REPORT

ON

FLY ASH AS A SOIL ADDITIVE

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SUMMARY

The addition of a selected self-cementing, Class C fly ash to blow sand soils improves their compacted strength greatly as opposed to the minimal strength improvement when fly ash is mixed with loess soil. By varying the percentage of fly ash added, the resulting blow sand-fly ash mixture can function as a low strength stabilized material or as a higher strength subbase. Low strength stabilized material can also be obtained by mixing loess soils with a selected Class C fly ash.

The development of the higher strength values required for subbase materials is very dependent upon compaction delay time and moisture condition of the material. Results at this time indicate that, when compaction delays are involved, excess moisture in the material has the greatest positive effect in achieving minimum strengths. Other added retarding agents, such as borax and gypsum, have less effect.

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PURPOSE AND SCOPE

This study was initiated to investigate the effects of adding self-cementing fly ash to base and soil materials.

Two fly ashes and several soil types, representing the range of soils giving problems when utilized as construction materials, were chosen.

The original goal was to determine if high strength mixtures of soil-fly ash could be produced. If so, then the resulting pavement design could take into account the contribution of the soil-fly ash mixture to the overall structural capabilities of the pavement system. As the study continued, a need was expressed by some for a low-strength mixture. That is, in situations where the nature of the soil made construction activities and traffic difficult, some means of stabilizing the soil was desired. This stabilization should produce a mixture that was strong enough to drive on, yet weak enough to be trimmed to final grade by standard equipment.

Preliminary strength results indicating a dependence upon the time delay before compaction were responsible for incorporating a study of retarders into the program.

MATERIALS

Fly Ash

The fly ashes were obtained from Council Bluffs No. 3 and Sioux City Port Neal No. 4 generating plants, both have self-cementing properties.

Soils

Initially, it was intended to obtain three different soil types: blow sand, loess and a medium clay (A-7-5 or A-7-6). These represent the range of problem soils encountered on highway construction projects and the study was designed to see if their engineering properties could be improved. Only the loess and blow sand were obtainable when the study began and a reassesment of the feasibility (methodology and economy) of incorporating fly ash into medium clay soils in the field resulted in the deletion of it as a test soil.

Retarders

A commercial, liquid fly ash retarder was obtained for use in the study. Several commonly available materials were also investigated as to their retardation potential, i.e., gypsum, borax and calgon.

LABORATORY PROCEDURES

Soil-Fly Ash Mixtures

The fly ashes were combined with the soil materials according to the following procedure:

I. Soil Characterization

   a. Determine the soil classification of the two soils.

