UM-HSRI-77-5

NOISE AND TRACTION CHARACTERISTICS OF RADIAL-PLY TRUCK TIRES

Final Technical Report

Contract No. DOT-OST-60157

Robert D. Ervin

January, 1977

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Ann Arbor, Michigan 48109

THE UNIVERSITY OF MICHIGAN

April 19, 1977

Mr. William Leasure
Contract Technical Manager
U. S. Department of Transportation
Office of Noise Abatement
5222 Trans Point Building
2100 Second Street, S.W.
Washington, D.C. 20590

Dear Mr. Leasure:

Enclosed please find the originals and twenty-five (25) copies of the revised and final draft of the final report on Contract DOT-OST-60157 entitled "Noise and Traction Characteristics of Radial-Ply Truck Tires." If you have any questions concerning this corrected draft, please call me.

Sincerely yours,

Robert D. Ervin
Project Director

jn
Encls.

xc: B. Humphrey
R. Hess
W. McCormick

Technical Report Documentation Page

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16. Abstract

This project has established a data base of noise and traction characteristics for a sample of six radial-ply heavy truck tires. The tire sample, representing both "rib" and "lug" type tread patterns, was tested according to procedures similar to those specified in Society of Automotive Engineers Recommended Practice J57, Sound Level of Highway Truck Tires and in a variety of laboratory and over-the-road traction experiments. Measurements of cornering stiffness and both lateral and longitudinal traction limits indicate that, unlike bias-ply heavy truck tires, radial-ply truck tires cannot be generally classified into distinct performance categories according to tread type. Further, the radial-ply lug tire is found to exhibit a smaller increment in noise level over the radial rib than is seen for bias-ply lug and bias-ply rib tires. These data complement comparable data in the open literature for bias-ply tires.

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TABLE OF CONTENTS

1. INTRODUCTION. 1

2. RESEARCH METHODOLOGY. 3

2.1 Tire Sample 3

2.2 Noise Level Measurements. 6

2.3 Traction Measurements 6

3. RESULTS 11

3.1 Noise Test Results. 11

3.2 Flat-Bed Results. 11

3.3 Mobile Traction Results - Longitudinal. 14

3.4 Mobile Traction Results - Lateral 19

4. CONCLUDING REMARKS. 27

REFERENCES. 29

APPENDIX A - METHODS AND RESULTS OF PASS-BY NOISE LEVEL MEASUREMENT PROGRAM. 31

APPENDIX B - INDIVIDUAL LATERAL FORCE PLOTS FROM MOBILE TRACTION TESTS. 37

1.0 INTRODUCTION

This document reports on an experimental program conducted by the Highway Safety Research Institute (HSRI) of The University of Michigan under Contract Number DOT-OST-60157 from the Office of Noise Abatement of the U. S. Department of Transportation. The project had as its primary objective the gathering of data descriptive of the noise and traction characteristics of lug- and rib-type truck tires of radial-ply construction. The terms "lug" and "rib" are meant to denote two basic tread configurations which differ in the orientations of the major elements in the tread pattern. The "lug"-type tread is one in which the major elements in the tread pattern are oriented in the transverse direction and are separated from one another by significant transverse grooves. The "rib"-type tread is characterized by tread elements oriented primarily in the circumferential direction and which are separated from one another by circumferential grooves.

Lug- and rib-type truck tires have been shown to contrast markedly in their noise generating properties while in the freely rolling state [1]. The study reported herein, while reconfirming that radial "lugs" are significantly noisier than radial "ribs," endeavored to further compare these two tire types in terms of their highway traction qualities. The project is thus seen as complementing a similar study [2] conducted using a sample of bias-ply heavy truck tires.

It should be noted that the restriction of this examination to noise and traction properties in no way presupposes a priority of these two topics in the evaluation of tire quality. Rather, the study reflects the fact that truck tire traction data are exceedingly scarce and are needed, in accompaniment with noise data, to factor vehicle safety considerations into the tire noise controversy.

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2.0 RESEARCH METHODOLOGY

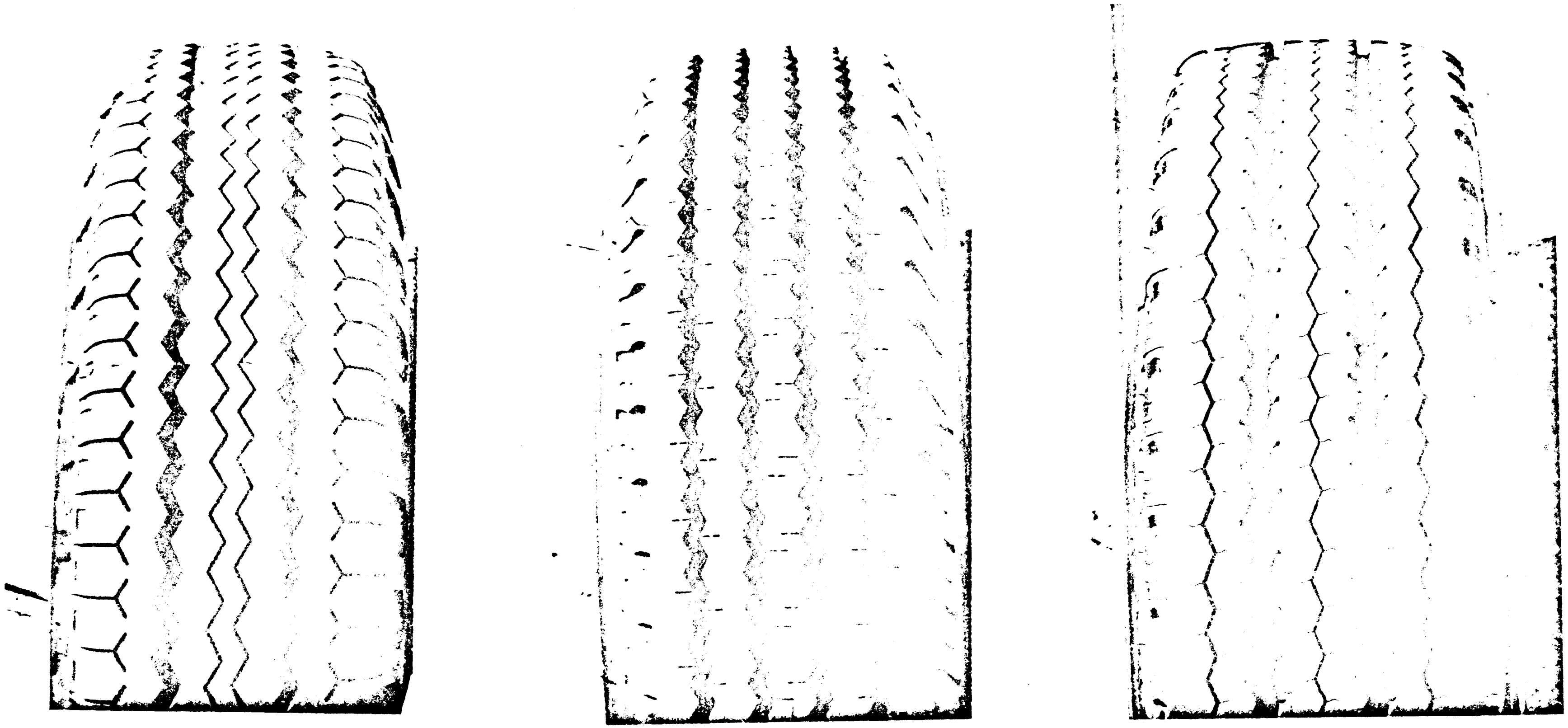
The methodologies employed in this study addressed the characterization of two diverse aspects of tire behavior. Measurements were conducted to describe both the noise and traction performance qualities of a sample of six truck tires, under conditions which were seen as relevant to the respective noise and traction interests arising from environmental and safety issues. With regard to noise generation, measurements were made according to procedures similar to those specified in Society of Automotive Engineers Recommended Practice J57, Sound Level of Highway Truck Tires. Traction measurements were conducted according to procedures developed at HSRI, since a standardized methodology has yet to be established.

2.1 Tire Sample

Six radial-ply heavy truck tires, identified below, were selected as test tires for the noise and traction experiments. All tires were size 10.00 x 20/G, where the "G" designation indicates a Tire and Rim Association (T&RA) rated load (for a single application) of 6040 lbs at a cold inflation pressure of 105 psi. The test sample, as illustrated in Figures 1a and 1b, contains three tires with "circumferential rib"-type tread patterns and three tires configured with tread patterns of either the "cross lug" or "aggressive rib" varieties.

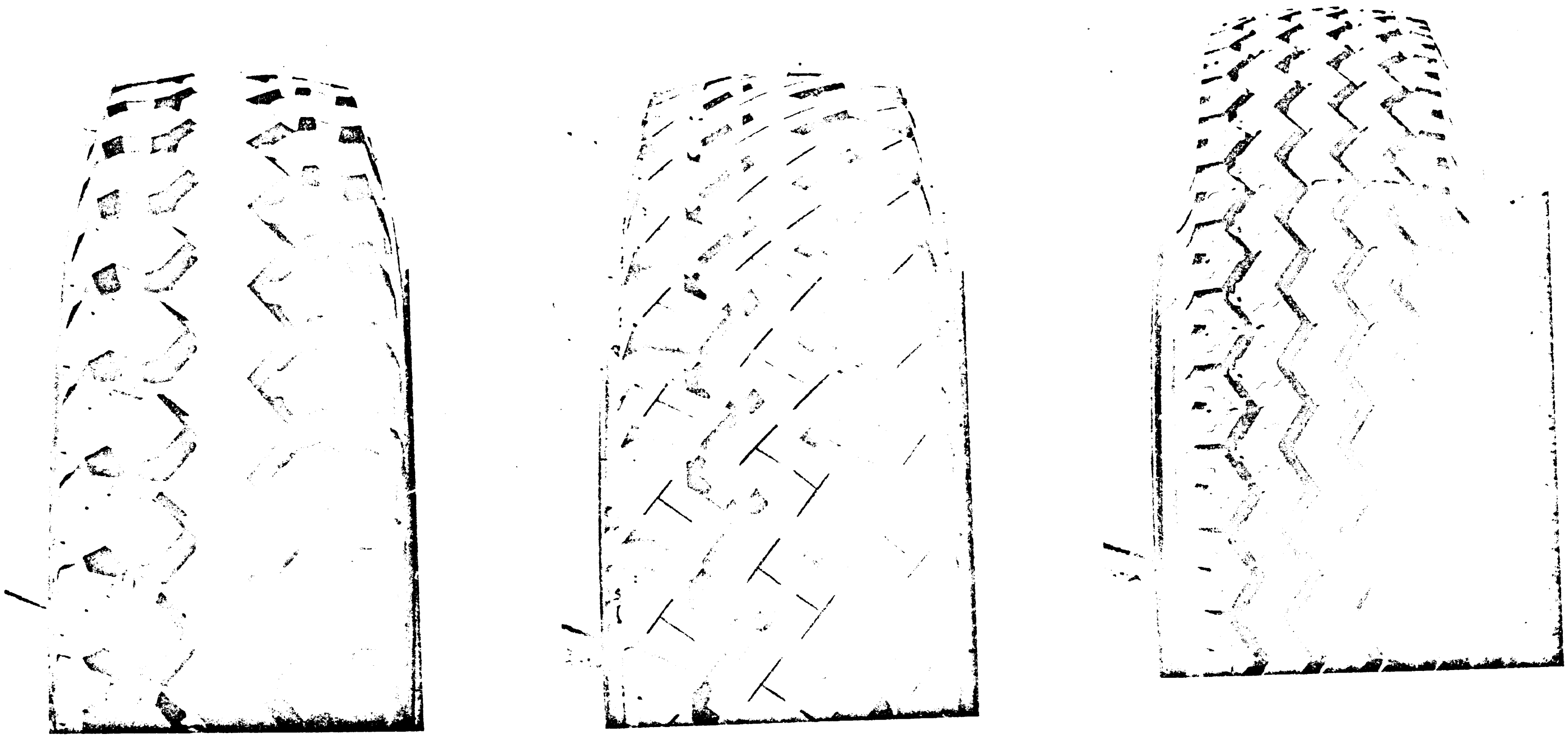
Sample of Radial-Ply Tires

Firestone Transteel Goodyear Unisteel R-1 Michelin XZA	Rib Tread
Firestone Transteel Traction Goodyear Unisteel L-1	Lug Tread
Michelin XZZ	Aggressive Rib



Firestone Transteel   Goodyear Unisteel R-1   Michelin XZA

Figure 1a. Photos of rib-type tread patterns represented in the tire sample.



Firestone Transteel Traction

Goodyear Unisteel L-1

Michelin XZZ

Figure 1b. Photos of lug-type and aggressive-type tread patterns represented in the tire sample.

Five specimens of each tire were procured directly from the respective manufacturers in common production lot sets.

2.2 Noise Level Measurements

Noise level measurements were conducted by the National Bureau of Standards at the facilities of the Dana Automotive Test Center in Ottawa Lake, Michigan. The noise level measurements were made according to procedures similar to those specified in SAE J57, Sound Level of Highway Truck Tires.

The basic procedure requires the installation of the test tires on the rear axle of a loaded, two-axle truck. The front axle of the vehicle is outfitted for these tests with a so-called "quiet" tire. The vehicle is coasted by the noise measurement instrumentation at a speed of 50 mph, while a measurement of the maximum A-weighted noise level is made.

Only fully treaded (new) tire samples were subjected to the matrix of coast-by measurements in this study. Noise tests were conducted first, following which the four tire specimens were utilized in the various traction experiments.

2.3 Traction Measurements

Traction measurements were made on each of the six sample tires using three different test devices. The first machine, the HSRI Flat-Bed Tester, is a low-speed laboratory dynamometer which was used to obtain precision measurements of the "cornering stiffness" parameter (C_α), defined as the slope of the side force (F_y) versus slip angle (α) relationship through the origin, viz.,

$$C_\alpha = \left.\frac{\partial F_y}{\partial \alpha}\right|_{\alpha=0}$$

In addition to measuring C_α, a tire property bearing on the directional response of trucks in normal driving maneuvers, other traction tests were conducted to characterize tire properties relevant to emergency braking and steering maneuvers. These other tests involved the use of two mobile traction dynamometers which were developed at HSRI. One machine measures a tire's longitudinal force (F_x) response to longitudinal slip (s), while another device measures the F_y versus α relationship, comparable to the flat-bed machine, but now obtaining data on real pavements at actual highway speeds.

All mobile tests were conducted on a Portland cement concrete track at the Dana Automotive Test Facility in Ottawa Lake, Michigan. This surface is characterized by ASTM skid numbers (dry) of 87 and (wet) of 62, as measured with the E-501-73 standard tire. Texture depths have been measured on this surface using the so-called "sand patch" tests, indicating an average texture depth of 0.014 to 0.024 inch. These surface properties are reasonably representative of concrete pavements making up the Federal Interstate Highway System in the United States.

2.3.1 Flat-Bed Tests. The HSRI Flat-Bed Tire Tester [2] mounts a single tire specimen within an instrumented support assembly from which force and moment reactions are measured. The tire is caused to operate at the desired slip angle on a flat plate at a velocity of 1.44 mph. The vertical load condition is maintained constant throughout the traverse of the flat plate, while a computerized data acquisition system samples the output of various measurement transducers.

In tests performed for this study, each tire was operated at ±1° slip angle orientations, and at vertical load (F_z) values of:

$$F_z = 1.0 \times \text{Rated Load} = 6040 \text{ lbs}$$

$$F_z = .5 \times \text{Rated Load} = 3020 \text{ lbs}$$

$$F_z = .25 \times \text{Rated Load} = 1510 \text{ lbs}$$

Varying F_z conditions were chosen to cover tire loadings such as prevail over the empty to fully-loaded usage of commercial vehicles. Since F_z is known to have a first-order influence on C_α, it is pertinent to examine this sensitivity as it signifies a sensitivity of vehicle directional behavior to loading.

One specimen of each tire was employed in the flat-bed tests; all tires were tested at their rated cold inflation pressure of 105 psi.

2.3.2 Mobile Traction Tests-Longitudinal. The HSRI Mobile Longitudinal Force Tester [2] is a semi-trailer device which mounts a single tire sample along its centerline. The test wheel is braked by a large commercial air-actuated brake as the trailer is towed at various velocities over the test pavement. The test wheel suspension incorporates a multi-component force transducer and an air spring loading system. The rotational velocity of the test wheel is transduced by a DC tachometer, which output signal is used in computing longitudinal slip.

Signals from transducers on the trailer are conditioned and recorded in a data acquisition module located on the towing tractor. The tractor also incorporates all other services needed in the operation of hydraulic, pneumatic, and electrical systems.

In this study, each tire specimen was subjected to a sequence of velocity and load conditions per the following test matrix:

Run #	Velocity	Normalized Vertical Load (F_Z/F_Z rated)	Brake Application
1	20 mph	1.0	Six Lockup Cycles - Each Run
2	20 mph	0.5	
3	20 mph	1.5	
4	20 mph	1.0	
5	40 mph	1.0	
6	55 mph	1.0	
7	20 mph	1.0	

Table 1

For each "run" in the sequence, the test-wheel brake is applied so as to approximate a ramp input of torque. The wheel is braked until "lockup," (s=100%) is achieved, following which the brake is automatically released. This "lockup cycle" is repeated five times at each test condition. In later processing of the tape recorded data, the F_x versus s function is determined as an average of the tire's behavior over the six cycles.

The seven-run test sequence provides the means for examining the tire's sensitivity to both load and velocity over a range of conditions such as can apply to the limit stopping of trucks from legal highway speeds in either the empty or fully-loaded condition. The "reference" condition of F_z = 1.0 × Rated Load and V = 20 mph is repeated three times to provide a means of assessing the statistical quality of the experiment as well as the basic stability of the traction behavior of the tire specimen.

One specimen of each tire was subjected to the indicated matrix of test runs on a dry concrete surface. A second specimen was tested per the same test matrix, but on a concrete surface which was wetted by a water film of 0.020 in. nominal thickness. The method for wetting the test surface is described in Section 2.3.4.

2.3.3 Mobile Traction Tests-Lateral. A second mobile device, namely, a tire side force dynamometer, is incorporated within the tractor-trailer system described previously. This dynamometer assembly is attached to the frame of the tractor and applies two test tires to the roadway at a controlled slip angle. Lateral and vertical reaction forces are transduced through a load cell mounted in the test-wheel spindle. The test tire is loaded by an air spring system, as with the trailer device. The slip angle is servo-controlled through a program of "slew and pause" increments, causing the test wheel to experience a predetermined set of steady-state levels of α. In later reduction of the data from magnetic tape, the time history of recorded signals is sampled and averaged over each of the "pause" intervals, yielding a set of F_y, F_z, and α numerics characterizing the tire's lateral traction response to the stated conditions.

Lateral traction measurements at slip angles ranging from 0 to 20° were conducted on specimens of each tire under both dry and wet pavement conditions. The matrix of vertical loads and velocities duplicated the test run sequence shown previously in Table 1, with the exception that a slip angle program was substituted for the lockup cycle process used in longitudinal force tests. Slip angle was incremented in each lateral force run to cover the values α = -1°, +1°, 2°, 4°, 6°, 12°, 20°. Each α level was maintained for a period of 1.0 second, while velocity and vertical load were held constant. As with the longitudinal measurements, one specimen was employed in tests on dry concrete and a second specimen was employed on concrete which was wetted with a water film of 0.020 in. thickness.

2.3.4 Wet Surface Testing. The wet pavement condition was achieved by means of an on-board watering system delivering a calibrated flow of water ahead of the test tire. Separate nozzles are employed just ahead of either the longitudinal or lateral test wheel positions to deliver flow rates which are adjusted at each test velocity condition to yield a nominal 0.020 in. thickness to the deposited film. Each nozzle is segmented to assure a uniform flow distribution across an 18-in. swath. The wet test process, itself, involves an initial pass over the test course to provide a preliminary wetting of the test pavement. On successive passes, the water delivery system is activated about two seconds prior to the initiation of the slip process (either longitudinal or lateral). The elapsed time between runs is maintained reasonably constant throughout the test sequence.

3.0 RESULTS

In this section, results of both the noise and traction experiments are presented and discussed.

3.1 Noise Test Results

Noise level measurements are shown in terms of maximum A-weighted fast response sound level in decibels in the bar graph of Figure 2. The two lug-type tires, the Goodyear L-1 and Firestone Transteel Traction, indicate noise levels which are 1.7 db and 4.5 db higher, respectively, than the average of the other four tires. The one aggressive rib tread pattern, Michelin XZZ, is seen to register a noise level which is just 0.3 db above the average of the four non-lug-treaded tires.

The above sound level values correspond to the "Fast Random" time constant mode of operation of a B & K #3347 Real Time Analyzer. The specific values further represent the averages of the two highest readings obtained within 2 db of one another in the repeated pass-by experiments.

Appendix A contains a detailed description of the noise test methods and results.

3.2 Flat-Bed Results

Cornering stiffness (C_α) as a function of normal load (F_z) for each of the six selected tires is shown in Figure 3. These data, in contrast with corresponding measures of bias tire behavior [2], show no methodical distinction between the properties of lug- and rib-type tread designs. We do note a distinction between tires produced by differing manufacturers, however, with the Michelin tires showing a steeper C_α/F_z slope than those exhibited by radials produced by two domestic manufacturers.

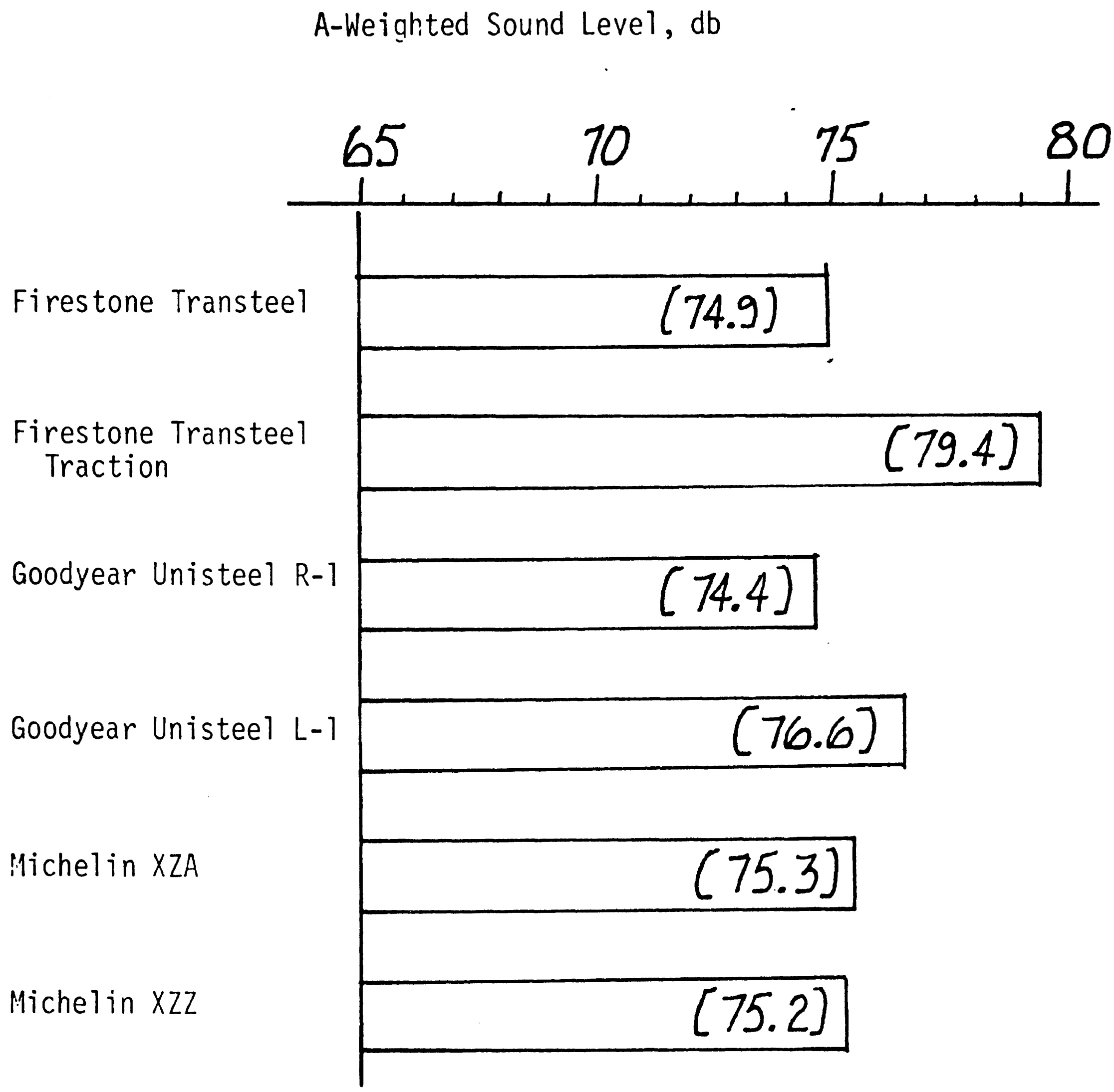


Figure 2. Fast response A-weighted noise levels measured on the six-tire sample.

