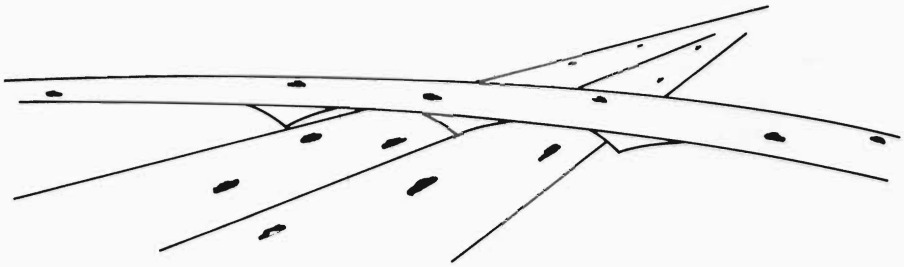

DEPARTMENTAL RESEARCH

Report Number : SS II.II

HOW TO PROVIDE NEEDED SKID RESISTANCE STATE OF THE ART-STATE OF THE PRACTICE

TEXAS HIGHWAY DEPARTMENT

HOW TO PROVIDE NEEDED SKID RESISTANCE
STATE OF THE ART - STATE OF THE PRACTICE

by

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ABSTRACT

This report includes the "State of the Art - State of the Practice of How to Provide Needed Skid Resistance in Texas" which was prepared for the Second International Skid Prevention Conference to be held in Pennsylvania in 1975.

INTRODUCTION

Recently members of the Texas Highway Department were asked to participate in the Second International Skid Prevention Conference to be held at Pennsylvania State University in September, 1975. The First International Skid Prevention Conference was held in Virginia in 1959.

As a part of the preparation for the "second conference", several agencies were asked to prepare a "State of the Art" and a "State of the Practice" for their agency. These agencies were requested to forward their statements to Mr. John L. Beaton with the California Department of Transportation. Mr. Beaton would then combine all statements to a "State of the Art - State of the Practice" for the United States to be presented at the Second International Skid Prevention Conference.

The State of the Art - State of the Practice prepared for Texas follows. Also to assist in the understanding of the statement, a "Chronological History of the Wet Weather Accident Reduction Program in Texas" was included. The history reveals the direction that studies in Texas have taken and some of the reasons for this direction. By chance, the history covers about ten years of study.

The author wishes to apologize for the manner of writing to be found following, such as the incomplete sentences. The reason for this manner of writing is to be found in Mr. Beaton's request that the statement be prepared in an outline form, to be as brief as possible. Mr. John F. Nixon, (Research Engineer), later requested a Special Report be prepared from the material.

"HOW TO PROVIDE NEEDED SKID RESISTANCE"

State of the Art - State of the Practice

I. Original Surfaces

A. Portland Cement Concrete

1. General

In our area we have little studded tire traffic and therefore the coarse aggregate is rarely exposed. The dominant skid characteristics of P.C. concrete pavements seem to be the fine aggregate - mortar combinations to provide good durable micro-texture and texturing the surface to provide sufficient macro-texture and drainage.

2. Fine Aggregate

The fine aggregate should be hard to have sufficient polish resistance and have angular faces to insure skid resistance. The size probably has some importance even though our present specifications seem adequate. I would suggest a dominant portion should be retained on the 100 mesh and pass the 40 mesh with little or possibly just sufficient - 100 mesh material as needed. In other words, the remainder on the -10 to +40 mesh sizes.

3. Coarse Aggregate

The coarse aggregate apparently has little influence on skid resistance of P.C. concrete. In some cases we have used synthetic coarse aggregate which may be 25% of the coarse aggregate (25% of the surface area is coarse aggregate) has become exposed. And in this case, the synthetic aggregate section had slightly higher SN_{40} values as compared to the conventional (limestone - silicious river gravel) section. But in general, the coarse aggregate should be used for structural strength.

4. Mortar - Mix Design

The mortar should be such that sufficient durability is maintained on the pavement surface. On our CRC pavement, we originally used 4½ sack concrete because we were attempting to obtain an optimum crack spacing of about 8 feet.

Through experience, we have come to realize almost any CRCP will have some small crack spacings - and this is where our maintenance and repair problems are. So for the past several years, most of the State has used 5 sack and some 6 sack mixes. The surface seems more durable probably because of the increased surface strength. Rarely will the SN_{40} values be under 35 (we feel SN_{40} values less than 35 are poor - following Kummer & Meyers NCHRP Report No. 37.) on P.C. paving. However, we do have some skid problems due to our past burlap drag texture being insufficient. (Low friction at high speed or tendency to hydroplane.)

Some of our first CRCP using 4½ sack with a manufactured limestone fine aggregate and crushed limestone coarse aggregate from the same source (ADT about 70,000) lost all texture and polished to an extent that it had the appearance of a marble tombstone in about 2 to 3 years. SN_{40} values were in the low to medium 20's. No extra surface water should be used for aid to finishing and the surface should not be overworked. The slipform paver and new texturing techniques should help us in this respect in the future.

5. Texturing

Texturing the surface is very important. We presently require 0.025-inch on paving and 0.035-inch on bridge decks (sand patch). Lightweight plastic (styrofoam) specimens showing four varying texture depths have been given to the field as examples to judge the texture on green concrete. Supposedly those specimens were used to aid the inspector - contractor team to make changes quickly in the field. I do not know the extent that they are used but a great deal of talk about texture has made its way to the construction people in the field. With our decentralized system, many and varied ideas have been attempted. One man asked us to look at his "garden rake" texture - kidding, of course - but a great amount of texture was evident. So I suspect the inspector and contractor initially attempt to obtain good texture, when the surface has hardened, measurements are obtained, and then adjustments are made if needed. Through experience and observing test results, the inspector recognizes if texture is adequate. Our specifications are worded such that the contractor is not penalized - he must change his technique - if the texture is not adequate. Also supposedly FHWA can not penalize us.

One of our research studies contained texture measurements at actual wet weather accident sites. Plots indicated that large numbers of accidents occur at the low textured sections but the accident numbers level off and low accident numbers occur at textures of about 0.035-inch (putty impression) or more. Due to this data, we recommended 0.035-inch as a minimum value. Our specification book was being reprinted during this time, and we caught the Bridge Division in time - thus the current bridge specifications. However, the Design Division had selected some information published by P.C.A. and their section covering pavements was being printed. Design was reluctant to change - thus the current paving specifications. Recent findings of research projects studying friction under simulated rainfall have led the interested Divisions to take another look. It is believed we need more texture. Recommendations have not been made from a study committee at this time, but it is possible that a finish method will be adopted rather than a texture value. We do believe the final texture after wear will be about 3/4 of the initial texture. Personally, I believe the method Georgia uses with transverse tines spaced at 1/2 inch is about right - or we need about 0.050-inch (sand patch) initially during construction. Our attempts indicate no construction problems or trouble adapting equipment for tines, broom, etc. A CMI slipform paving train was used. If concrete is allowed to take an initial set or harden, then it is difficult to attain texture by any method. We have not attempted sprinkling skid resistant aggregate on a fresh concrete surface. This method does appear feasible.

