalt with polish susceptible material.

b. Use aggregates which sacrificial surfaces are continously renewed by traffic action such as sandstone.

c. Use vesicular aggregate which provide internal drainage.

3. For road surfaces with traffic count of less than 1500 average vehicles daily any limestone that passes the normal physical tests can be used.

4. Improve the texture depth for asphaltic concrete surfaces. This may involve changing of the specification.

5. Increase crown slope for all type of pavement surface.

Appendix 2

(A) Detail of Mu-meter, method of test and sample of calculation.

The Mu-meter is a continuous recording friction-measuring trailer shown in fig. 8 & 9.

It comprises a triangular frame on which are mounted the two frictional measuring pneumatic wheels, the rear wheel which drives the recorder and stabilizes the machine, the ballast, the load cell and the recorder mechanism. It can be towed by a vehicle fitted with a standard towing hook, together with a remote read-out stowed in and operated from a cab of a towing vehicle. On towed, it generates a side force friction between the tested surface and the two pneumatic tires that are set at a fixed toe out angle of 7½ deg. to the line of drag. The frictional force is sensed by a transducer (load cell) located in the apex of the trailer's A frame and load data is transmitted to the recorder by hydraulic pressure through a flexible to the recorders interconnecting pipe to the recorder's Bourdon tube and indicating machanism.

(B) Preparation of the Mu-meter for use (8)

1. Check the wheel nuts for tightness
2. Check the tire pressure (9) at ambient temperature
3. Lay out the checking board ensuring that the board and surrounds are clean. Position the machine approximately one meter behind and with the measuring wheels in line with the abrasive surfaces of the checking board. The operators should avoid walking on the abrasive surfaces when the check is carried out.
4. One operator should pull the machine forward over the board, at the same time the second operator should follow to oscillate the roll chart as the machine is pulled over the checking board, thus lessening the friction between the recorder stylus and the roll chart surface.
5. The stylus marking on the roll chart in this check should read $77 \pm 3$ with a clean dry checking and tires, but reading will gradually fall below this figure as the board abrasive surface wears, becomes ingrained with dirt or if the atmosphere is humid.

**Sample of Calculation**

A portion of Route No. 4 which is a asphaltic concrete surface was measured by the Mu-meter. The following datas are taken:-

- Speed of the Mu-meter = 60 kph.
- Length of the portion approximate 500 metres.
- Average surface texture depth (By sand patch method) = 0.286 mm.
- Wet pavement condition.
- The reading of Windows B1 and C1 from the Remote Read-out Unit (or B2 and C2 or B3 and C3) are:

  B1 = 655, this represents 655x6.096 metres of the roadway measured.

  C1 = 352, this represents the summation of friction value taken at every 6.096 meters.

The readings of integrators A and B from the Recorder are:

A = 393, this value taken at every 6.096 metres.

B = 741, this represents the approximate of 741x6.096 metres.

Approximate average friction value

$$= \frac{\text{Window A}}{\text{Window B}} = \frac{393}{741} = 0.530$$

Approximate average friction number

$$= 0.530 \times 100 = 53.0.$$

Exact average friction value

$$= \frac{\text{Window C1}}{\text{Window B1}} = \frac{352}{655} = 0.537$$

Exact average friction number

$$= 0.537 \times 100 = 53.7$$

Note The approximate average friction value is for check only.

The British Portable Tester

The British Portable Tester was developed by the Road Research Laboratory to provide highway engineers with a routine methos of measuring the coefficient of friction of a road surface in both wet and dry conditions. The apparatus measures the frictional resistance between a rubber slider and the road surface.

The details of this apparatus, the method for using and the suggested values of skid resistance can be found in the Road Research Technical Papers No. 66 and 27, Road Research Laboratory (11, 12).

The Sand-Patch Method

The Sand-Patch is a method used to determine the average texture depth of the test section. In the test, a known volume of fine sand of uniform particle size is placed on the road surface, and then spreaded to form a circular patch with a level surface. The texture depth is then, simply the volume of sand used, divided by the area of the patch.