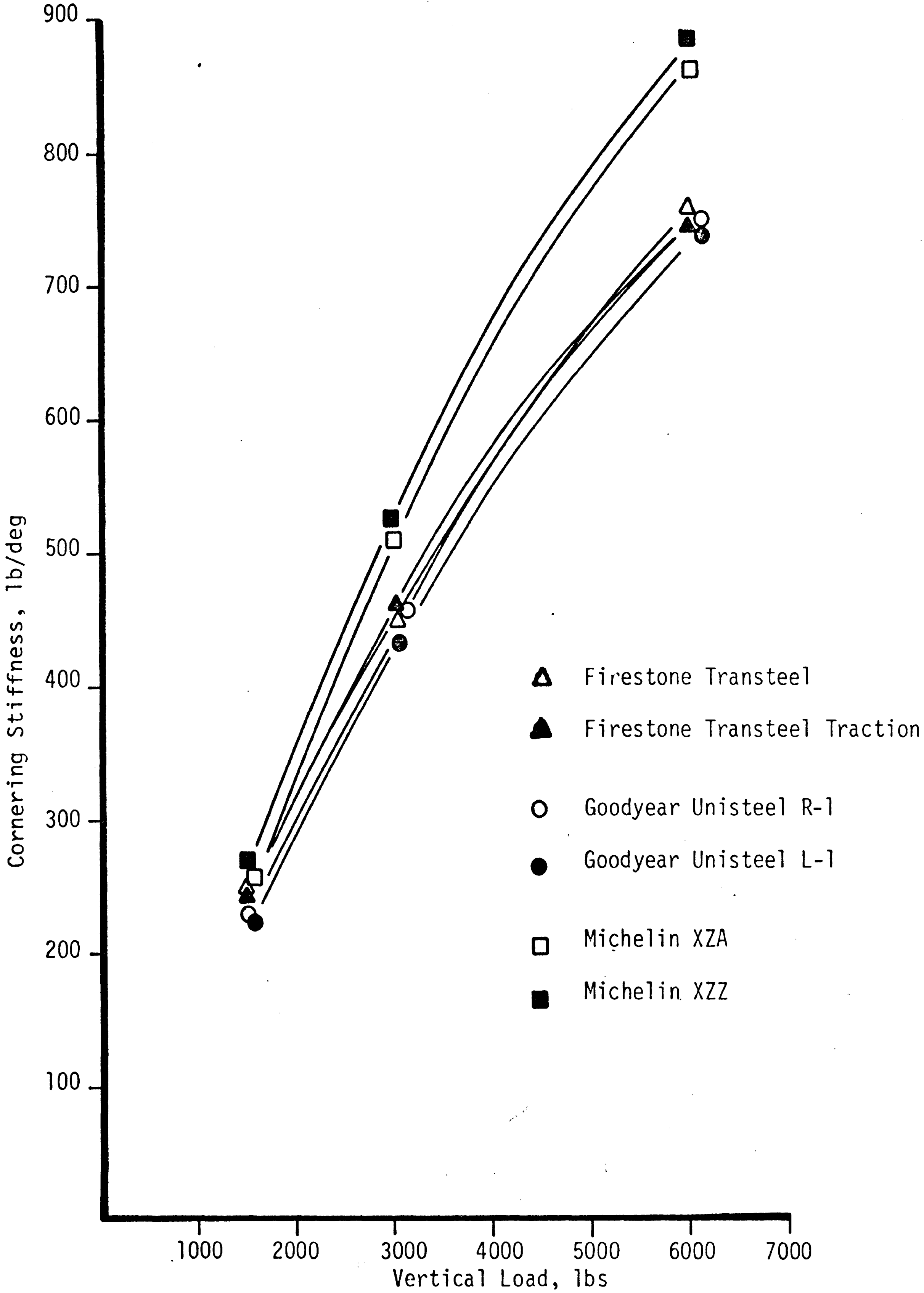

900
800
700
600
500
400
300
200
100
Cornering Stiffness, lb/deg
1000
2000
3000
4000
5000
6000
7000
Vertical Load, lbs
Firestone Transteel
Firestone Transteel Traction
Goodyear Unisteel R-1
Goodyear Unisteel L-1
Michelin XZA
Michelin XZZ

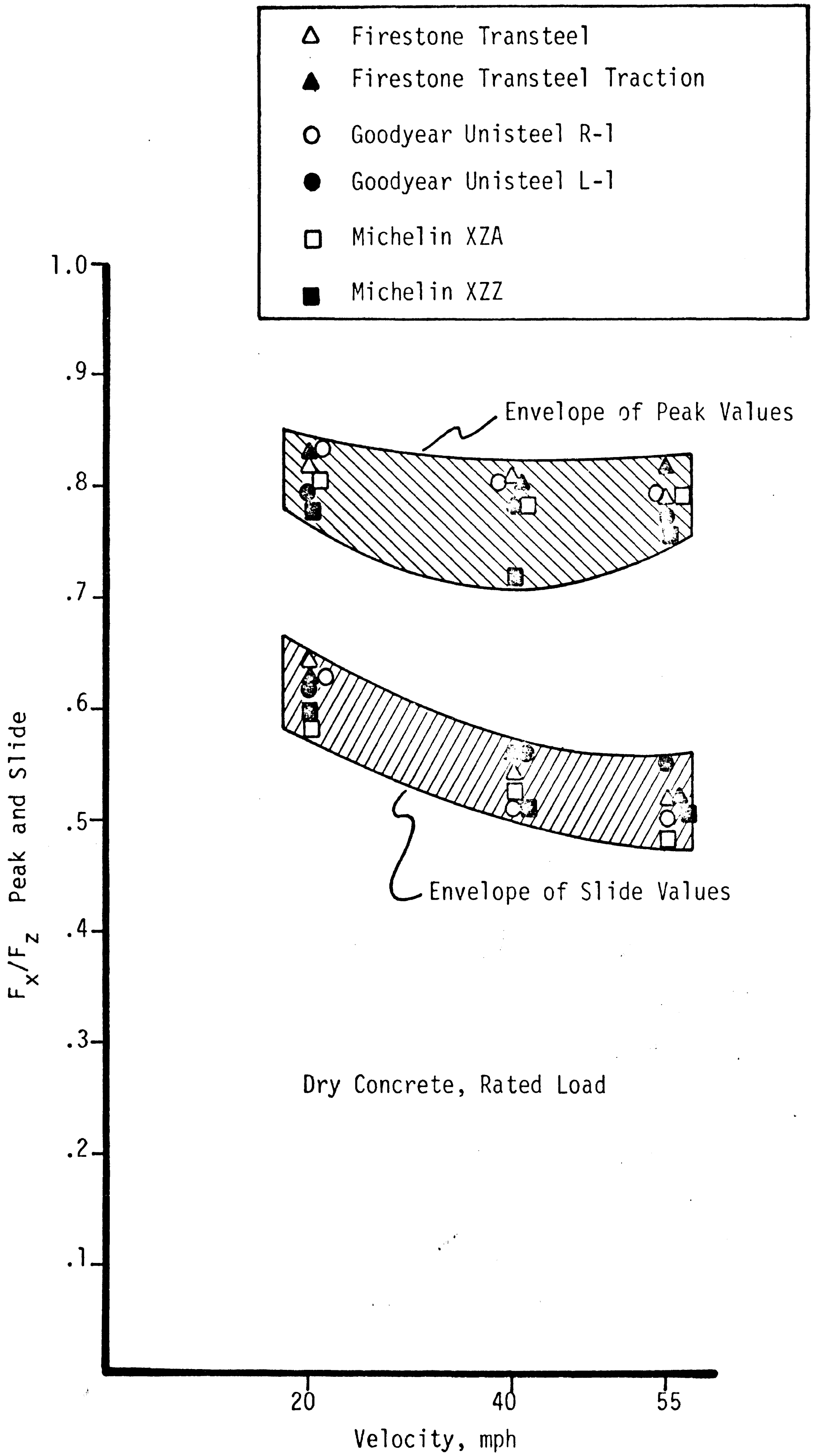
Figure 3

Moreover, we do not draw the distinctive observations concerning the implications of lug-rear, rib-front distributions of radial tire types on a vehicle such as were drawn in the case of bias-ply tires [2]. Those observations concerned the decrease in understeer level which accrued from the typical distribution of lug tires on (rear) driving axle(s) and rib tires on the (front) steering axle. Since radial tires are not seen to methodically link C_α level to tread type (i.e., lug or rib), there are no grounds for hypothesizing an understeer effect accruing simply from a lug/rib mix of radial-ply tires.

3.3 Mobile Traction Results - Longitudinal

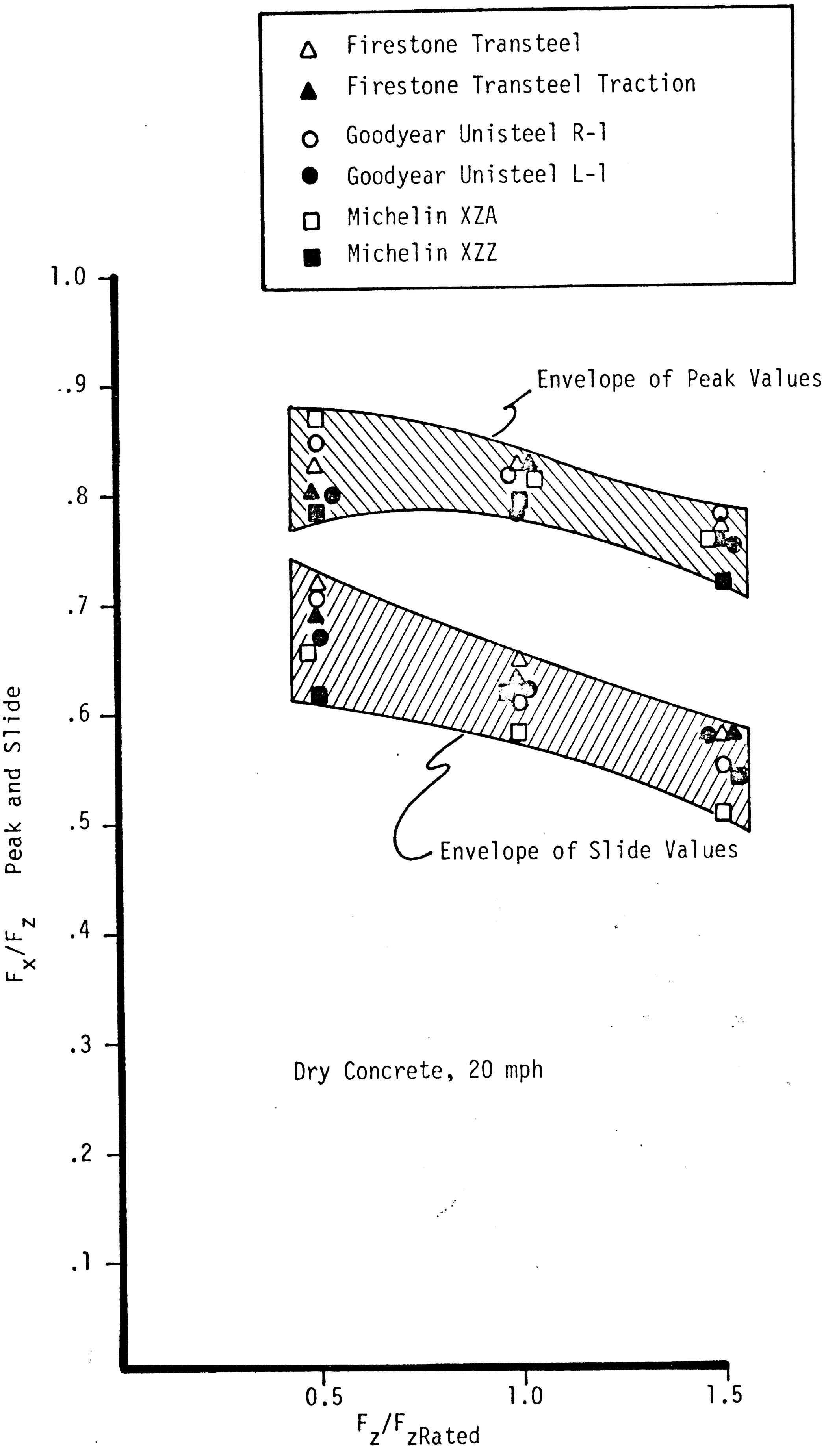
Measurements of the longitudinal traction properties of the six-tire sample were obtained according to the seven-run sequence of load and velocity conditions described earlier. For each tire and test condition, the so-called "μ-slip" behavior was obtained, and then reduced in this study to plots of the "peak and slide" values of F_x/F_z. Shown in Figures 4 and 5 are the peak and slide traction sensitivities to velocity and load, respectively, as obtained on dry concrete. In both plots we find that the rib/lug distinctions for radial tires, in general, are not strong; with the rib tires averaging a maximum "advantage" of 4% over the lug tires for the range of 0.5 to 1.5 x Rated Load. This observation, again, contrasts sharply with the much stronger rib/lug distinctions seen in the peak longitudinal traction capability of bias-ply truck tires wherein ribs were seen to register 13% higher than lugs.

Shown in Figures 6 and 7 are the velocity and load sensitivities of peak and slide values of F_x/F_z as measured on wet concrete. In the data describing the velocity sensitivity of peak F_x/F_z we see the greatest net separation of average performances between radial ribs and lugs. Here, the performance of the average rib tire is approximately 6% higher than that of the average lug (or "aggressive rib") sample. This distinction is lessened in importance,



Firestone Transteel
Firestone Transteel Traction
Goodyear Unisteel R-1
Goodyear Unisteel L-1
Michelin XZA
Michelin XZZ
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
F_x/F_z Peak and Slide
Envelope of Peak Values
Envelope of Slide Values
Dry Concrete, Rated Load
20
40
55
Velocity, mph

Figure 4


Firestone Transteel
Firestone Transteel Traction
Goodyear Unisteel R-1
Goodyear Unisteel L-1
Michelin XZA
Michelin XZZ
1.0
.9
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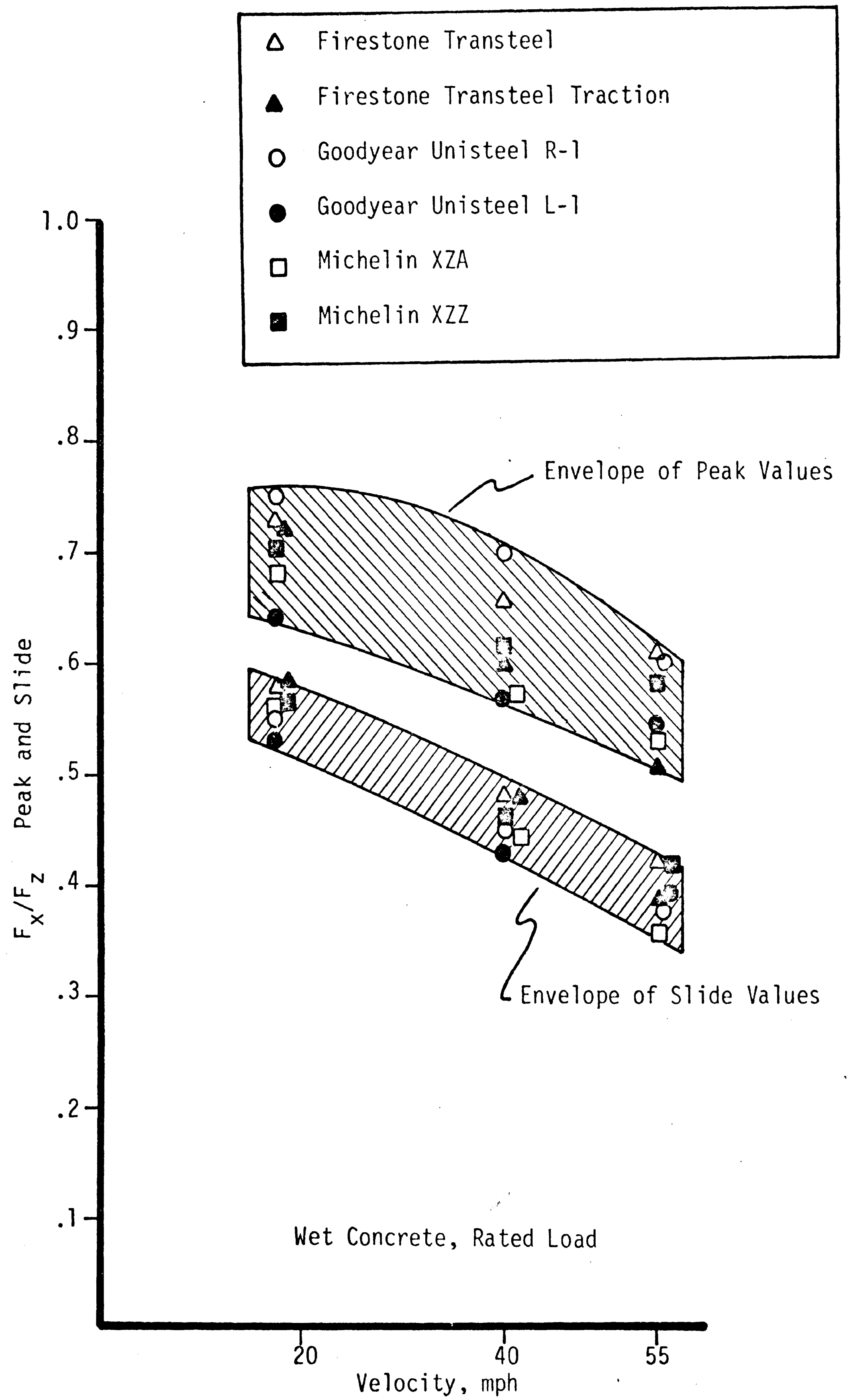
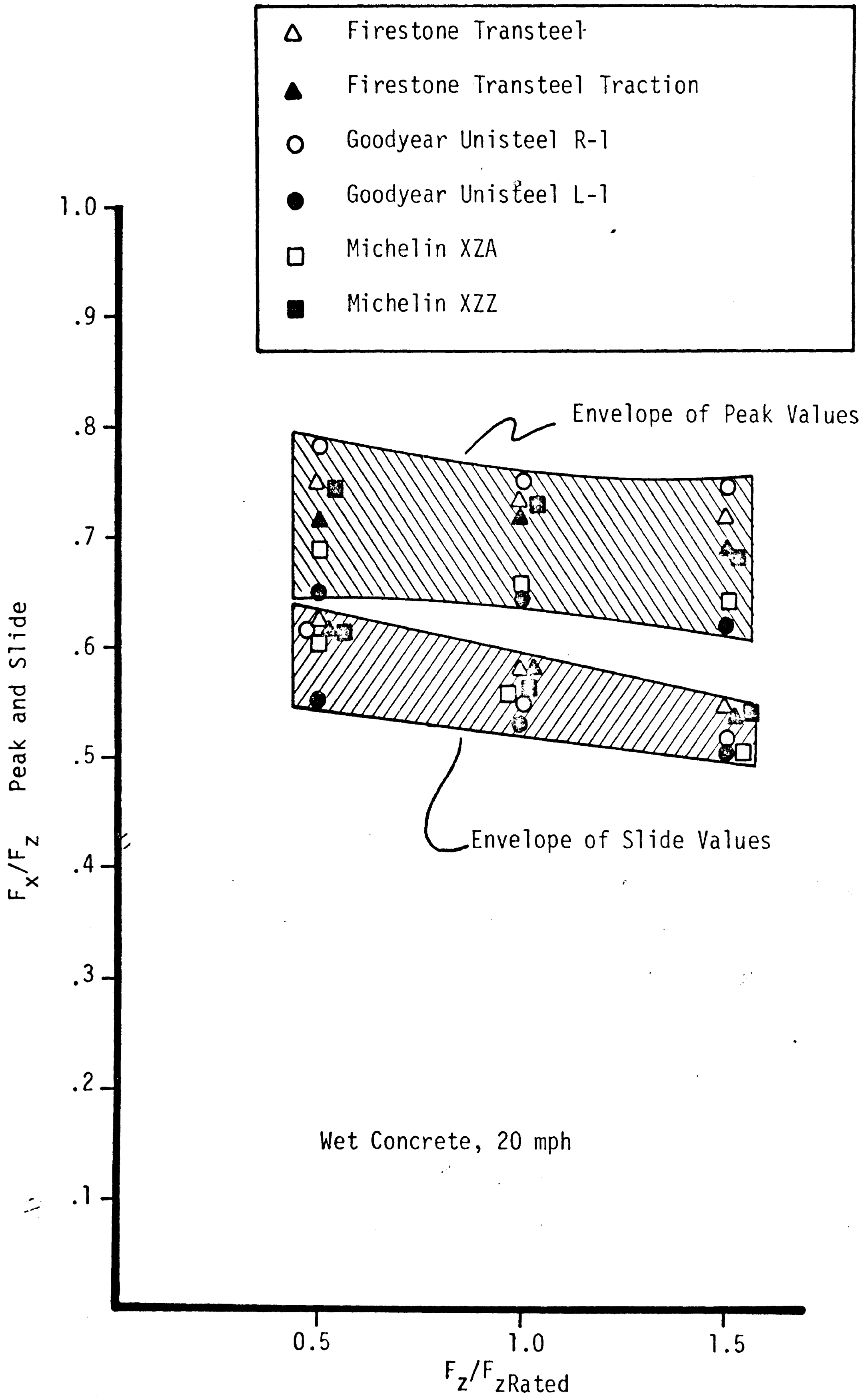
.7
.6
.5
.4
.3
.2
.1
F_x/F_z Peak and Slide
Envelope of Peak Values
Envelope of Slide Values
Dry Concrete, 20 mph
0.5
1.0
1.5
F_z/F_{zRated}

Figure 5



Firestone Transteel
Firestone Transteel Traction
Goodyear Unisteel R-1
Goodyear Unisteel L-1
Michelin XZA
Michelin XZZ
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
F_x/F_z Peak and Slide
Envelope of Peak Values
Envelope of Slide Values
Wet Concrete, Rated Load
20
40
55
Velocity, mph

Figure 6



Firestone Transteel
Firestone Transteel Traction
Goodyear Unisteel R-1
Goodyear Unisteel L-1
Michelin XZA
Michelin XZZ
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
F_x/F_z Peak and Slide
Envelope of Peak Values
Envelope of Slide Values
Wet Concrete, 20 mph
0.5
1.0
1.5
F_z/F_{zRated}

Figure 7

it should be noted, by the substantial degree of "mixing" which occurs among rib and lug data—quite in contrast with data taken on the sample of bias tires [2] which showed virtually no mixing and a 23% spread in average (F_x/F_z) peak values on wet concrete.

Regarding "slide" traction values, the data taken on wet and dry concrete display virtually no significant rib/lug distinctions in the case of the radial truck tire. This observation again contrasts radials with bias-ply tires, the latter of which showed an average 16% lower slide traction performance of lug tires on wet concrete.

In summary, the longitudinal peak and slide traction measurements for radial-ply truck tires represented in this sample, are not seen to be significantly discriminated according to tread type. As a note regarding the statistical quality of the longitudinal traction measurements, the data obtained in the three repeat runs for each tire and surface are shown in Table 2. The tabulated data show that relatively good repeatability was obtained, with a typical standard deviation of approximately .012 for either peak or slide traction coefficients on both surfaces.

3.4 Mobile Traction Results - Lateral

Tests were conducted on the lateral traction dynamometer to permit examination of the friction-limited lateral force behavior of the six-tire sample. Data resulting from these tests were reduced to the plotted format of Figures 8 through 11. These data indicate the basic sensitivity of the F_y/F_z versus α relationship to velocity and vertical load under the two subject surface conditions. As with longitudinal traction measurements, the tire exhibits a steeply rising (elastic) behavior followed by a friction-determined saturation. In the case of lateral traction, the angular slip range of interest is limited to about $\alpha = 20°$, thereby eliminating any need

Table 2. Peak and Slide Values of F_x/F_z Obtained from three (3) Repeated Runs on Each Tire.

		Dry (Repeat Number) 1	2	3	Ave.	Std. Dev. 1 × σ	Wet (Repeat Number) 1	2	3	Ave.	Std. Dev. 1 × σ
Firestone Transteel	Peak	.82	.81	.84	.823	.012	.75	.73	.72	.733	.012
	Slide	.65	.65	.63	.643	.009	.58	.58	.57	.577	.005
Firestone Transteel Traction	Peak	.85	.82	.81	.827	.017	.73	.72	.70	.717	.012
	Slide	.65	.63	.62	.633	.012	.58	.58	.57	.577	.005
Goodyear Unisteel R-1	Peak	.83	.80	.84	.833	.017	.74	.75	.76	.750	.008
	Slide	.61	.59	.62	.607	.012	.55	.55	.56	.553	.005
Goodyear Unisteel L-1	Peak	.78	.78	.81	.790	.014	.67	.61	.64	.640	.025
	Slide	.62	.62	.62	.620	.000	.54	.52	.53	.530	.008
Michelin XZA	Peak	.82	.82	.81	.817	.005	.68	.64	.67	.663	.017
	Slide	.57	.59	.58	.580	.008	.56	.55	.56	.557	.005
Michelin XZZ	Peak	.79	.73	.78	.767	.026	.74	.70	.69	.710	.022
	Slide	.62	.59	.59	.600	.014	.60	.56	.56	.573	.019

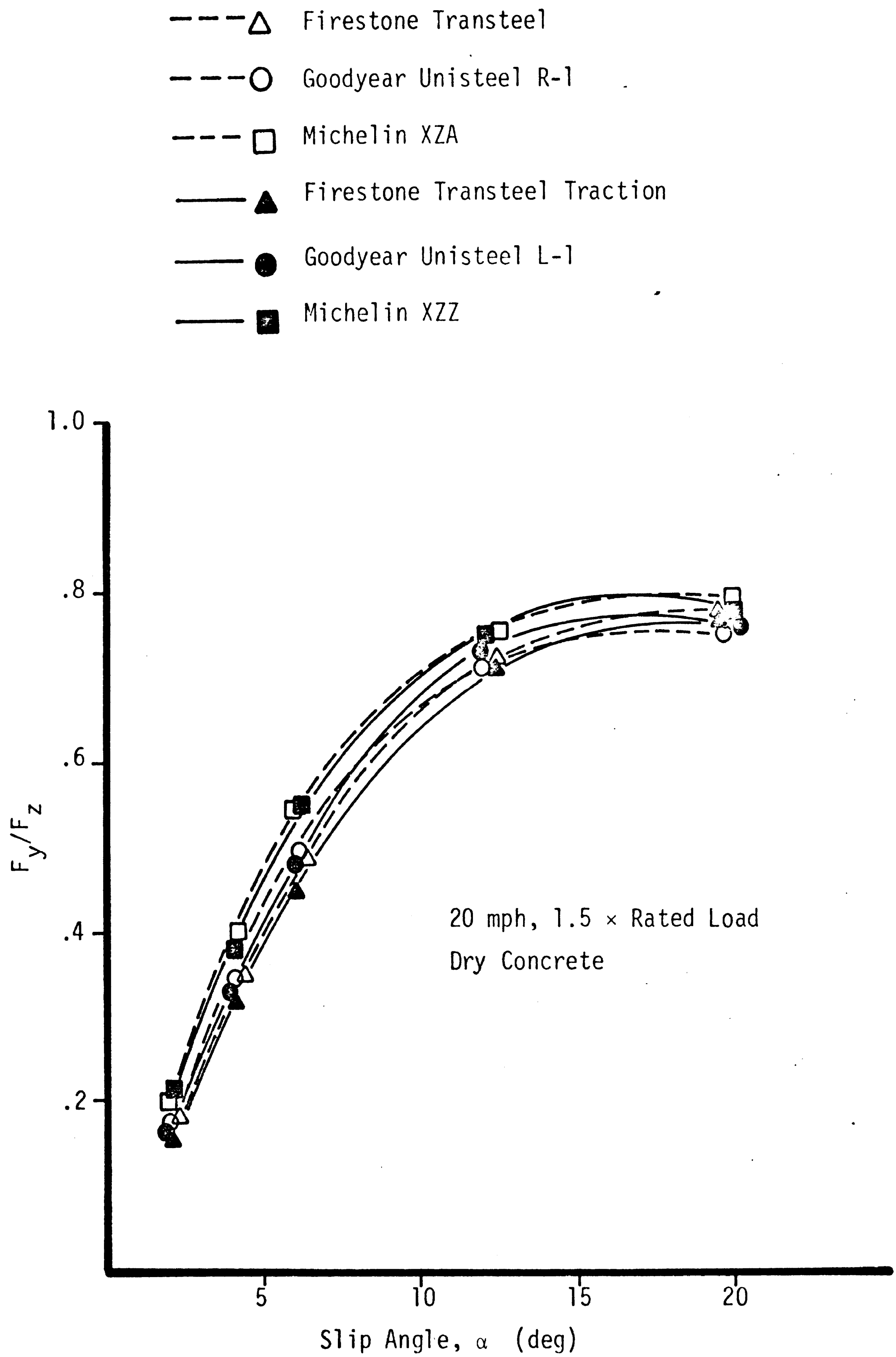

Firestone Transteel
Goodyear Unisteel R-1
Michelin XZA
Firestone Transteel Traction
Goodyear Unisteel L-1
Michelin XZZ
1.0
.8
.6
.4
.2
F_y/F_z
20 mph, 1.5 × Rated Load
Dry Concrete
5
10
15
20
Slip Angle, α (deg)

