TEXAS TRANSPORTATION INSTITUTE

TEXAS HIGHWAY DEPARTMENT

COOPERATIVE RESEARCH

Hydroplaning

in cooperation with the
U. S. Department of Transportation
Federal Highway Administration
Bureau of Public Roads

BIBLIOGRAPHY 191

SURVEY OF LIBRARY FACILITIES PROJECT

HYDROPLANING

1. PAVEMENT GROOVING AND TRACTION STUDIES. National Aeronautics and Space Administration, NASA SP-5073, 1969. 521 pp. Available: Clearinghouse for Fed. Sci, and Tech. Info. (Springfield, Va. 22151). $3.00. HR Abstracts, Aug 1969.

   In 1965 a comprehensive research program on the effectiveness of runway grooving as a means for increasing tire traction under operational conditions was undertaken by NASA. The program involved many elements, such as construction of a research runway, selection of test pavements, groove patterns and grooving test aircraft, and data acquisition. On November 18 and 19, 1968, at the Langley Research Center, a conference was held to provide an opportunity for opinions. The 27 papers in this publicatinn represent the results of this conference. Included are papers on highway traction studies and results from studies of highway grooving and texturing conducted at the NASA Wallops Island Station and by several state highway departments.

2. Gengenbach, W. EXPERIMENTAL INVESTIGATION INTO THE AQUAPLANING OF TIRES ON WET ROADS. Automobil-Industrie (Vogel Verlag, 7 Max Planck Strasse, Wuerzburg, Germany), Vol. 12, No. 4, pp. 74-79, 1967. (In German) MIRA Automobile Abstracts, 68/1/6, p. 6, Jan. 1968. HR Abstracts, June 1968.

   Experiments were carried out to determine the parameters affecting aquaplaning and particularly, the influence of water-film depth. The limiting speed for aquaplaning of a tire was determined by varying the water-film depth, not the drum speed. Experimental results presented for the aquaplaning of smooth cross-ply and radial tires show the limiting speed as a function of water-film depth at various inflation pressures and loads and the lift coefficient as a function of degree of loading. The limiting speed decreases with increasing water-film depth. The load on the tire at the moment of aquaplaning may be calculated from the water pressure in front of the tire. Experiments with a cross-ply tire showed that a greater water-film depth is required to initiate aquaplaning at 4 or 6-deg side-slip angle than at 0 or 2 deg. The c_H values, which are characteristic for aquaplaning, were experimentally determined for standard tires of varying tread pattern and for six tires with simple geometric groove patterns only. It was found that c_H values for tires with a predominantly longitudinal pattern were about half, and values for those with a predominantly transverse pattern about a quarter of, those for smooth tires.

3. Pasquet, A. and Berthier, J. SOME FACTS ABOUT WATER, ROADS AND PNEUMATIC TIRES. Bulletin de Liaison des Laboratoires Routiers: Ponts et Chaussees (58, Boulevard Lefebvre, Paris 15eme, France), No. 26, p. 1-1 to 1-24, July/Aug. 1967 (In French). HR Abstracts, January 1968.

   The author discusses the main phenomena which affect the resistance to slipping of tires: influence of speed, grip and viscoelastic losses, presence of water on the pavements and its expulsion from the point of contact. Standards for the construction of pavements are suggested. The role of water on the pavement and tire in relation to slipping resistance is discussed. The laws of friction between dry surfaces are examined and the modifications of these laws by a film of water are introduced. Reasons for the reduction in slipping resistance are analyzed and the effect of the thickness of the water film as a factor in hydroplaning is considered.

4. Sabey, Barbara E. and Lupton, G. N. PHOTOGRAPHY OF THE REAL CONTACT AREA OF TIRES DURING MOTION. Great Britain Road Research Laboratory, RRL Report LR64. 1967. 18 pp. (Available from British Information Center, 845 Third Ave., New York, N.Y. 10022). HR Abstracts, January 1968.