The details of the Sand-Patch method for measuring texture depth and the classification of the surface texture of a road can be found in the Road Research Technical Paper No. 27, Road Research Laboratory, (12)

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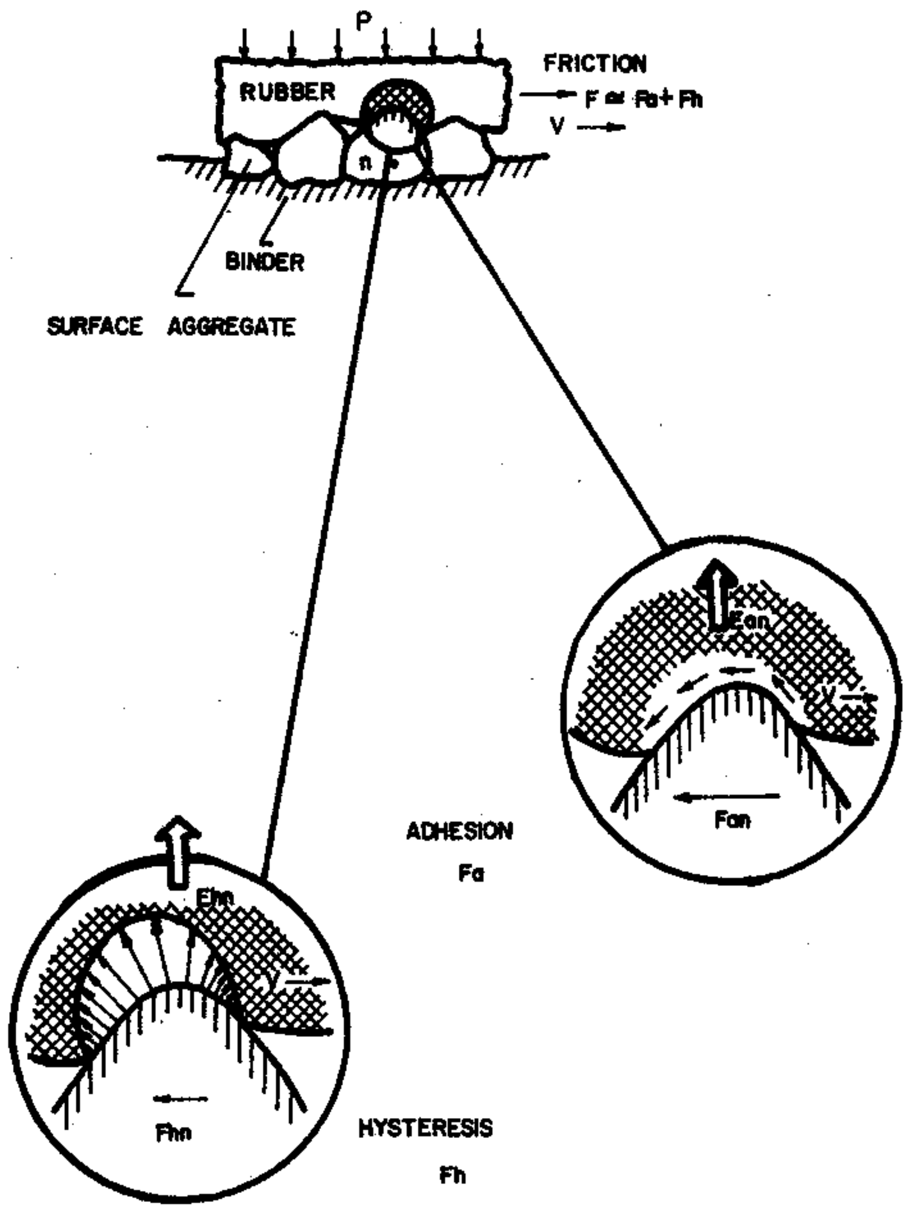