II. Proctor Densities/Optimum Moisture

   a. Determine proctor densities and optimum

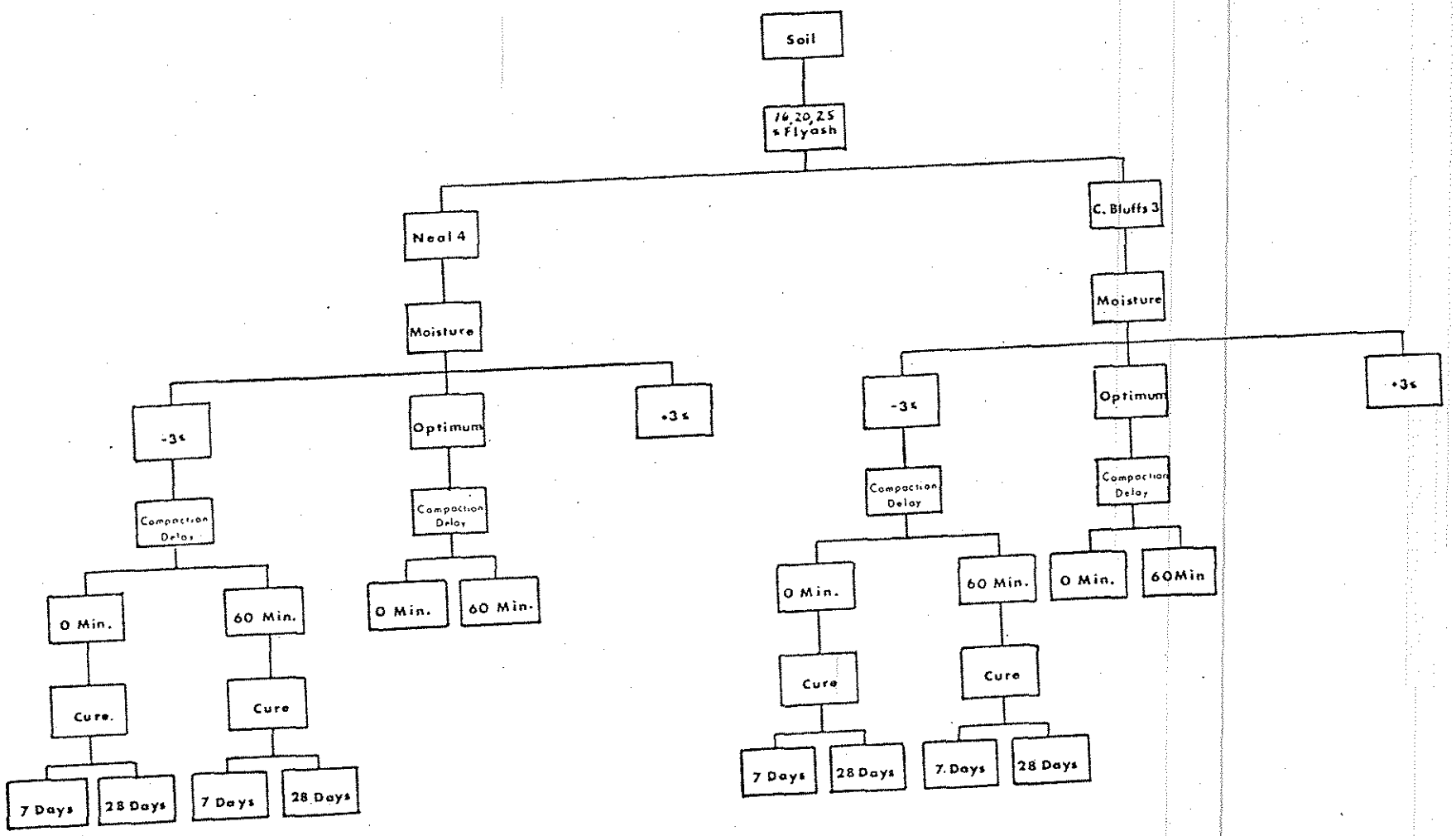

Soil
16,20,25 s Flyash
Neal 4
C. Bluffs 3
Moisture
Moisture
-3s
Optimum
+3s
-3s
Optimum
+3s
Compaction Delay
Compaction Delay
Compaction Delay
Compaction Delay
0 Min.
60 Min.
0 Min.
60 Min.
0 Min.
60 Min.
0 Min.
60Min
Cure.
Cure
Cure
Cure
7 Days
28 Days
7 Days
28 Days
7 Days
28 Days
7. Days
28 Days

Figure 1

fly ash added.

Soil-Fly Ash-Retarder

The specimens involved in the retarder study were prepared the same as the previous fly ash-soil samples. Preliminary trial mixes were made holding most variables constant to see if a proposed retarder had any positive effect. The two that did show potential benefits, borax and gypsum, were included in an expanded study that varied the amount of retarder.

TEST RESULTS AND INTERPRETATION

Soil-Fly Ash

Using the loess and blow-sand soils, soil-fly ash specimens were prepared using the variable fly ash percentages, moisture contents, compaction times and curing times. The results of this phase are shown in Figures 2 thru 9.

High Strength

In evaluating soil admixtures for high strengths, two schools of thought exist as to evaluation criteria. Soil-cement proponents use a minimum compressive strength of 300 psi with a curing time of 7 days.

Soil lime advocates, considering the slower reaction time of lime versus portland cement, use a 28 day curing time. Since the two fly ashes in this study have self-cementing properties, the 7 day curing time was chosen as the evaluation criteria for soil-fly ash mixtures.