Figure 8

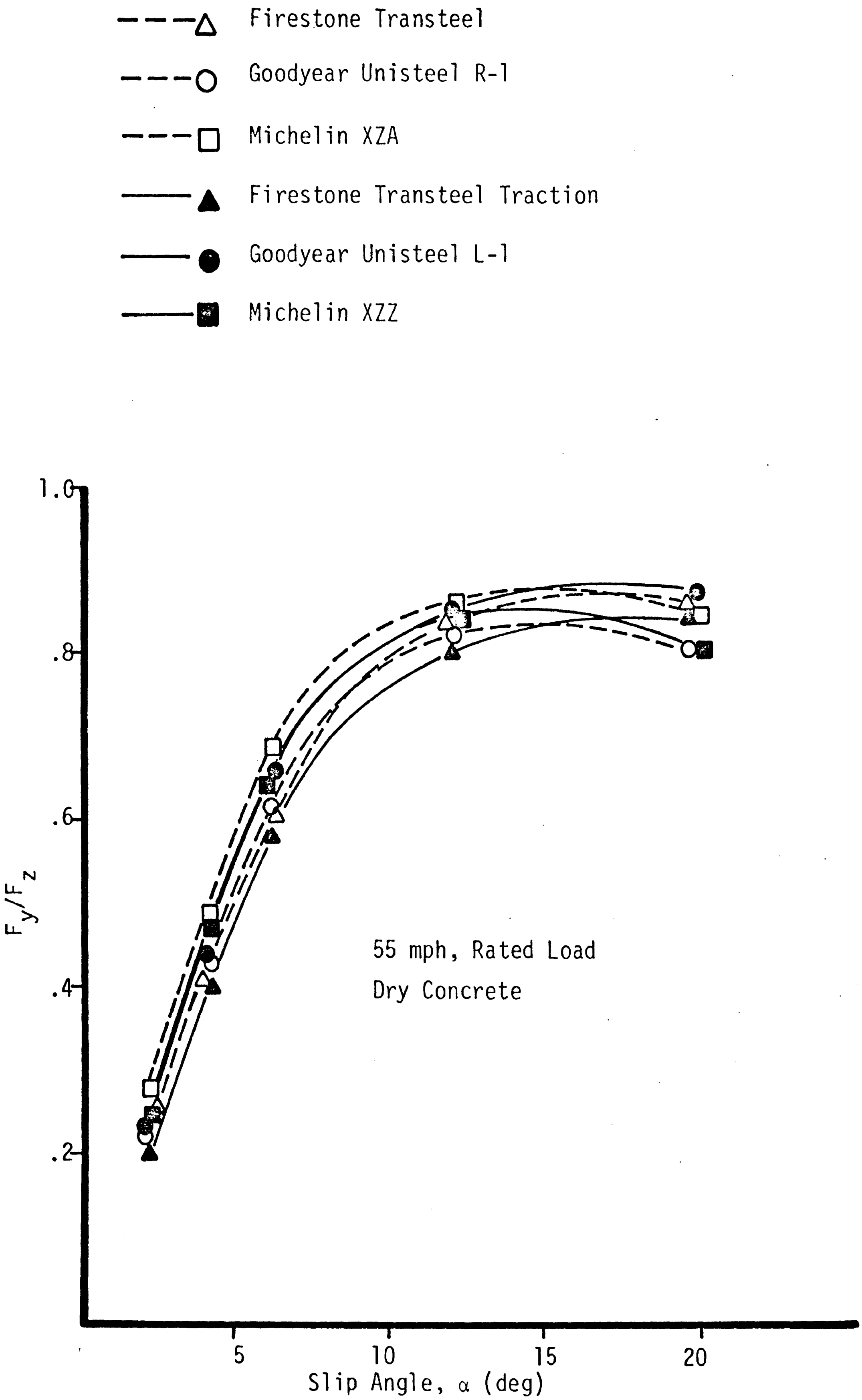

Firestone Transteel
Goodyear Unisteel R-1
Michelin XZA
Firestone Transteel Traction
Goodyear Unisteel L-1
Michelin XZZ
1.0
.8
.6
.4
.2
F_y/F_z
55 mph, Rated Load
Dry Concrete
5
10
15
20
Slip Angle, α (deg)

Figure 9

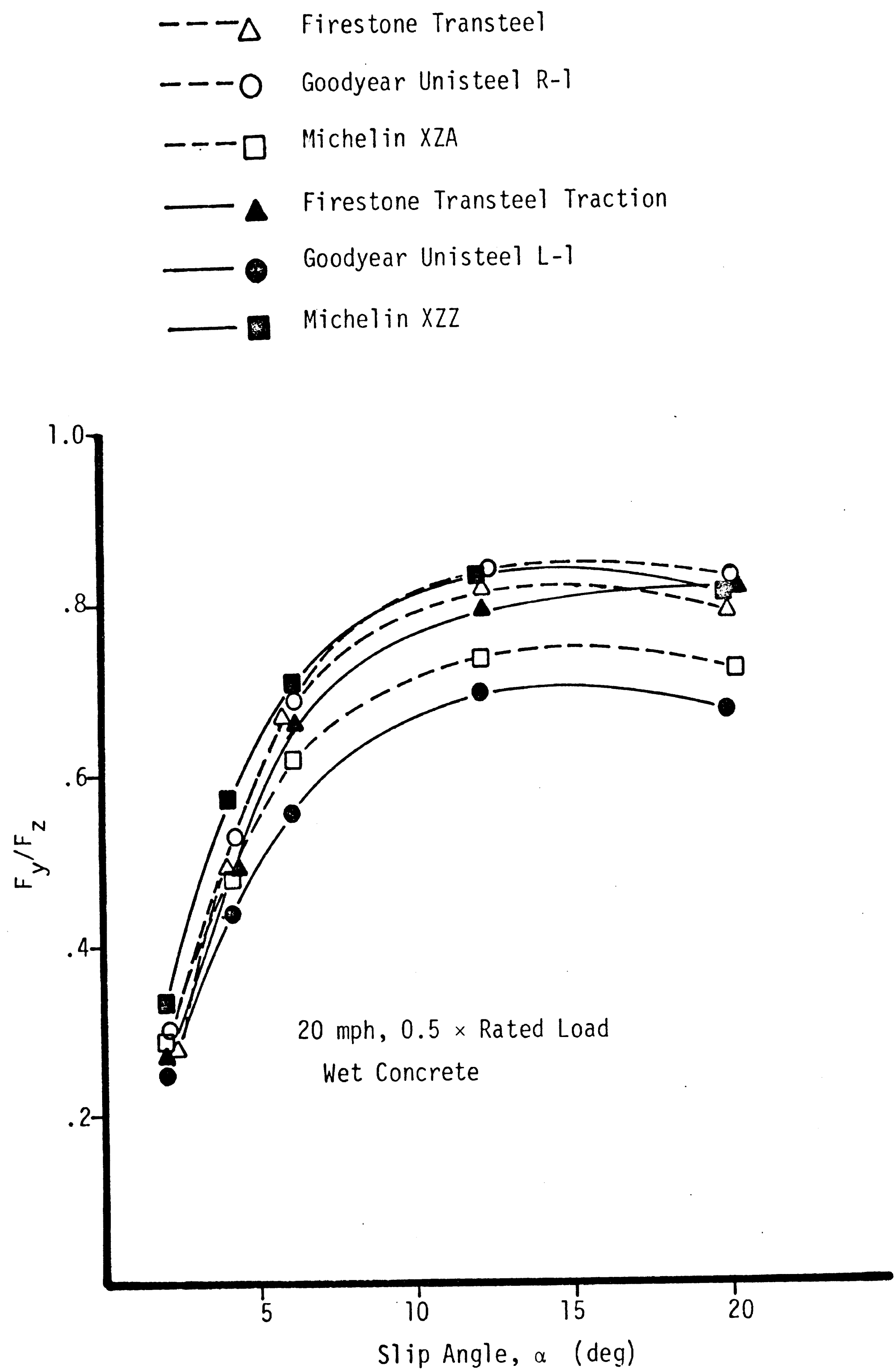

Firestone Transteel
Goodyear Unisteel R-1
Michelin XZA
Firestone Transteel Traction
Goodyear Unisteel L-1
Michelin XZZ
1.0
.8
.6
.4
.2
F_y/F_z
20 mph, 0.5 × Rated Load
Wet Concrete
5
10
15
20
Slip Angle, α (deg)

Figure 10

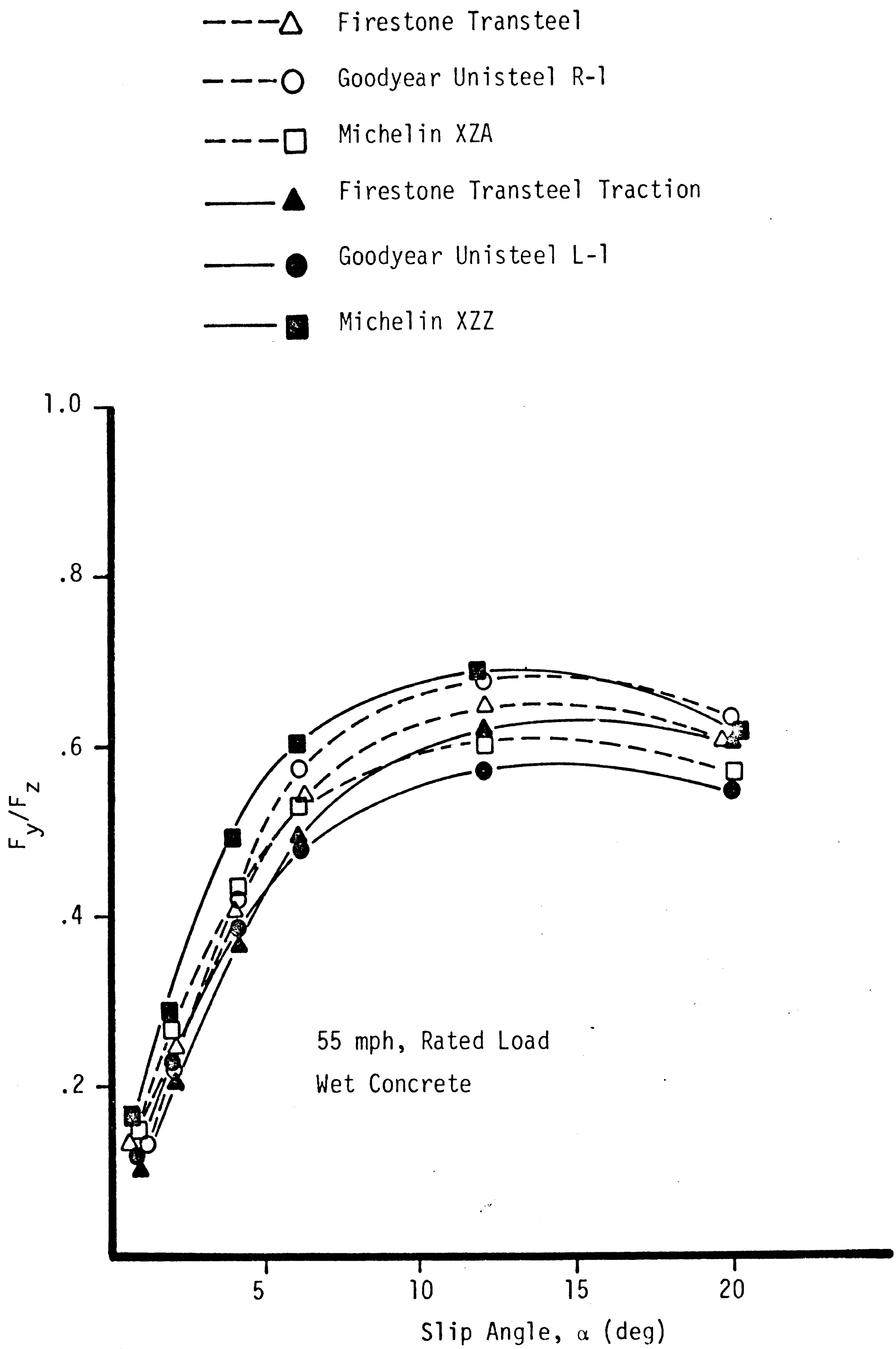

Firestone Transteel
Goodyear Unisteel R-1
Michelin XZA
Firestone Transteel Traction
Goodyear Unisteel L-1
Michelin XZZ
1.0
.8
.6
.4
.2
F_y/F_z
55 mph, Rated Load
Wet Concrete
5
10
15
20
Slip Angle, α (deg)

Figure 11

to characterize performance at high slip velocities such as are relevant to longitudinal traction. All four figures serve to support the conclusion that no appreciable differentiation can be made between the lug- and rib-type radial-tire samples on the basis of their lateral traction capabilities on wet or dry concrete.

Thus we find, as was the case with bias-ply truck tires, that the ability of the lug-type radial tire to generate lateral forces, at elevated slip angles, is comparable to the capability of its rib-type counterpart.

In contrast to the repeatability appreciated in mobile longitudinal experiments, the mobile lateral test is characterized by less than an ideal level of repeatability. This situation derives from a deterministic, rather than random, process arising out of the "destructive" character of the test. As pneumatic tires are operated at large slip angles and at highway-type velocities, they accrue a peculiar and very concentrated pattern of treadwear which causes, generally, a significant increase in the maximum side force capability. As the treadwear continues throughout a sequence of traction tests, the side force at $\alpha = 20°$ may increase, although data shown in Appendix B reveal that this effect is less pronounced for radial tires than was found to accrue for bias-ply tires [2]. In fact, the data in Appendix B illustrating F_y versus α repeats show a mixed behavior in which the change in peak side force with test runs is not necessarily of the "increasing" polarity, nor is it necessarily monotonic.

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4.0 CONCLUDING REMARKS

This study has served to provide a common data base of noise and traction properties for radial-ply truck tires. As such, it has provided an objective set of information to assist the decision making of those who are concerned with the contrast in these characteristics.

Measurements of maximum A-weighted noise levels have shown lug-type truck radials to be an average of 3 db higher in noise level than radial tires with rib-type patterns.

The traction measurements conducted in this study reveal no major distinctions between the performances of lug- and rib-type radial truck tires. While a small, but not insignificant, advantage of rib over lug treads was observed in regard to peak braking traction, the data were sufficiently mixed that a clear statement concerning all lug tires versus all rib tires with radial carcass construction is not possible.

While it is not the intent of this study to discuss the relative merits of lug and rib tires beyond the context studied here, the reader should note that significant other areas of tire performance do exist and should be duly accounted for in any program which seeks a comprehensive evaluation of tire quality.

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1. Leasure, W.A., Jr., Corley, D., Forrer, J., and Flynn, D., Truck Noise - I; Peak A-Weighted Sound Levels Due to Truck Tires. Addendum, Department of Transportation Report OST-TST-72-1 (National Bureau of Standards, Washington, D.C., July 1972.

2. Ervin, R.D. and Wild, R.E., The Noise and Traction Characteristics of Bias-Ply Truck Tires: Vol. 1 - Dry, Vol. 2 - Wet. Highway Safety Research Institute, Univ. of Michigan, Ann Arbor, Report No. UM-HSRI-PF-76-2, Jan. 1976 and Oct. 1976.

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Radial Truck Tire Noise Study

Introduction

A recent trend in truck tire usage has been towards the use of tires having radial-ply construction. This trend is due primarily to the potential for improved fuel economy and tread wear provided by radial-ply tires over conventional bias-ply tires. Since radial-ply truck tires are coming into more common use, a better understanding of the characteristics of these tires is required. The existing data on the noise generated by radial tires is limited primarily to passenger car tires. Thus, there exists a need to develop and expand a data base on radial truck tire noise.

This appendix presents the results of a study of the noise generated by radial truck tires. A brief description of the field test program is given, followed by a presentation of the data—maximum A-weighted sound levels measured at 50 feet for coastbys at 50 mph—for six different types of radial truck tires.

Field Test Program/Test Results

The field data acquisition portion of this study was conducted at the Dana Corporation Technical Center, Ottawa Lake, Michigan. Located at the Technical Center is a 45-foot-wide oval track, 1-3/4 miles long with 1500-foot-long straightaways and 6° maximum banked corners. The track consists of 3 lanes of 9-inch-thick reinforced concrete. A test site which conformed to the requirements of the Society of Automotive Engineers Standard SAE J57—Sound Level of Highway Truck Tires—was established along one of the straightaways across from the entrance to the track. The inside lane of the track was used as the vehicle path (concrete) and a measurement area consistent with SAE J57 was established in the entrance to the asphalt turn-around pad. Figure 1 shows an overall view of the test track with the location of the test site noted.

The six radial tires investigated in this study were:

1) Goodyear Unisteel R-1

2) Goodyear Unisteel L-1

3) Firestone Transteel

4) Firestone Transteel Traction

5) Michelin XZA

6) Michelin XZZ

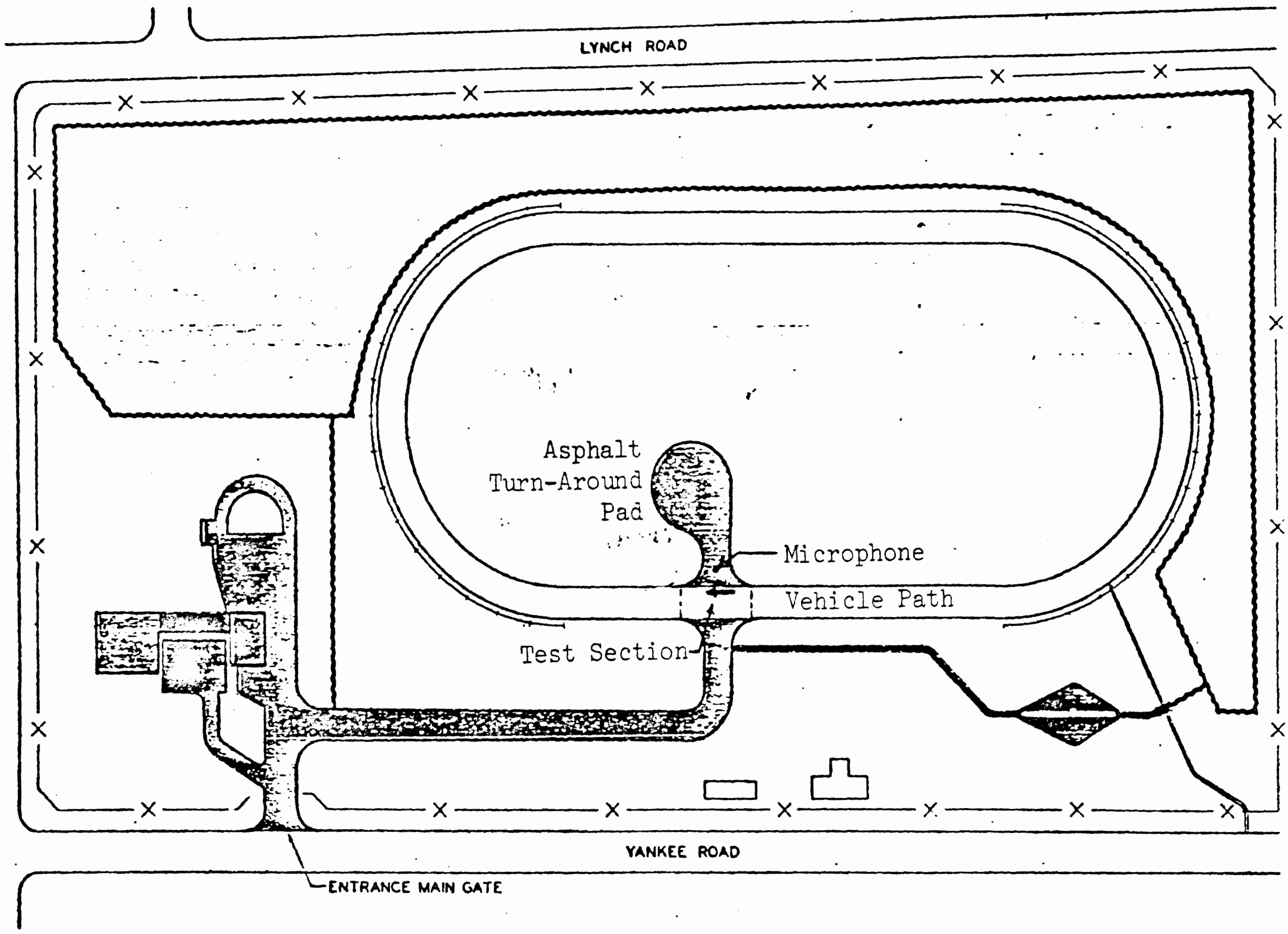


Figure A-1. Plan view of track at Dana Corporation Technical Center showing the location of the established test site.

The test vehicle was a 4 x 2 single-chassis GMC 6500 flat-bed truck. Blank tires (tires with full tread depth but no tread pattern) were always mounted on the steering axle and the test tires (in one case blank tires) on the drive axle. A series of weights were distributed on the flat bed to provide the required tire loading. The axle loadings and inflation pressures were:

9.00-20 blank tires at 80 psi on steering axle and G-rated 10.00R-20 test tires at 95 psi on drive axle,

front axle	8,320 pounds
rear axle	20,500 pounds
gross vehicle weight	28,820 pounds

These loadings do not precisely correspond to 100 percent of the rated tire load for dual applications at the given inflation pressure as recommended by the Tire and Rim Association; the loading is approximately 3 percent under the maximum rated tire load of 5300 pounds per tire. This resulted because small weights were not available at the test site and it was too time consuming to redistribute the larger weights to provide the exact loading.

The operational procedures and measurement/analysis instrumentation utilized in this test program were similar to that used in previous DOT/NBS truck tire noise studies. The test procedure was essentially identical to that specified in SAE J57 with the exception that the distance between the point of entrance and point of exit of the test section was 167 feet and "fast" meter response was utilized. An increased test section length was used so that the noise of the test vehicle running over the tape switches at the beginning and end of the test section would not interfere with the recording of the tire noise through the normal 100-foot test section.

Analog tape recordings were made using a microphone located at 50 feet from the centerline of vehicle travel for coastbys at 50 mph. Three test runs were made for each set of test tires. The analog tapes were analyzed using a B & K 3347 real-time analyzer with the time constant set in the "fast random" position.

A comparison with the data obtained in previous DOT/NBS studies of truck tire noise shows that radial tires are as quiet as or quieter than similar truck tires of bias-ply construction. This is particularly evident for the Goodyear Unisteel L-1 which has a certification level of 77 dB compared to 78 to 83 dB for typical bias-ply cross-bar truck tires.

Table A-1. Maximum A-weighted sound levels for various types of radial truck tires as measured at 50 feet for coastbys at 50 mph.

Test Tire	Speed mph	Maximum A-Weighted Sound Level, dB re 20μPa B & K 3347 RTA Time Constant "Fast Random"
Blanks	50.2	73.0
	50.4	74.4
	50.8	74.4
Goodyear Unisteel R-1	49.9	74.0
	50.6	74.4
	50-2	74-4
Goodyear Unisteel L-1	50.6	76.2
	52.0	76.8
	50.4	76.4
Firestone Transteel	50.8	75.0
	49.5	74.6
	49.5	74.8
Firestone Transteel Traction	50.2	78.0
	51.0	79.4
	50.6	79.4
Michelin XZA	50.8	74.8
	50.2	75.8
	50.4	74.6
Michelin XZZ	50.4	74.6
	50.4	74.6
	51.8	75.8

Summary

It can be concluded that, in general, radial truck tires are as quiet as or quieter than similar bias-ply tires and thus, based solely on noise considerations, would be preferable for over-the-highway use. Other factors yet to be ascertained include fuel economy, traction and handling, and tire costs.

APPENDIX B

INDIVIDUAL LATERAL FORCE PLOTS FROM MOBILE TRACTION TESTS

The following plots represent the lateral force, F_y, or the normalized lateral force, F_y/F_z, versus slip angle, α, behavior of each tire in the test sample. These data were obtained using the HSRI mobile dynamometer on a dry and wet Portland cement concrete pavement. Each tire is represented by three plots for each of two conditions, indicating the influence on lateral traction of

1) velocity
2) load
3) repeated test runs

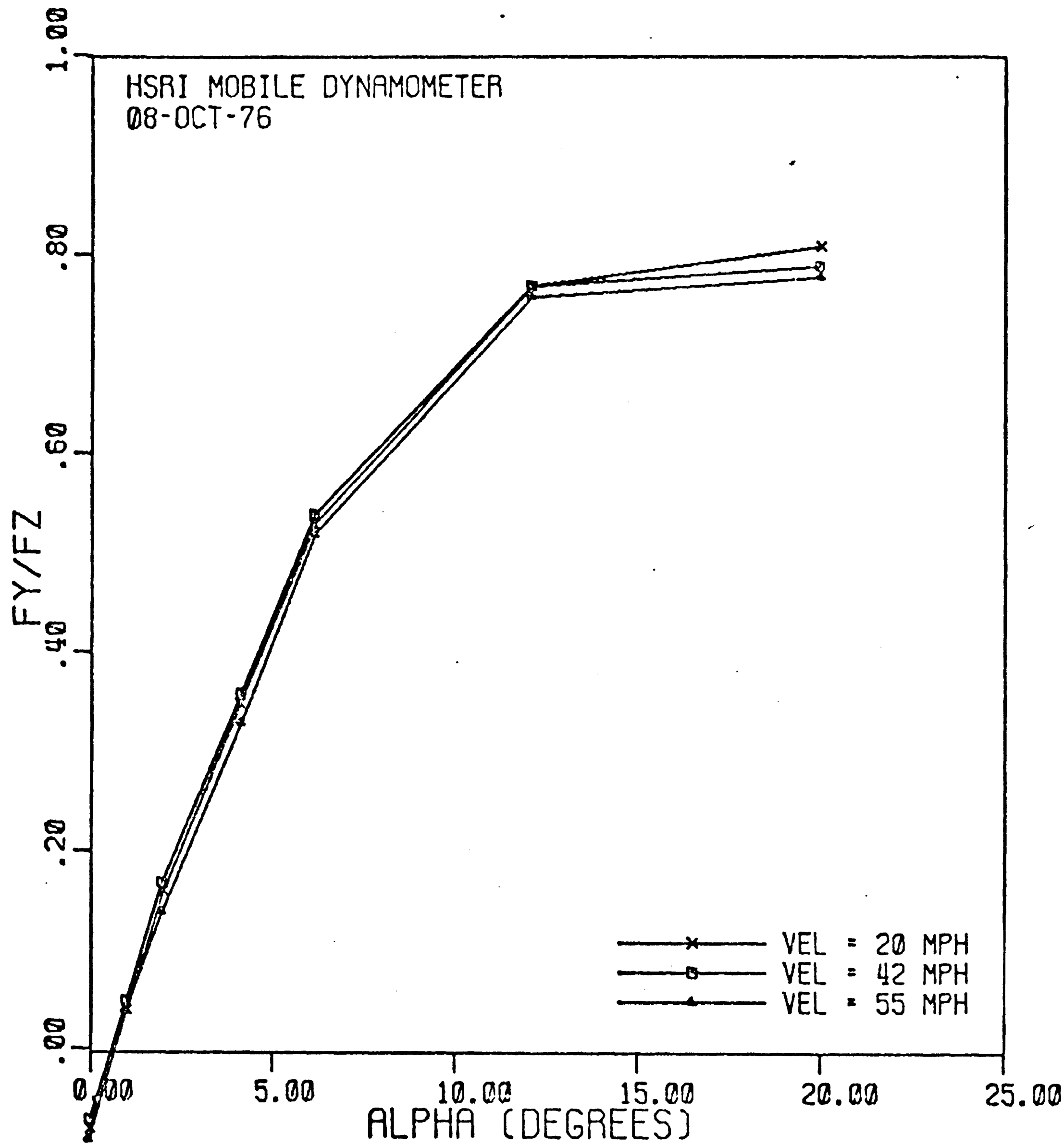
Accordingly, the first plot for each tire represents tests conducted all at rated load, but at velocities of nominally 20, 40, and 55 mph.