Fig. 1 The components of friction force between tire and pavement

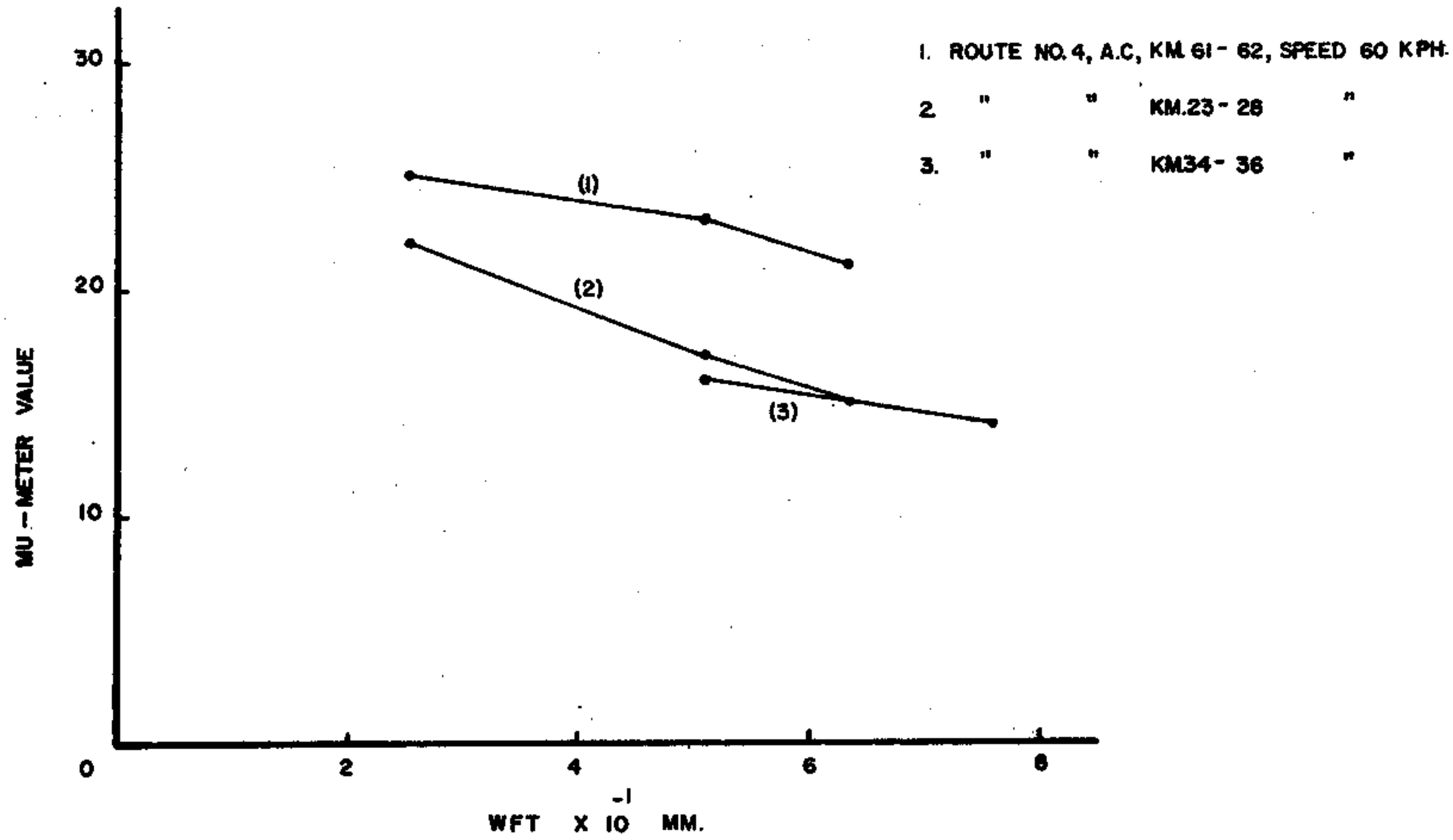



