NON-DESTRUCTIVE TESTING OF CONCRETE

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Research Report No. 51

Research Project No. 69-1C
Louisiana HPR 1 (8)

Conducted by
LOUISIANA DEPARTMENT OF HIGHWAYS
Research and Development Section
In Cooperation with
U. S. Department of Transportation
FEDERAL HIGHWAY ADMINISTRATION

November 1970

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SYNOPSIS

This research project was initiated to evaluate the performance of an ultrasonic testing device (see Figure 1) in predicting compressive strengths from tests performed on samples of fresh concrete.

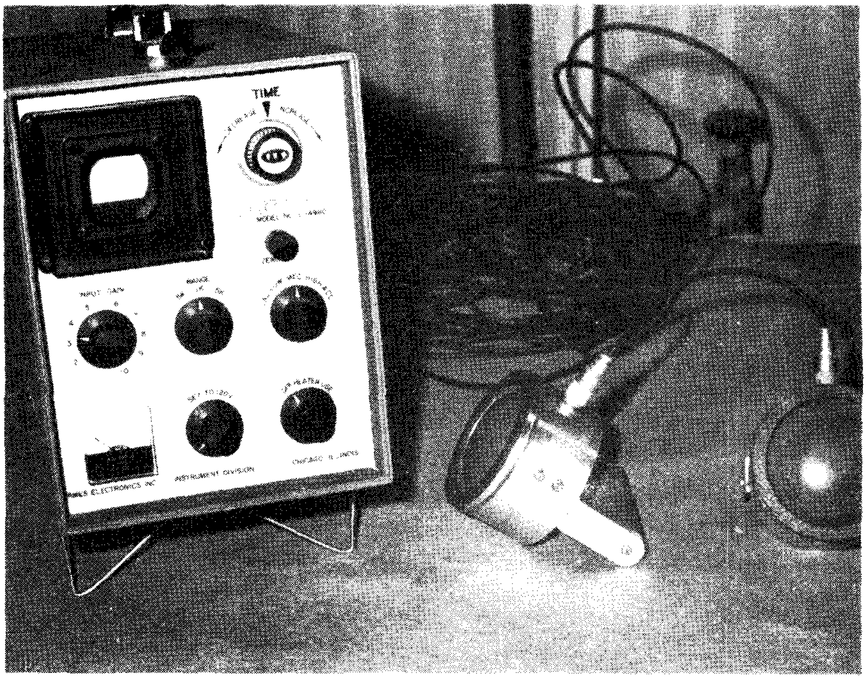

Figure 1

James Electronics Ultrasonic Pulse Velocity Measurement Equipment

The initial phase of this study involved laboratory preparation of concrete cylinders using various water cement ratios. These were tested using ultrasonic equipment and the results were to be used in developing standard curves for predicting compressive strengths of fresh concrete. Had the laboratory results proved satisfactory, the next phase was to correlate the ultrasonic results taken in the field on actual construction sites with the compressive strengths of the roadway cylinders. Hopefully, as a result of the findings of this study an ultrasonic concrete testing program could be implemented, whereby concrete not conforming to specification requirements for compressive strength could be rejected prior to being placed in a structure.

Results of the laboratory phase of the project were not encouraging. Very little predictability of compressive strength on sand and gravel mixes was possible until several hours after addition of water to the mixes. Experimentation with more homegeneous sand mixes yielded no better results. Further investigation with the present available equipment seems unwarranted.

INTRODUCTION

The use of pulse velocity measurements in concrete as a measure of the integrity of the structure dates back to 1940. Since that time the procedures, equipment and techniques have been improved and sophisticated to where today ultrasonic testing has become routine in determining various properties of hardened concrete. As knowledge and techniques improved, attempts were made at predicting the properties of fresh concrete. Reports from one supplier of pulse velocity equipment indicated a good correlation between compressive strength and pulse velocities of fresh concrete at early ages.

This study describes the work performed in an attempt to establish a series of curves from which 28 day compressive strengths could be predicted from samples of concrete immediately after mixing.

METHOD OF PROCEDURE

Testing began in September 1969, after operational procedures were demonstrated to the Concrete Research Unit by Mr. Lynn McLean, a factory representative of James Instrument Company.

The fresh concrete samples were placed into standard 6 inch by 12 inch wax-coated cardboard cylinder molds, rodded, and velocity readings were taken by pressing the transducers diametrically opposite one another against the cylinder walls with the aid of a supplied coupling gel. Mixes tested had water-cement ratios in the range of 0.40 to 0.71, with a constant fine to coarse aggregate ratio of 40 to 60 percent.

In these tests, velocity readings were taken hourly for twelve consecutive hours, then again at 24 hours. At 7 days and 28 days the velocities were checked again, at which time representative cylinders were broken to determine compressive strength.

ANALYSIS OF DATA

The figures included in this report summarize the work that has been done to date. Velocities represented on Figures 2 thru 8 are average values derived from readings on a minimum of four cylinders, and compressive strengths at 7 and 28 days are averages of at least two of these cylinders.

Figures 3 and 4 show velocity measurements taken on two typical days in which mixes were prepared. The shape of the curves have almost no meaning at all until 7 or 8 hours after the addition of water to the mix, and there is an unexplainable plunge in the velocity readings beginning about three hours after water was added. Prediction of compressive strength from Figure 4 seems impossible during the first 12 hours, and considerable difficulty was encountered in obtaining suitable indications on the scope during the first four to five hours on both figures.