FIGURE 2

NEAL #4 ASH AND LOESS

COMPRESSIVE STRENGTH (PSI) VS TREATMENT
1 = 16% ASH 2 = 20% ASH 3 = 25% ASH

7 DAY CURE

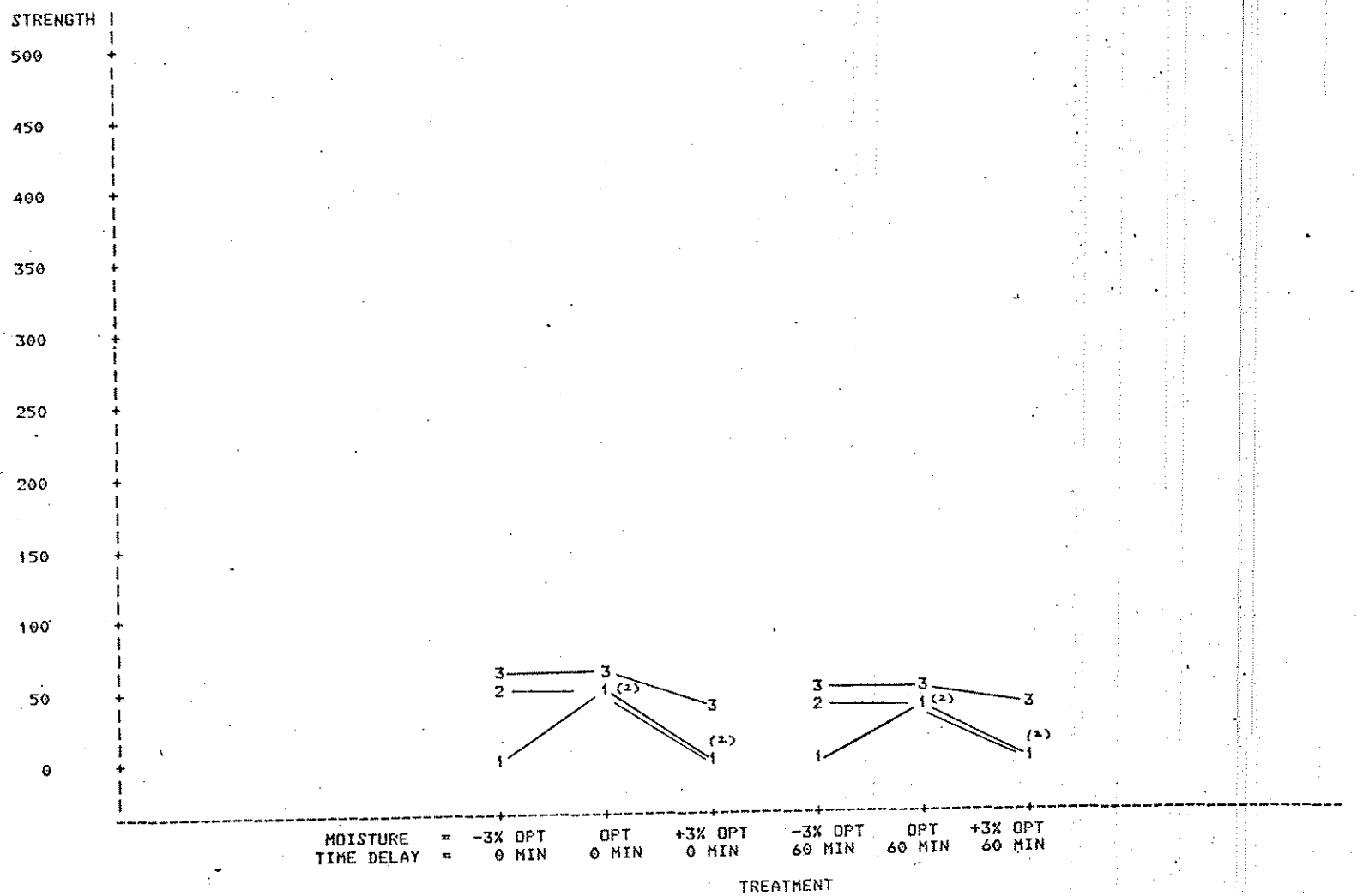


FIGURE 3

NEAL #4 ASH AND LOESS