6. Modification of Surface Mortar Characteristics

We are unfamiliar with hardeners other than Polymers, then only slightly because the use of Polymer Concrete is in the research stage. The research project is studying the use of monomers on the surface of concrete bridge decks - basically to prevent water-salt scaling. Rarely would the penetration depth exceed 1/2 inch. Two attempts to use the monomer-polymer in the field on bridge decks have been made. In the first attempt, the experiment failed because our technique to change the monomer to a polymer was not sufficient (no penetration of monomer into the concrete). The second attempt was successful. Lab experiments indicate no delamination (different thermal coefficients) problems.

We tested a series of polymer concrete specimens on the circular track (2 different monomers with various curing treatments). I first believed the polymer would "plug-up" the micro texture and lower the friction - but this is not so (at least on the surface).

I do not trust our circular track wear - especially the BPT values, but the polymerized specimens did seem to be more durable (wear resistant) with slightly higher BPT values when compared to conventional concrete. On a few specimens, small lightweight (synthetic) aggregate was used on the surface to prevent monomer evaporation. The lightweight stuck to the surface - of course, excellent BPT values resulted. However, some abrading or wear of the lightweight aggregate resulted (test concluded after about 70,000 wheel applications).

I believe monomers should not be used at the present time on concrete paving because of excessive cost in comparison with the benefit received.

7. Development of a Standardized Laboratory Wear and Polish Machine - Concrete

You are probably aware of ASTM's attempts to develop "Recommended Practices" on several laboratory polishing devices - circular track, standard wheel, small torque device, etc. I believe one is about as good as another, give or take the inadequacies and good points of each. I believe it will be impossible to get each State or agency to agree on a standard method, even with FHWA or FAA, etc. pushing. Perhaps it is better if various methods are available. The agency can select a method best suited for its materials or location.

Because we have never had much trouble with concrete, it is our feeling we should use the methods outlined in Part III following to attain a durable skid resistant concrete pavement. These do not include a polish machine. We would not be adverse to a polish machine if one were available meeting our needs. We have just completed a research project using a circular track. The equipment we fabricated proved to yield poor results. We did not use a variable radius feature on our track (wheel tracked in the same wheel path) and perhaps this is the reason for our disappointment. We are, however, skeptical of the variable radius tracks. Others appear pleased with their tracks (North Carolina, National Crushed Limestone Assoc. and as nearly as we can determine, California).

A polish machine must produce accelerated results or contain several specimens; the specimens must be of sufficient size to fully represent the pavement surface being studied; and polish in a manner of actual traffic (preferably in a tangential manner).

However, the chief problem to be overcome is a friction testing apparatus which will produce better values than those now available. We feel the equipment covering these items is not available and we prefer experimental sections on a highway which can be tested with a skid test trailer.

8. Development of Methods for Preparing Laboratory Test Surfaces that Simulate PCC Surfaces

   In the meeting in Washington, the committee suggested we review the methods - which I assume that we have used in our State. Our experience has been with the circular track. We did try a few mortar specimens on the British Wheel but these disintegrated (centrifugal force).

   Texas Transportation Institute prepared the concrete specimens for the circular track. Full documentation of the preparation may be found in Research Report 126-3F but following are interesting items:

   1. Size - Approximate 12" x 12" x 4"

   2. Batched in a small Lab Mixer

   3. Variables were Cement Factor, Curing Compounds, Curing Temperature and Humidity, Curing Time, Fine Aggregate Type, Fineness Modulus and Surface Texture.

   4. A small amount of vibration used in the molds.

   I do not believe serious trouble will be experienced in preparing specimens which simulate PCC surfaces.

B. Asphaltic Concrete

1. General

   At the Washington meeting some confusion existed in how we should forward information on the various types of asphaltic concrete. I will cover them within the Asphaltic Concrete heading but treat Penetration Seals as a different <u>pavement</u> type.

   Basically we again believe sufficient micro-texture and macro-texture should be available on asphaltic concrete pavement surfaces. Each texture type should have an angular shape. Following Kummer and Meyers NCHRP Report No. 37, we adopt the theory concerning the adhesion and hysterisis components of friction. Also we believe surface water drainage is needed whether internal (plant mix seals) or external (through channels provided by macro-texture or tire grooves). In our usual dense mixes, we feel the major micro-texture (adhesion) component is developed from the texture on the coarse aggregate surface. Because the coarse aggregate is "proud" of the surface, the fine aggregate matrix is of lesser importance to the skid resistance. I should say we are generally not concerned with the new "as constructed" surface but the surface in its polished state. In the regular mix, we feel the macro-texture (hysterisis and drainage) is developed from the coarse aggregate particles as they are positioned in the surface of the mix matrix. However, we do believe that it is possible to reduce the size or quantity of the coarse aggregate, increasing the quantity of intermediate or fine aggregate, and still obtain a skid resistant surface (trend toward sand asphalt) - if hard sharp angular aggregate particles are used. However, if the mix is dense, water drainage becomes a problem and low SN's are found at the higher speeds (tendency to hydroplane).

2. Dense Mixes

Our regular (estimate about 80% of the asphaltic concrete surfaces) asphaltic concrete (See Texas Specification for Type D HMAC) has a top size of 3/8 inch with around 60% to 70% by weight retained on the 10 mesh screen. Asphalt contents vary from 5% to 7% by weight. There have been some 5/8" to 1/2" top size (Type C) surfaces placed and a small number of surfaces tending toward sand asphalt.

a. Aggregate Properties

The regular tests for structural durability are needed. For skid resistance a coarse aggregate with good, durable (or renewable) micro-texture and angular shape is required. Our most durable skid resistant coarse aggregates are those with minute particle attrition loss such as scoria, synthetic, lightweight sandstone and some slags. Our Ryolite is also highly skid resistant, but this is a hard aggregate having relatively high micro-texture heights (thus long skid resistance life). Of intermediate durability in skid resistance are granites, traprock, quartizites and some limestones. Of poor durability are dense limestones and silicious (flint like) river gravels. We feel the British Wheel does an excellent job of ranking coarse aggregate materials for skid resistance characteristics.

The intermediate and fine aggregate should be hard, sharp and angular. The best of the fine aggregates will be the silicious field sands. Crushed or manufactured limestone sands will be poorer. A fine aggregate bulking test could be used in specifications for shape and the insoluble residue test for hardness. (Even though we do neither and have experimented only slightly with both tests with the exception of the insoluble residue of fine aggregate for concrete).

b. Binder Properties

Asphalt types we now use for temperature or seasonal conditions should be used. (Basically, at present, we take what we can get). Additives such as latex will probably not affect skid resistance because traffic abrades asphalt from the surface available to the tire for stopping. We know very little about how asphalt durability (hardening or weathering) affects the fine aggregate matrix. The effects must result on the surface to a great extent, probably in fine aggregate attrition. Texas Transportation Institute (Professor Gallaway) indicates it would be possible to design the asphalt content in such a manner as to provide for a slow aggregate attrition from the mix - thus providing a new texture with traffic cumulations. We have been reluctant to attempt this because of the fear of structural decay. However, the same would apply to poor asphalt. Except for excessive amounts - recommend asphalt be considered for structural durability only.

c. Paving Mixture Properties

(1) Grading - Basically use grading for structural durability. If low volume, low speed roadway; coarse aggregate materials are in short supply and a hard sharp angular fine aggregate available,the mix may be designed using local materials.