Figures 5 and 6 show plottings of points from various water-cement ratios used throughout the testing program, and represent wave velocity versus compressive strengths at 7 and 28 days, respectively. Relationship can be seem between compressive strength and water-cement ratio, but there seems to be little correlation between wave velocity and compressive strength, especially on the 7 day graph (Figure 6)

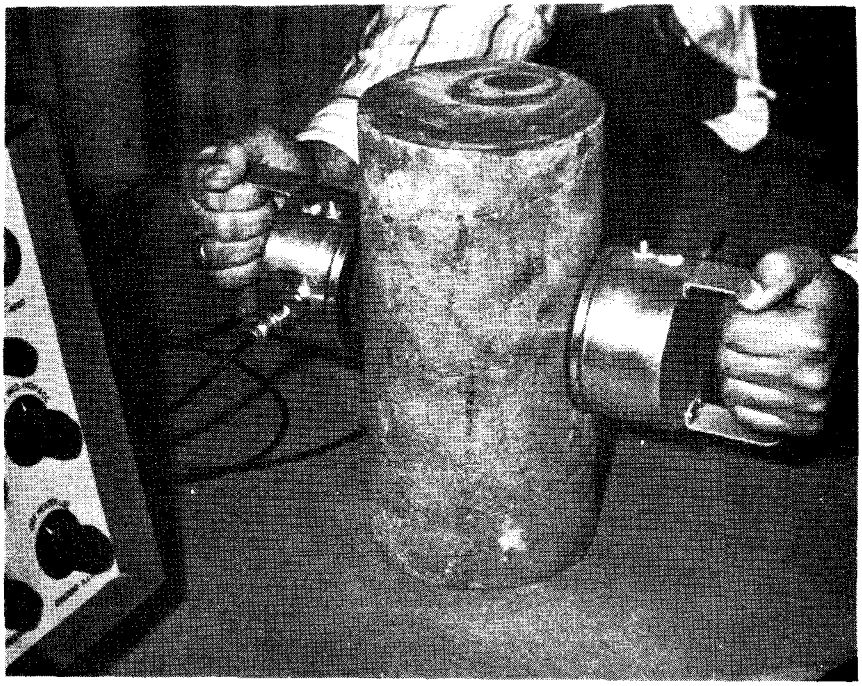