COMPRESSIVE STRENGTH (PSI) AS A FUNCTION OF FLYASH % & TREATMENT
1 = 16% ASH 2 = 20% ASH 3 = 25% ASH

28 DAY CURE

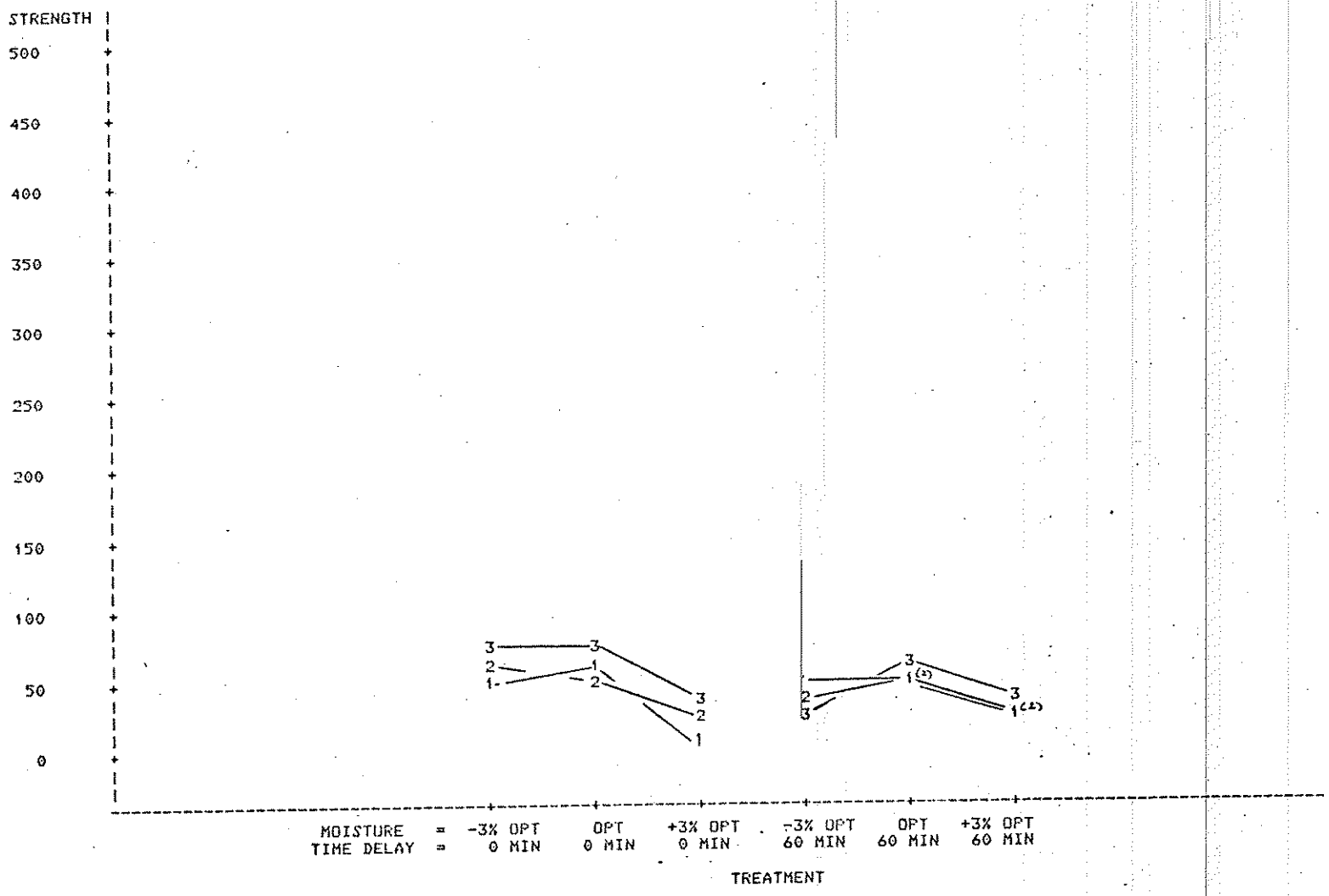


FIGURE 4