FIG. 2 RELATIONSHIP BETWEEN MU-METER VALUE AND WFT

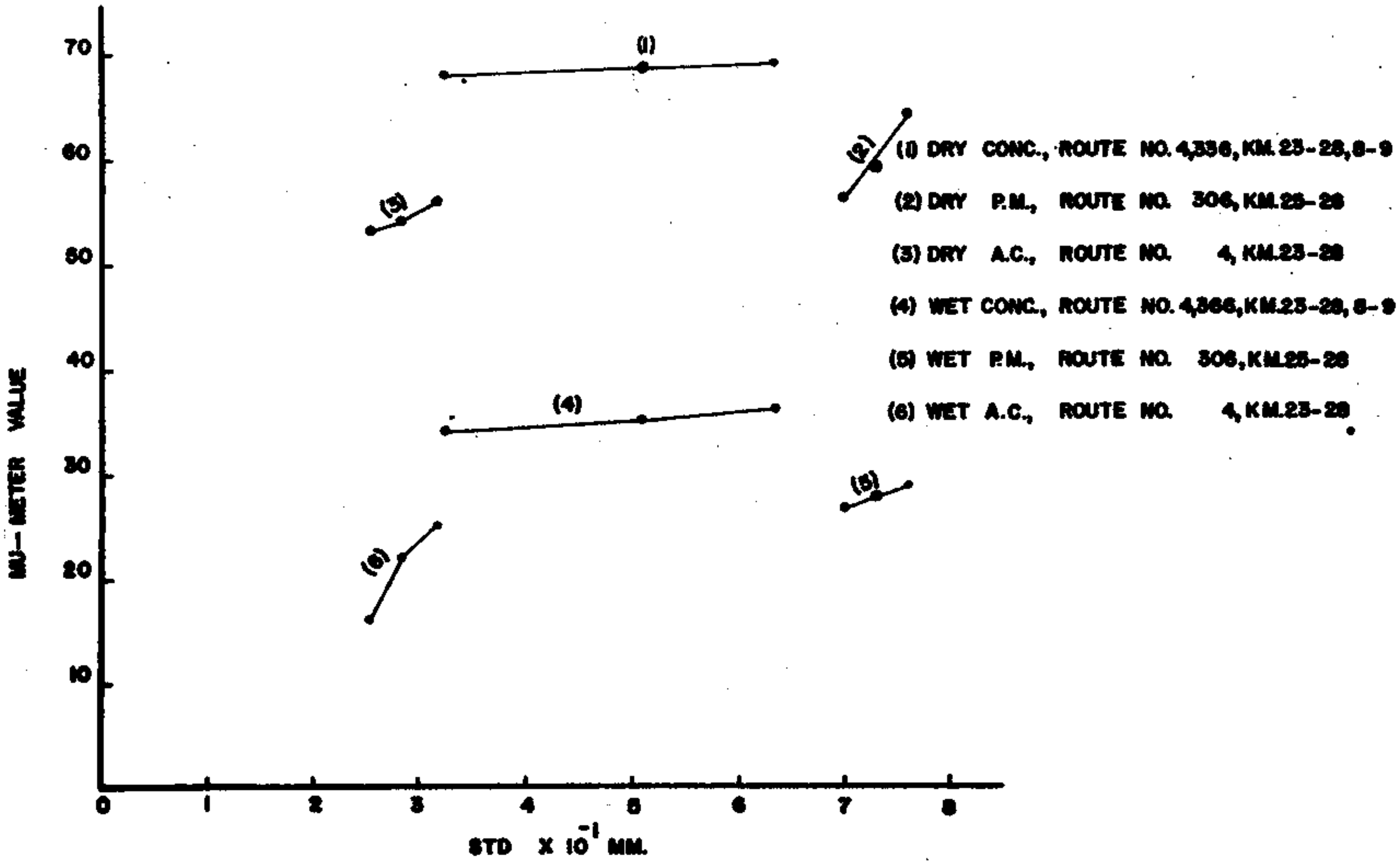



FIG. 3 RELATIONSHIP BETWEEN MU—METER VALUE AND STD.