Similarly, the second plot for each tire represents tests conducted at 40 mph and at vertical loads of approximately F_z = 0.5, 1.0, and 1.5 times the T&RA rated load. The final plot serves to document the stability of the tire specimen as a force-producing mechanism over the sequence of test runs. These data indicate the tire's F_y/α behavior as measured during each of three "spot checks" at conditions of F_z = rated load and V = 20 mph.

Plots are presented in the order in which data were gathered, with dry surface measurements first, followed by the data on wet surfaces. Tires are identified by a code number on each plot corresponding to the model name on the following chart. Note that the following plots illustrate, in many cases, an offset in the value of F_y at zero slip angle. This offset represents an anomaly in the measurement system and can be corrected by a vertical transfer of the data to obtain $F_y = 0$ at $\alpha = 0$. Summary plots shown previously in Figures 8 through 11 incorporate the necessary correction.

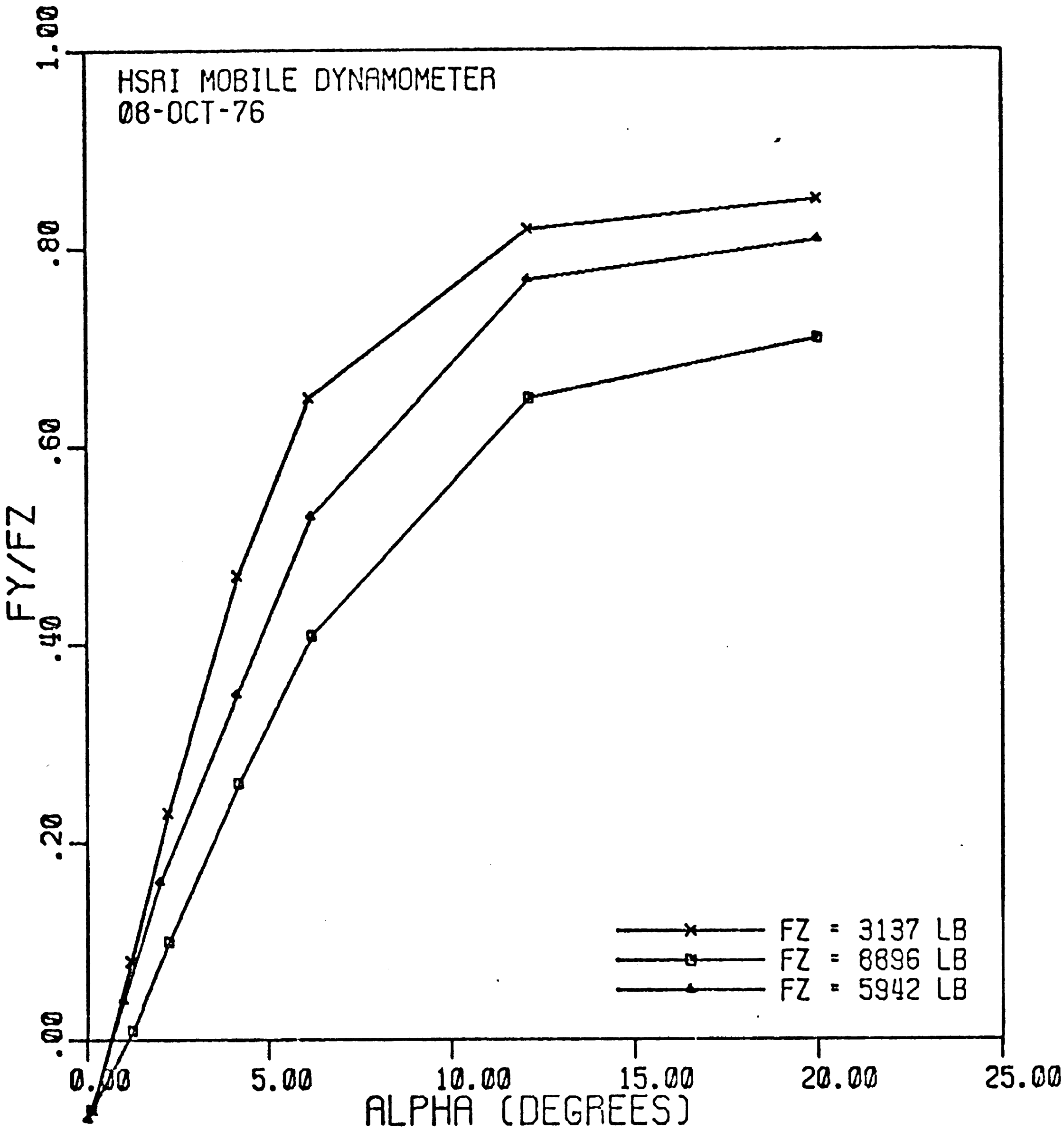
NOISE-TRACTION STUDY, RADIAL TIRES

Tire Test Code	Manufacturer	Model
ONA/B-13-C-Date	Firestone	Transteel
ONA/B-14-C-Date	Firestone	Transteel Traction
ONA/B-15-C-Date	Goodyear	Unisteel R-1
ONA/B-16-C-Date	Goodyear	Unisteel L-1
ONA/B-17-C-Date	Michelin	XZA
ONA/B-18-C-Date	Michelin	XZZ
ONA/B-19-D-Date	Firestone	Transteel
ONA/B-20-D-Date	Firestone	Transteel Traction
ONA/B-21-D-Date	Goodyear	Unisteel R-1
ONA/B-22-D-Date	Goodyear	Unisteel L-1
ONA/B-23-D-Date	Michelin	XZA
ONA/B-24-D-Date	Michelin	XZZ



ONA/B-13-C-8/23 DRY CONCRETE (DANA)

FZ = 6019 LB



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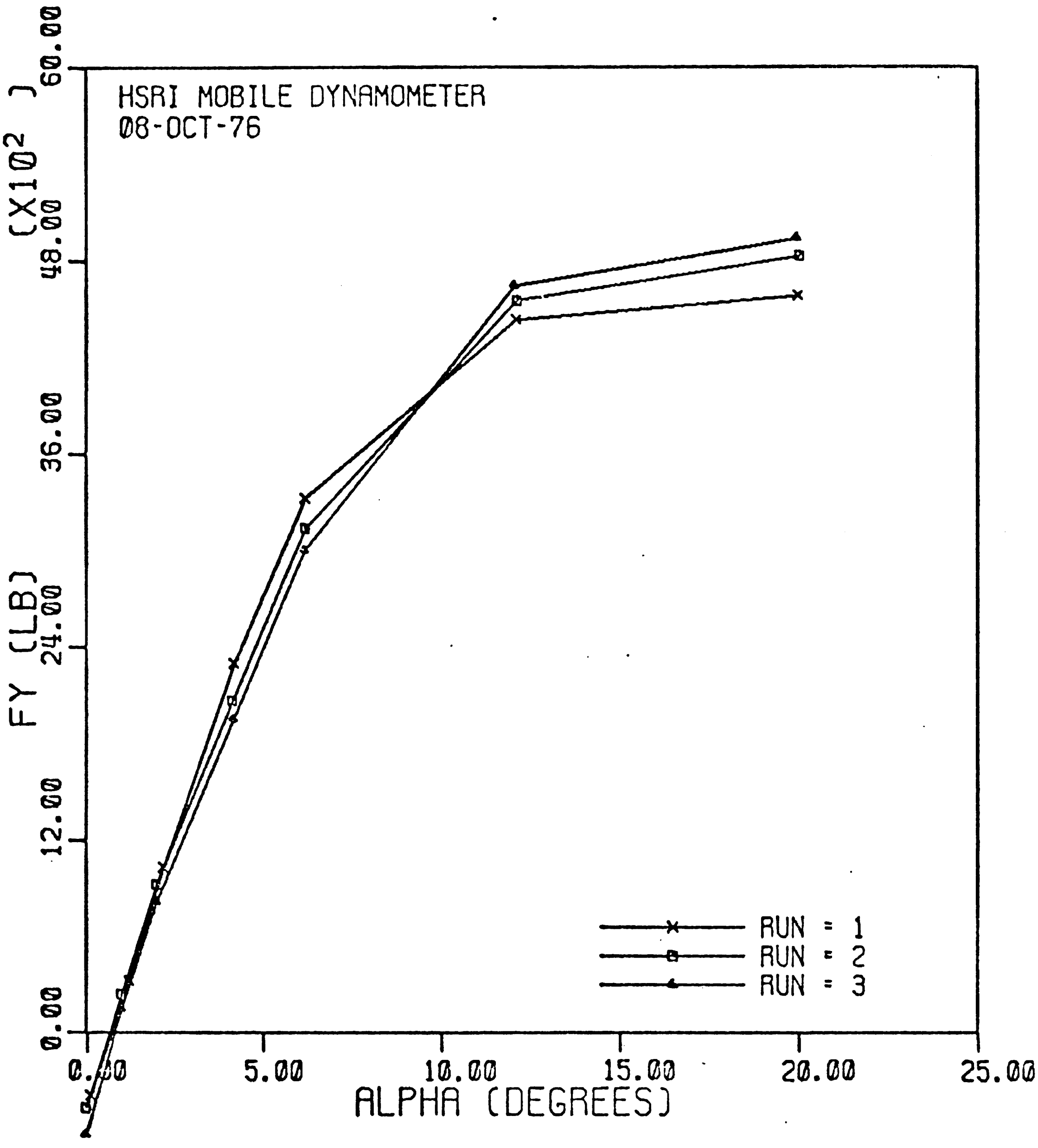
VEL = 20 MPH



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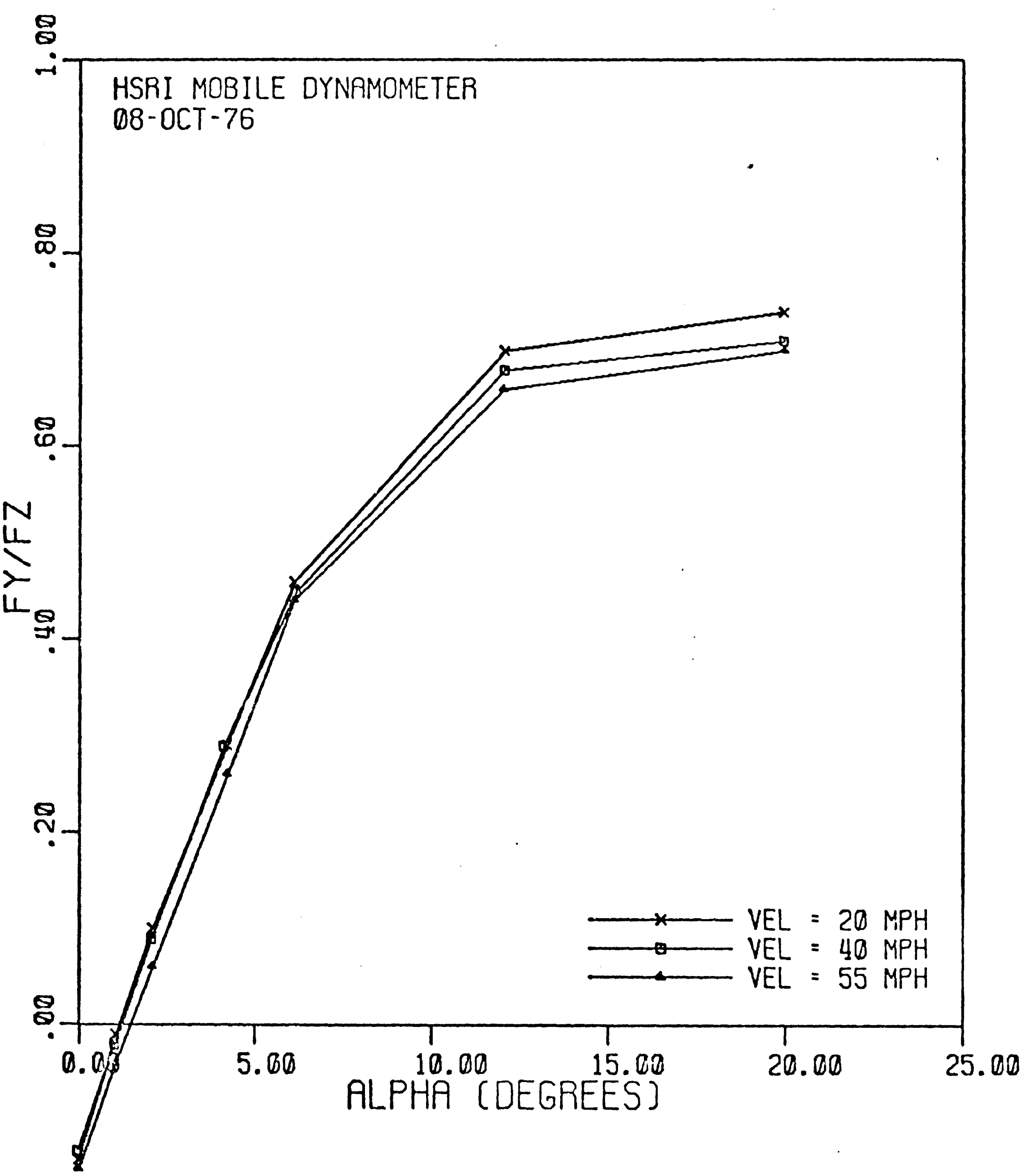
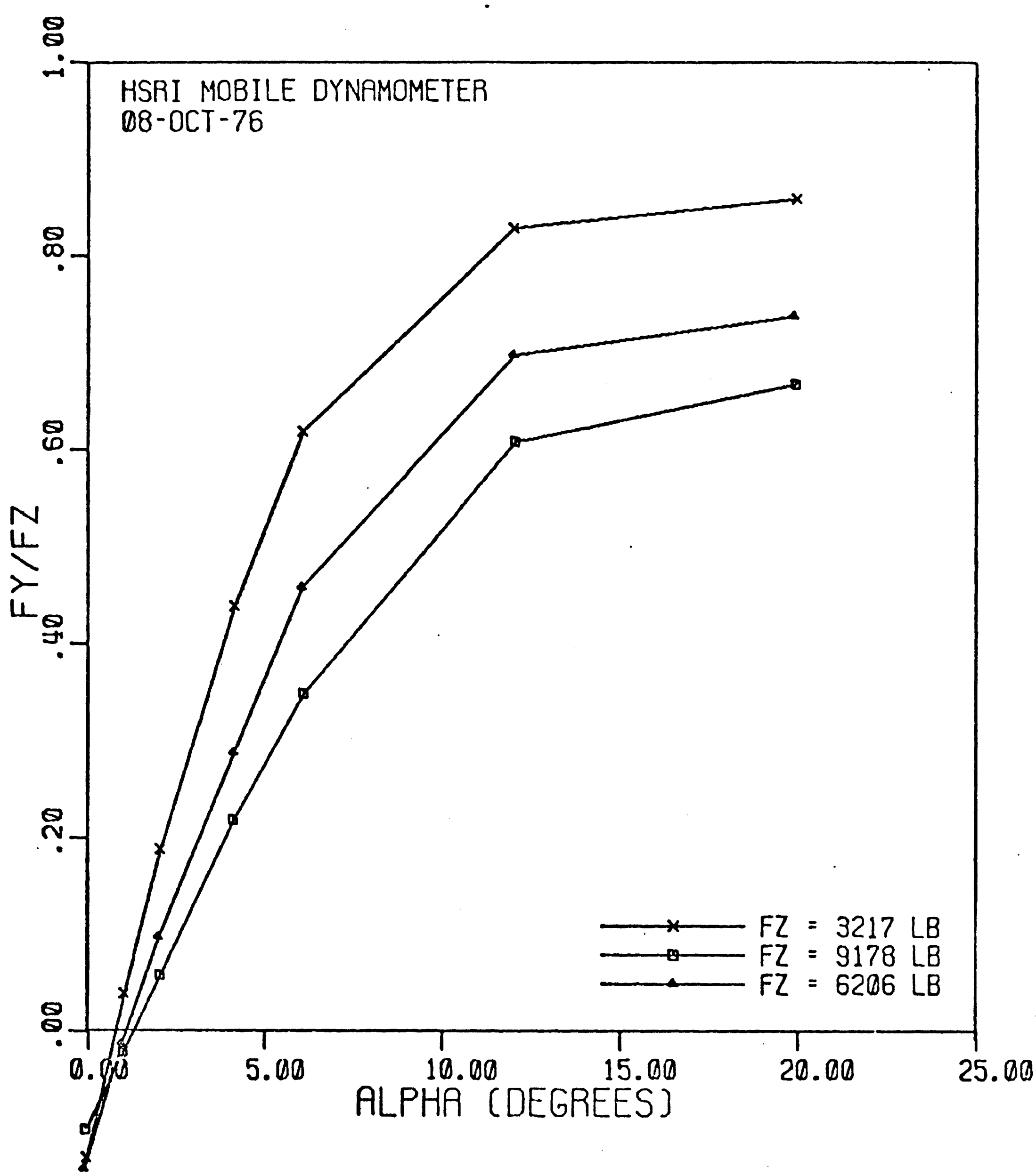
FZ = 6014 LB VEL = 20 MPH



ONA/B-14-C-8/23 DRY CONCRETE (DANA)

FZ = 6304 LB



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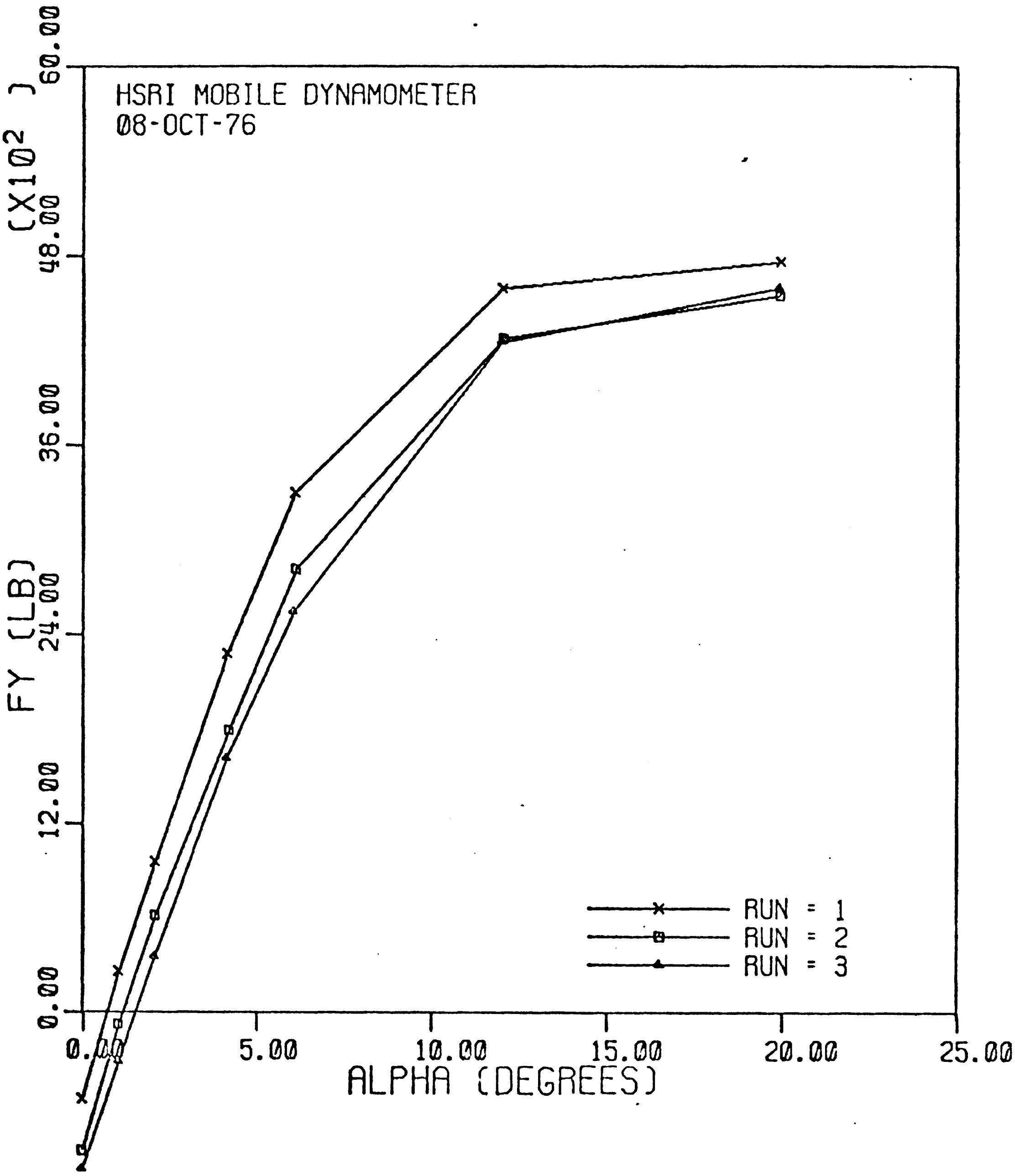
VEL = 20 MPH



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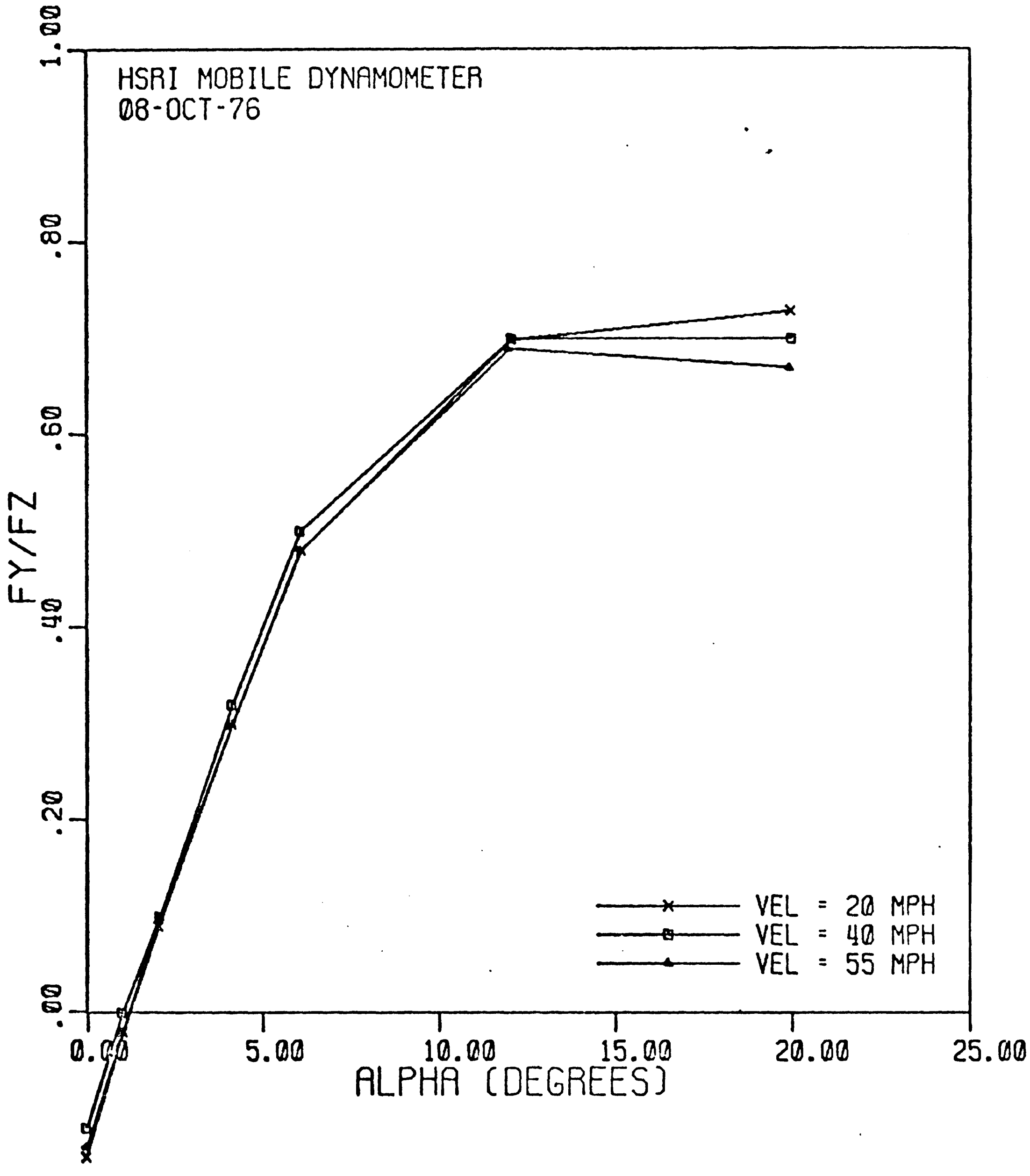
FZ = 6228 LB VEL = 20 MPH