COUNCIL BLUFFS ASH AND LOESS

COMPRESSIVE STRENGTH (PSI) AS A FUNCTION OF FLYASH % & TREATMENT
1 = 16% ASH 2 = 20% ASH 3 = 25% ASH

7 DAY CURE

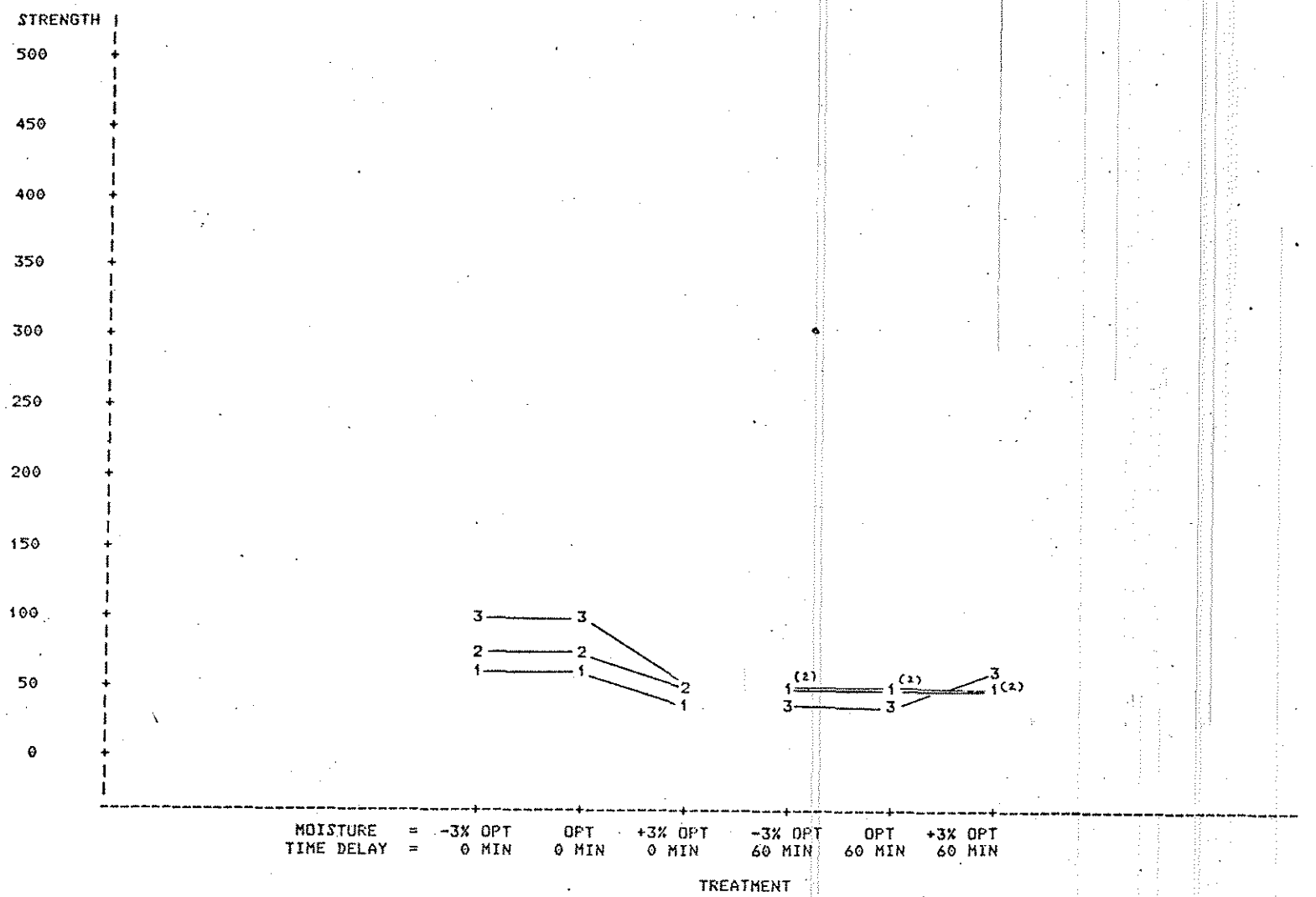


FIGURE 5