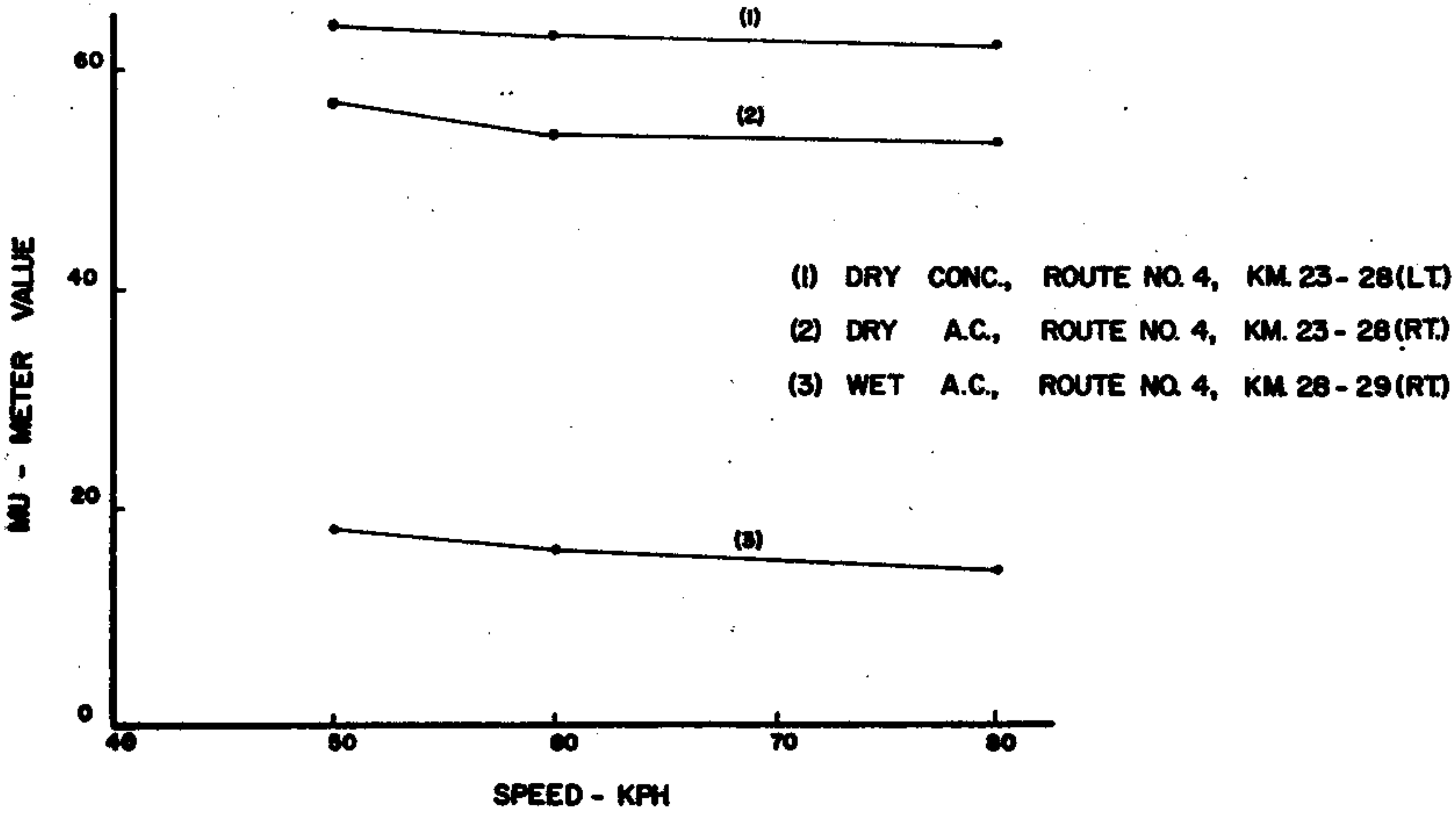



FIG. 4 RELATIONSHIP BETWEEN MU - METER VALUE AND SPEED

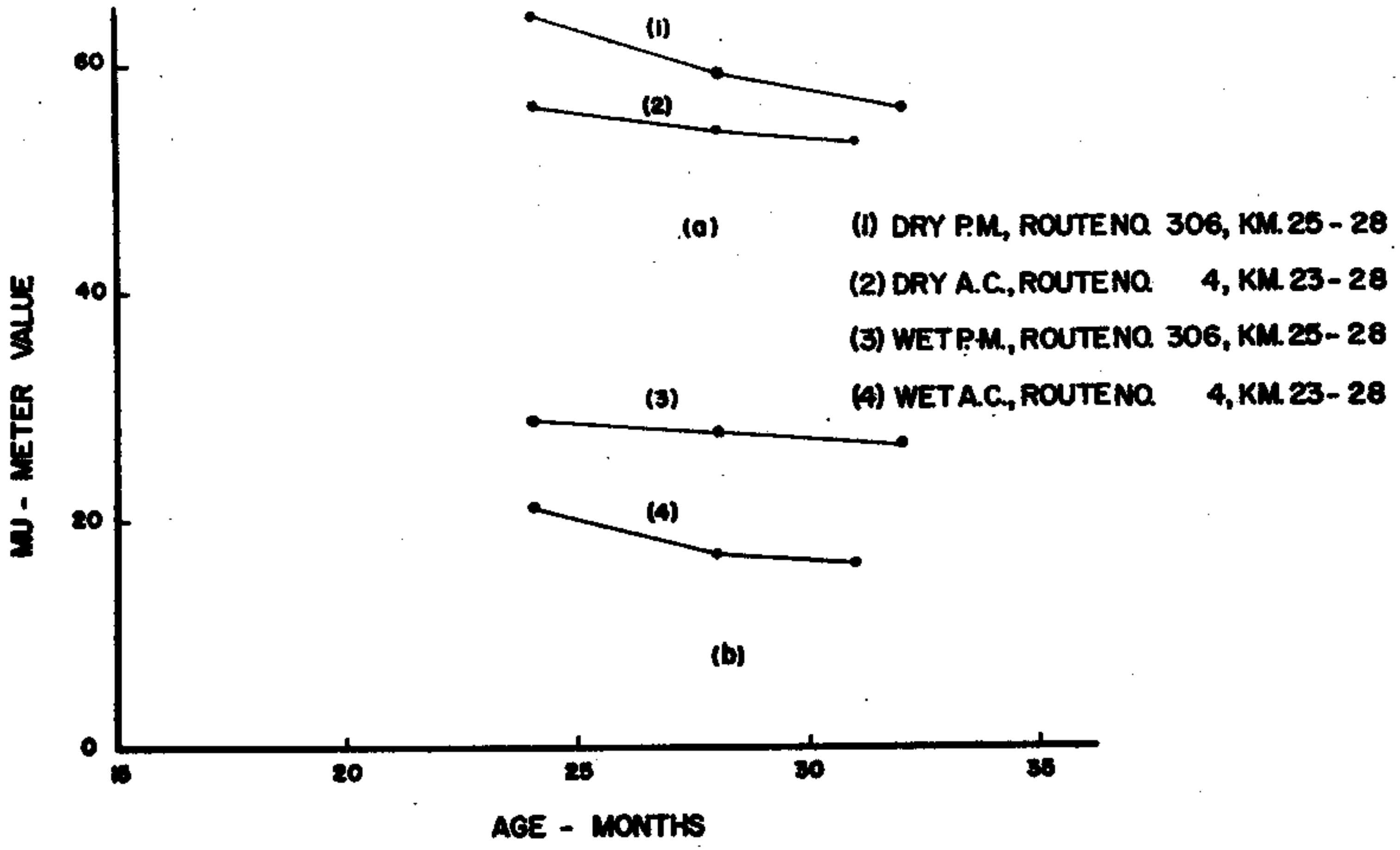



Fig. 5 (a), (b) RELATIONSHIP BETWEEN MU-METER VALUE AND AGE

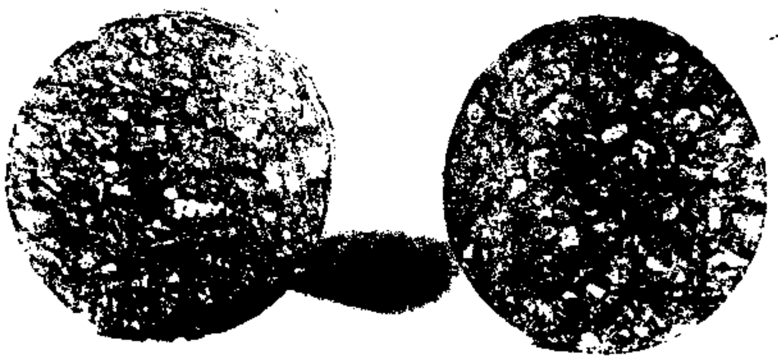


Fig. 6 Asphaltic concrete surface cored samples. (left) Shows polishing of limestone aggregate route no.4, sta. 27+900, on wheeltrack, age 2 yrs., Mmv. = 21 (60 kph., wft.= 0.508, std.= 0.318 mm.) (right) Shows polishing and bleeding in limestone surface route no.4, sta. 23+100, on wheeltrack, age 31 months, Mmv. = 16 (60 kph., wft. = 0.508, std. = 0.254 mm.)