Figure 2

Measurement of Pulse Velocity on 6 by 12 Cylinder

FIGURE 2
MEASUREMENT OF PULSE VELOCITY ON 6 BY 12 CYLINDER

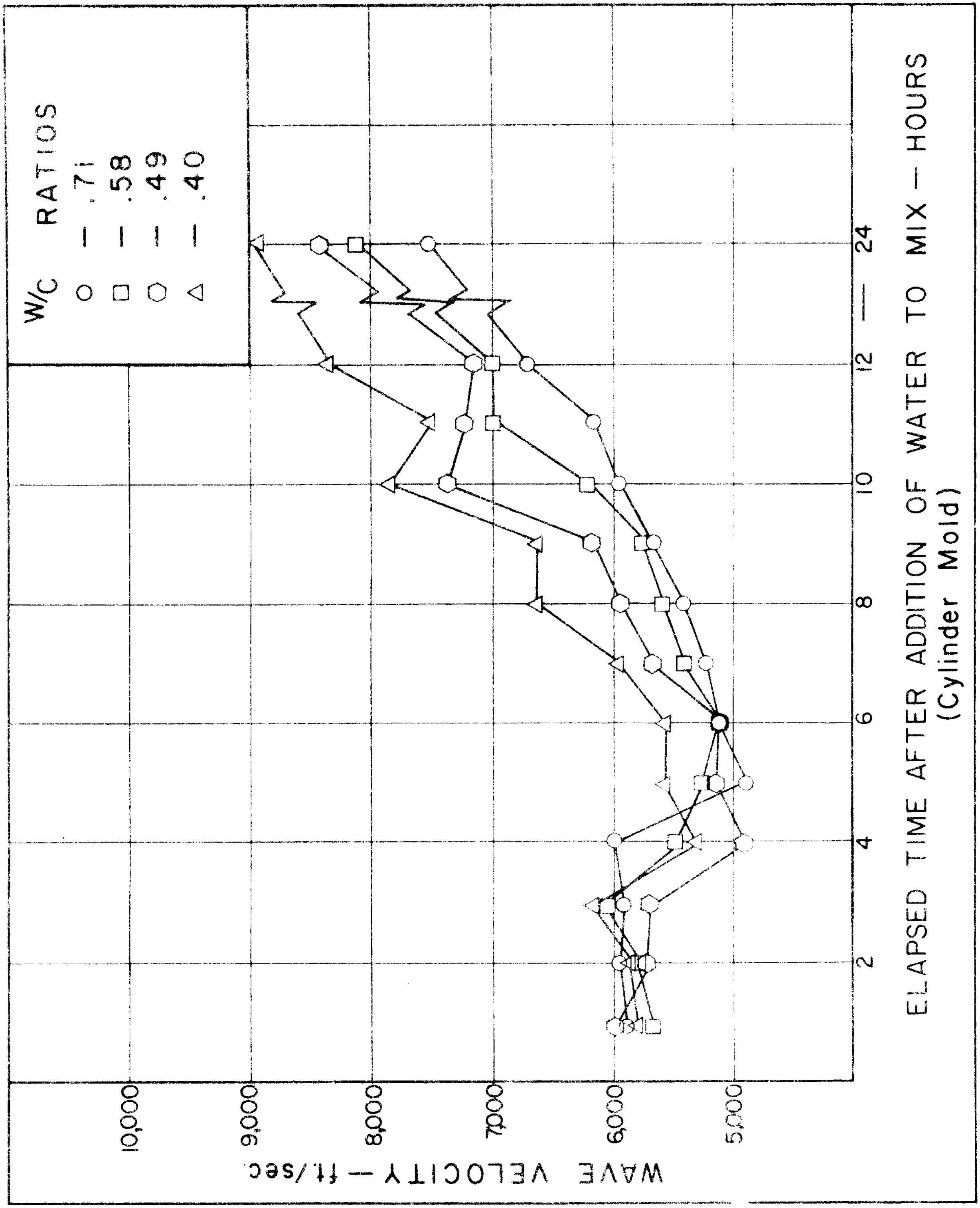

Figure 3

Wave Velocity vs Hours After Addition of Water to Mix for Four Water-Cement Ratios

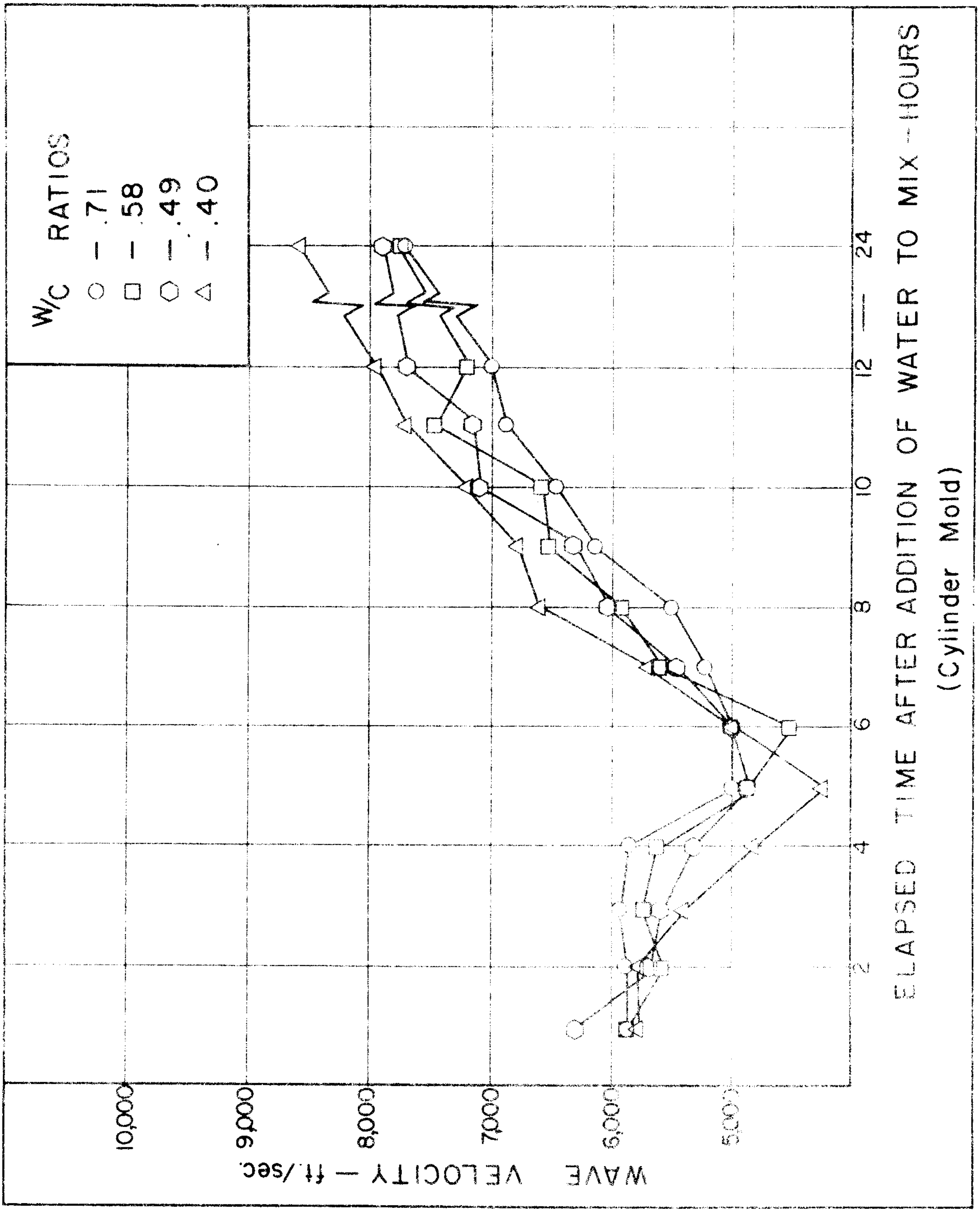

Figure 4

Wave Velocity vs Hours After Addition of Water to Mix for Four Water-Cement Ratios (October 22, 1969)