This report describes a new technique of photographing the contact patch of a tire on a moving vehicle by means of an optical system which enables the real area of contact on either a dry or wet glass surface to be ascertained. The vehicle tire runs over a glass plate let into the surface of the Road Research Laboratory's test tract. By using a prism arrangement below the plate and photographing from beneath at angles greater than the "critical" angle for glass to water or glass to air interface, a clearly defined area of contact can be obtained. A sheet of perspex is used to protect the glass surface from scratches curing test. Preliminary tests with normal running tires have established the test procedure necessary to obtain clear and precise photographs at speeds up to 45 mph. Measurements of the records obtained show substantial reduction in contact length with increased speed.

5. Horne, Walter B. TIRE HYDROPLANING AND ITS EFFECTS ON TIRE TRACTION. NASA Langley Research Center. Langley Station, Hampton, Va. Highway Research Board Record No. 214. pp. 24-33.

This paper first discusses the buildup of fluid pressures in the tireground footprint region of wet pavements that can lead to three distinct types of traction loss; namely, dynamic hydroplaning, viscous hydroplaning or thin-film lubrication, and the reverted rubber skid. The paper then discusses how pavement surface texture, pavement water depth, tire tread design, vertical load, and tire inflation pressure affect fluid pressure buildup in the footprint. Finally, two promising methods for alleviating fluid pressure buildup are discussed. These methods are pavement grooving and air jets placed in front of tires.

6. Harris, A. J. ROAD SURFACE TEXTURE AND THE SLIPPERINESS OF WET ROADS. Ministry of Transport, British Road Research Laboratory. Highway Research Board Record No. 214. pp. 18-23.

The texture required of a road surface, so that it shall be as resistant to skidding as possible, is harsh for low speeds and harsh and large-scale for high speeds. The function of the texture is to assist drainage of the water to achieve dry contact as quickly as possible and maximum deformation of the tire tread surface by the asperities of the road surface. This is achieved by easy (large) flow channels and by sharp (harsh) asperities generating high pressure. These conclusions are illustrated in an examination of how the skidding resistance of actual surfaces varies with speed, and how rubber hysteresis increases friction. Aquaplaning is also considered. How suitable textures are being obtained in the United Kingdom and the researches relevant to this subject being planned or in progress at the Road Research Laboratory are discussed.

7. Horne, Walter B. PHENOMENA OF PNEUMATIC TIRE HYDROPLANING. U.S. National Aeronautics and Space Administration, Washington, D. C., Technical Note TN D-2056, Nov. 1963, 52 p. (Available from Office of Technical Services, Washington, D. C., $1.50).

When runway or road surfaces become flooded or puddled with either slush or water, both aircraft and ground vehicles such as automobiles can at some critical ground speed encounter the phenomenon of tire hydroplaning. The effects of hydroplaning can be serious to these vehicles since tires under hydroplaning conditions become detached from the pavement surface and the ability of tires to develop braking or cornering traction or guiding vehicle motion is almost completely lost. Tire hydroplaning was first noticed and demonstrated experimentally about 1957 during a tire treadmill study.

Recent research on pneumatic tire hydroplaning has been collected and summarized with the aim of describing what is presently known about the phenomena of tire hydroplaning. A physical description of tire hydroplaning is given along with formulae for estimating the ground speed at which it occurs. Eight manifestitations of tire hydroplaning which have been experimentally observed are presented and discussed. These manifestitations are: detachment of tire footprint, hydrodynamic ground pressure, spindown of wheel, suppression of tire bow wave, scouring action of escaping fluid in tire-ground footprint directional stability. The vehicle, pavement, tire and fluid parameters of importance of tire hydroplaning are listed and described. Finally the hazards of tire hydroplaning to ground and air-vehicle ground performance are listed, the procedures are given to minimize these effects.