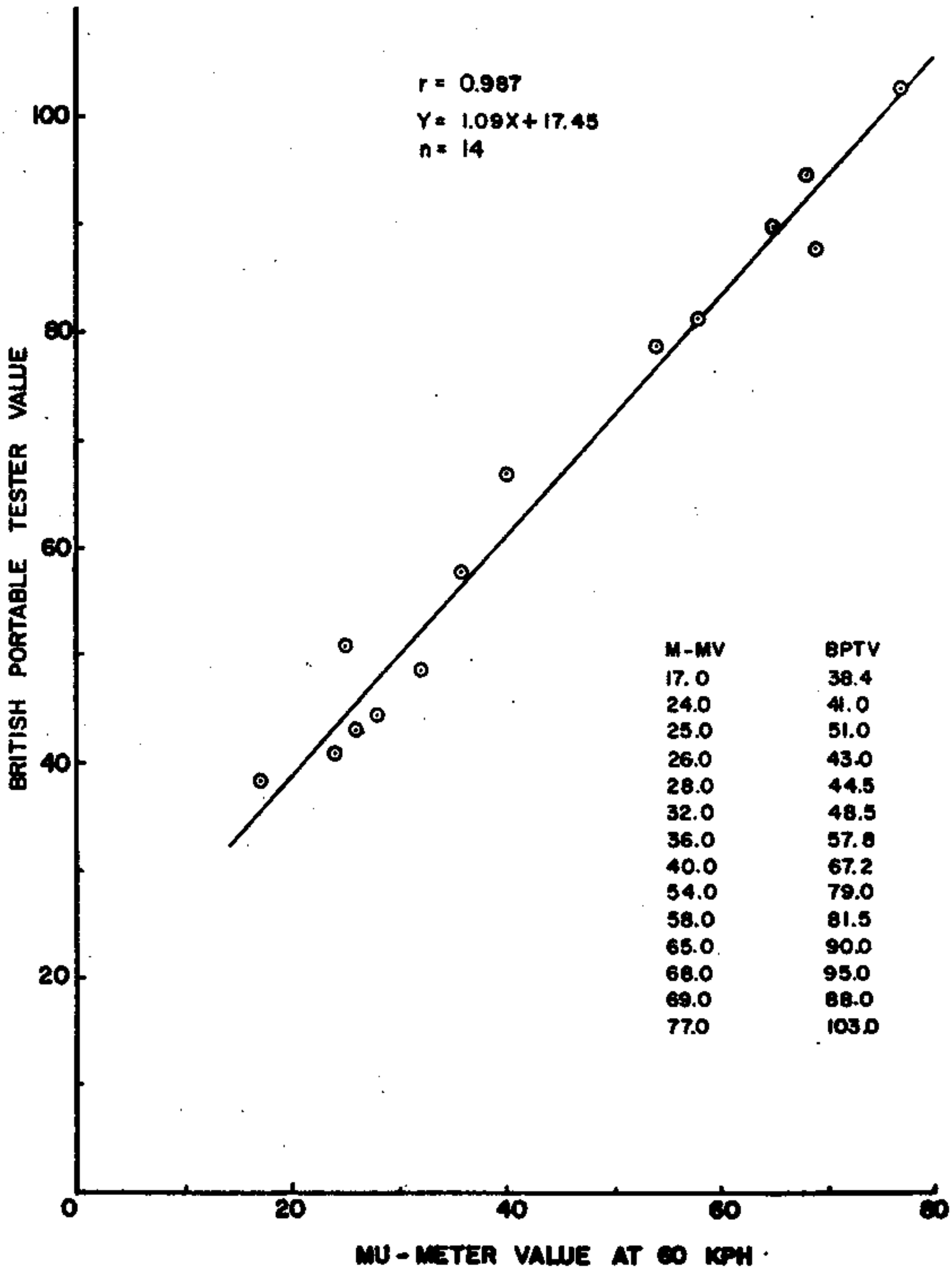



FIG. 7 CORRELATION RESULTS

## [illegible] 2

# Mu – Meter Test Results

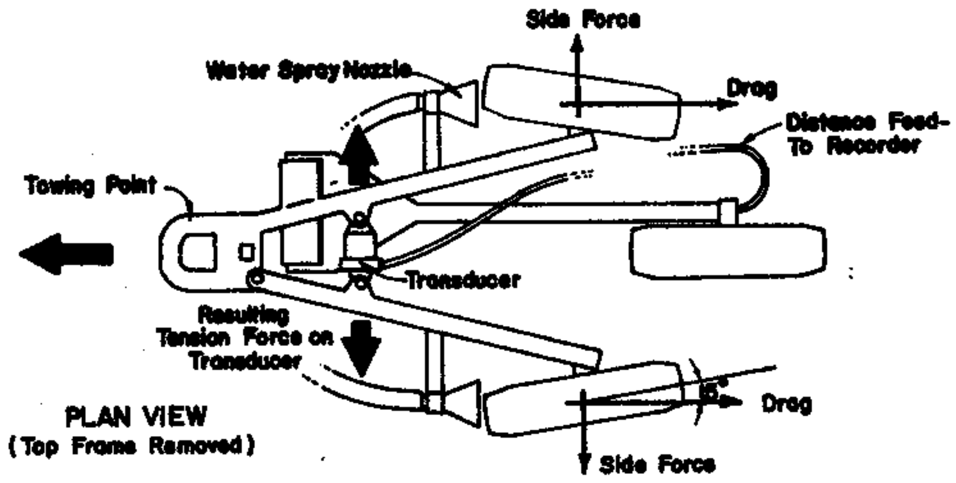
Route No. 4 : Asphaltic Concrete (Rt.)