(2) Asphalt Content - Use amount needed for structural durability.

(3) Surface Water Action - This area is one of our unsure spots in providing a skidding accident reduction program. In dense graded mixes, we have no sure way of providing macro-texture. We have found that where the laydown machine "pulled" the surface, SN_{40} values can result where these values are 30 numbers higher than where the mat was dense and tight-knit. Consideration

should be given to texturing the pavement during rolling (at least in southern areas).

(4) Resistance to Wear and Polish under Traffic
As stated previously, our discussion concerns the material or pavement in the "as polished" condition. We have little trouble with the SN_{40} values of newly constructed pavement with the possible exception of the asphalt coating on Plant Mix Seals so we naturally think of the polished condition.

(a) Development of Methods for Preparing Laboratory Test Surfaces that Simulate A.C. Surfaces

We believe considerable problems will be experienced in this area. The mix design will not be too much trouble but texturing the surface similar to an AC surface, disposition of the aggregate particles in the specimen and compacting the specimens are problems. Also, we experienced considerable difficulty on the circular track in containing the specimens. (They squirmed, shifted and disintegrated.) Experience, more knowledgeable personnel or different testing apparatus will probably overcome the containing difficulties. We feel the initial texturing of an A.C. specimen is not that important because after polish the initial texture has been removed. Distribution of the aggregate in the mix of the specimen is important because this influences the final texture. Compaction is also important. We used a gyrating motion stemming from eccentric horizontal and vertical acting cams. (About 30 seconds with a precompaction load which was 10% of the final settling load). The final settling load delivered about 200 psi to the specimen. Heating elements were used on the platens during compaction. Our specimen density was about 90% of the Hveem specimen density.

(b) Development of Standardized Laboratory Wear and Polish Machine - Asphaltic Concrete

Our comments under the same subject with P.C. concrete apply to Asphaltic Concrete. Again we are pleased with the British Wheel because the emphasis can be placed on the components of the mix rather than the mix performance.

We do not use "End Product" specifications, so this principle is in line with our present specification procedure.

3. Open Graded Mixes

We have only attempted about 15 to 20 different surfaces using Open Graded Mixes which we call Plant Mix Seals. This amounts to probably less than 50 - two lane miles. However, this mix is gaining popularity and we expect quite a bit more use in the future. Several different types of aggregate have been used and the more skid resistant aggregate works well(those with higher Polish Values). Most of the jobs have used a gradation similar to our penetration seals (1962 Texas Specifications for Grade 4 or 5 seal) with higher than normal asphalt contents (say 6½ to 8% asphalt by weight). This means we are probably using less fines in our Plant Mix Seals than most agencies. We are encouraged by TTI (Professor Gallaway) to use more fines because they feel this will improve the tendency to have low initial SNs.

The SN_{40} values are lower initially (say 35 to 40 with high Polish Value aggregate); generally improve within several hundred thousand traffic applications (say less than 1/2 million); but never seem to become as high as the regular mix or a good penetration seal. Even though we have never tested the mix under heavy rainfall, we believe the PMS will result in higher SNs at the higher speeds, smooth tires, heavy rainfall conditions as compared to the regular dense graded mixes.

Basically we have duplicated the construction procedures of other states. We find the PMS should be mixed, transported and placed in a relatively cool state (say between 200 to 300^{o} F).

The tranportation length should be short or transport time small. The surface to receive the mix should be water proof and in good condition. (All our work has been rehabilitation - none on new surfaces.)

4. Sand Asphalts

We have not placed a sufficient number of sand asphalt surfaces to adequately provide comment. Some 3 to 4 years ago, an ALCOA slag (wet bottom boiler slag) was placed extensively for a few years (Texas Spec-Type E Modified). This was a dense mix with very little aggregate of a size greater than a +10 mesh. SN_{40} values would start around 50 and rarely go below 35 with traffic polish. However, a research project involving a study of wet weather accidents found an excessive number of accidents on these sections. This mix is no longer used and most of the existing surfaces have been overlaid. On one occasion we obtained tests on this mix at 60 mph with a smooth ASTM tire and standard water (.020 in. approximately). The SN_{60} values gave an average of 10. We would not recommend this type mix on high speed highways unless the mix was designed for internal drainage such as Kentucky Rock Asphalt. We have no experience with internally draining sand asphalt mixes, but we would be hesitant to recommend any sand asphalt for a high speed surface.

5. Penetration Seals

Even though this paving type is not an asphaltic concrete, seals are used extensively in this State as the surface on newly constructed sections. There is a tendency to not use seals, even in rehabilitation, on high volume highways. Intersections and geometric locations where seals have been used show poor results since the friction between the time and the rock causes the rock to dislodge. Our most used gradation is a Texas Spec. Grade 4 which has the majority of the aggregate on the 3/8 to 1/4 sieve. In rehabilitation, if considerable flushing is noted on the existing surface, a larger size aggregate is frequently used (Maximum size gradation is Grade 1 with majority of aggregate on 3/4" to 5/8"). Recently an attempt was made to use more of a one size aggregate in seal coat work. Also there appears to be more aggregate stripping than consolidation or flushing and with the "one-size" spec (particularly with a high polish value aggregate) more asphalt is needed. With the "one size" spec, one tends to note that not as much aggregate is needed and there is a tendency to reduce the rock rate. I feel all these features have improved the structural durability and therefore the friction. Almost any seal coat durability is influenced by moisture content (also some dirty aggregate problems) in the aggregate but more particularly rainfall during or soon after construction (rainfall 48 hours after construction has been noted to cause problems).

A skid resistant aggregate with good micro-texture and shape should be used in seal coats. Again we feel the British Wheel test does a good job in providing a test procedure and specifications for skid resistant aggregate.

Synthetic Aggregate

The above information about seal coats also applies to the situation in which synthetic aggregates are used. One size, a sufficient asphalt layer and an optimum aggregate application rate should be considered. The rock rate is critical for lightweight synthetic aggregate because we have found if too much aggregate is used, to the extent that loose particles lie on the surface, these loose particles crush to a smaller size; lodge in the lower layers of asphalt and force the asphalt to rise on the aggregate so that flushing is induced. Much for the same reasons we do not recommend flat wheel rollers be permitted when synthetic lightweight aggregate is used.