A simple expression giving a good approximation for the speed at which hydroplaning takes place was reported as $V_p + \_0.35 \sqrt{p}$, where V_p is the velocity above which hydroplaning will take place in miles per hour and p is the tire pressure in pounds per sq, inch. From this it may be seen that an automobile with a tire pressure of less than 25 pounds per sq, inch will hydroplane at less than 50 miles per hour, whereas a truck or bus with 80 lbs tire pressure will be safe at over 90 miles per hour as far as hydroplaning is concerned.

8. Huber, E. W. COMPARATIVE TESTING OF VARIOUS TYPES OF ASYMMETRICAL AND SYMMETRICAL SPIKED WINTER TYRES. Automobiltechnische Zeitschrift (Franchk' she Verlagshandlung Pfizerstrasse 5, Stuttgart 0, Germany), Vol. 68, No. 7, pp. 235-238, July 1966. (In German). MIRA Monthly Summary, 66/9/18, p. 11, Sept 1966. HR Abstracts, May 1967.

Pneumatic tire hydroplaning is described, and related research and facilities are reviewed. Included are results from studies of conditions in a wet tire footprint area, a discussion of the influence of significant variables, and some effects of tire hydroplaning on vehicle performance. It is shown that present tire tread design techniques and pavement surface treatment can substantially alleviate hydroplaning effects on pneumatic tires over most vehicle operating speed ranges when the pavement is wet or slightly flooded. The results also show that when pavements are deeply flooded, neither the best tire tread desig nor the best pavement surface treatment can prevent hydroplaning at the critical hydroplaning speed; however, the use of air jets to remove fluid from the pavement in front of the tire shows promise as a means of alleviating hydroplaning under this condition.

9. Hofferberth, W. BEHAVIOR OF PNEUMATIC TIRES ON WET ROADS. ATZ-Automobiltechnische Zeitung (Franchk'sche Verlagschandlung, Pfizerstrasse 5, Stuttgart, Germany, Vol. 67, No. 9, pp. 314-320, Sept. 1965. (In German) MIRA, p. 7, Nov. 1965. HR Abstracts, September 1966.

Tire adhesion on dry roads and wet roads and the effects of tire-tread composition are examined. There is great difficulty in defining a wet road; questions of thickness of water film effects of road dirt, oil, etc., and of how long rain has been falling must be considered. A normal wet road is considered to involve surface water approximately tenths of a millimeter deep. Very heavy rain may produce a depth of 1.5mm or more and deep puddles. Tread mixtures of SBR or variants of SBR have good adhesion or normal wet roads at temperatures of 0 to +20 C without the drawbacks of butyl mixtures. With surface water more than 1.5 mm deep, aquaplaning occurs above a certain critical speed: adhesion is lost, causing difficulties in braking and steering. In America, similar trouble has occurred on aircraft runways.

10. Sawyer, Richard H. and Kolnick, Joseph J. TIRE-TO-SURFACE FRICTION-COEFFICIENT MEASUREMENTS WITH AC-123B AIRPLANE ON VARIOUS RUNWAY SURFACES. U. S. National Aeronautics and Space Administration, Washington, D.C., Technical Report R-20, 1959.

An investigation was conducted to obtain information on the tire-to-surface friction coefficients available in aircraft braking during the landing run. The tests were made with a C-123B airplane on both wet and dry concrete and bituminous pavements and on snow-covered and ice surfaces at speeds from 12 to 115 knots. Measurements were made of the maximum (incipient skidding) friction coefficient, the full-skidding (locked wheel) friction coefficient, and the wheel skip ratio during braking.