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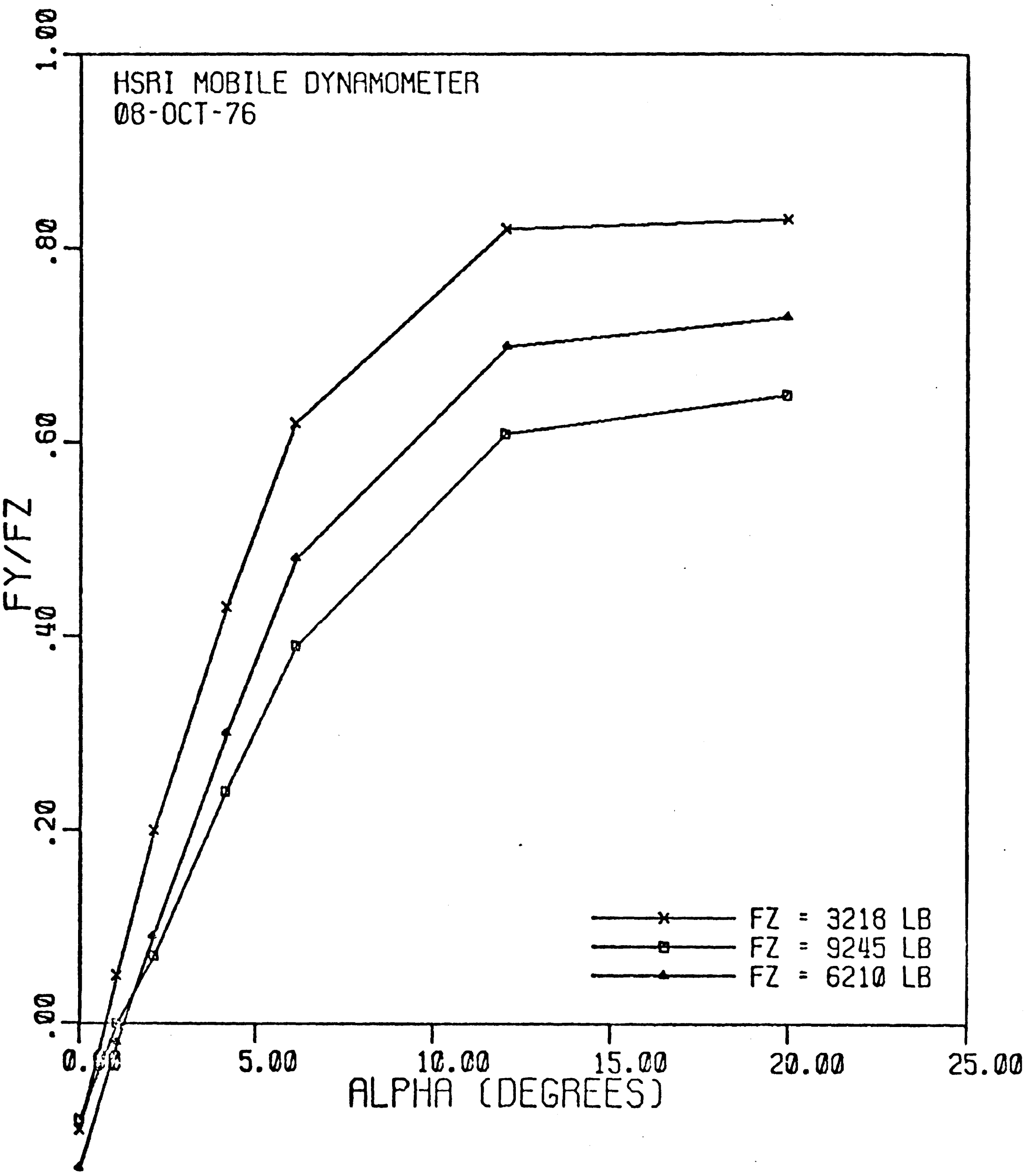

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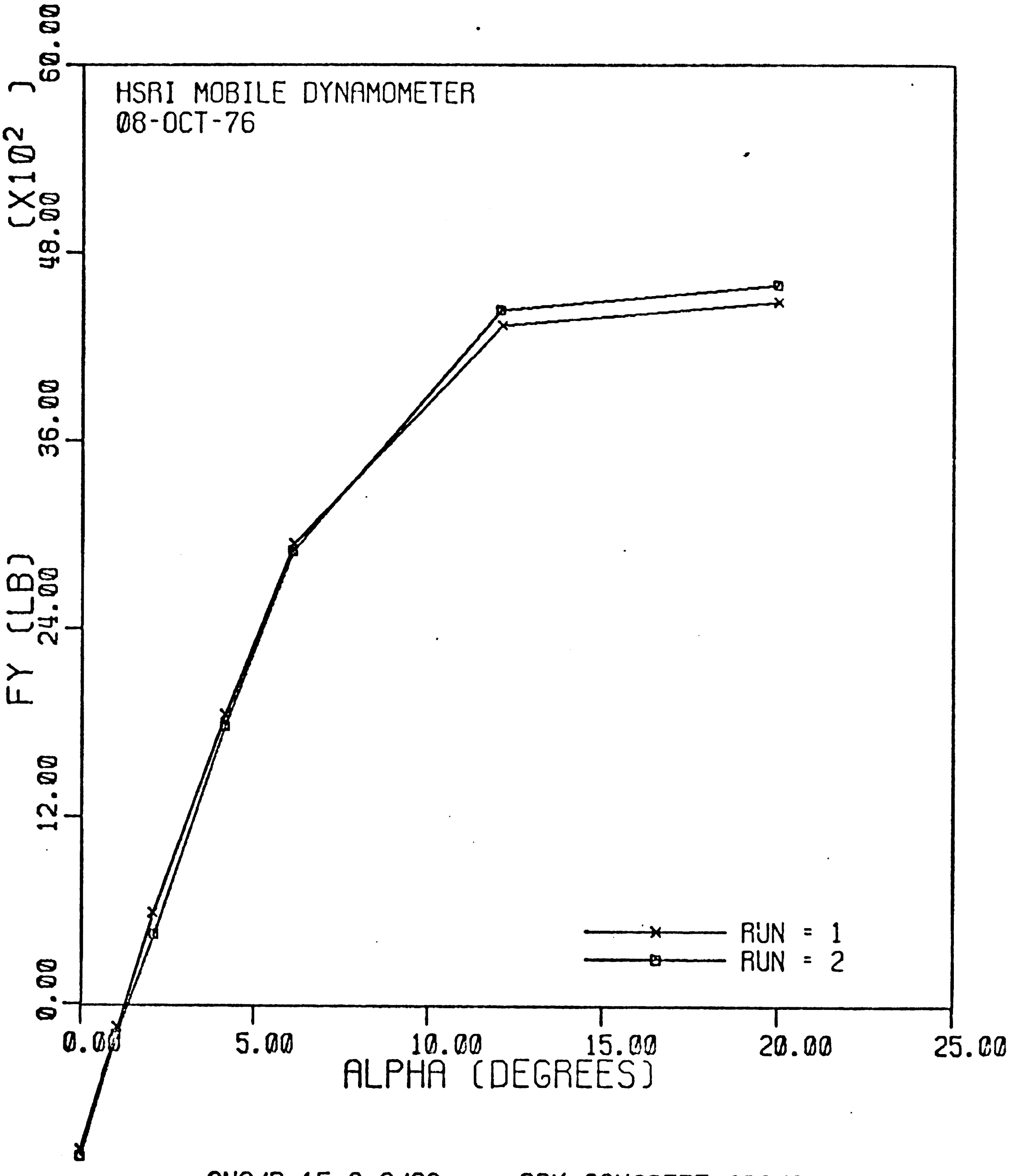

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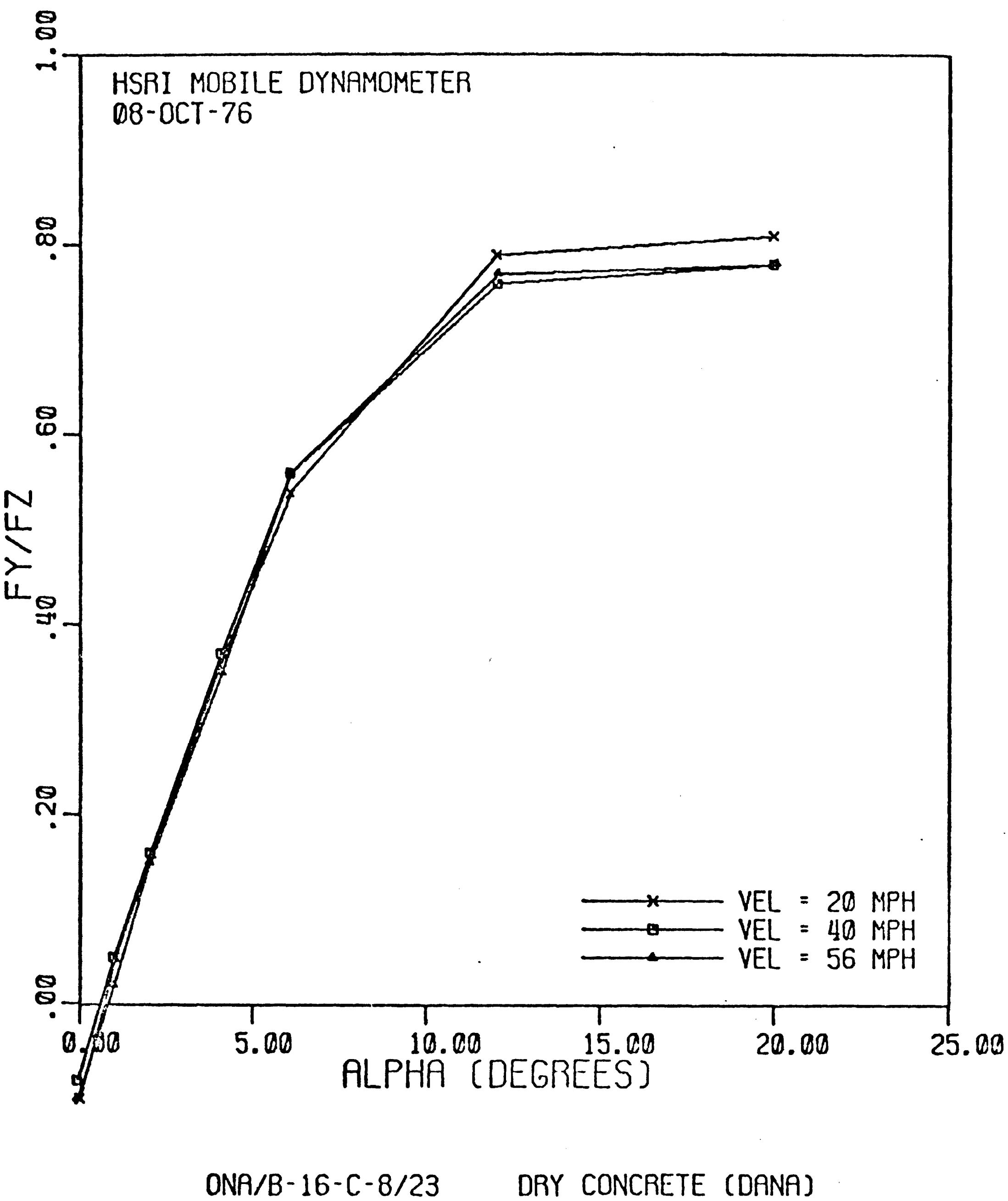
FZ = 6256 LB VEL = 20 MPH



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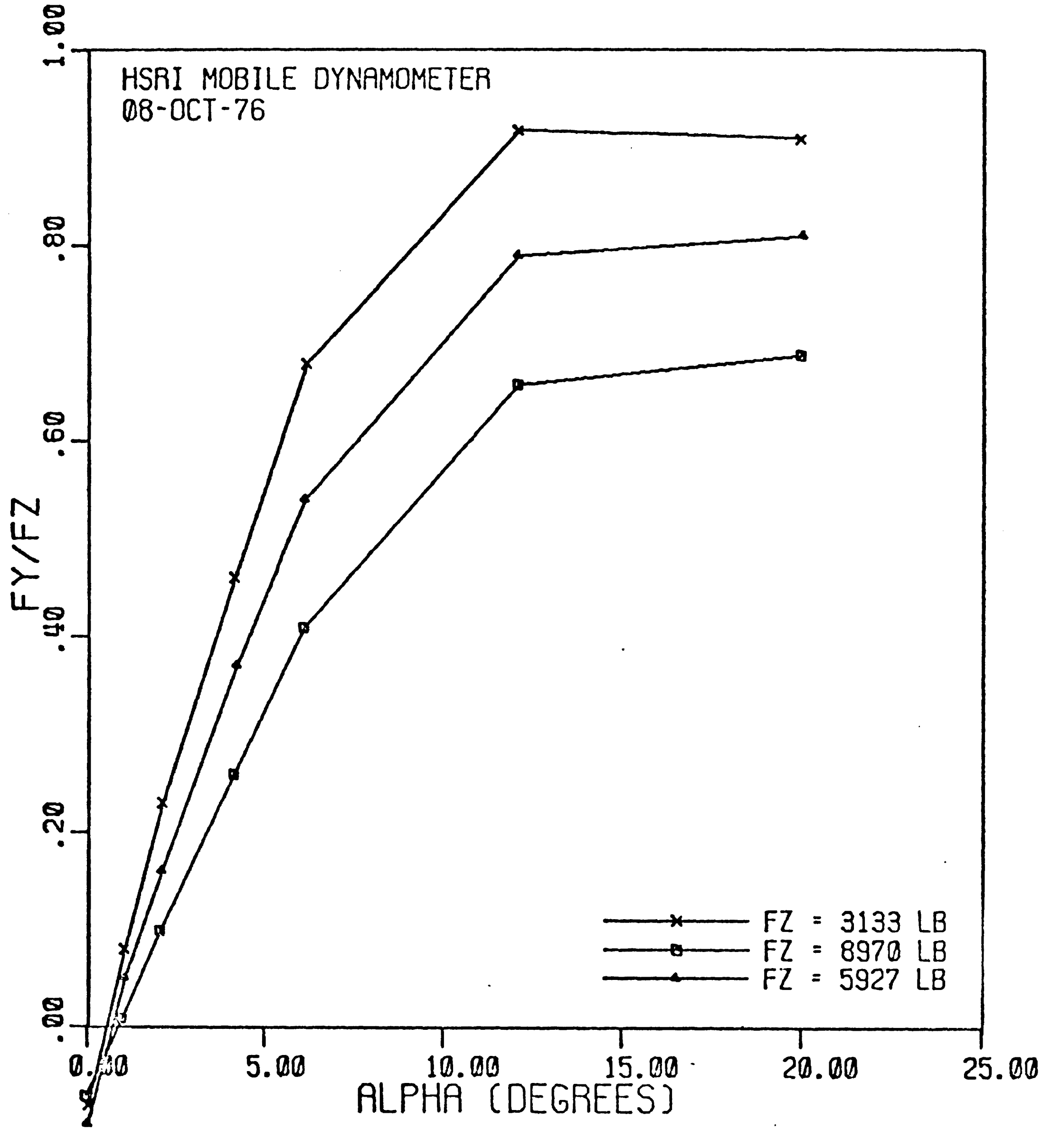
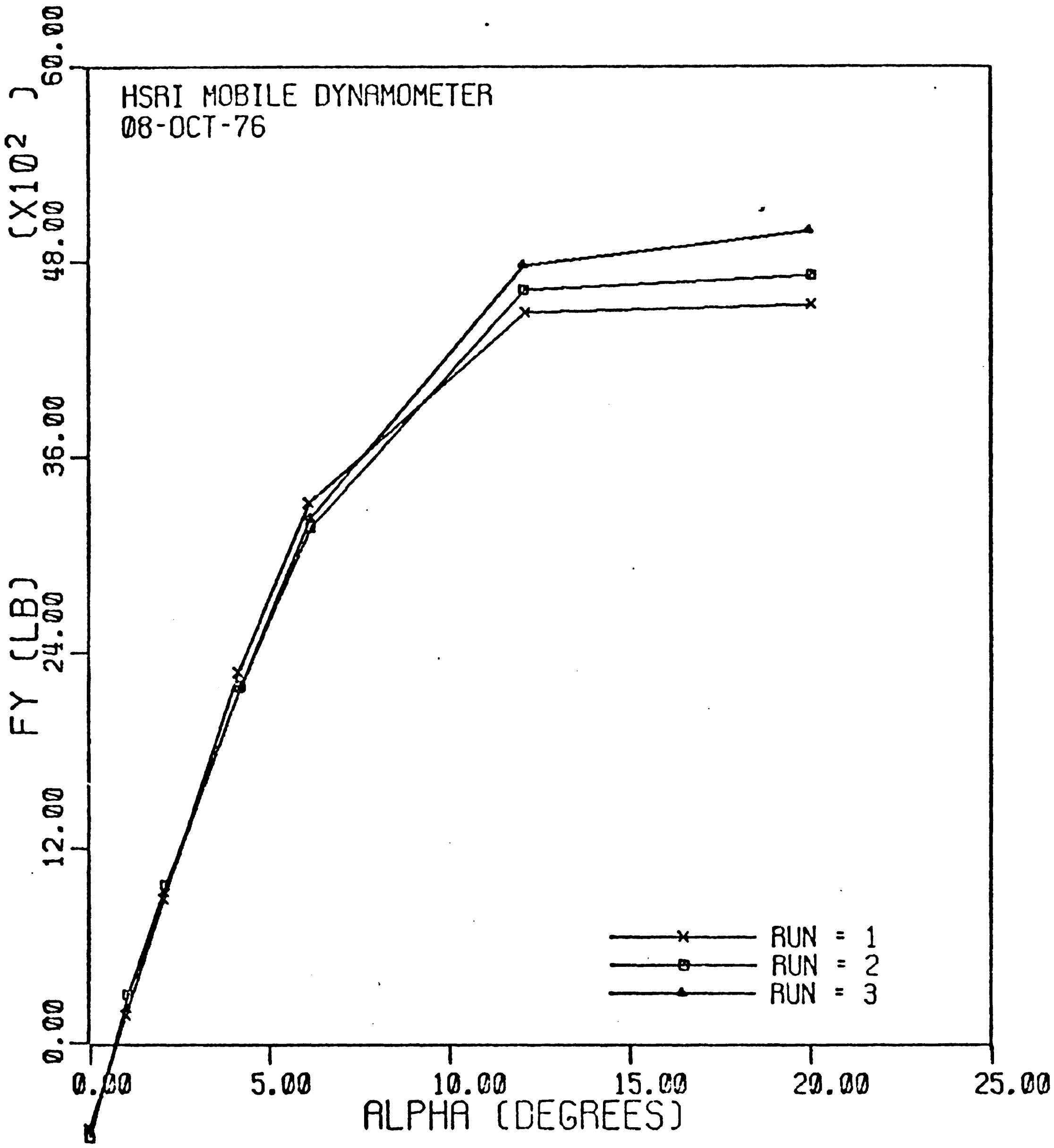
FZ = 5941 LB



ONA/B-16-C-8/23 DRY CONCRETE (DANA)
VEL = 21 MPH



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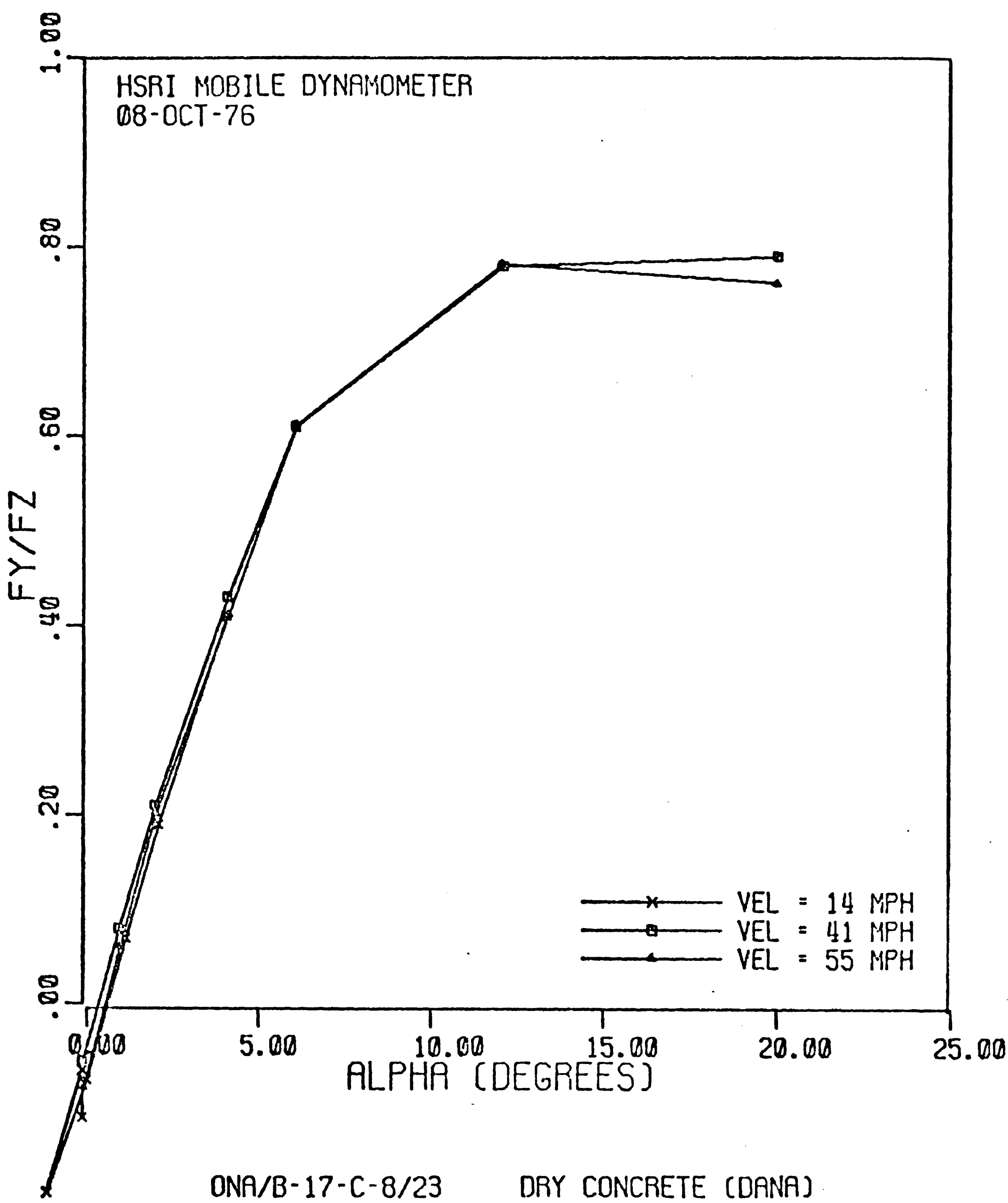
FZ = 5964 LB VEL = 14 MPH



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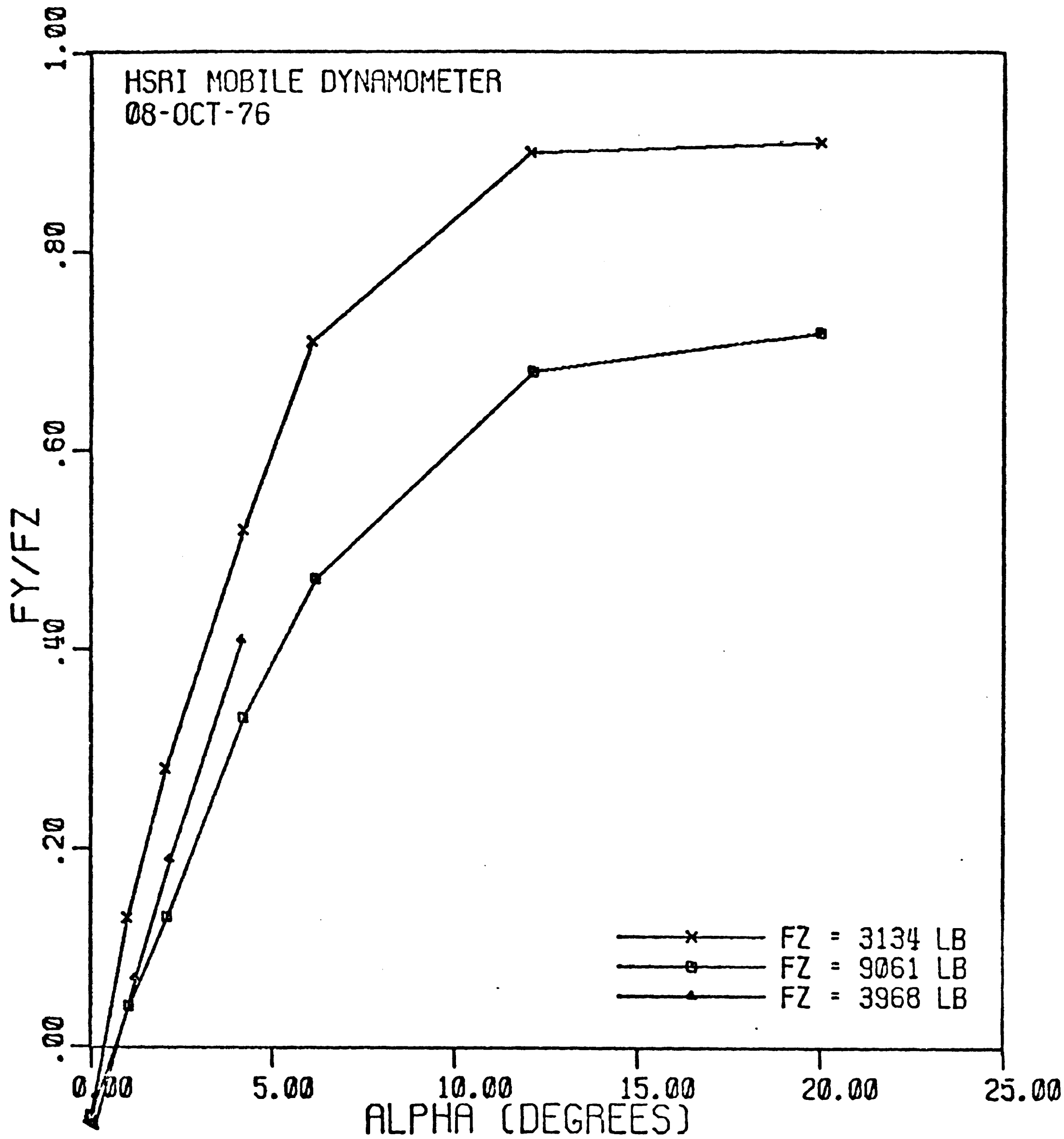
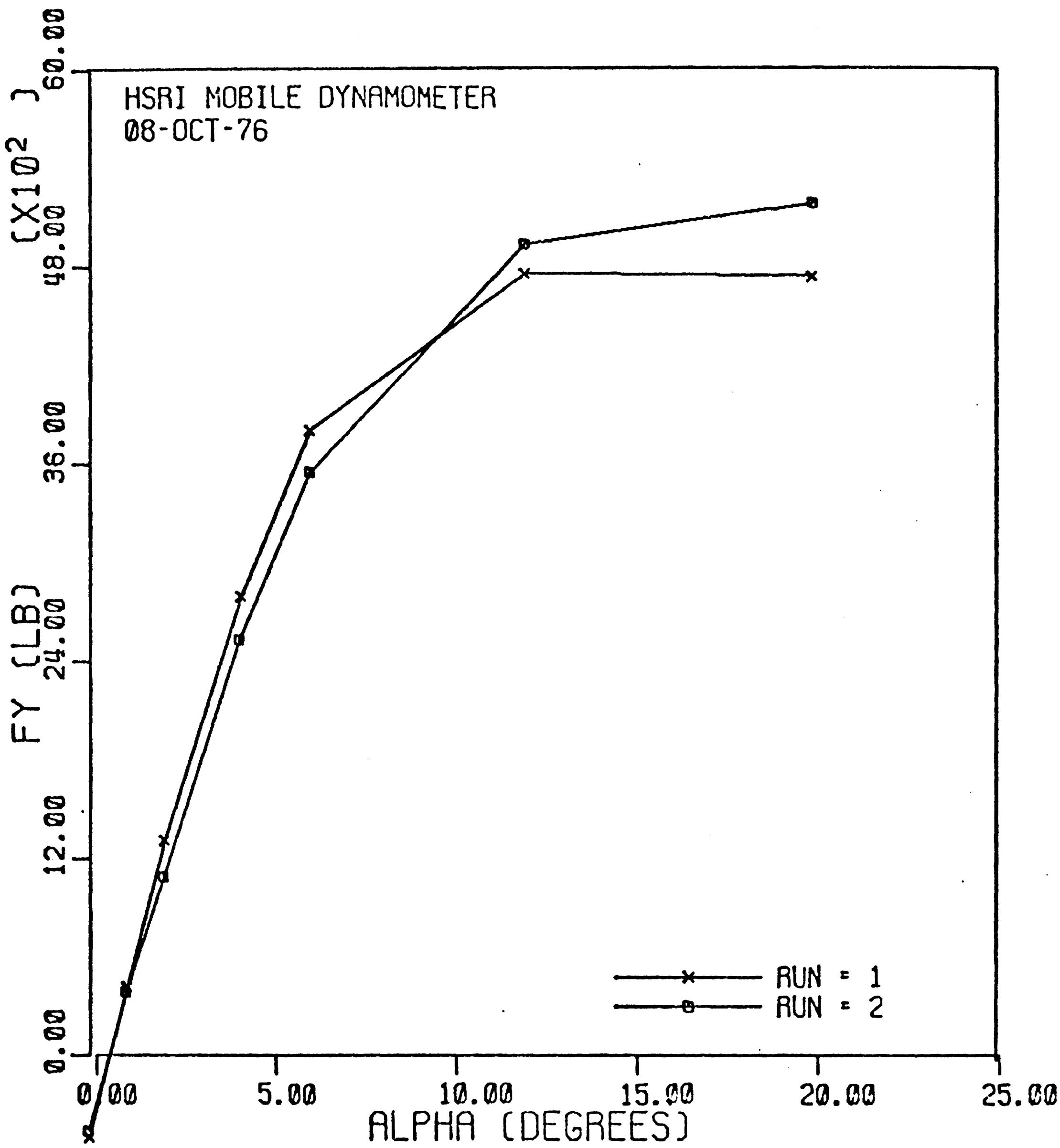
FZ = 5445 LB