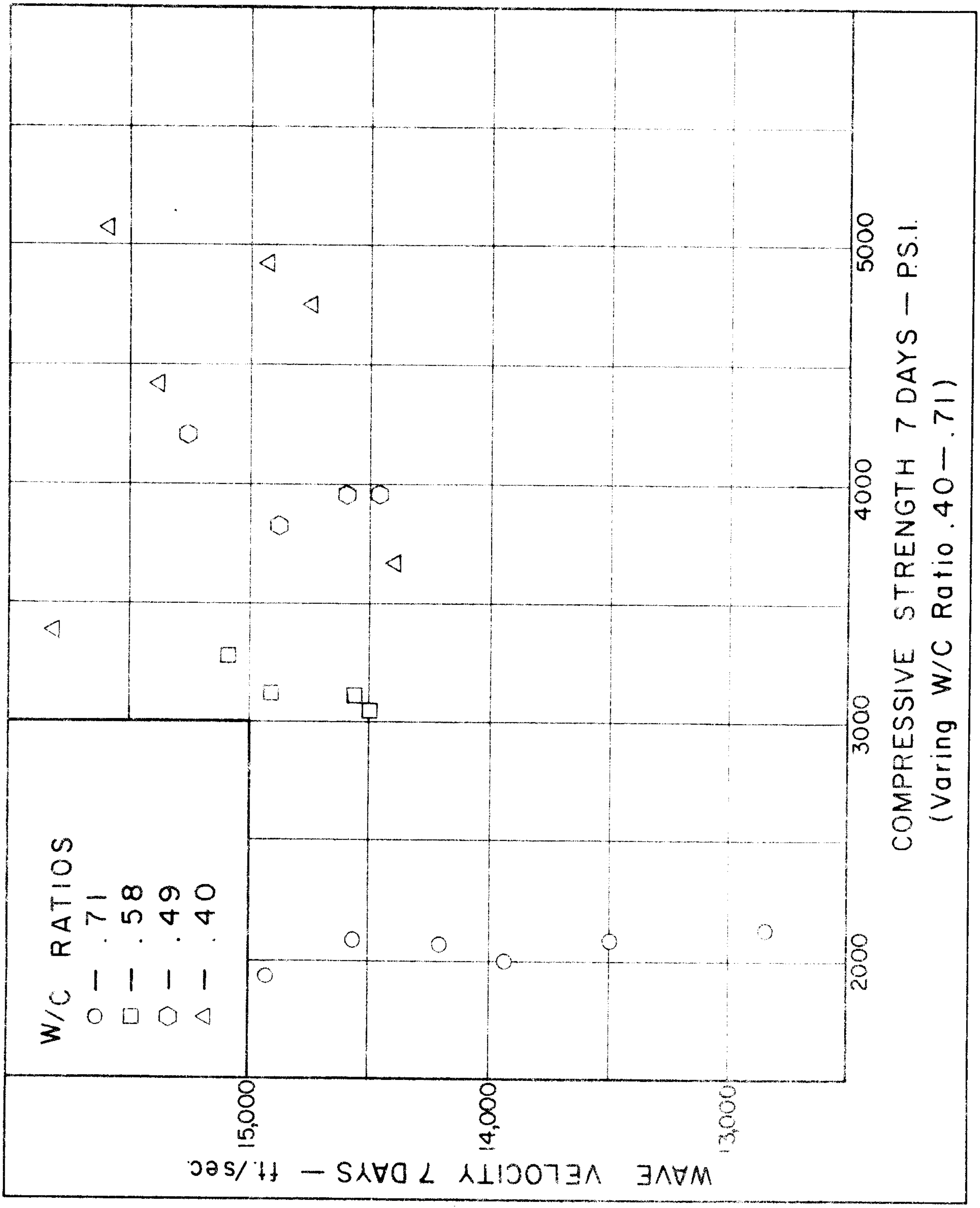

Figure 5

Wave Velocity vs Compressive Strength at Seven Days for Four-Water-Cement Ratios

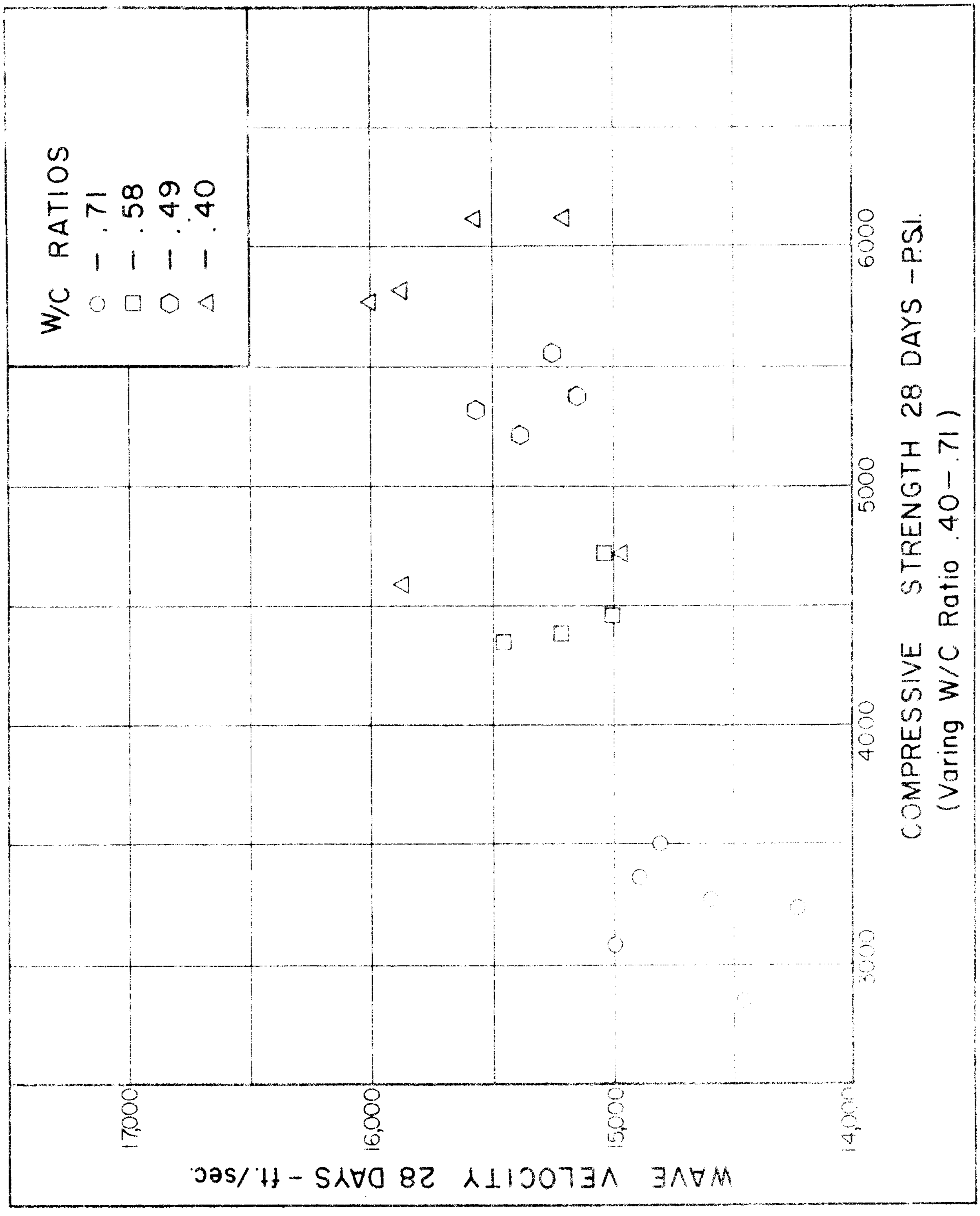

Figure 6

Wave Velocity vs Compressive Strength at Twenty-Eight Days for Four Water-Cement Ratios

Figure 7 shows wave velocity versus compressive strength for the various mixes from 7 to 28 days. Points were derived by averaging values plotted for each water-cement ratio on Figures 5 and 6. Although it will not help accomplish the immediate objectives of the study at this time, predictability during this 7 to 28 day period shows some promise.

After these initially proposed steps using the four mixes did not yield satisfactory results, different types of containers were used to recheck the same types of mixes. The containers were one cubic foot plywood forms with small windows cut in the ends. Thin sheets of polyethylene were put over the windows to confine the concrete and allow as near direct as possible coupling of the transducers to the fresh concrete. Experimentation with the cubical boxes was made because of doubts which arose pertaining to the efficiency in coupling of the pulses to the cardboard cylinder molds and pulse conductive action of the waxed cardboard itself. As can be seen from Figure 8, readings were unobtainable through the wooden forms until 3 to 5 hours after addition of water to the mix, even though amplitude of pulses was increased to facilitate pickup.

The last series of tests made in conjunction with the project consisted of mortar mixes using only sand, water and Portland cement in the waxed cardboard cylinders. This testing was done in an attempt to eliminate any possible misleading velocity readings resulting from irregularities in the aggregate such as size, density and angularity.

Compressive strength versus pulse velocity for 7 and 28 day readings are shown indiscriminately in Figure 9. Somewhat of a linear trend can be seen but scattering of points makes any useful predictability impossible. It must also be realized that these were highly idealized mixes and would seldom be encountered in the field.

Figure 10 consists of points representing compressive strength at 7 and 28 days versus pulse velocity taken just prior to breaking for all cylinders prepared during testing with the exception of the sand cement-water mixes.

Since this graph includes points representative of most of the mixes tested during the study, it is a good indication of the difficulty in compressive strength prediction from pulse velocity readings. An example of this can be seen in the fact that there are compressive strengths from 2000 to 5000 psi within the relatively narrow range of 14,500 to 15,000 ft/sec. wave velocity.

There was some correspondence with the general manager of the instrument division of the manufacturer concerning problems with obtaining the desired results in testing.

They were sent a summary of our work up until the preparation and testing of the mortar mixes and asked to assist us in determining whether our problems were that of technique or inability of the equipment to produce the needed results. Representatives of the company had shown data in the form of curves and had given verbal verification that the equipment would be suitable for use in this project, but no helpful suggestions were presented to us in their return correspondence.