COUNCIL BLUFFS ASH AND LOESS

COMPRESSIVE STRENGTH (PSI) AS A FUNCTION OF FLYASH % & TREATMENT
1 = 16% ASH 2 = 20% ASH 3 = 25% ASH

28 DAY CURE

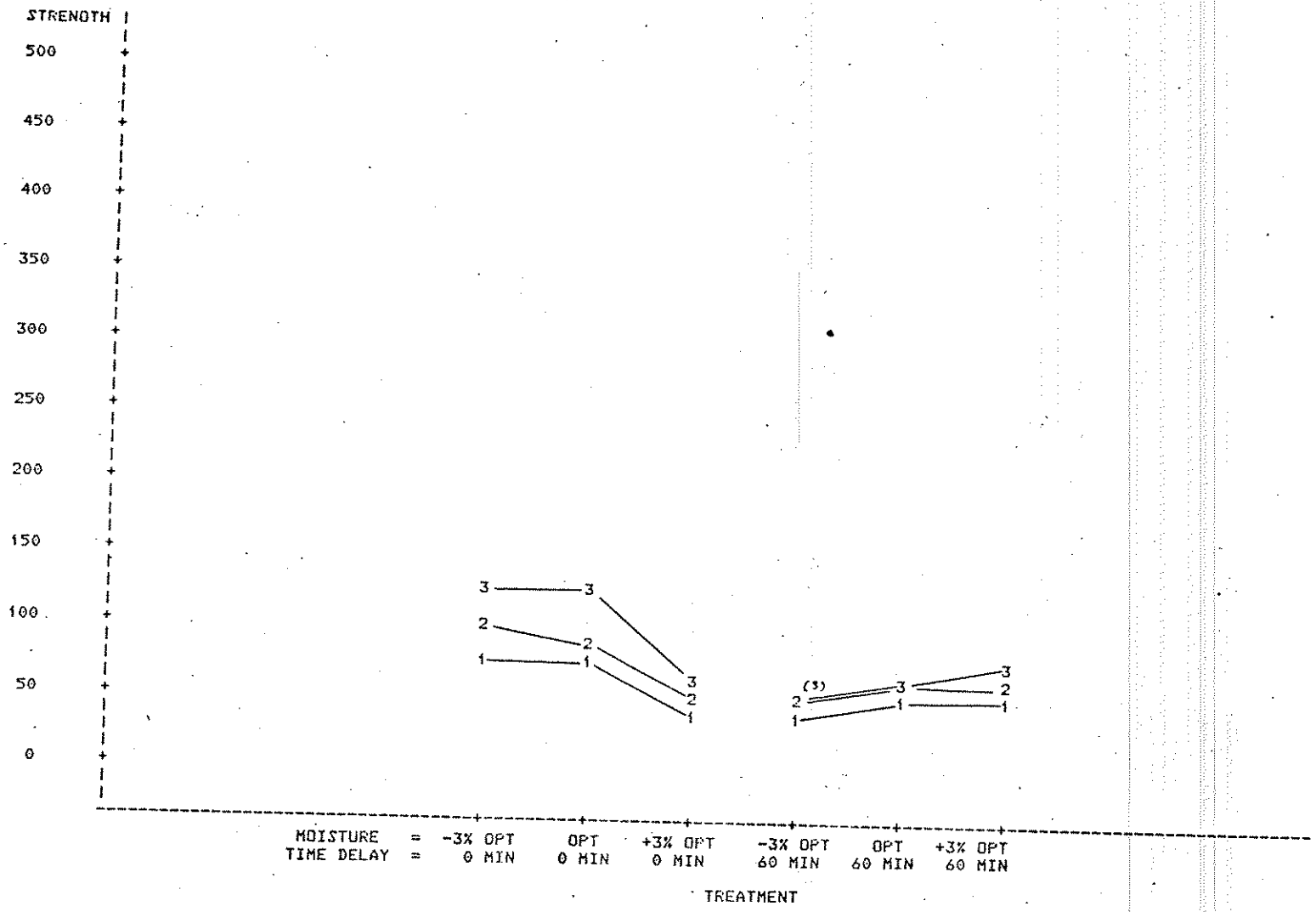


FIGURE 7