The mean value of the maximum friction coefficient on both dry portland-cement concrete and dry bituminous pavements was about 0.8, with no effect of speed or load evident over the ranges investigated. For snow-covered surfaces, the mean value of maximum friction coefficient varied from 0.25 to 0.37; the lower values were apparently associated with icy subsurfaces under the snow and the higher values with bare pavement subsurfaces. Over the ranges of the investigation, no effects of speed or surface temperature (3° F to 32°F) on the maximum friction coefficient were evident. On an ice surface, the mean value of the maximum friction coefficient was 0.18 at surface temperatures of both 19°F and 32°F, with no apparent dependence on speed. For wet portland-cement concrete and bituminous pavement surfaces, values of maximum friction coefficient varied from 0.04 to more than 0.80. The variations in maximum friction coefficient were believed to be associated primarily with variations in depths of water along the runway. The extemmely low values were ascribed to planing of the tire on a film of water.

Full-skid (that is, locked wheel) friction coefficients on the dry, snow-covered, and ice surfaces were found to decrease with decrease in speed as the skid progressed, reaching values between about 0.1 and 0.2. On the wet surfaces the full-skid friction coefficient was near zero at the higher speeds and increased to about 0.3 as the skid progressed to lower speeds.

11. Sawyer, Richard H., Batterson, Sidney A. and Harrin, Eziaslav N. TIRE-TO-SURFACE FRICTION ESPECIALLY UNDER WET CONDITION. U.S. National Aeronautics and Space Administration, Washington, D. C., NASA Memo 2-23-59L, March 1959.

The results of measurements of the maximum friction available in braking on various runway surfaces under various oonditions is shown for a C-123B airplane and comparisons of measurements with a tire-friction chart on the same runways are made. The results of studies of wet-surfcce friction made with a 12-inch-diameter low-pressure tire on a tire-friction treadmill, with an automobile tire on the tire-friction cart, and with a 44 x 13 extra-high-pressure type VII aircraft tire at the Langley landing-loads track are compared. Preliminary results of tests on the tire-friction treadmill under wet-surface conditions to determine the effect of the wiping action of the front wheel of a tandem-wheel arrangement on the friction available in braking for the rear wheel are gieen.

12. Horne, Walter B., Joyner, Upshur T. and Leland, Trafford J. W. STUDIES OF THE RETARDATION FORCE DEVELOPED ON AN AIRCRAFT TIRE ROLLING IN SLUSH OR WATER. U.S. National Aeronautics and Space Administration, Washington D. C., Technical Note D-552, September 1960.

A series of unbraked (freely rolling) taxi tests were conducted at the Langley landing-loads track with a 32 x 8.8, type VII, 22-ply-rating ribbed-tread aircraft tire to obtain data on tire retardation forces developed during rolling in both slush and water. The forward speeds of the tests ranged from 59 to 104 knots. Tire inflation pressures of 350 and 115 pounds per square inch were used.

Results indicated a parabolic increase of retardation force with increasing forward velocity for both slush- and water-covered runway surfaces. The retardation force was found to increase approximately linearly with increasing water depth. Drag coefficients appropriate to the equations used are presented. Calculations made to determine the effect of slush on the take-off distance of a jet transport are in agreement with data obtained from an actual take-off in slush for this airplane.

This is an interim report which deals with the effect of slush on the acceleration and the ground-run distance of airplanes during take-off.

13. Horne, Walter B. and Leland, Trafford J. W. INFLUENCE OF TIRE TREAD PATTERN AND RUNWAY SURFACE CONDITION ON BRAKING FRICTION AND ROLLING RESISTANCE OF A MODERN AIRCRAFT TIRE. U.S. National Aeronautics and Space Administration. Washington, D.C., Technical Note D-1376, September 1962.

A series of taxiing tests was conducted at the Langley landing-loads track with both braked and unbraked (freely rolling) single and tandem wheels equipped with 32 x 8.8 type VII aircraft tires of different tread designs to obtain data on tire and braking characteristics during operation on dry and on contaminated concrete and asphalt runways. Contaminants used were water, slush, JP-4 jet fuel, and organic and detergent fire-extinguishing foams. Forward velocities for the tests ranged from approximately 13 to 104 knots. Vertical loads of approximately 9,000 to 22,000 pounds and tire inflatinn pressures of 85 to 350 pounds per square inch were used.