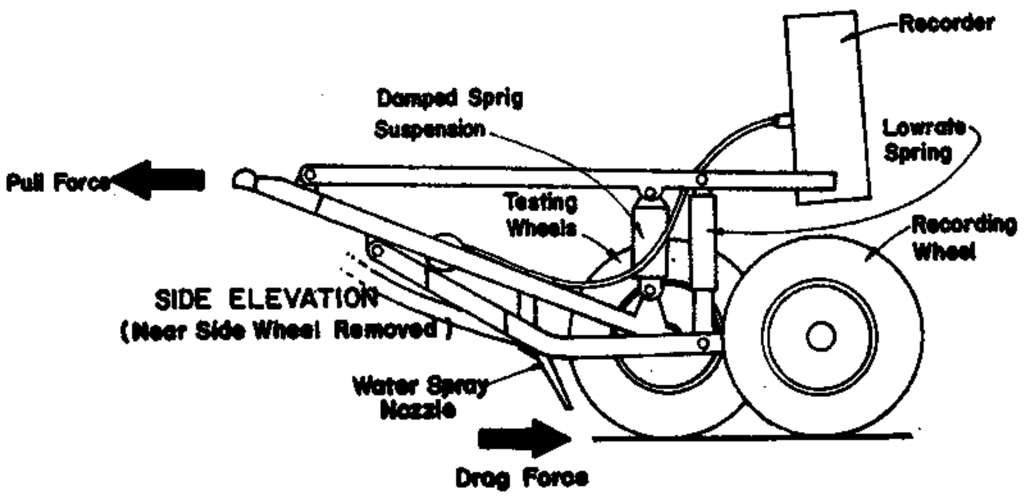
| Age, Months | Km. | ADT | Av. Mu – Meter Value Dry | Av. Mu – Meter Value Wet | Speed Kph. | Av. W F T mm. | Av. S T D mm. |
|---|---|---|---|---|---|---|---|
| 24 | 23 – 28 | 10,044 | 56 | 25 | 60 | 0.254 | 0.318 |
| 〃 | 〃 | 〃 | — | 21 | 〃 | 0.508 | 〃 |
| 28 | 〃 | 〃 | 54 | 22 | 〃 | 0.254 | 0.286 |
| 〃 | 〃 | 〃 | — | 17 | 〃 | 0.508 | 〃 |
| 〃 | 〃 | 〃 | — | 15 | 〃 | 0.635 | 〃 |
| 〃 | 〃 | 〃 | — | 14 | 〃 | 0.762 | 〃 |
| 31 | 〃 | 〃 | 53 | 16 | 〃 | 0.508 | 0.254 |
| 28 | 〃 | 〃 | 57 | — | 50 | — | 0.286 |
| 〃 | 〃 | 〃 | 54 | — | 60 | — | 〃 |
| 〃 | 〃 | 〃 | 53 | — | 80 | — | 〃 |
| 31 | 28 – 29 | 〃 | — | 18 | 50 | 0.508 | 0.254 |
| 〃 | 〃 | 〃 | — | 16 | 60 | 〃 | 〃 |
| 〃 | 〃 | 〃 | — | 14 | 80 | 〃 | 〃 |
| 31 | 34 – 36 | 7,330 | — | 16 | 60 | 0.508 | 0.254 |
| 〃 | 〃 | 〃 | — | 15 | 〃 | 0.635 | 〃 |
| 〃 | 〃 | 〃 | — | 14 | 〃 | 0.762 | 〃 |
| 2 | 61 – 62 | 6,110 | 55 | 21 | 60 | 0.635 | 0.381 |
| 〃 | 〃 | 〃 | — | 23 | 〃 | 0.508 | 〃 |
| 〃 | 〃 | 〃 | — | 25 | 〃 | 0.254 | 〃 |
| | | | Route No. 4 : Concrete (Lt.) | | | | |
| 120 | 23 – 28 | 8,032 | 68 | 34 | 60 | 0.508 | 0.325 |
| 127 | 〃 | 〃 | 64 | — | 50 | — | 0.318 |
| 〃 | 〃 | 〃 | 63 | — | 60 | — | 〃 |
| 〃 | 〃 | 〃 | 62 | — | 80 | — | 〃 |
| | | | Route No. 336 : Concrete | | | | |
| 1 | 8 – 9 | 30,000 | 69 | 36 | 60 | 0.508 | 0.635 |
| 〃 | 〃 | | 68.5 | 35 | 〃 | 〃 | 0.508 |
| | | | Los Angeles Abrasion Test = 29.0 | | | | |
| | | | Route No. 306 : Penetration Macadam | | | | |
| 24 | 25 – 28 | 1,500 | 64 | 28.5 | 60 | 0.508 | 0.762 |
| 28 | 〃 | | 59 | 27.5 | 〃 | 〃 | 0.730 |
| 32 | 〃 | | 56 | 26.5 | 〃 | 〃 | [illegible] |

Fig. 8 Complete surface friction test unit with Mu-meter.

FIG. 9

MU-METER SCHEMATIC



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