NEAL #4 AND BLOW SAND

COMPRESSIVE STRENGTH (PSI) AS A FUNCTION OF FLYASH % & TREATMENT
1 = 16% ASH 2 = 20% ASH 3 = 25% ASH

28 DAY CURE

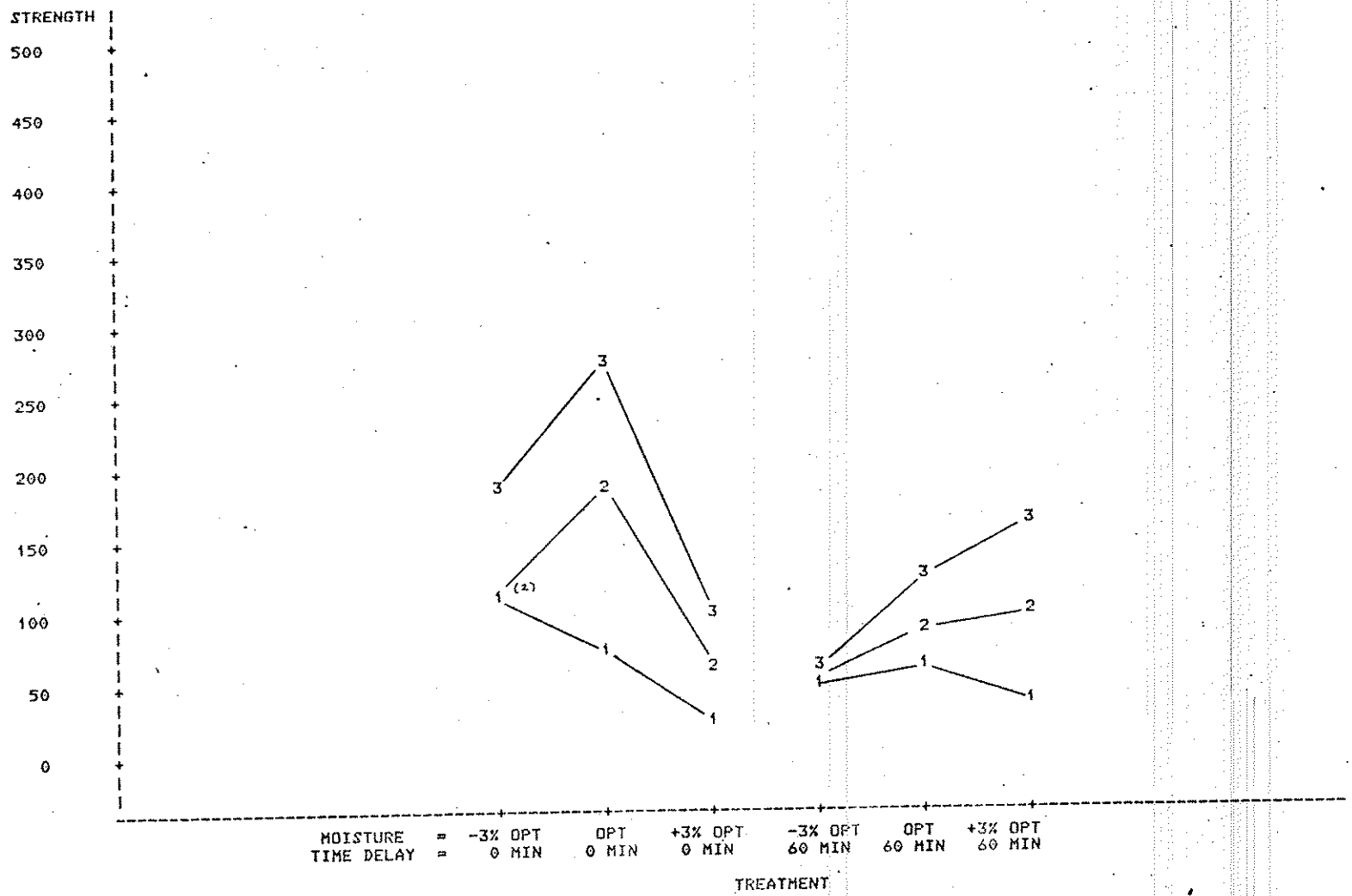


FIGURE 8