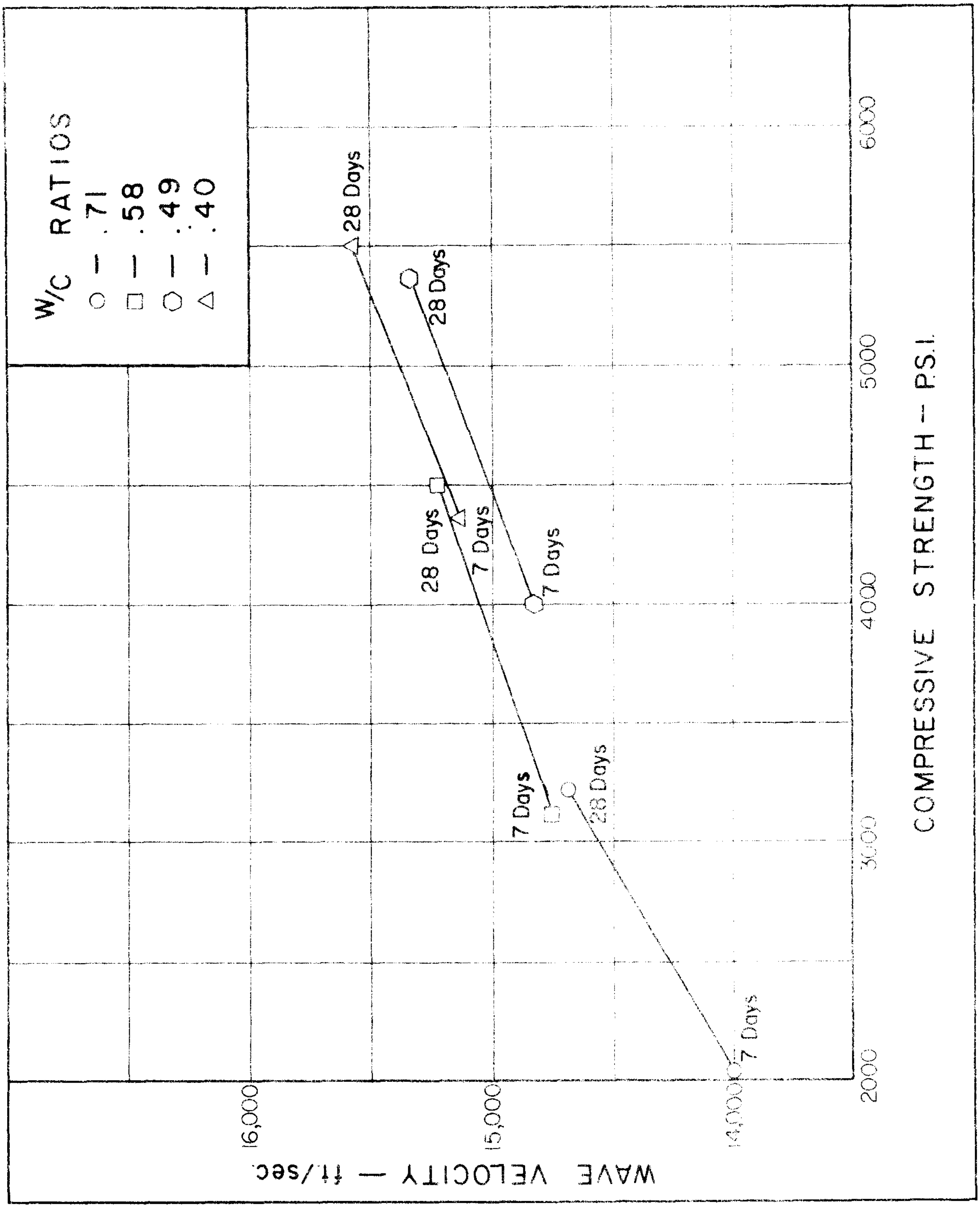

Figure 7

Wave Velocity vs Compressive Strength for Four Water-Cement Ratios from Seven to Twenty-Eight Days (derived from Figures [illegible] and [illegible])