Results indicated that the unbraked tire rolling resistance increased with increasing forward velocity on dry and on contaminated runway surfaces. Peak tire-ground friction coefficients developed during wheel braking decreased

rapidly with increasing velocity on contaminated runways but remained relatively unchanged on dry runways as the forward velocity was increased. Dry-runway friction coefficients were found to be relatively insensitive to tire tread pattern. However, the magnitude of the friction coefficients developed by tires on contaminated runways was extremely sensitive to the tire tread pattern used, with circumferential-groove treads developing the highest values of friction coefficient, and smooth and dimple treads the lowest values for the tread patterns and runway conditions investigated.

.4. Batterson, Sidney A. BRAKING AND LANDING TESTS ON SOME NEW TYPES OF AIRPLANE LANDING MATS AND MEMBRANES. U.S. National Aeronautics and Space Administration, Washington, D.C., Technical Note D-154 , October 1959.

An experimental investigation was made at the Langley landing-loads track to obtain friction coefficients developed during braking and landing on various types of metal landing mats and prefabricated membranes. The tests were made at forward speeds of about 85 knots with static vertical loads of 20,405 and 13,020 pounds. The results indicated the effect of each type of mat and membrane on the variation of the coefficient of friction. Braking tests were made for both dry and wet surface conditions.

.5. Hall, Albert W., Sawyer, Richard H. and McKay, James M. STUDY OF GROUND-REACTION FORCES MEASURED DURING LANDING IMPACTS OF A LARGE AIRPLANE. National Advisory Committee for Aeronautics, Washington, D.C., Technical Note 4247, May 1958.

Some results are presented of tests conducted on a large bomber-type airplane to determine the ground-reaction forces imposed on the main landing gear under actual landing conditions. The data were obtained from 30 landings made at vertical velocities up to 8.4 feet per second and at forward ground speeds from 81.0 to 119.5 knots on both wet and dry concrete runways.

The vertical force on the landing gear truck at which the oleopneumatic shock strut began to compress varied over a wide range. There appeared to be no relation between this breakout force and any other force or condition of the impact

The computed variation of maximum vertical force with vertical velocity agreed reasonably well with the experimental results.

Frequently there was an unequal division of the vertical force on the two wheels of a truck, which resulted in unsymmetrical drag forces particularly during the time when one wheel had spun up and the other was still in the process of spinning up.

The mean value of coefficient of friction for the dry runway varied from 0.40 at the beginning of spin-up to a maximum value of 0.72 at a slip ratio of 0.13. The mean value of coefficient of friction for the wet runway varied from 0.20 at the beginning of spin-up to a maximum value of 0.41 at a slip ratio of 0.07.

In the low vertical-force range, the side force varied with drift angle and vertical force. At high vertical forces, side force varied primarily with drift angle and further increase of vertical force had little effect on side force at a given drift angle.

6. Harrin, Eziaslav N. INVESTIGATION OF TANDEM-WHEEL AND AIR-JET ARRANGEMENTS FOR IMPROVING BRAKING FRICTION ON WET SURFACES. U.S. National Aeronautics and Space Administration, Washington, D.C., Technical Note D-405, June 1960.

In an attempt to improve tire braking characteristics on wet surfaces at high speeds, preliminary tests were made on a tire treadmill to determine the effectiveness of two methods of clearing away water ahead of a braking wheel. One method consisted of mounting a free-rolling or idling wheel ahead of a braking wheel, and the other method consisted of directing an air jet on the water-covered surface ahead of a braking wheel. Tests were made with smooth and diamond-treaded 3.00 x 7 tires (about 12 inches in diameter) on the braking wheel and a smooth 3.00 x 7 tire on the idling wheel. In the blowing tests, two nozzles having different diameters were used with air-jet pressures up to about 100 pounds per square inch. Measurements of tire friction coefficients were made with 0.09 inch of water on the belt of the treadmill over a range of speeds from 26 to 93 feet per second.