Our chief synthetic aggregate is a lightweight produced by firing shale. We have 5 sources in the State. It appears the better aggregate has a hard rather dense coating (presized before burning) in comparison to the aggregate which has no hard exterior. The aggregate with the dense rind is a little heavier ($45\#/ft^3$) than the aggregate without the rind ($38\#/ft^3$). The aggregate without the rind is a little softer and there have been some crushing problems. We use an aggregate freeze-thaw test (along with several other tests) to specify durable lightweight aggregate for seals, asphaltic concretes and P.C. concretes.

6. Slurry Seals

Slurry Seals were used to a small extent some 5 to 10 years ago. Skid resistance was poor after about one million traffic applications (SN_{40} generally in the 20's). Our slurries used a large asphalt content which eventually worked its way to the surface (thus the poor friction). It would be rare that a slurry seal would be used today and we do not recommend them.

7. Sprinkle Treatment

Because this procedure presently provides sufficient skid resistance at the lowest cost, our experience is provided. We have only placed one job of this surface type which consisted of less than 5 - two lane miles. However, it does appear to be a low cost method of achieving sufficient skid resistance while using local materials. As you know, a small quantity of skid resistant aggregate is sprinkled on the surface of a newly placed asphaltic concrete (before rolling). After rolling, the skid resistant aggregate is on the surface and available to the tire. The one surface which we have placed is producing excellent results. (SN_{40} - Untreated in mid 20's - treated mid 40's). However, the highway on which the surface was placed is not heavily traveled and more experimentation is needed on various roadways.

II. Rehabilitation Surfaces for Worn or Bleeding Surfaces

A. General

The items as outlined above for Asphaltic Concrete (Dense Mixes, Open Graded Mixes, Seal Coats and Sprinkle Treatments) apply in this area. We do not know how to treat a flushed surface before treatment, nor do we really modify our designs for this event. Only on two occasions have we overlaid an existing surface with P.C. concrete. Other than these treatments, the following information is offered:

B. Grooving

Our first attempt at grooving was in 1962 when approximately 10 - two lane miles were grooved longitudinally. Since that time, grooving has been used in about 15 other occasions. Generally the grooving locations have been on small lengths, mostly horizontal curves, with one longer length of grooved asphaltic concrete. Total length grooved would probably be less than 50 - two lane miles. When the sections are grooved longitudinally, the "after" SN_{40} values remain about the same as the "before" values; however, in almost every event, there is a significant reduction in accidents. We believe this is probably due to "tracking" or improved transverse friction. (It should be noted that in every event there have been a large number of accidents before treatment.) On one occasion transverse grooving was used. In this area, the SN_{40} values were in the mid 20's before grooving; the mid 50's after grooving and the mid 30's about one year after grooving (about 10,000 ADT per lane). We believe the SN_{40} values would have been back in the mid 20's if continued testing had been made.

The grooved asphaltic concrete retained the groove shape and the grooves did not close up. Several groove styles (1/8" x 1/8" x 1/2" & 1/8" x 1/8" x 1") have been attempted but 1/8" x 1/8" x 3/4" is usually used.

We recommend longitudinal grooving as a rehabilitation technique but generally for the smaller (high accident) locations and basically on PC concrete. We feel other rehabilitation techniques are less costly and grooving should be used where quick action is necessary.

C. Acid Etching

Our one attempt at acid etching produced poor results. SN_{40} increases of about 3 or 4 (highest 9) were produced by treatment but even a small amount of traffic reduced this small improvement. Because of cost and equipment needed, this treatment is not recommended even for quick intermediate action.

D. Hydra Broom

A high pressure stream of water directed vertically on a polished surface (P.C. concrete on both experiments on which this was attempted) has produced increased SN_{40} values of about 14. Stereo photo pairs indicate an improved micro texture; however, it is believed that most of the improvement in SN_{40} values results from cleaning the surface. The SN_{40} values decrease with traffic applications on the treated sections but this reduction is rather slow.

Recommended use of this treatment is border line. If a high accident area occurs and immediate treatment is needed, use of this method could be considered. However, lasting benefit should not be expected nor will high speed friction be improved to a great extent. A more permanent remedial treatment should be considered as soon as possible.

E. Localized Treatment of Flushed Areas

A small heater has been used to heat flushed areas. A Limestone Rock Asphalt was spread on the heated surface and rolled with a light flat wheel roller. This treatment was observed recently and skid resistance values were not obtained. The rock did stick but the impregnated asphalt probably assisted. The heater only heats an area about 2' x 2' in size. About one to two minutes are used to heat this area, then the heater is manually moved to the next 2' x 2' location. This is of course a maintenance operation (and slow). Also the manual movement (unit housed on a small two wheel trailer) leaves a ragged appearance to the edge. In the area recently observed, the wheel paths were heavily flushed (no aggregate visible before treatment). In a one day interval about 1/2 mile was treated. However, the area treated was a high accident location where four lanes narrowed to two in a horizontal curve. In other words, intermediate treatment was needed in only a small area until a more permanent treatment could follow. This principle could be used on larger equipment. The aggregate should probably be precoated or preheated - but why waste the asphalt that is in place?

III. <u>Specifications to Provide Required Skid Resistance for Original and Rehabilitation Surfaces</u>

A copy of Texas current specifications and test procedures to insure continuing adequate skid resistance is attached. Basically we attempt to include the idea of providing adequate high speed friction. The idea of providing high speed friction is that of (1) providing a sufficient SN_{40} value plus (2) providing good drainage.

The provision of a sufficient SN_{40} value is through components of the surface mix. The provision of good drainage is through internal drainage in the case of Plant Mix Seals or specifying the texture on P.C. concrete pavements via the Sand Patch Method. At the present time we feel Seal Coats have sufficient texture, but we have no way of providing texture on dense graded asphaltic concretes. We feel this is an area that needs work.

Rigid Pavements

The existing "Texas Standard Specifications - 1972" cover the requirements Texas uses for obtaining skid resistant surfaces on Portland Cement Concrete pavements. The following summarizes the items occurring in the Standard Specifications:

Laboratory Tests	Field Tests
Minimum Insoluble Residue Value for Fine Aggregate	Minimum Texture Inches
28% (Tex-612-J)	0.025 Pavements 0.035 Bridges (Tex-436-A)

With a strong durable concrete on the surface, we feel the 28% insoluble residue value on the fines will provide a hard durable fine aggregate. This does not completely insure that the aggregate will be sharp and angular, so some test to assure this feature is needed. We believe an "Aggregate Bulking Test" would provide a ranking of fine aggregate angularity. We have found that the 28% insoluble residue requirement virtually eliminates manufactured sand. (Our manufactured sand is basically limestone. A sandstone when crushed for sand will not meet the fineness requirements in gradation.) This means that our fine aggregate in concrete is silicious and our silicious aggregates are sharp and angular. Therefore an angularity test has not been recommended in this State. However, I personally feel it is needed to insure a good micro-texture (adhesion) component for a P.C. concrete surface.