ONA/B-17-C-8/23 DRY CONCRETE (DANA)
VEL = 18 MPH



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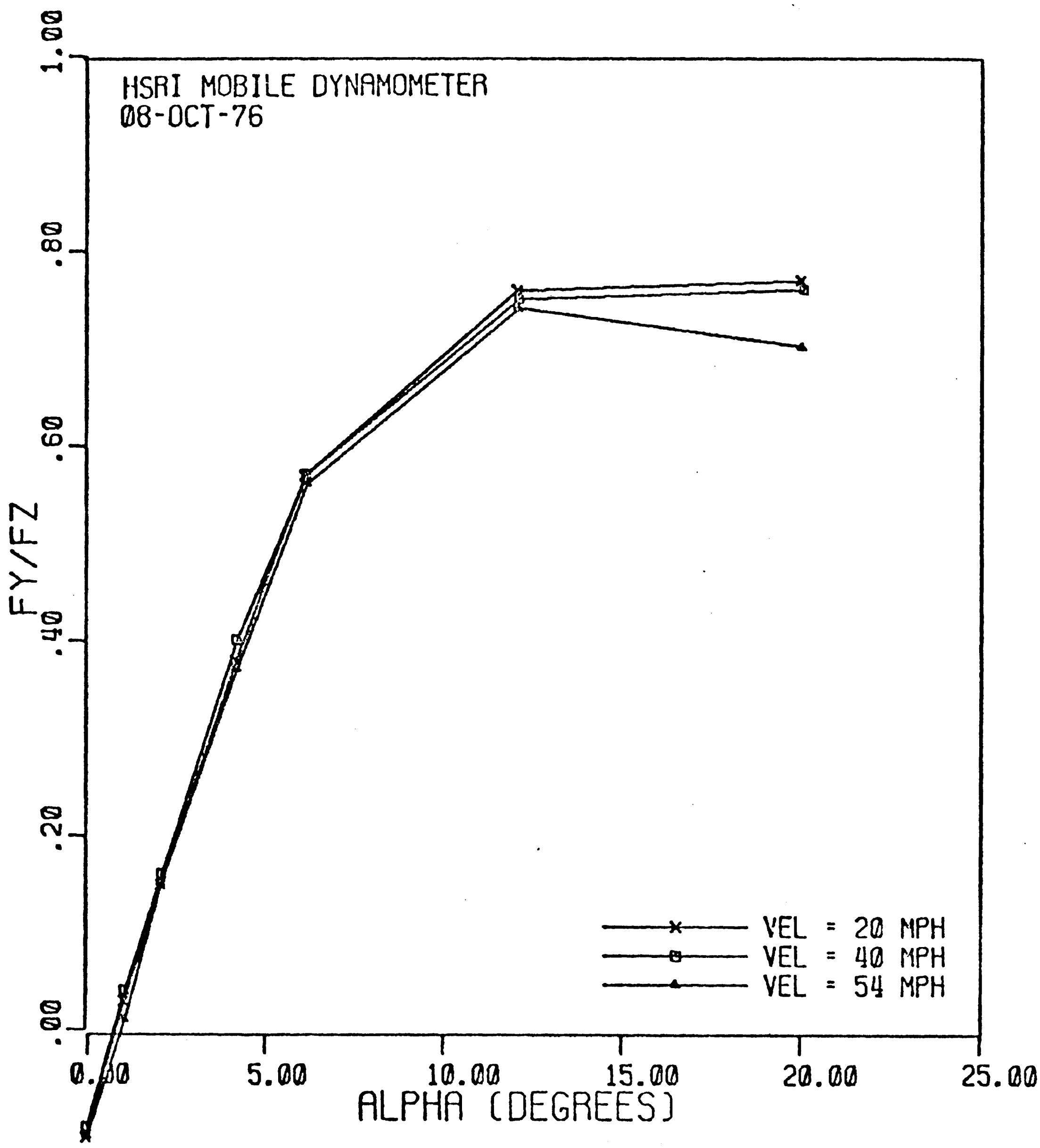
FZ = 6130 LB VEL = 20 MPH



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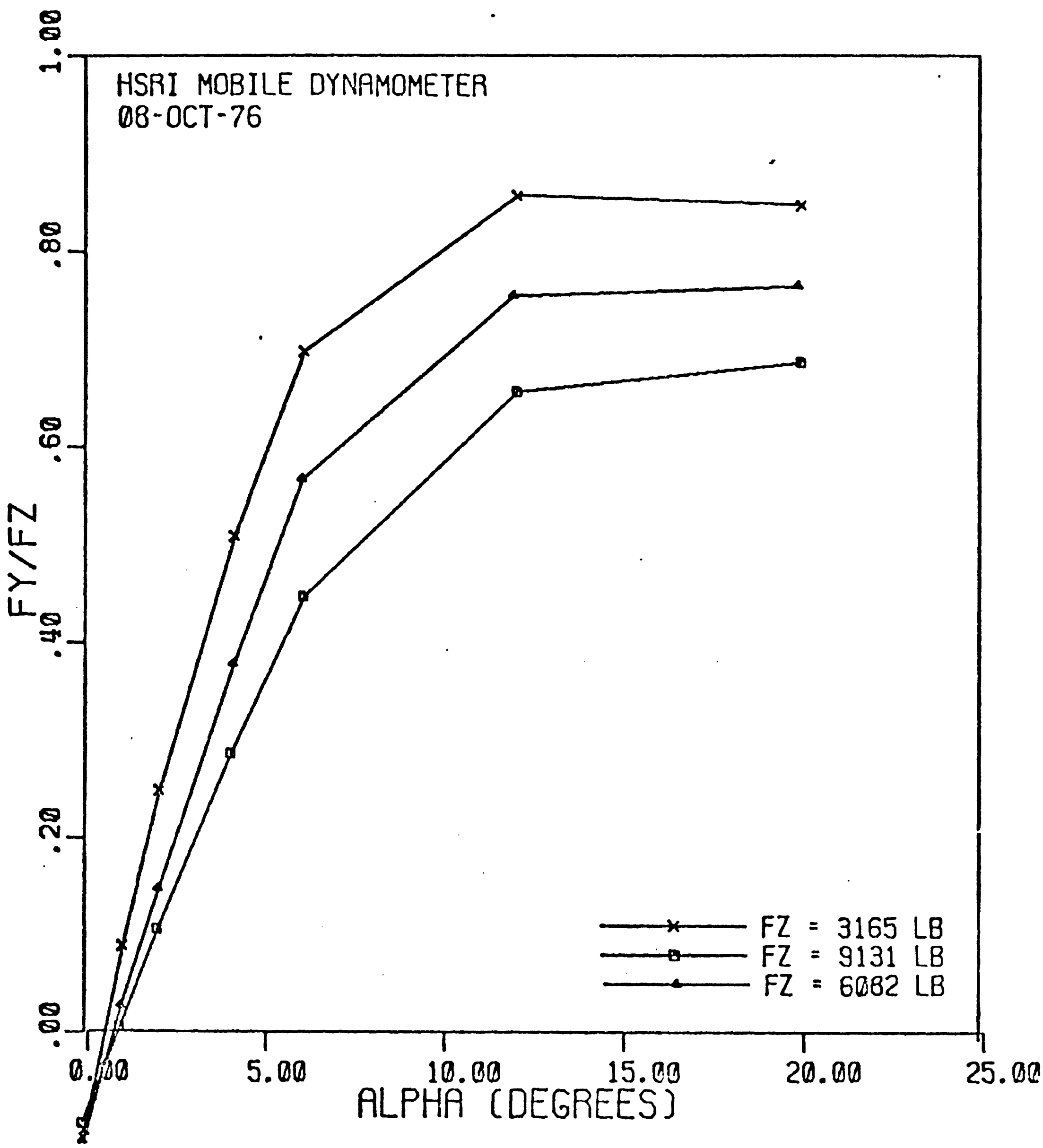

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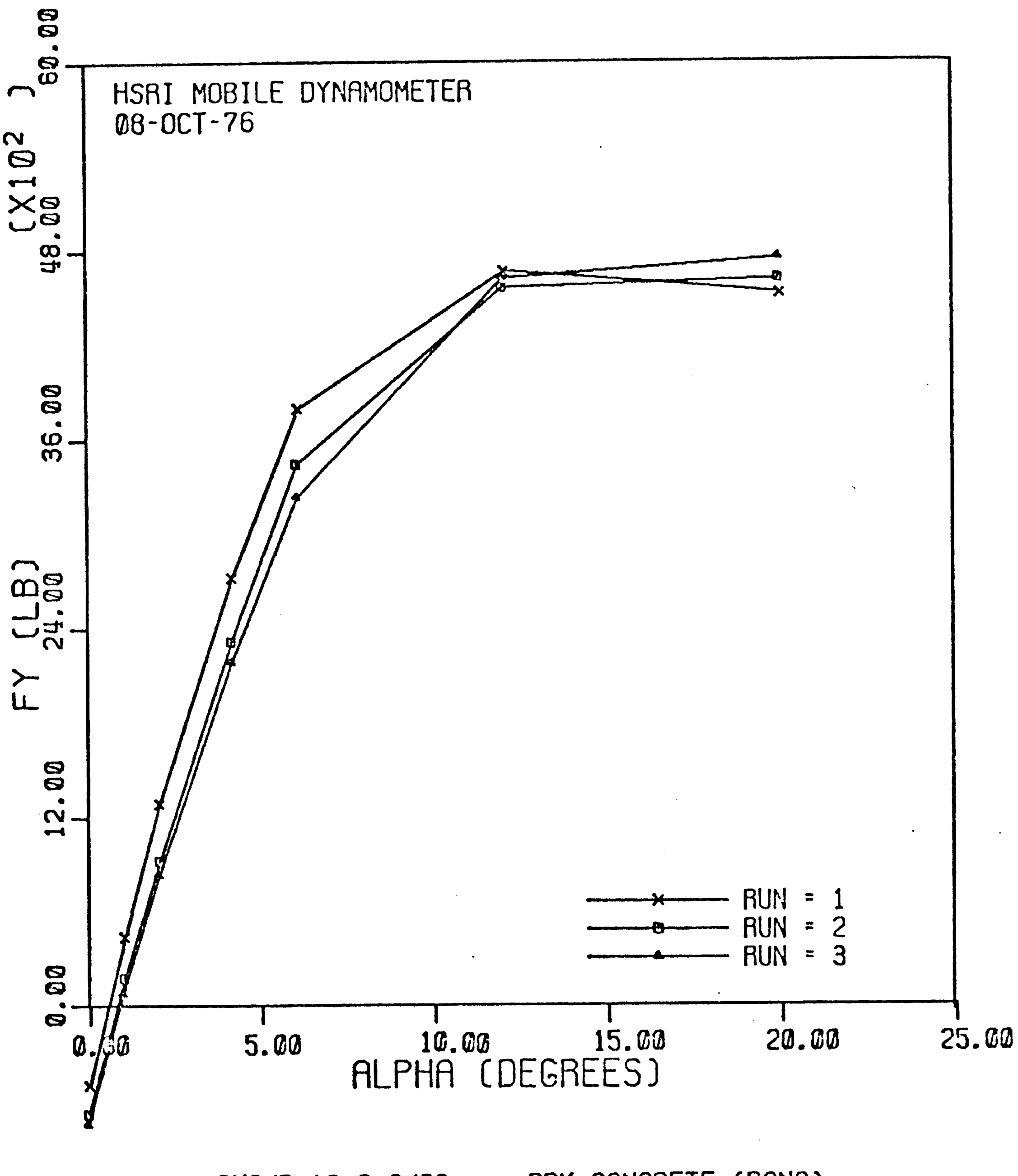
VEL = 20 MPH



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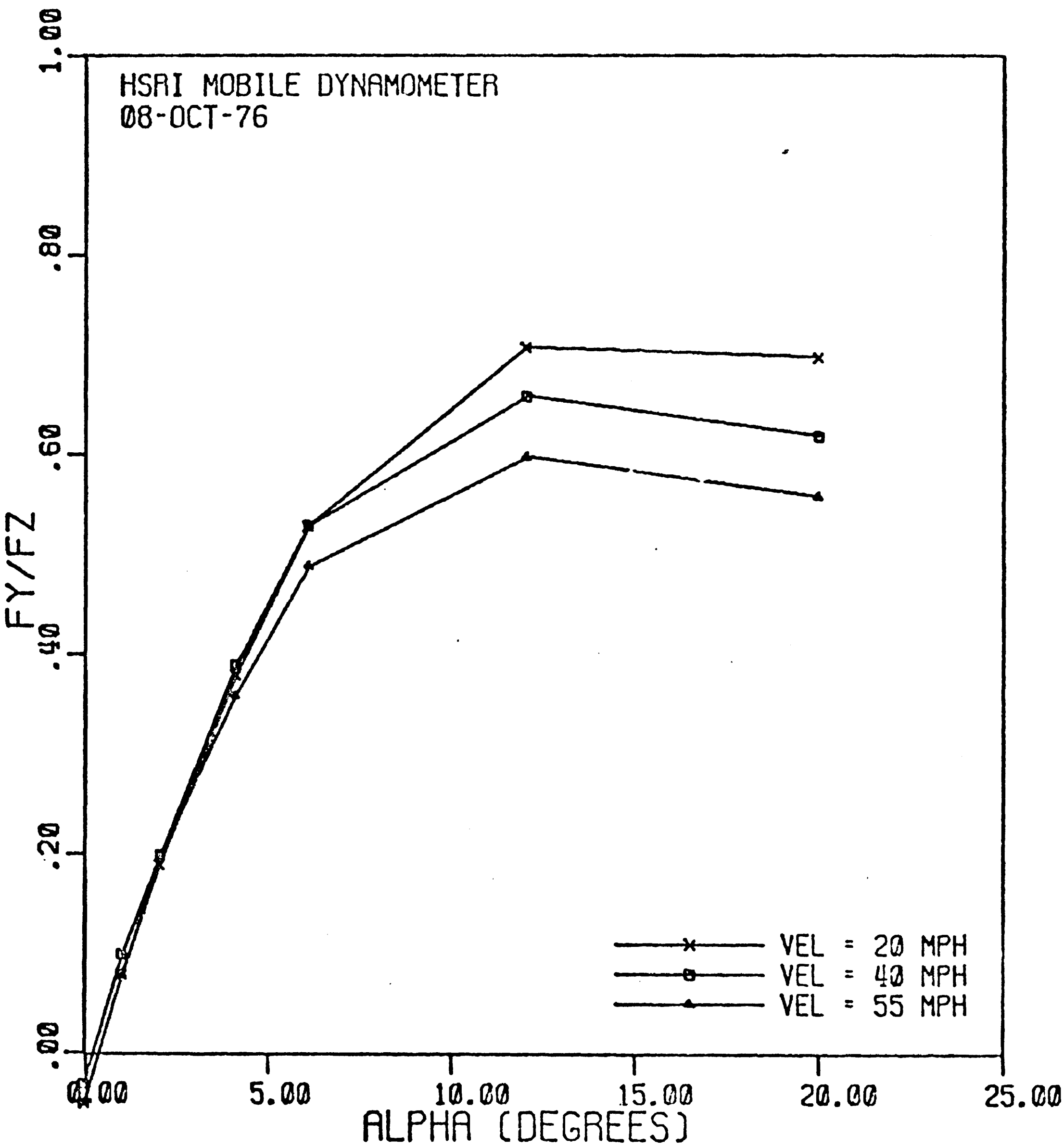
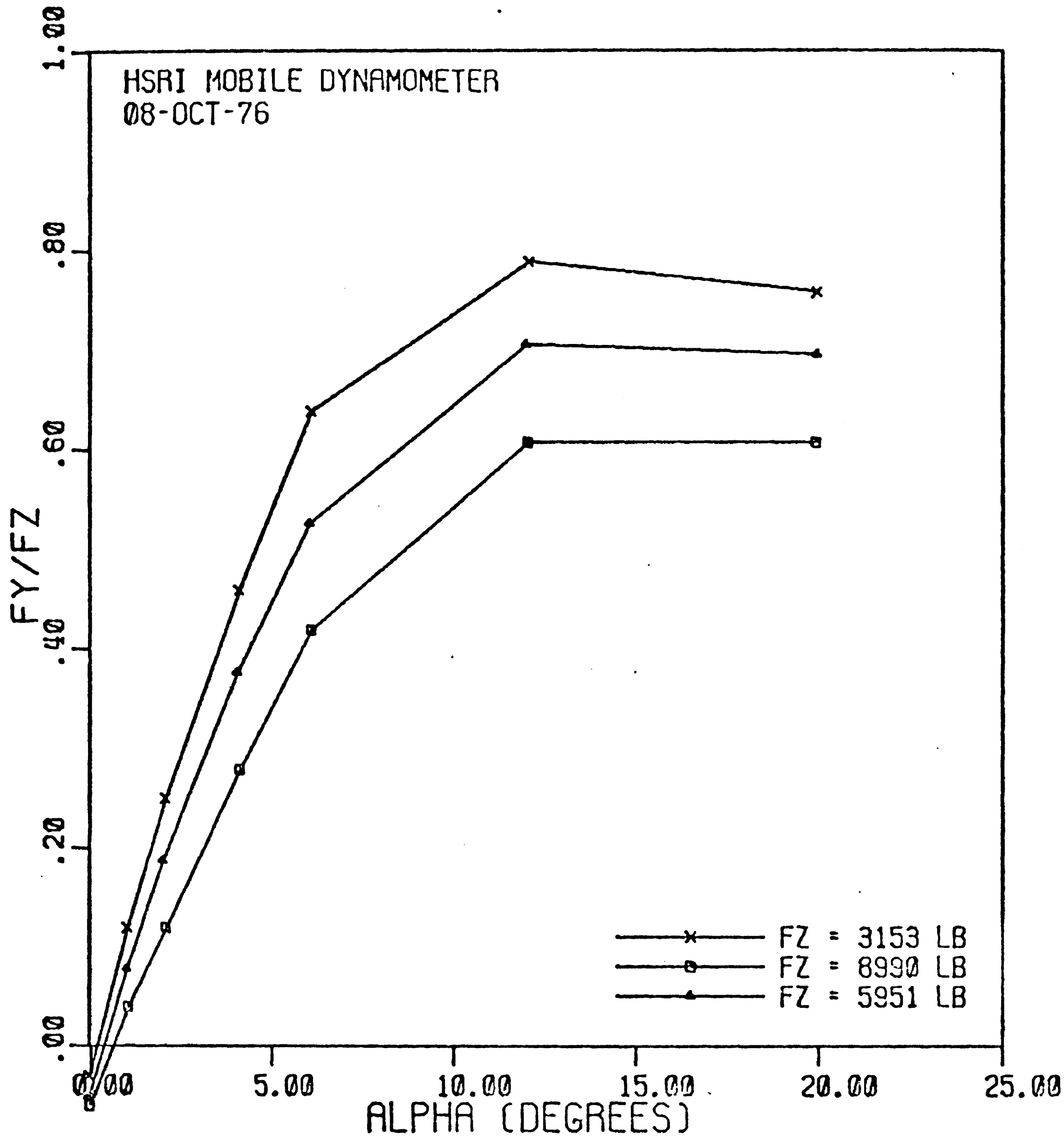
FZ = 6153 LB VEL = 20 MPH

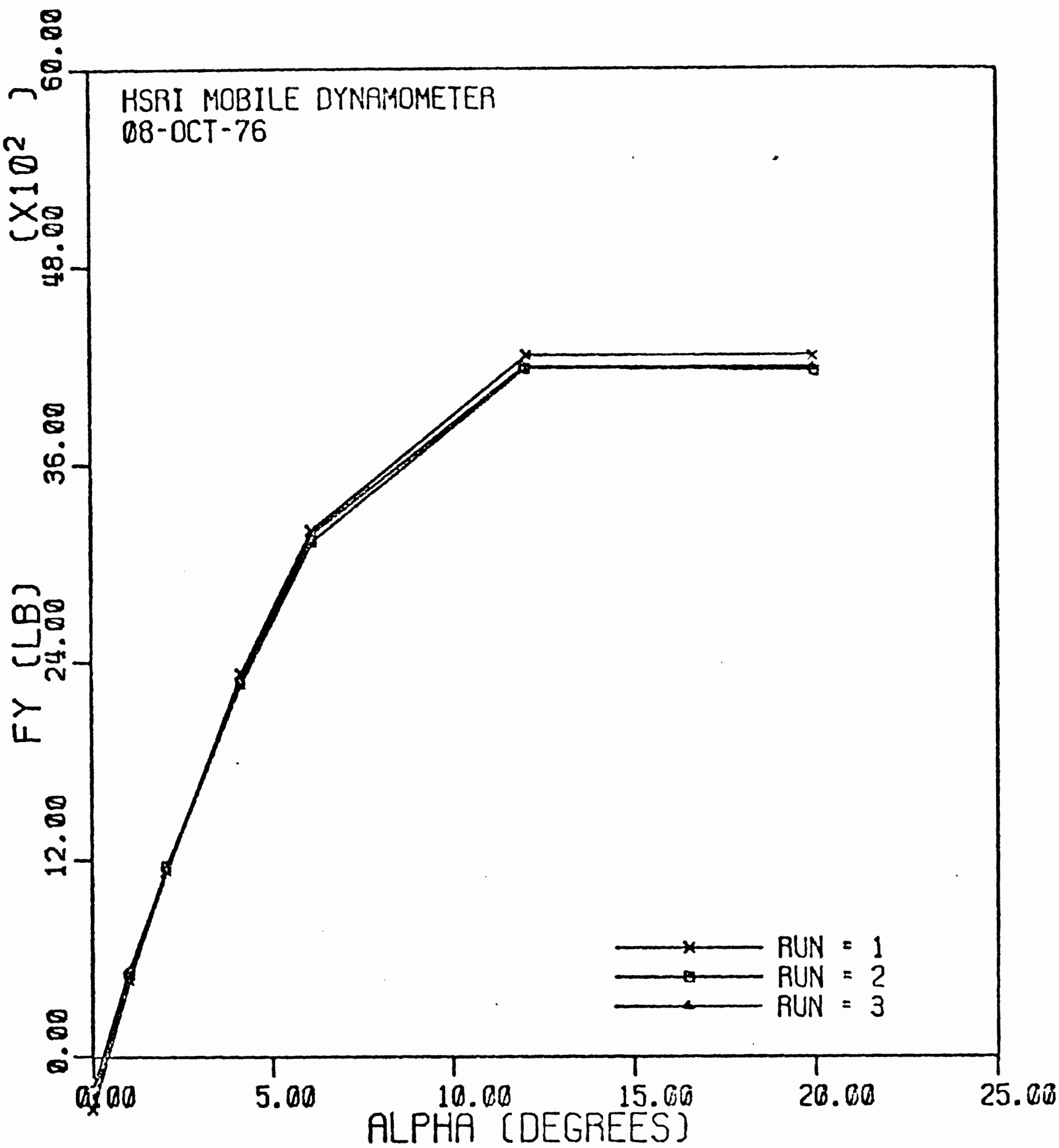


ONA/B-19-D-8/25 WET CONCRETE (DANA)

FZ = 6003 LB



ONA/B-19-D-8/25 WET CONCRETE (DANA)
VEL = 20 MPH



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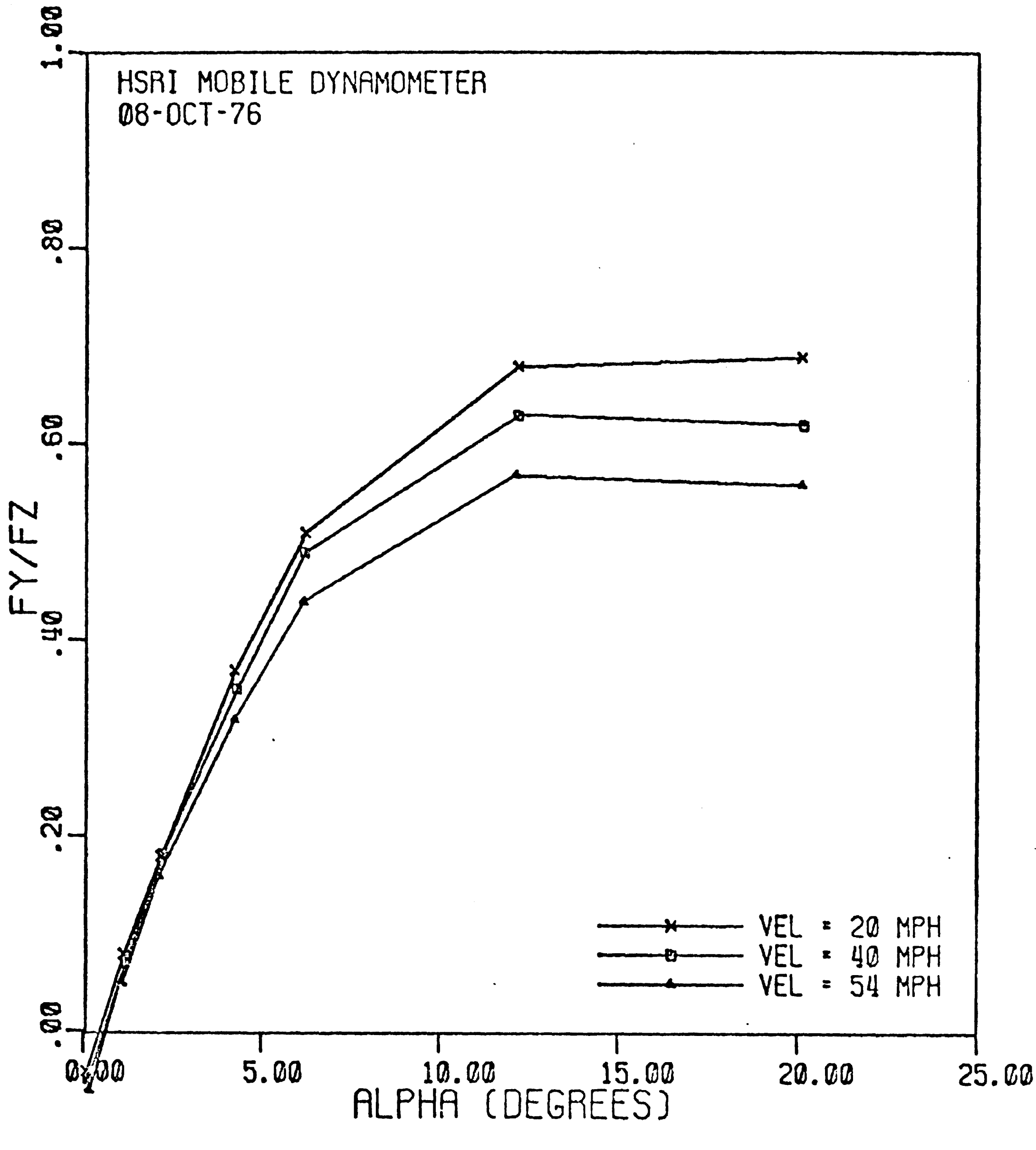