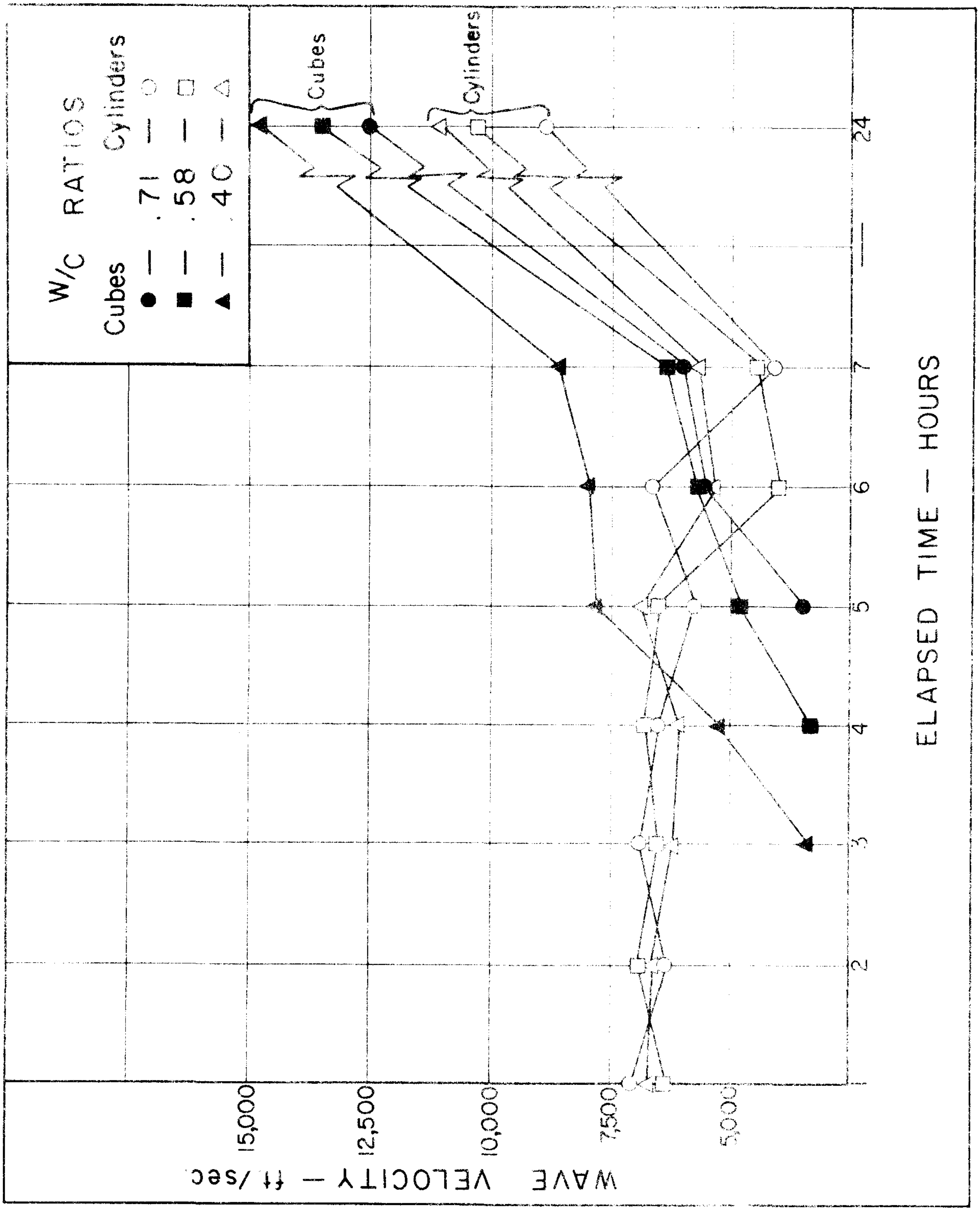

Figure 6

Wave Velocity vs Hours after Addition of Water to Mix for Three Water-Cement Ratios Using Cylinders and Cubical Molds.