We believe the texture requirement should be raised to 0.050 inch (sand patch) on both pavements and bridges. I personally recommend transverse tines, randomly spaced, which would average at a 1/2 inch spacing with the minimum distance between tines (center-to-center) to be not less than 1/4 inch (1/8 inch tine width). The texture requirement is still needed along with the finish technique because concrete can harden before finishing.

Flexible Pavements

The "Texas Standard Specifications - 1972" do not cover our present requirements. These requirements were established by an "Administrative Order" and through various "Special Provisions" and "Special Specifications". The following summarizes the items which are required on the surfaces of all Federally financed projects:

Laboratory Tests (British Wheel)

For the coarse aggregate in (1) Seals or Surface Treatments, (2) Asphaltic Concretes, (3) Plant Mix Seals, (4) Slurry Seals, and (5) the Cover Stone used in Sprinkle Treatments.

Minimum Polish Value	Present ADT Grouping
None	0-749
30	750-1999
33	2000-4999
35	5000-Over
35	All Interstate Highways

(Tex-438-A)

Because there are some aggregates that cannot be tested with the British Wheel; some aggregates produce different field results than indicated by the British Wheel (particularly Limestone Rock Asphalt); and in some mixes the fine aggregate increases the friction to an acceptable level, provision has been made to establish the adequacy of a mix through skid performance data on an individual basis.

We feel a texture requirement is needed on dense graded asphaltic concrete. This value should be 0.050 inch minimum (sand patch). Because our dense asphaltic concretes (particularly overlays) are so thin (generally 1-1½ inches) we have been hesitant to recommend texture requirements. This means that no skid resistant overlay should be placed in the future without (1) insuring structural adequacy through level ups and impervious layers and (2) placing a sufficient thickness to allow texturing and still provide a mat of structural integrity.

IV. Future

We feel future work should include a mix design procedure of dense graded asphaltic concrete for skid resistance. This procedure would use the mix design (type of aggregate, gradation, asphalt type and content) to predict various texture parameters and use the texture parameters to predict skid resistance. We have developed a tentative mix design procedure and a research project is presently studying the validity of the design plus studies of the influence of asphalt characteristics on the design.

We feel future work is needed on the effects of construction on skid resistance. When we study the polish rates of different construction jobs even using exactly the same mix, large variations in skid resistance are noted as traffic applications cumulate. Some of this variance is probably due to "weathering" or seasonal effects, but there must be some variance resulting from construction differences.

CHRONOLOGICAL HISTORY OF WET WEATHER ACCIDENT REDUCTION PROGRAM IN TEXAS - 1972

1962 - First Skid Resistance Values obtained in Texas. These values obtained in San Antonio, Texas with a stopping distance car. Studies made of before and after friction of longitudinally grooved concrete pavement.

1963 - Research Project 1-8-63-45 initiated. Fabrication completed on first skid test trailer. By 1964 skid resistance values had been obtained in every District in the State. Education as to the meaning and general range of friction values found began in the Districts.

1965 - Research Report 45-2 issued to the Divisions and Districts recommending suggested minimum maintenance skid resistance values. This recommended minimum value was not a requirement because sufficient information relating to accidents was not found.

1966 - Research Report 45-3 completed concerning road film and temperature corrections for Skid Numbers. Sample size information developed to determine the number of skid tests necessary for survey tests with skid trailer.

1966 - Texture recognized as important. Research Report 45-4 distributed describing macro and micro texture in relation to skid resistance. Measurements obtained with a small probing device which obtained a micro-profile of the surface. A profile point was obtained every 0.0004 inch horizontally at a vertical sensitivity of 0.000006 inch.

1968 - May - Fabrication completed on 3 additional skid trailers to be used for survey work. Data sheets, computer programs, and information retrieval system developed for flow of skid resistance information to and between Districts, Maintenance Division and Design Division. Training Sessions held for truck operators and for two observers in each District. Reports of statewide summary are prepared and forwarded to each District annually.

1968 - Research Study No. 1-8-69-133, "A Pilot Study to Determine the Degree of Influence of Various Factors Pertaining to the Vehicle and the Pavement to Traffic Accidents under Wet Conditions" was established. The Highway Department obtained Skid Numbers and Texture measurements at accident sites and the Department of Public Safety collected tread depths and tire pressures on the accident vehicles.

1969 - Research Study No. 1-8-69-133 completed on a study of 500 wet weather accidents accomplished in cooperation with Department of Public Safety. Study indicated the following order of importance of items associated with a wet skidding accident.

	Approximate % Contribution
1. Pavement Texture or Water Drainability of the Surface ---	29%
2. Tire Tread Depth of Accident Vehicles ---	27%
3. Trailer Skid Number ---	20%
4. Speed of Accident Vehicles ---	16%
5. Tire Pressure of Accident Vehicles ---	8%

It was found that 40% of the wet weather accidents occurred on low textured pavements. These low textured pavements comprised only 10% of the pavements available to the driver in the area studied. No plant mix seals or internally draining surfaces were used in the State at the time of study. Also, of the single vehicle wet weather accidents, over 50% of the accident vehicles were found to have 2/32 inch tread depth or less on the rear tires. In comparison, a sample of the "normal" vehicle was found to contain only 13% of the vehicles with tires of 2/32 inch tread depth or less on the rear tires.

a. Work was immediately initiated to change the standard specifications to require sufficient texture. The 1972 Standard Specifications presently reflect this change (0.035 inch for bridges and 0.025 inch for pavements, sand patch).
b. Recommendations were sent to the Governor's Safety Council recommending a minimum tread depth of tires at the time of

vehicular inspection. Following testimony from Highway Department and Department of Public Safety personnel, a minimum tread depth requirement was included in House Bill No. 60 and signed into law (2/32 inch).

c. Recommendations were sent to the Governor's Safety Council recommending the establishment of regulatory inclement weather speed zones. Following testimony from Highway Department and Department of Public Safety personnel, a clause was included in Senate Bill No. 183 per mitting regulatory speed zoning during inclement weather.(As of December, 1974, not one regulatory speed sign has been placed in the State. Basically the 55 mph speed deleted the necessity. See Research Report 135-2 for requirements.)

1969 - Revised our design for stopping sight distance on crest vertical curves to accommodate more realistic coefficients of friction found in skid resistance inventory.

1969 - Research Study 2-8-69-138 initiated on the study of the influence on pavement friction by surface water depth due to various rainfall intensities, tire types, tread depths and tire pressures.

1969 - Research Study No. 2-8-70-147 initiated on the study of automobile hydroplaning as associated with highway surfaces.

1969 - Research Study No. 1-10-69-126 initiated on the polishing characteristics of Texas aggregate.

1970 - Research Reports, 134-5 and 134-7, submitted concerning some of the first work ever done on driver behavior and driver demand in manuevering along horizontal curves and while in a passing manuever. Results indicated drivers develop much sharper curvatures than the "design" for horizontal curves. Results of research immediately used in developing allowable speed values for use in regulatory speed zoning during inclement weather.