17. Horne, Walter B., Smiley, Robert F. and Stephenson, Bertrand H. LOW-SPEED YAWED-ROLLING CHARACTERISTICS AND OTHER ELASTIC PROPERTIES OF A PAIR OF 26-INCH-DIAMETER, 12-PLY-RATING, TYPE VII AIRCRAFT TIRES. National Advisory Committee for Aeronautics, Washington, D.C., Technical Note 3604,,May 1956.

The low-speed (up to 2 miles per hour) cornering characteristics to two 26 x 6.6, type VII, 12-ply-rating tires under straight-yawed rolling were determined over a range of inflation pressures and yaw angles for two vertical loads, one load approximately equal to the rated vertical load for these tires. The cornering characteristics of one tire rolling along circular paths of different radii were investigated for one condition of vertical load and inflacion pressure. Static tests were also performed to determine the vertical, lateral, torsional and fore-and-aft elastic characteristics of the tires. Several vibration tests were also performed to determine the dynamic lateral elastic characteristics of the tires. The quantities measured included lateral or cornering force, drag force, torsional moment or self-alining torque, pneumatic caster, vertical tire deflection, lateral tire deflection, wheel torsion or yaw angle, rolling radius, and relaxation length. Some supplementary tests which included measurements of tire footprint area and the variation of unloaded tire radius with inflation pressure were made.

During straight-yawed rolling the normal force generally increased with increasing yaw angle within the test range. The variation of normal force with yaw angle was considerably different for the two vertical loads tested. The pneumatic caster was at a maximum at small yaw angles and tended to decrease in value with increasing yaw angle. The sliding-drag coefficient of friction tended to decrease in magnitude with increasing bearing pressure. The coefficient of turning for turning radii of approximately 5, 10, and 15 feet was found to be between 3×10^{-6} and 4×10^{-6} lb^{-1}-in.$^{-2}$ at a vertical load of 9,000 pounds and a tire inflation pressure of 134 pounds per square inch.

18. Gray, W. E. AQUAPLANING ON RUNWAY. Royal Aeronautical Soc--Jl. 67: 629, May 1963, p. 302-04.

Reference is made to NASA experiment investigating landing in very heavy rain which renders wheel brakes ineffective due to layer of water on runways; British experiments indicate that high localized pressure at front of footprint delays penetration of water under tire, and also permits it to penetrate all way back once it has passed that barrier; water is unable to escape sideways owing to higher contact pressures along sides of footprint arising from wall stiffness--unless there are traverse grooves in tire or runway to let it out; critical discussion of NASA experimental results.

19. Willis, J. M. N. EFFECTS OF WATER AND ICE ON LANDING. Shell Aviation News: 296 1963, p. 16-20.

Experimental results obtained at Royal Aircraft Establishment with measurements of braking coefficient on wet surfaces; effect of water depth; aquaplaning and its occurrence; summary of trends observed due to presence of water slush, ice and snow; possible future investigation.

20. Horne, W. B. and Leland, T. J. RUNWAY SLIPPERINESS AND SLUSH. Royal Aeronautical Soc--Jl 67:633, Sept 1963 p. 559-71.

When runway surfaces become contaminated with fluid on fluid-like substances such as water, slush, oil, foam, mud, etc., following operatiog problems arise--loss in braking traction, in ground directional stability, and in take-off performance; United States' research efforts made, equipment used and results of some tests, roles played by various aircraft, tire, fluid, and runway surface parameters in contributing to or alleviating fluid forces developed on aircraft; fluid displacement life and six types of tire hydroplaning; runway slipperiness effects on braking wheel. 25 references.