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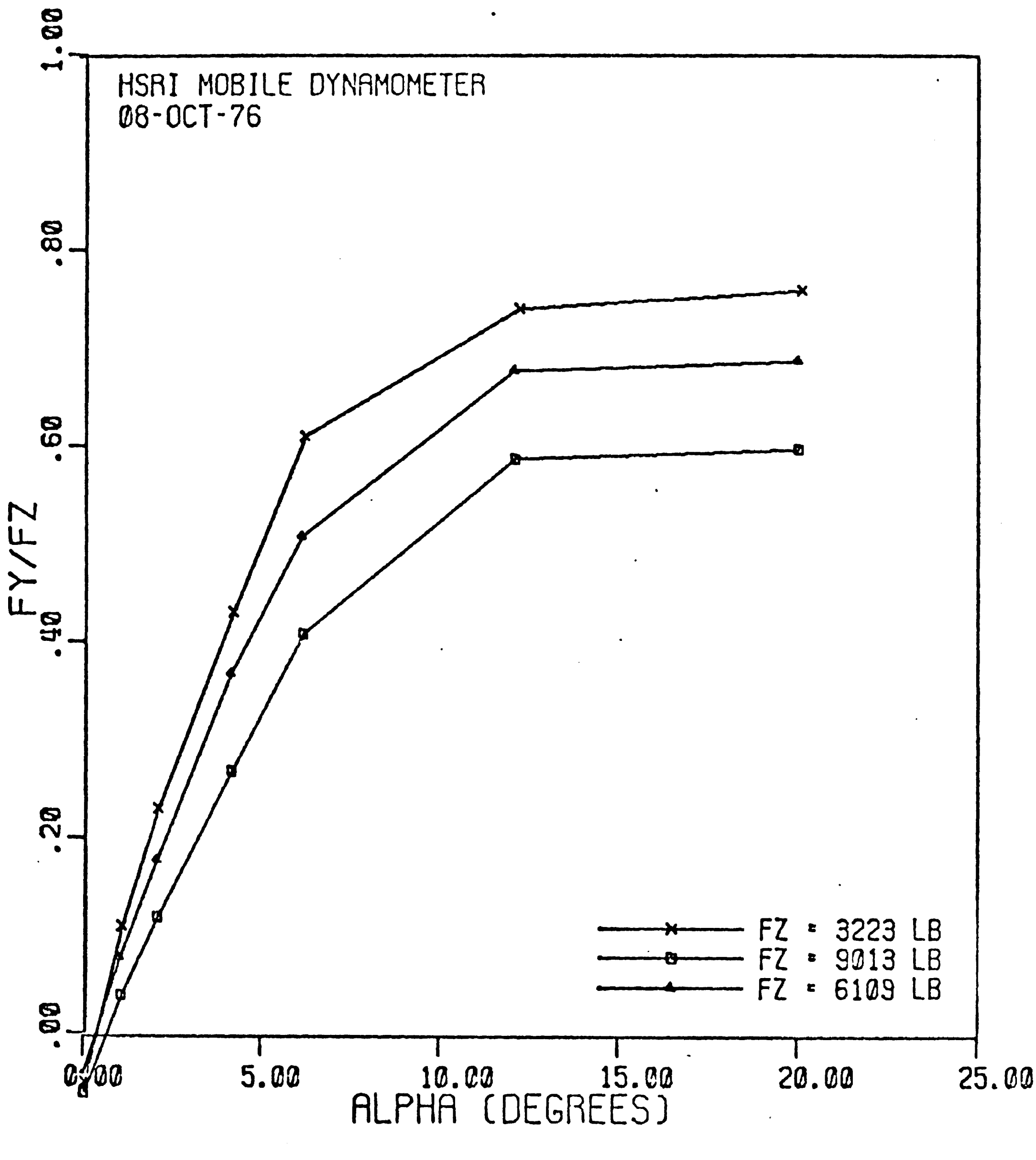
FZ = 6171 LB



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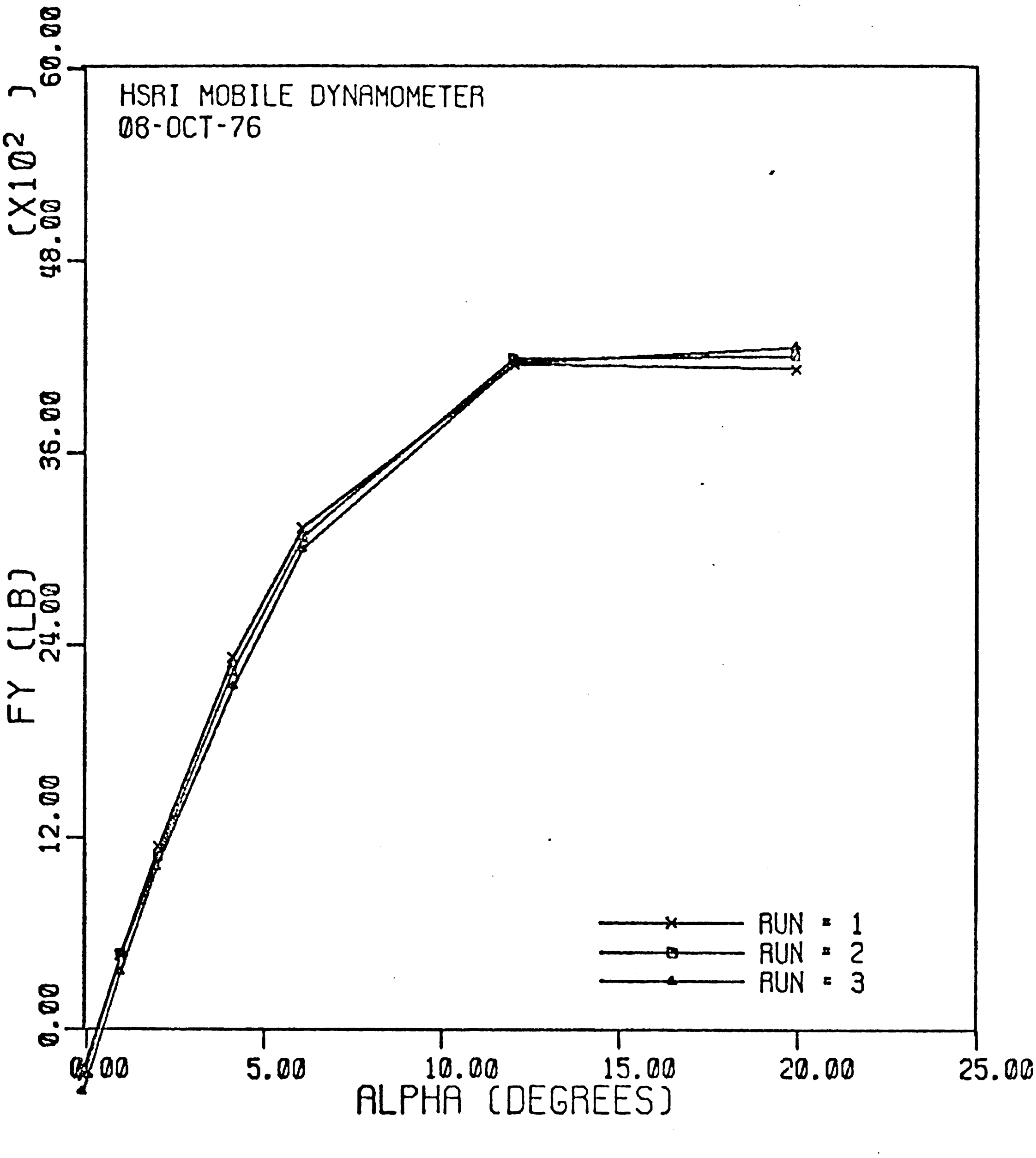

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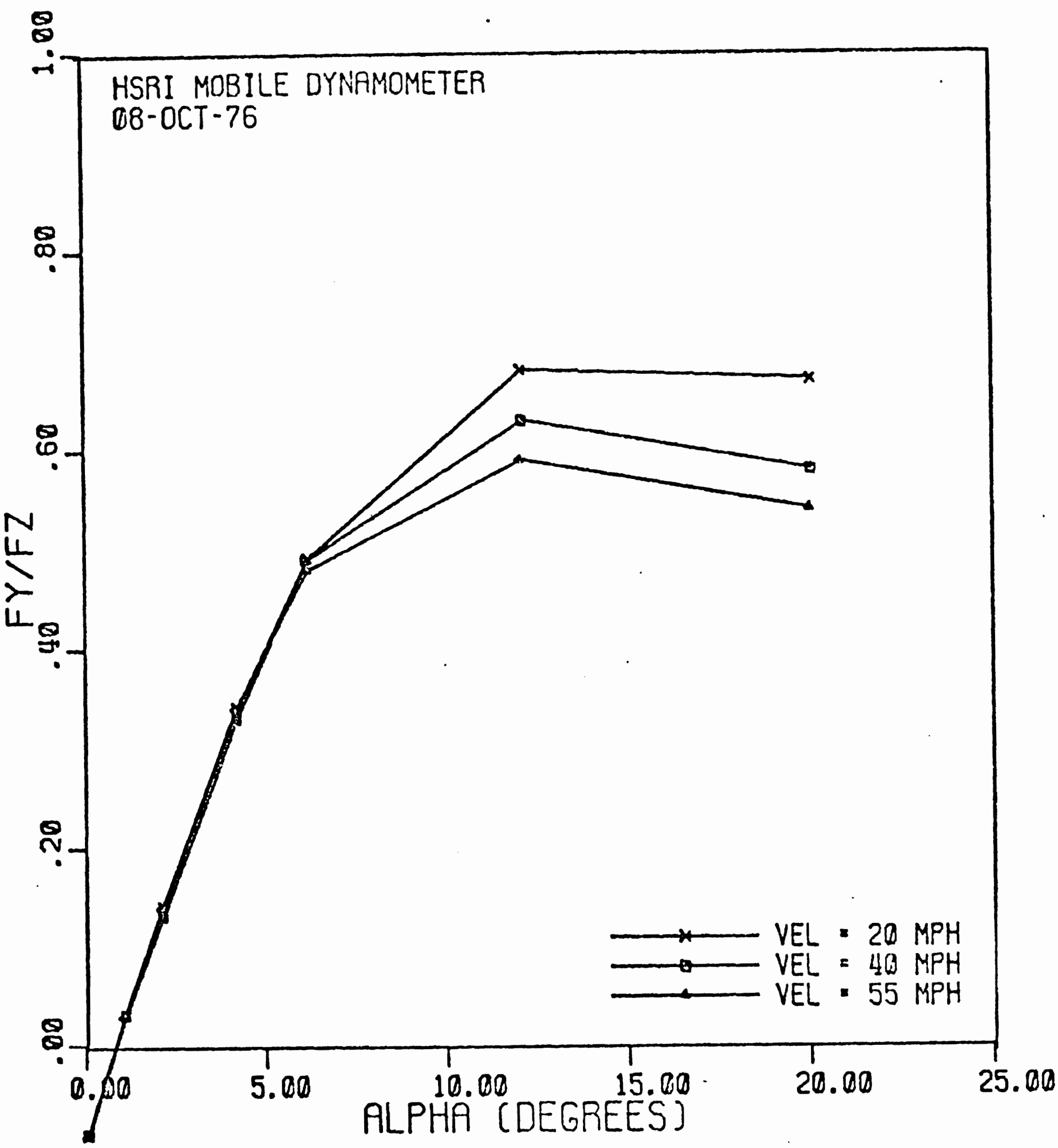

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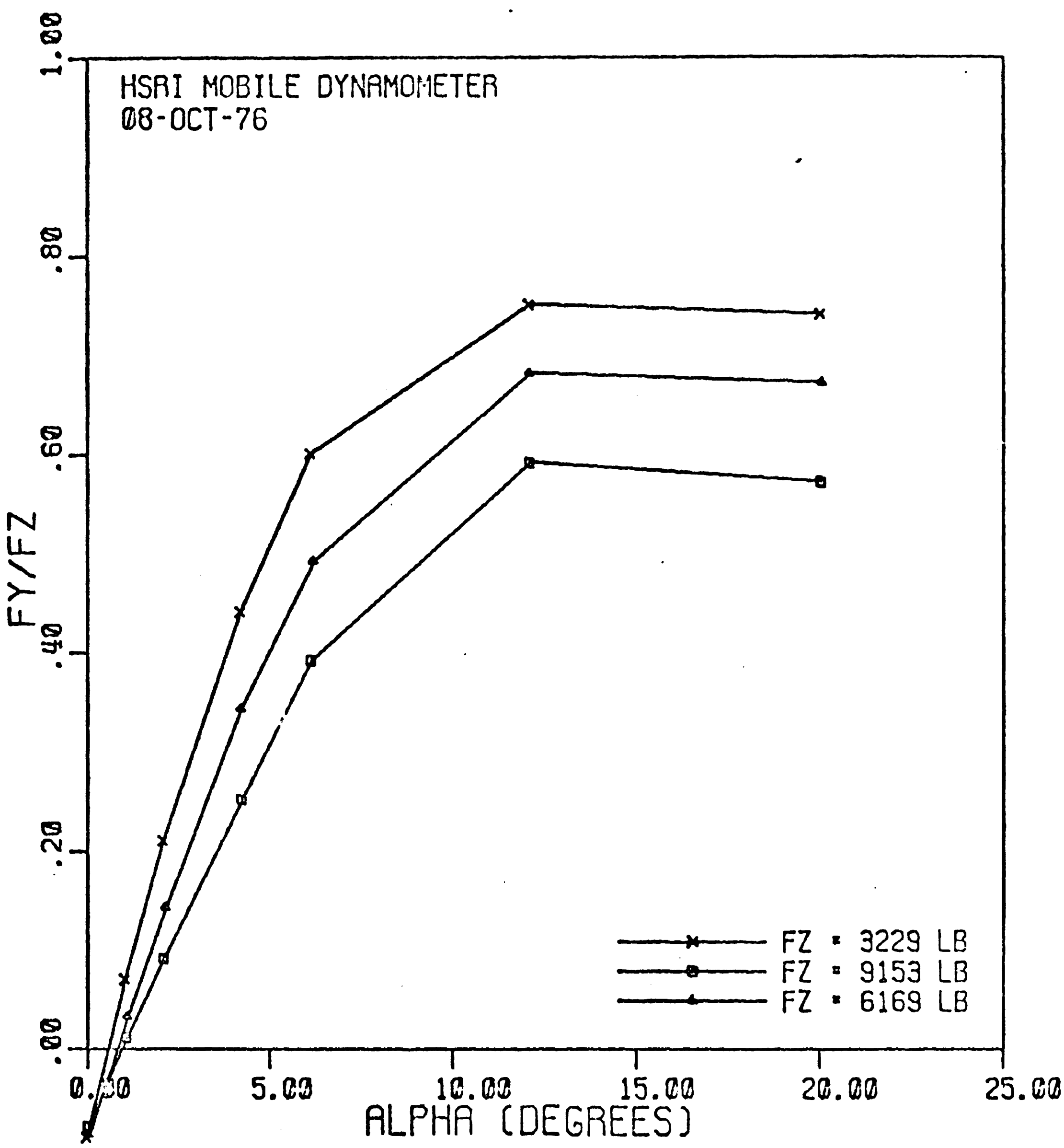

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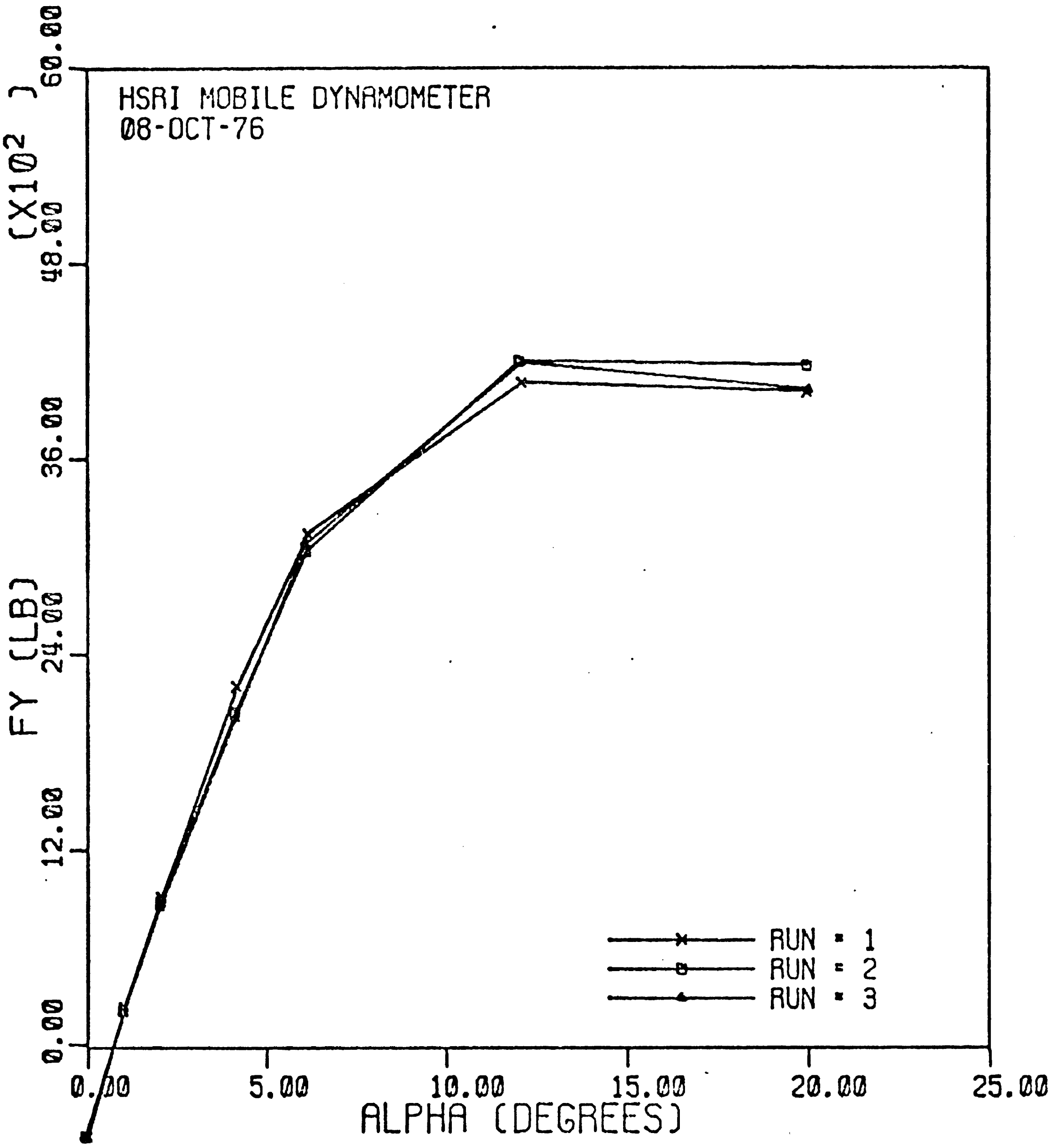

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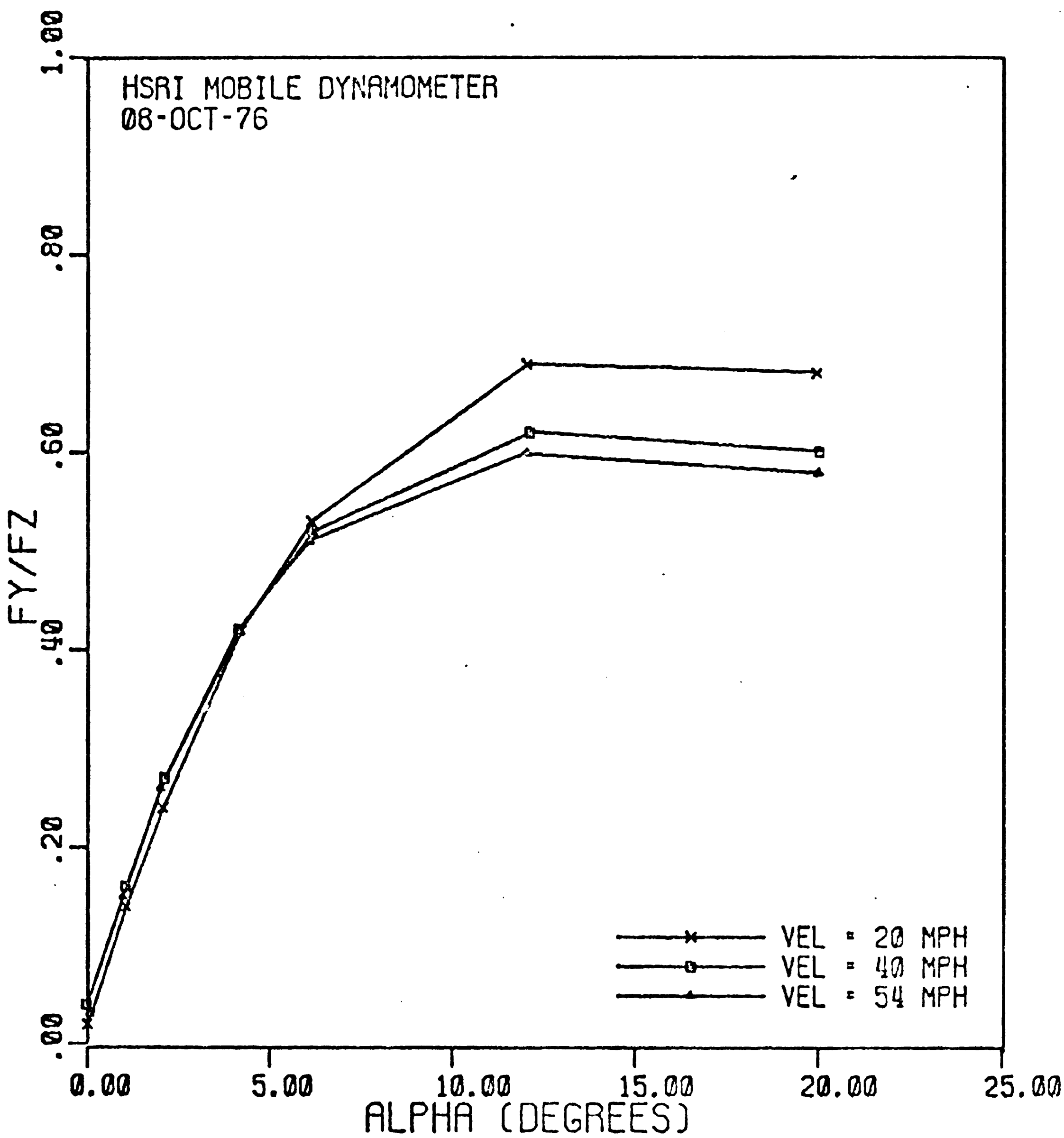

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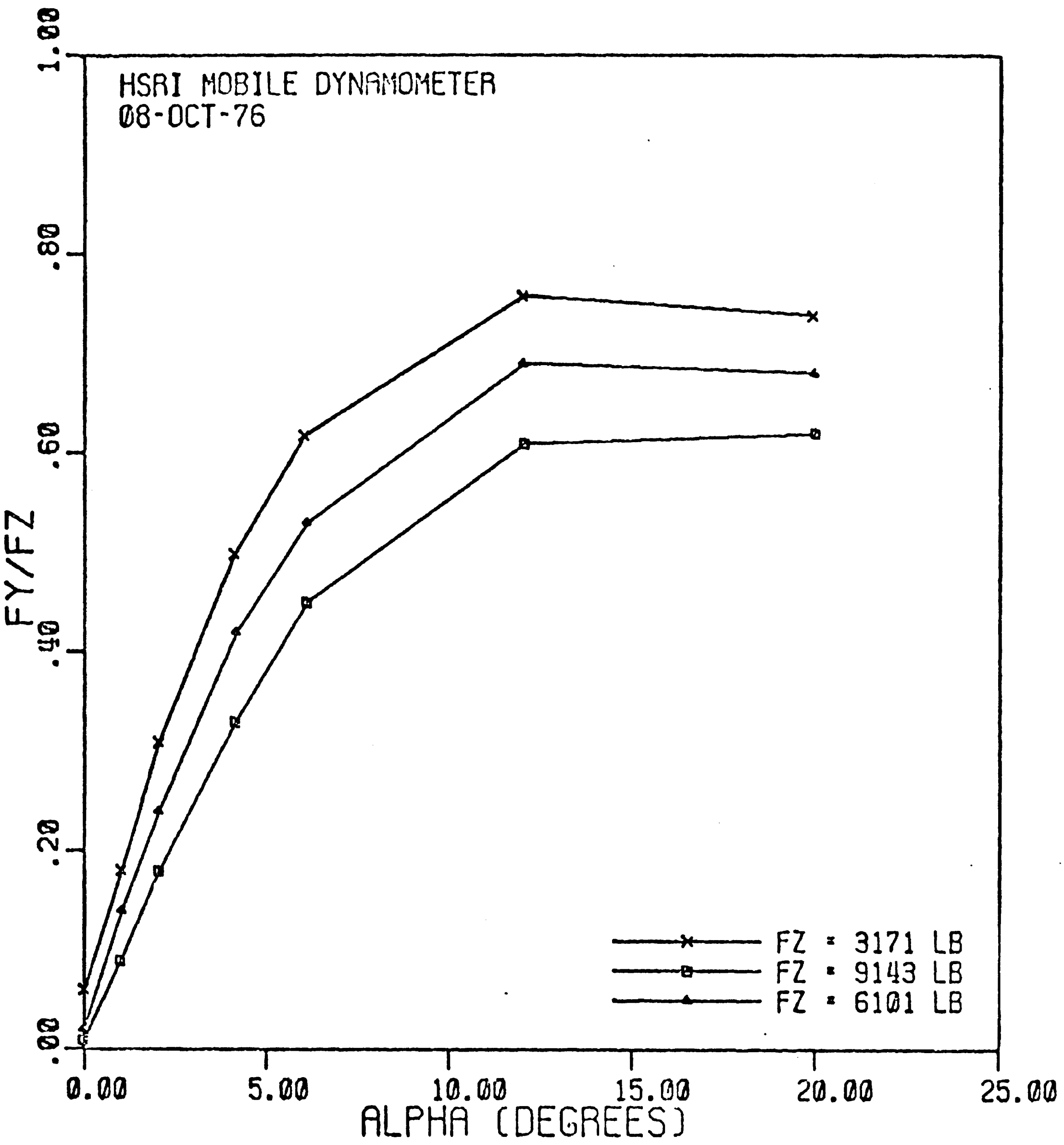