1970 - Research Study No. 1&2-10-70-135 initiated to develop a systems design for reduction of skidding accidents. Project to monitor all State participating research projects in pavement friction and skidding accident area and to combine results into useable data. Studies began using existing individual accident data and to combine results into useable data. Studies began using existing individual accident reports. First study (of both arid areas and of areas with large rainfall quantities) indicates many surfaces with extremely low friction that have not even had a wet weather accident in several years. This means that it would be an extreme waste of money to provide high skid resistance to all surfaces below a minimum friction level. Criteria should be established for critical wet pavement sections.

1970 - First phase of Research Project No. 1-10-69-126 completed. Decision made to use a test procedure to obtain sufficient skid resistance rather than require a minimum "as constructed" skid number. Since experience and reports indicate most of pavement friction for flexible pavement surfaces results from coarse aggregate - research concentrated on these aggregates. Literature search indicates only one test procedure for specifying skid resistance in common use - the "British Wheel". A British Wheel was purchased; some British work duplicated to study validity of British Wheel polish on Texas aggregate; a test procedure adopted which is a slight mutation of the British method; an inventory of the British "Polish Value" of about 90 Texas sources was obtained; and a final test procedure and specifications were developed whereby a non-polishing aggregate may be specified on contract work. Research continued on aggregate blends and fine aggregate studies using a circular track (ASTM standard test tire used on a track with 10-foot diameters).

1971 - Texas Transportation Institute completes first phase of Project No. 2-8-69-138 concerned with water depths on the pavement surface. Recommendations for increased cross-slope were made and several Districts (field) adopted a 1/4 inch/foot cross slope in design. An equation predicting the water depth on the pavement surface was developed as follows:

$$d = 3.38 \times 10^{-3} (1/T)^{-.11} (L)^{.43} (I)^{.59} (1/S)^{.42} - T$$

where d = average water depth above the top of texture (in.) (note - can be negative)
T = average texture depth (in.) (putty impression)
L = drainage - path length (ft.)
I = rainfall intensity (in./hr.)
S = cross slope (ft./ft.)

1971 - First series of tests completed of skid tests under simulated rainfall (nozzles on overhead pipes). Skid tests made with THD trailer as water depths, speed, tire type, tread depth and tire pressure were varied. Nine test pads with different surfaces were used. SN_{40} values and texture values obtained on pads. First equation developed on these nine pads was:

$$\ln f = -0.28809 + 1.03081 \ln \Big\{ SN_{40} \big[0.938 + (-0.19 + .00675\ \text{Vel})(\text{Tread}-2.33) \big] + \big[(\text{Text})(\text{WD})(29 + (-3600 + (75-135\ \text{Tread})(\text{Vel.}-36.4))) \big] \Big\} + 0.34903 \ln \left(\frac{40}{\text{Vel}}\right)$$

where:

Vel = vehicle speed in mph

SN_{40} = basic friction value (skid number in a standard test)

Tread = tire tread depth (either a "1" for a smooth tire or a "2" for a full treaded tire).

Text = pavement surface texture - putty impression method.

WD = water depth on the pavement surface (inches above - or below texture asperities).

The skid numbers found in the above work were all exceedingly low for smooth tires at high speeds (say 60 mph) and in light rainfalls. Most of our surfaces would result in values in the "teens". The only feasible method of correcting this situation would be to impose wet weather speed zoning. Maximum effort given to this area.

Reflection on the data collected above indicated for the first time friction values "available" to the driver which were in the range of those theoretically "required" by the vehicle in stopping, cornering and passing manuevers. Questions - Can the skid trailer measure the actual friction available to a vehicle if operated in inclement weather? Can the SN_{40} values be modified for speed, water depth, tread depth, etc. to predict the "available" friction for design rainfall, tire, cross slope, etc. conditions?

Is this the reason why certain vehicles lose control and others do not - because of different tread depths, tire pressures, speeds, etc. Because of these questions, work was initiated to begin a project to correlate the skid trailer with various vehicles in inclement weather conditions.

Research work to continue with simulated rainfall on Portland Cement concrete pavements with various textures.

1971 - Manual (Report No. 138-2) prepared for establishing criteria and methods of zoning for wet weather speeds. Procedure involves selecting high accident locations, determining the "required" friction for the worst geometric event in the section (stopping, horizontal curve, passing, etc.) and comparing the required friction with the "available" friction. If "required" friction exceeds the "available" friction, speed is reduced until a safe condition exists.

1971 - Approximately 92,800 lane miles were tested with the survey skid test trailers from May, 1968 through November, 1971. Or approximately 26,500 lane miles of our total 70,000 miles of highways are tested each year. Since January 1972 (through April, 1972), the skid resistance of over 10,000 lane miles of pavement have been surveyed in Texas (actually 10,791.3 lane miles) with our trailers.

1972 - First results in from the hydroplaning study 2-8-70-147. Hydroplaning speed not only influenced by tire pressure as reported by NASA but by tread depth, tire width, water depth and surface macro-texture. Skid trailer run in hydroplaning trough and skid numbers of 15 or less found when a marked spindown occurred on the unbraked tire. Also the "hydroplaning trailer" (measuring a percent spindown of the tire-wheel) was run on the pads under simulated rainfall (see Project 2-8-69-138). When the hydroplaning trailer measured 5% spindown, the test unit yawed so much the driver lost control when the unit maneuvered to "dry" pavement at the completion of test. The unit was not damaged but no further tests were attempted. A few weeks prior the skid trailer measured a Skid Number of 14 in the same conditions.

It was found that 10% spindown can occur at speeds as low as 40 mph. Work to continue on other surfaces placed in the hydroplaning trough.

1972 - Fabrication began on the second generation Skid Test Survey Trailers. There will be four duplicate trailers with one for research and three for inventory. A skid resistance performance data system to be developed. Skid trailers to be fully automated to the extent that no values will be hand-written. All will be handled by the computer via teletype paper tape. The automated trailers and skid resistance performance data system to be tied together in a fully automated data collection, storage and retrieval system known as System Skid-R. Stored information is concerned with each individual construction job where the same material, pavement type, etc. was used: Information includes:

<u>Location</u>
District, County, Control-Section, Mile Points
<u>Material</u>
Pavement Type, Coarse Aggregate Type, Gradation, Binder Content, Coarse Aggregate Source, Fine Aggregate Source
<u>Surfacing Information</u>
Date Placed, Date Tested, Average Daily Traffic
<u>Skid History</u>
Past 5 tests plus most recent test, total cumulative traffic at time of each test

1972 - Found and ran preliminary study of four sites to place wet weather speed signs. All four sites in sharp horizontal curves (12, 18, 18 and 18° curves). Found that District (field) had previously noted and treated sites (penetration seal using synthetic aggregate on each). This suggests waiting on accident reports with analysis and printout by computer - too slow to help Districts. Also analysis indicates wet speed should be 35 mph (using SN_{40} and texture for new surface). Advisory signs were previously posted for 35 mph. Sample of both wet and dry speeds indicate 85th percentile about 35 mph (not much difference between wet and dry speeds). Also District placement of penetration seal has apparently reduced accidents (discussions with man living near selected sites). This suggests we need a wider variety of sites (some at higher speed routes) and perhaps effort should be given to a "planned" variety corrective measures other than just speed signing.