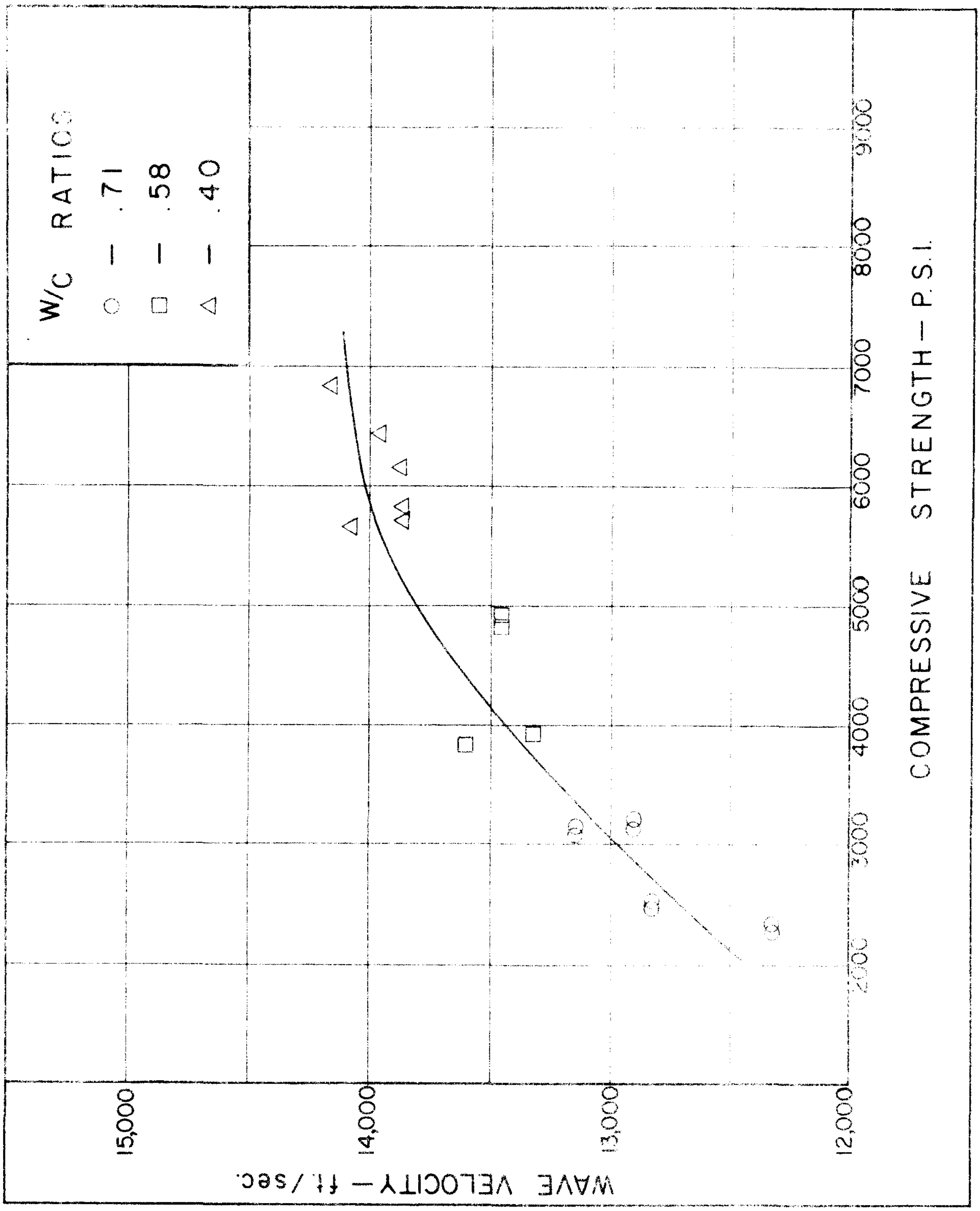

Figure 9

Wave Velocity vs Compressive Strength for Mortar Mixes

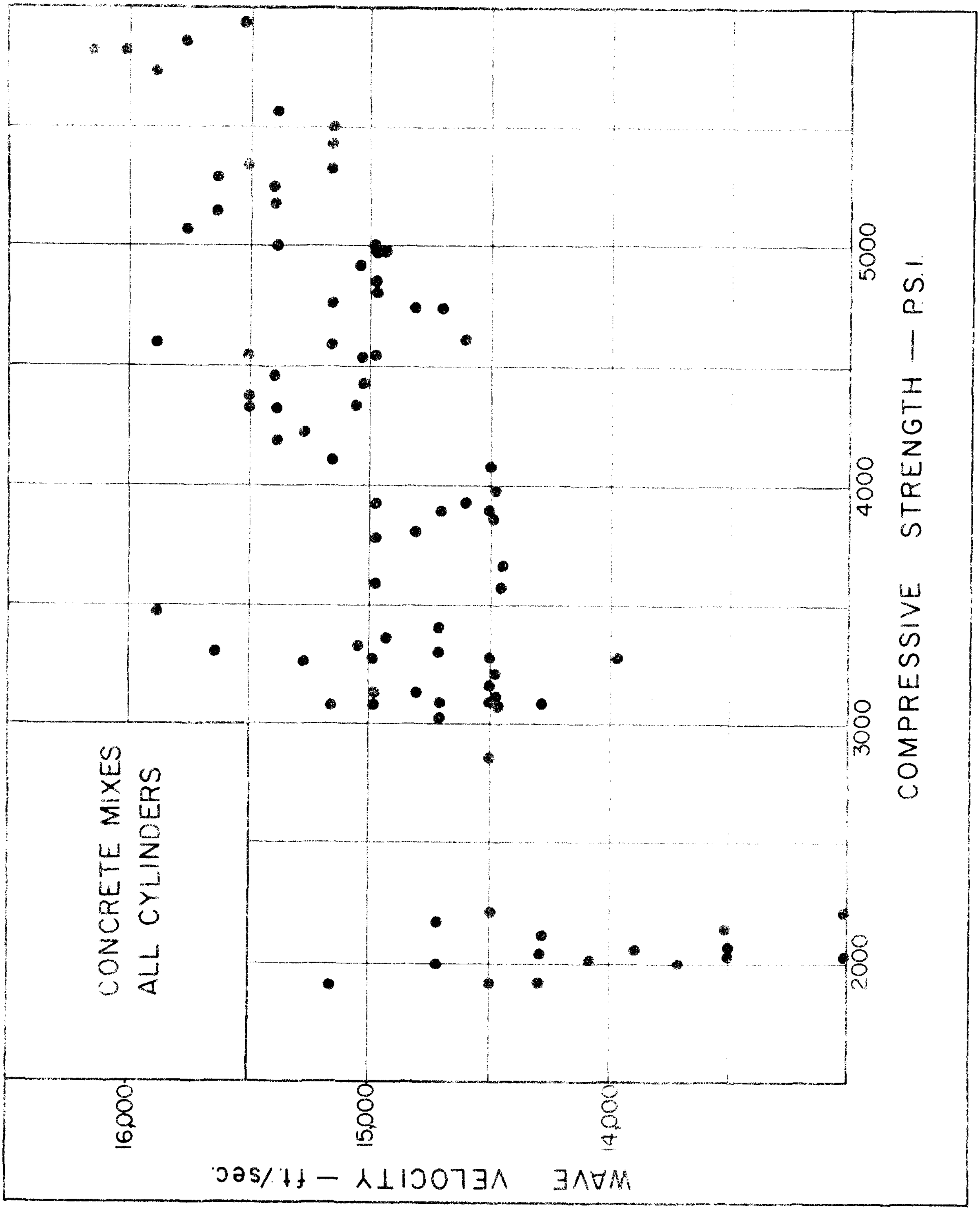

Figure 10

Wave Velocity vs Compressive Strength for All Cylinders Excluding Mortar Mixes

CONCLUSIONS

The prediction of compressive strengths from fresh concrete cannot be accurately accomplished by use of the ultrasonic equipment used in this study. The purpose of this study was to develop standard curves for predicting compressive strength of concrete from tests performed on samples of fresh concrete. Knowing only the pulse velocity of fresh concrete as determined by the James Electronics equipment, predictability of compressive strengths does indeed seem futile.

RECOMMENDATIONS

It is recommended that further investigation into prediction of compressive strength using the James Electronics equipment be discontinued.

This equipment has been found useful in checking for defects in prestressed concrete such as honeycombs, cracks and voids.

Investigation will be continued and expanded along these lines for other possible uses of the equipment.