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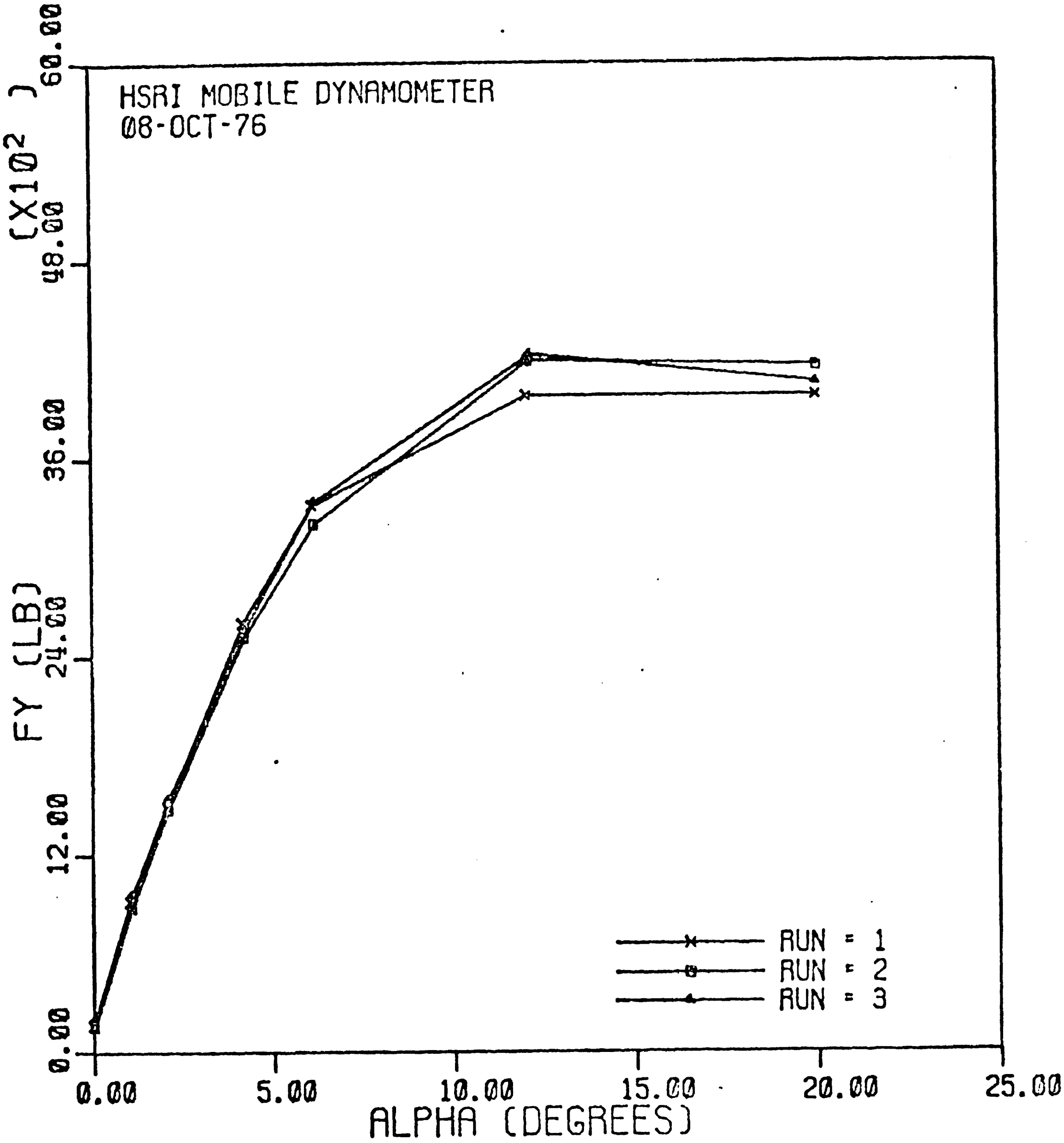
VEL = 20 MPH



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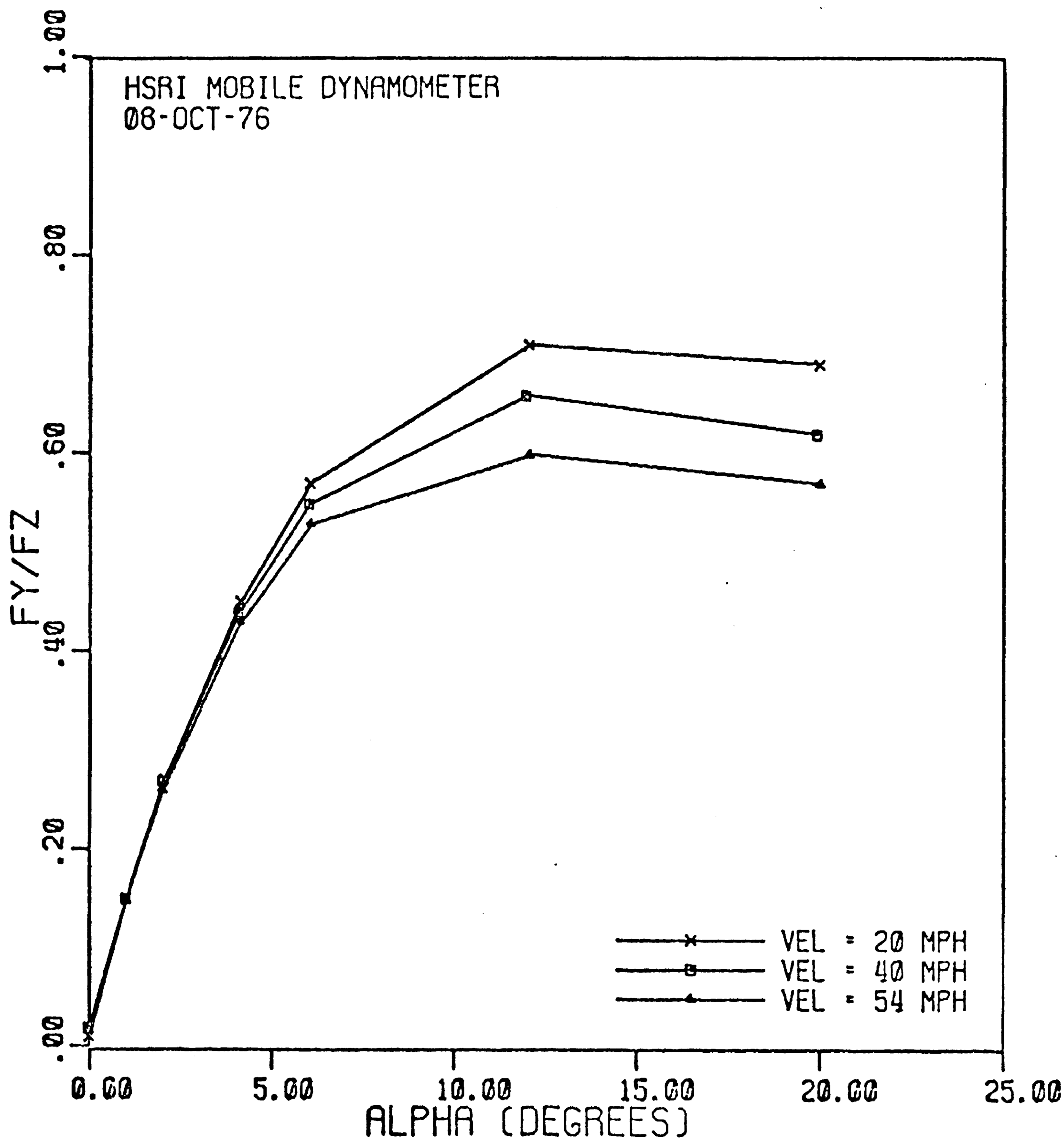

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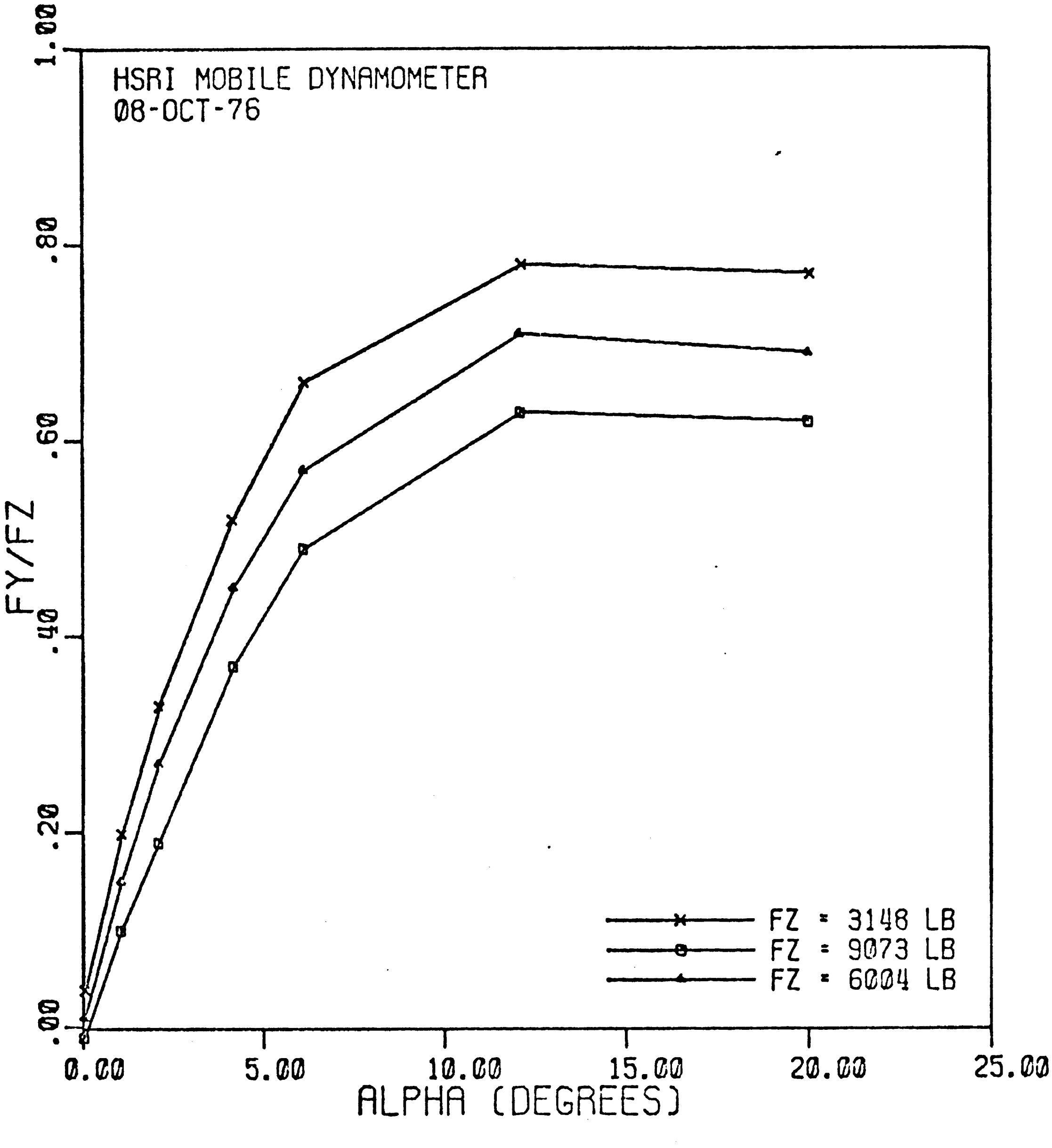
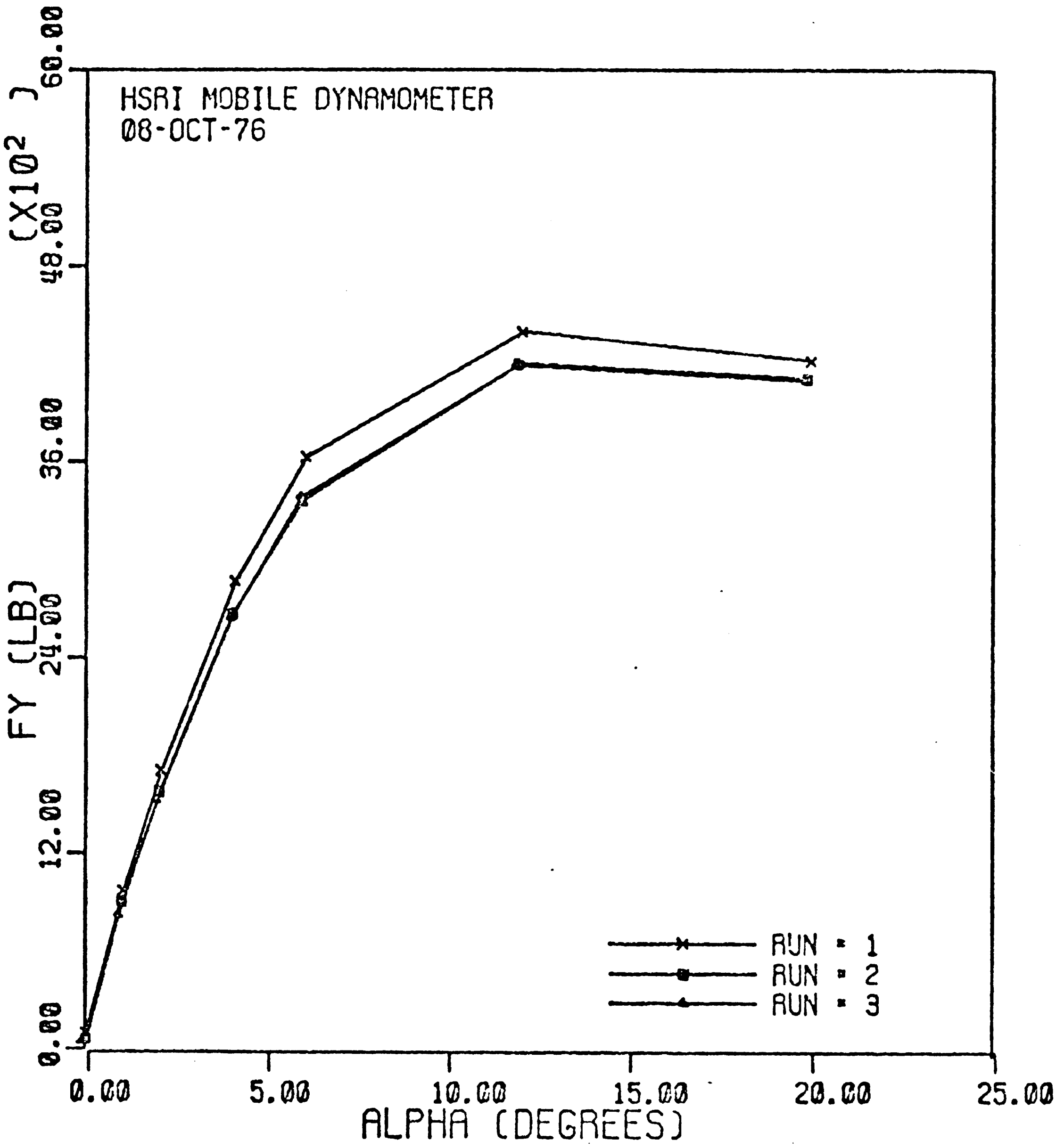


ONA/B-23-D-8/30 WET CONCRETE (DANA)
VEL = 13 MPH



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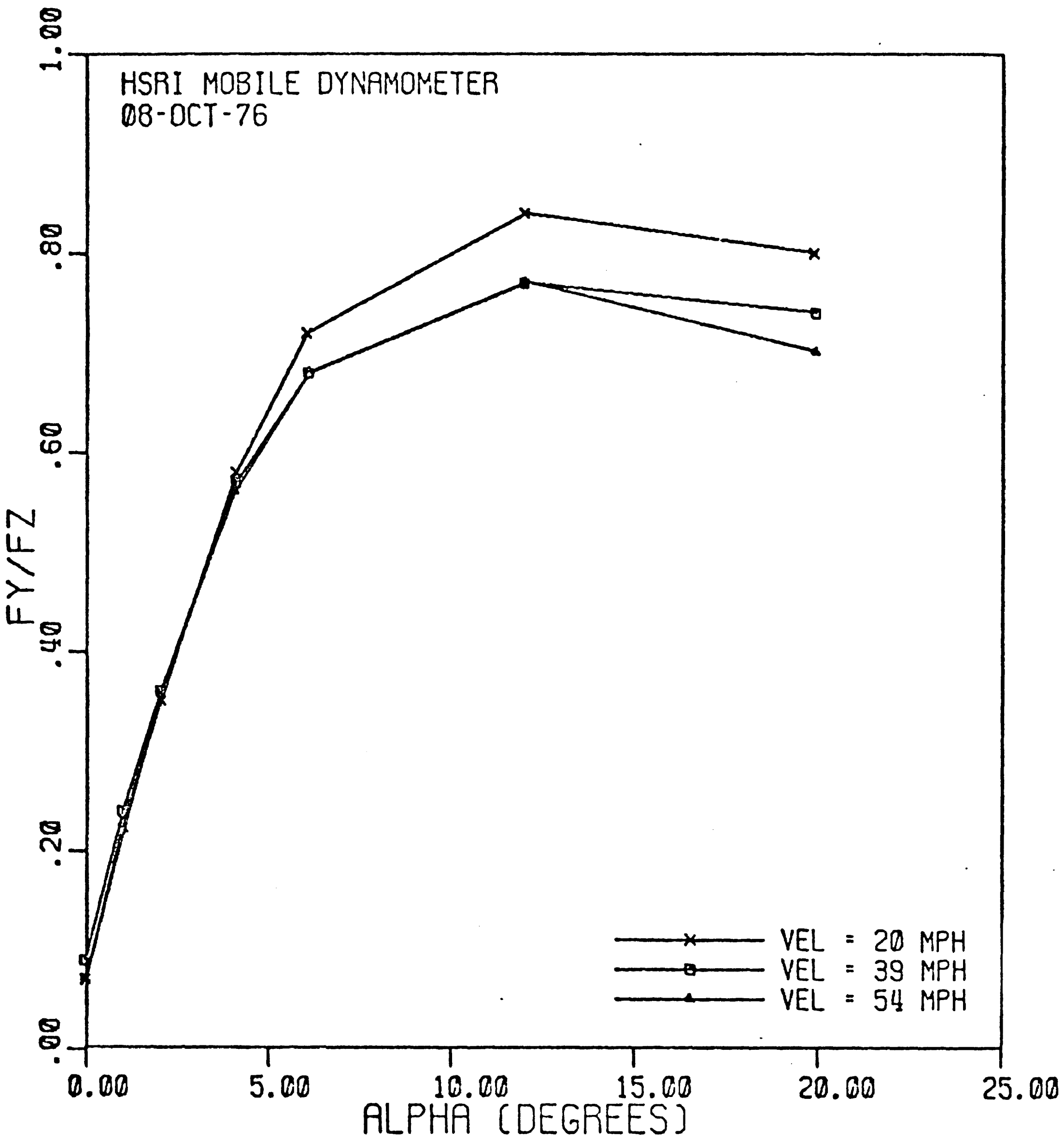
FZ = 6006 LB VEL = 13 MPH



ONA/B-24-D-8/30 WET CONCRETE (DANA)
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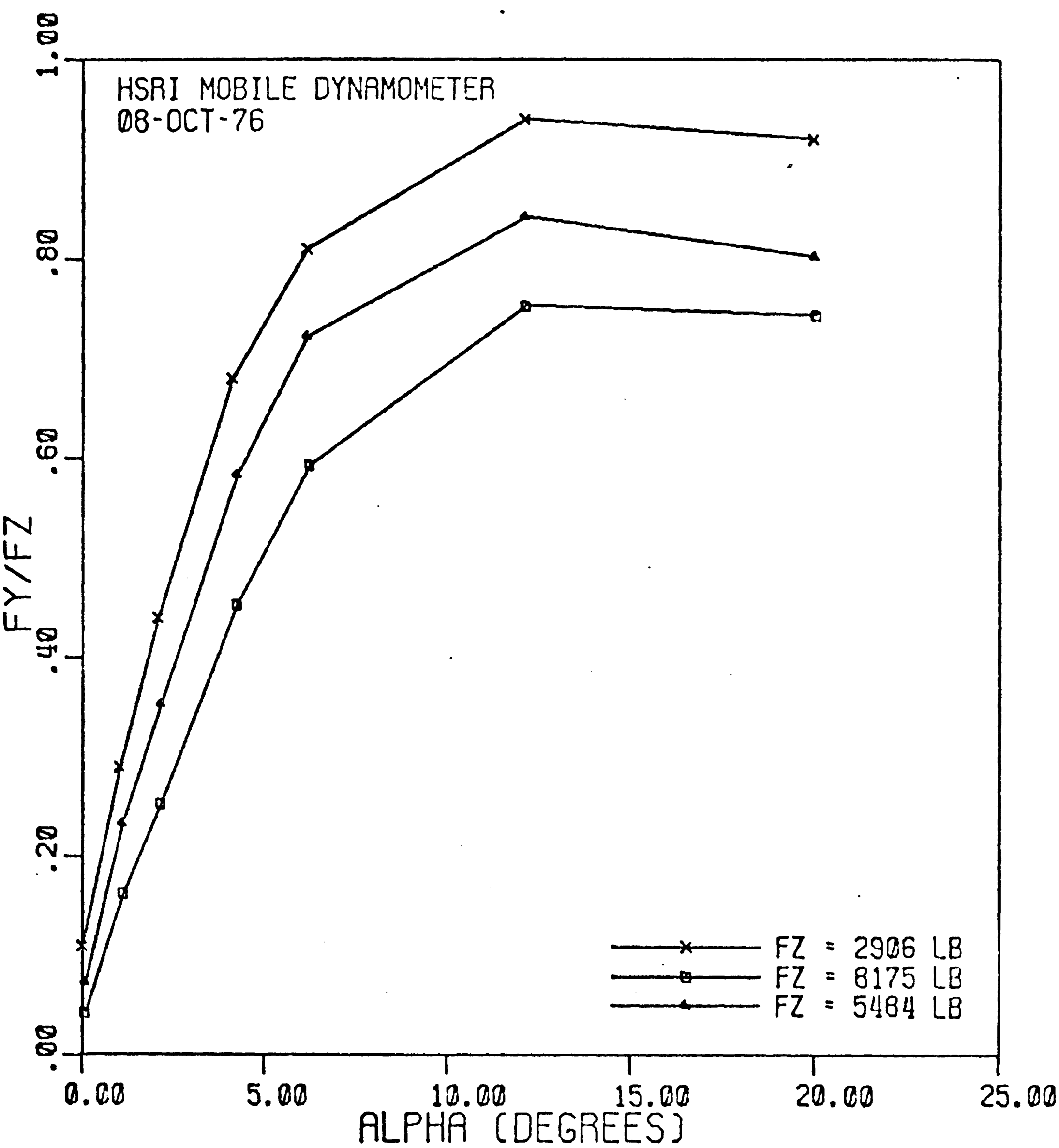

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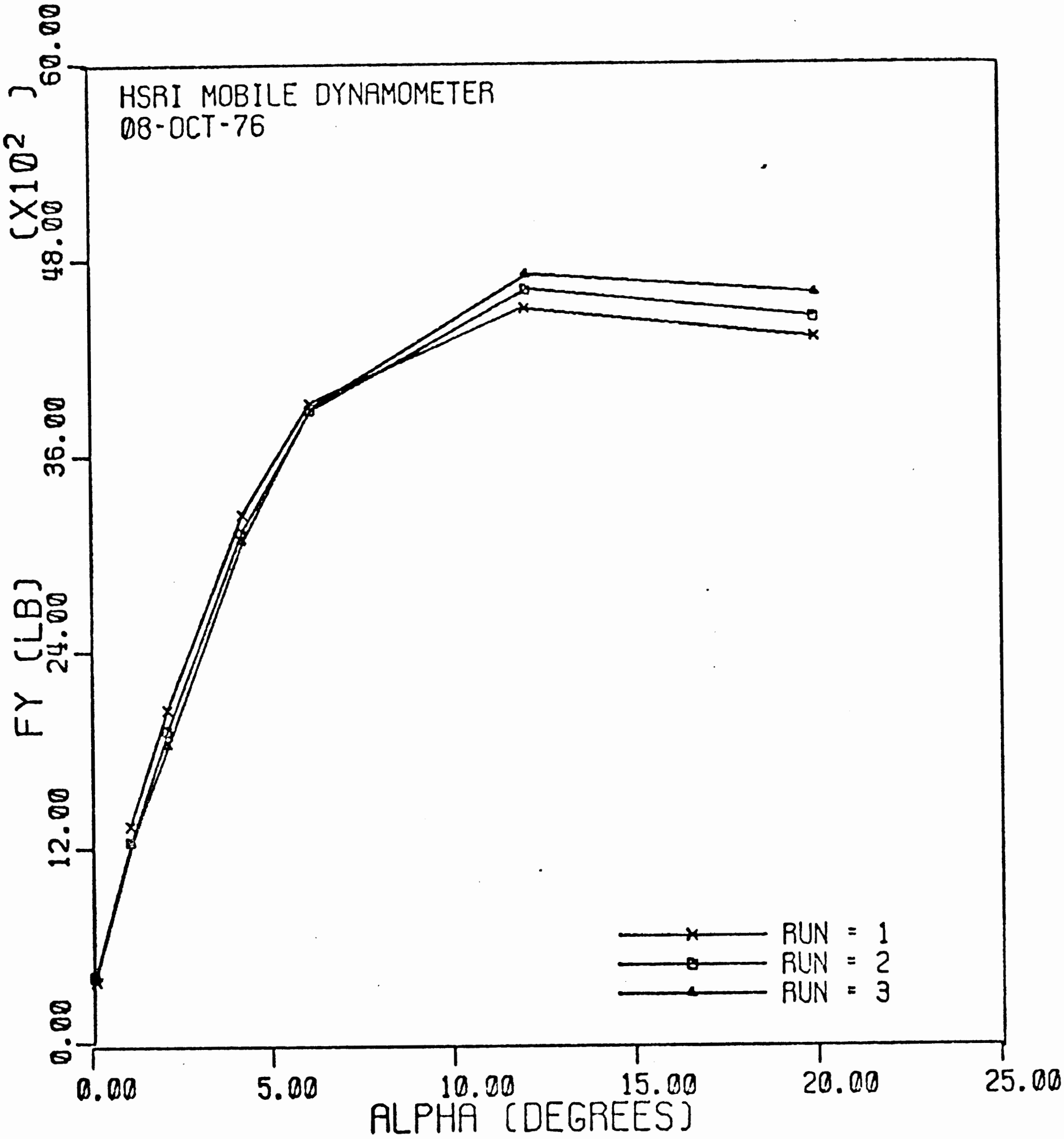
VEL = 20 MPH



ONA/B-24-D-8/30 WET CONCRETE (DANA)
FZ = 5494 LB VEL = 19 MPH