1972 - Finished work started in 1970 in developing a "Design Rainfall Intensity" and a method of predicting the "Percent Wet Time" for our highways. The "Design Rainfall Intensity" was found to vary randomly across the State with little variance. Decided to use one "Design Rainfall Intensity" to represent the State. Using

Weather Bureau records, the average 85th percentile intensity was 0.14 inches/hr. - This was selected as the "Design Rainfall Intensity". When report was submitted to FHWA, a local representative heavily involved in our work recommended we do not publish because our work was based on rainfall intensities measured in a one hour time interval. FHWA contact man believes much higher intensities can be found within the hour. We believe he is correct - report not published - continued work to determine if measurements over shorter time length available.

The "Percent Wet Time" was found to vary across the State (say 4% wet time for El Paso to 10% wet time for Beaumont). The "county" (254 in the State) was used as the minimum breakdown. Therefore, the "Percent Wet Time" was found for each county in the State. The "Percent Wet Time" was found to be related to the "Total Annual Rainfall" for the reporting station. So rather than count the number of hours of rainfall for every reporting station, the "Total Annual Rainfall" is used in a predicting equation. The "Total Annual Rainfall" is available through Weather Bureau records for over half the counties in the State (each year) - a contour map is developed from this information.

Using the "Percent Wet Time", wet weather accident rates may be calculated for the State each year. A computer program was developed to calculate the wet weather accident rates for each Control-Section within each county and for each county within each District in the State. Also, those 0.1 mile locations receiving 3 or more wet weather accidents are reported. Also studies indicated heavier traveled highways experience more wet weather accidents (about 1 accident for each 3000 miles of vehicular travel), so critical areas were selected as:

1. Spot Locations - 3 or more wet weather accidents in a 0.1 mile section

2. Longer Lengths - Those Control Sections having more than one wet weather accident for every 3000 vehicular miles of travel.

Since every accident is not associated with wet pavement dangers, a computer program was developed to summarize the details of each individual accident occurrence within each "critical" Control-Section so that District Traffic Engineers may more readily determine the sections needing treatment. The wet weather accident rates (listed along side the total accident rates), a listing of critical areas and the summary of individual accidents per "critical" Control-Section were developed into a package to be distributed to the "field" annually. At present, years 1971, 1972 and 1973 have been issued. It has been found that wet rates can be 10 times the "total" rates with the average being about 4 times greater.

1972 - Studies with the "Circular Track" in Project No. 1-10-69-126 studying aggregate blends in asphaltic concrete completed. Studies indicate vehicular friction is developed from what the tire touches. Aggregates with known British Wheel Polish Values may be blended with the resulting Polish Value to be a direct function of the volumetric proportions of the mix. However, it appears as if the fine aggregate must also be considered. Therefore, if the friction properties of each aggregate type induced into the mix were known, the resulting (polished) friction value would be a function of the volumetric proportions of the mix. An example would be:

35% Synthetic Aggregate (Polish Value = 40) 0.35 x 40	=	14.0
35% Limestone (Polish Value = 25) 0.35 x 25	=	8.8
30% Field Sand (Equivalent Polish Value=30) 0.30 x 30	=	9.0
(Asphalt disregarded)		
RESULTING POLISH VALUE	=	31.8

(We feel a Polish Value = 35 is sufficient for a heavily traveled roadway.)

However, it is not possible to obtain an Equivalent Polish Value for fine aggregate at the present time. (British Wheel Test is for coarse aggregate.) But the big reason for not using the above information is in the dissimilarity in the way the Circular Track polishes specimens and in the way actual traffic polishes a pavement. In other words, the Circular Track ground the specimens smooth (no macro texture) - actual traffic does not. This means (with the slow speed of the British Portable Tester used on the track)the fine aggregate was in contact with the friction tester along with the coarse aggregate and the macro texture was not involved in the BPT values. Therefore, volumetric percentages - and all the aggregate types were shown to be important. For this reason, the above information on aggregate blends was not recommended for use except in an experimental nature. Further experiments with the Circular Track (studies of various fine aggregates) were deleted. However, the studies have developed some interesting ideas:

1. First, we must be close to developing useable information. The Polish Value blends of coarse aggregate are reliable except for the differential wear (of aggregates with high attrition loss - the most skid resistant - compared to the harder aggregates - which generally have low friction) which can be expected under actual traffic conditions.

2. The texture must be accounted for in mix design procedures. Schonfeld's original report on stereo photo interpretation contained mix design suggestions and uses texture parameters to predict skid resistance. It would be possible to use these parameters in mix design.

A tentative asphaltic concrete mix design procedure using Schonfeld's procedure to predict friction was developed. The "A" and "B" parameters - Macro height and width were mutated to be a function of the coarse aggregate "weighted average volumetric" gradation. Parameters "C" and "E" - coarse aggregate shape and micro-texture - were combined by Schonfeld and mutated to be a function of the British Wheel Polish Value. Parameter "D" - the "density" was changed to be a function of the volumetric percent coarse aggregate (+ 10 mesh). Parameter "F" the background micro-texture was changed to be a function of the volumetric fine aggregate gradation.

Coarse aggregate exposure estimated but future work needed to establish if it is a function of asphalt durability, percent asphalt climatic weathering, etc. Differential wear of aggregate blends estimated as a direct function of L.A. wear but future work needed in this area. Fine aggregate exposure estimated but future work is needed to establish exposure and attrition as a function of asphalt percentages and properties. Wear of fine aggregate established as a function of Insoluble Residue test but work needed to verify or disprove.

Work in Portland Cement concrete specimens indicate final texture is about 75% of the initial texture. Project 1-10-69-126 concluded.

1972 - Project 2-10-72-163 "Tire Pavement Friction As a Function of Vehicle Maneuvers" initiated. Idea is to relate the one tire of the skid trailer to the four wheels of an automobile in inclement testing conditions. Three vehicles to be used - a 1963 Ford, a 1971 Ford and a 1971 Volkswagon.

1973 - Area Advisory Committee (Members composed of Districts and Divisions) suggest research overloaded in skid resistance field. Efforts made to reduce number of skid resistance projects.

1974 - Project 2-8-70-147 "Variables Associated with Hydroplaning" completed. Findings similar to those reported above. Equation developed predicting Percent Wheel Spindown as a function of water depth, tire pressure, tread depth, vehicle velocity and pavement texture.