21. HYDROPLANING IS HOW TO BUILD A 3500-POUND WATER SKI. The Air Force Driver, Vol. 2, April 1969, p. 1-4.

A non-technical article aimed at the members of the U.S. Air Force to encourage them to exert care while driving personal and military vehicles on wet pavements. Explains cause of hydroplaning and suggests the use of radial belted bias-ply tires as a possible solution to the problem. Indicates that worst location or the spot at which hydroplaning may occur is on cruves where there are puddles or standing water. Reviews briefly the work done by NASA at Langley Research Center.

22. Boness, R. J. THEORETICAL TREATMENT OF AQUAPLANING TIRES. Automobile Engineer 58: June 1968, p. 260-4.

Although considerable experimental evidence is available, no theoretical treatment of mechanism of hydroplaning exists; paper attempts to develop formula for calculations of thickness of water film under tire and to compare these theoretical predictions with existing experimental evidence; numerical procedure. 10 refs.

23. Horne, W. B., Yager, T. J. and Taylor, G. R. RECENT RESEARCH ON WAYS TO IMPROVE TIRE TRACTION ON WATER, SLUSH, OR ICE. Ingeniew 78: Sept 30, 1966, p. 139-50.

Three main factors that cause almost complete loss of tire traction on wet runways are discussed, namely, dynamic hydroplaning, viscous hydroplaning, and tire tread rubber reversion; how pavement surface texture, runway water depth, tire tread design, vertical tire land, and tire inflation interact with these factors; method for measuring average texture depth of runway surface is given which shows promise as means of classifying runway surfaces as to their slipperiness when wet; test of two promising methods for increasing tire traction on wet runways; i.e. air jets placed in front of tires and pavement grooving are described; 23 refs.

HIGHWAY RESEARCH IN PROGRESS

1. FRICTIONAL CHARACTERISTICS OF VEHICLE HYDROPLANING. Cornell Aeronautical Laboratory, Bureau of Public Roads, Traffic Systems. Est Compl: Feb. 1968.

An improved mathematical analysis is being developed which quantitatively predicts the actions that occur when a highway tire rolls or slides on a pavement surface which is covered with a water film such that all or part of the normal force is supported by hydrodynamic pressures.

2. A PILOT STUDY TO DETERMINE THE DEGREE OF INFLUENCE OF VARIOUS FACTORS PERTAINING TO THE VEHICLE AND THE PAVEMENT ON TRAFFIC ACCIDENTS UNDER WET CONDITIONS. Texas Highway Department, Bureau of Public Roads. Active.

The pilot study involves a detailed investigation of wet pavement accidents. Additional data include detailed measurements of vehicle and pavement factors which are thought to contribute to skidding or hydroplaning. Analysis will include a correlation of factors to determine what patterns or trends exist.

3. Tomita, H. SKID RESISTANT AIRFIELD PAVEMENTS. Naval Civil Engineering Laboratory, Port Hueneme. Est Compl: June 1970.

Methods are developed to make new and existing airfield pavements resistant to skidding of aircraft on wet or dry surfaces. The scope and method include: (1) Theoretical considerations involved in hydroplaning of aircraft tires on pavement surfaces, (2) Laboratory studies of the effects of pavement materials, mix designs and various finish textures on surface drainage ability and skid resistance, (3) Investigation of field methods and procedures for treating existing surfaces by various means and the proper steps involved during construction, overlaying or seal coating pavements to obtain skid resistant surfaces, and (4) Investigation of field methods for standardizing the evaluation of the skid resistance of naval airfield pavement surfaces.

Reports issued:

Friction Coefficients Between Tires and Pavement Surfaces, U.S. NCEL Technical Report TR-303, June 1964.

4. Mullen, W. G. SKID RESISTANCE AND WEAR PROPERTIES OF AGGREGATES FOR PAVING MIXTURES. North Carolina State University, Bureau of Public Roads. Est Compl: 1971.

Individual aggregates and mixtures are being tested in the laboratory as to their resistance to wear, polishing, skidding and hydroplaning so as to determine the most skid resistance combinations for use of North Carolina highways. Maximum emphasis is given to the use of materials native to the states.