1974 - Project 2-8-70-141 "Quality of Portland Cement Concrete Pavement As Related to Environmental Factors and Handling Practices" completed. A portion of this project studied several different textures (tines, broom, burlap drag and brush) on a CRC pavement in East Texas and a CRC pavement in West Texas. Skid tests with trailer performed under simulated rainfall similar to that done in 2-8-69-138 Project. Again Skid Numbers under even light rainfall with smooth tires and high speeds very low (some in sub-teens). Data included in with 2-8-69-138 data for total analysis. Report 138-7F includes final results. Project 141 personnel recommend changing present texture specifications at time of construction from 0.025 (sandpatch) to 0.070 or more. Many Division personnel believe this too high. Project also found texture wear levels after about 1½ to 2 years with final texture about 3/4 of initial texture regardless of texture type. This means two different CRC pavements in two areas of the State found final texture wear similar to that found on the Circular Track - probably sufficient evidence to use this data.

1974 - Project 2-10-72-163 completed. Researchers found that if maximum stopping deceleration and maximum cornering deceleration are found for a given vehicle,combinations of cornering and stopping deceleration (available tire, vehicle, pavement friction) can be predicted by:

$$\text{Combination Acceleration} = \sqrt{(\text{Stopping a})^2 + (\text{Cornering a})^2}$$

(previously reported by others)

Where: friction = Combination Acceleration (g's)

No two vehicles were exactly the same but worst condition estimates can be made. One interesting fact is that if a geometric event requires cornering-and a stopping event is needed - part of the available stopping friction is used up in cornering.

"Over-steer" and"Under-steer" principles of the vehicles were noted in that the Fords tended to "mush out" of control whereas the VW tended to "spin out" (rear end around). Slick tires revealed much worse conditions but heavier water depths and smaller tire pressures - slightly worse conditions. Results to be recommended for use in geometric design (such as curved off ramps) and in checking for needed maintenance. At present, no direct relationship between the skid trailer and automobile is evident as had been planned.

1974 - Report 135-3 concerning visibility in rainfall submitted. Included in the report was rainfall intensity information of measurements of shorter duration than one hour. Indications are that a one inch per hour intensity should be used for "design".

1974 - Second generation skid test units, and information storage and retrieval system - Skid R completed. Training sessions held for operators (drivers), observers and computer terminal operators. As with the previous trailers, the research unit is maintained by the Research Section in Austin; one inventory unit is housed in Lubbock with the operator from District 5; another unit in Tyler with the operator from District 10 and the third inventory unit in San Antonio with the operator from District 15. There is one or more observer(s) in each District who selects route, handles data, and updates pavement changes via a computer terminal to the central computer in Austin. Data collected on the teletype tape in the skid unit is turned over by the observer to the terminal operator which is in turn fed through the District teletype to the central computer in Austin.

Through means of a common number (CSN), denoting a particular construction job, which is inserted by the observer through thumbwheel switches to the teletype in the test unit, the data as it is received by the computer is associated with historical data which has been stored by that CSN number. The combined data is then sent back to the District terminal and printed in a series of seven reports which (1) print the individual skids; (2) provide a frequency distribution type report for administrative purposes showing the skid resistance condition of all construction jobs in the District and ordering the worst jobs for possible future work; (3) offer summary reports of all highways in a District for design and maintenance District administrative personnel (one by CSN and another by Control-Section-Mile Point); (4) offer summary reports by county for Resident Engineers and Maintenance Foremen and (5) offer two materials reports for District Laboratory Engineers, one which denotes the pavement type, mix type, material type, age and low-average-high SN_{40} values ranked from lowest to highest SN_{40} value. The second report denotes the pavement type, mix or gradation type, material type, binder content, coarse aggregate material source and lists SN_{40} values and total cumulative traffic at the time of skid test. The latter report also lists the previous skid history - total traffic of up to the last 12 skid test periods. Note that every construction job in the District is included in each report; however, only the low-average-high SN_{40} value per CSN is reported in all reports other than Report (1).

As the reports are being sent to the District terminal, the low-average-high SN_{40} value and the total cumulative traffic for the test period in question are stored in the central computer. Summary reports are available from the Austin Design; Maintenance; Materials and Tests; and Planning and Research Divisions by their terminals.

The Texas Highway Department is decentralized and the Districts elect to use or not use System Skid-R. The Districts must place the historical data on file and update the data as the surface changes. Once on file only about 10 to 20% of the surfaces are overlaid (etc.) each year and need to be updated. However, from about May, 1974, to December, 1974, approximately 25,000 miles (72,000 miles in the State) were tested on the new system. Some 21 of the 25 Districts have established all or some portion of historical data on file. Not using the research unit, it is estimated that 3 units can cover the State each year - still leaving 40% down time.

1974 - Only three skid resistance projects established for research. Of these 1&2-10-70-135 (the parent or umbrella project) has been in existence. Projects 1-10-74-204 and 1-9&10-74-216 are new. Area Advisory Committee indicates need for cheaper materials and methods of obtaining skid resistant pavements.

1974 - Project 1-10-74-204 established. Object is to develop energy saving and low cost methods of revising skid resistance on old surfaces. Heater planer; heater scarifier - added asphalt - sprinkle treatment; heating flushed areas then treating with other materials; hydra-brooming and treating areas with ground glass are methods to be attempted.

1974 - Project 1-9&10-74-216 established. Object is to further study the British Wheel Laboratory device in relation to skid trailer but to concentrate on "Polish Rates" rather than final "Polish Value". Attempts will be made to develop methods for utilizing cheaper local materials on medium and light traveled highways by using polish rate information. Some study devoted to seasonal variation in SN_{40} values as pavement polishes.

1974 - With the enforcement of PPM 21-16, an Administrative Order (prepared by Design Division after consulting with FHWA) requiring coarse aggregate surfacing materials used on Federal jobs to meet the following:

MINIMUM POLISH VALUE	PRESENT ADT
None	0-749
30	750-1999
33	2000-4999
35	5000-Over
35	All Interstate Highways

The Research Section prepares a Manual offering "Guidelines for Skidding Accident Reduction" including:

1. Suggestions in performing a Skid Resistance Inventory.
2. A Systematic Procedure for Identifying and Correcting Hazardous Skid Prone Locations.
3. Design, Construction and Maintenance Practices to Assure Adequate Skid Resistance.

4. Provisions for Preparing an Annual Report.

Maintenance Division prepares a package of Safety Guidelines which includes Skidding Accident Reduction features suggested in the manual above.

Future - Believe study should be given to cornering friction and incipient braking which should rightfully be studied together. Anti-lock brake devices are a thing of the near future. We have very little feel as to whether a SN_{40} value predicts either the maximum longitudinal friction or maximum cornering friction. Basically we do not know which pavement properties are the most effective for the slipping tire condition.

Future - Studies to Predict Future Critical Accident Locations. It is not sufficient to continually improve accident locations as dictated by number and severity of past accidents. Numbers of accidents are closely associated to amount of traffic and highway capacity. Most of our accident problem stems from highways designed for a 20 year life that are 35 to 40 years old. The original designs are outdated due to the rapid advancement of the vehicle manufacturing industry. Using present information and predictions of future traffic, estimates could be made of future critical areas of the older highways. Information developed from this study could be used by District Personnel for planning such as Rights-of-Way Acquisition, etc. before actual need arises.