COUNCIL BLUFFS ASH AND BLOW SAND

COMPRESSIVE STRENGTH (PSI) AS A FUNCTION OF FLYASH % & TREATMENT
1 = 16% ASH 2 = 20% ASH 3 = 25% ASH

7 DAY CURE

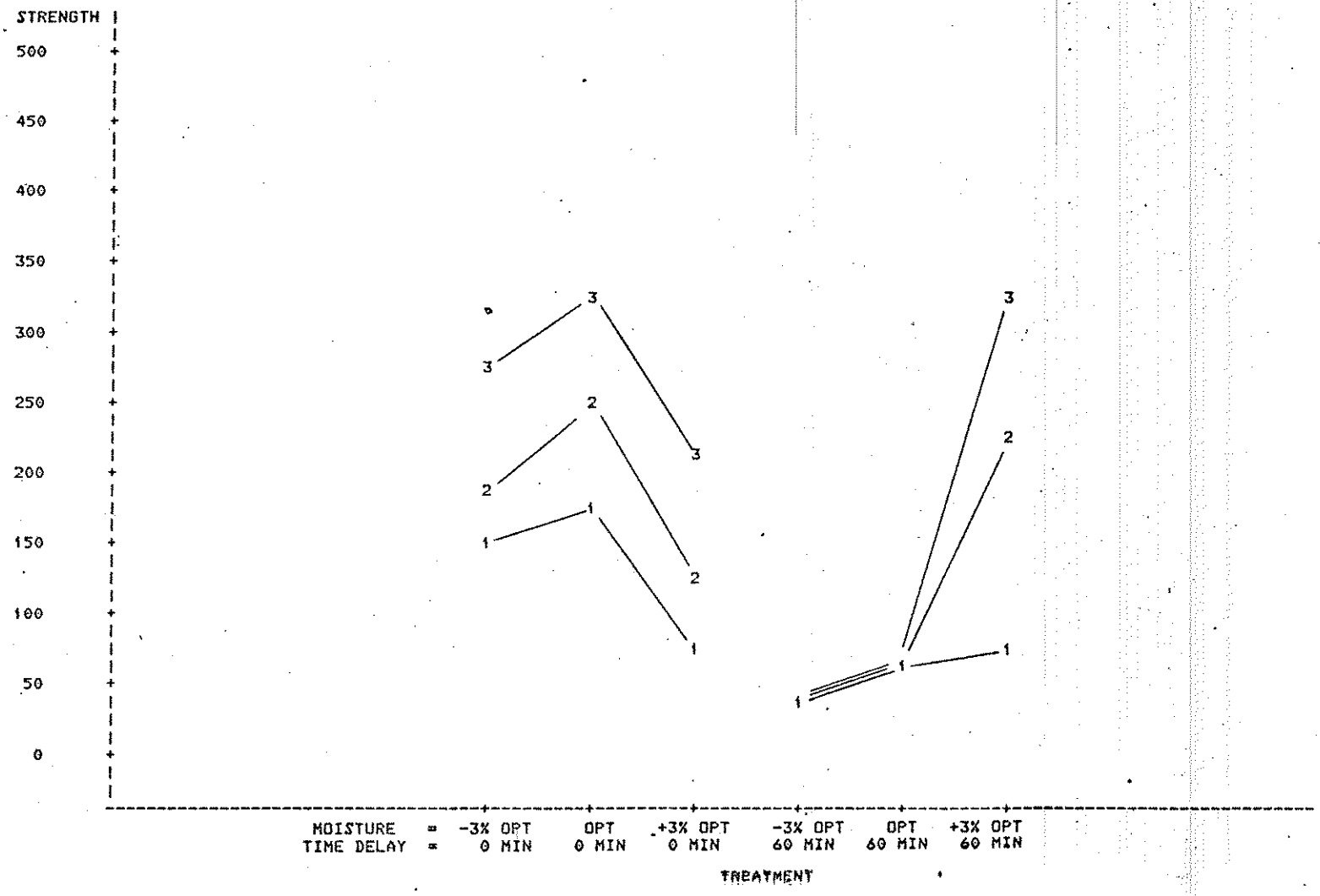
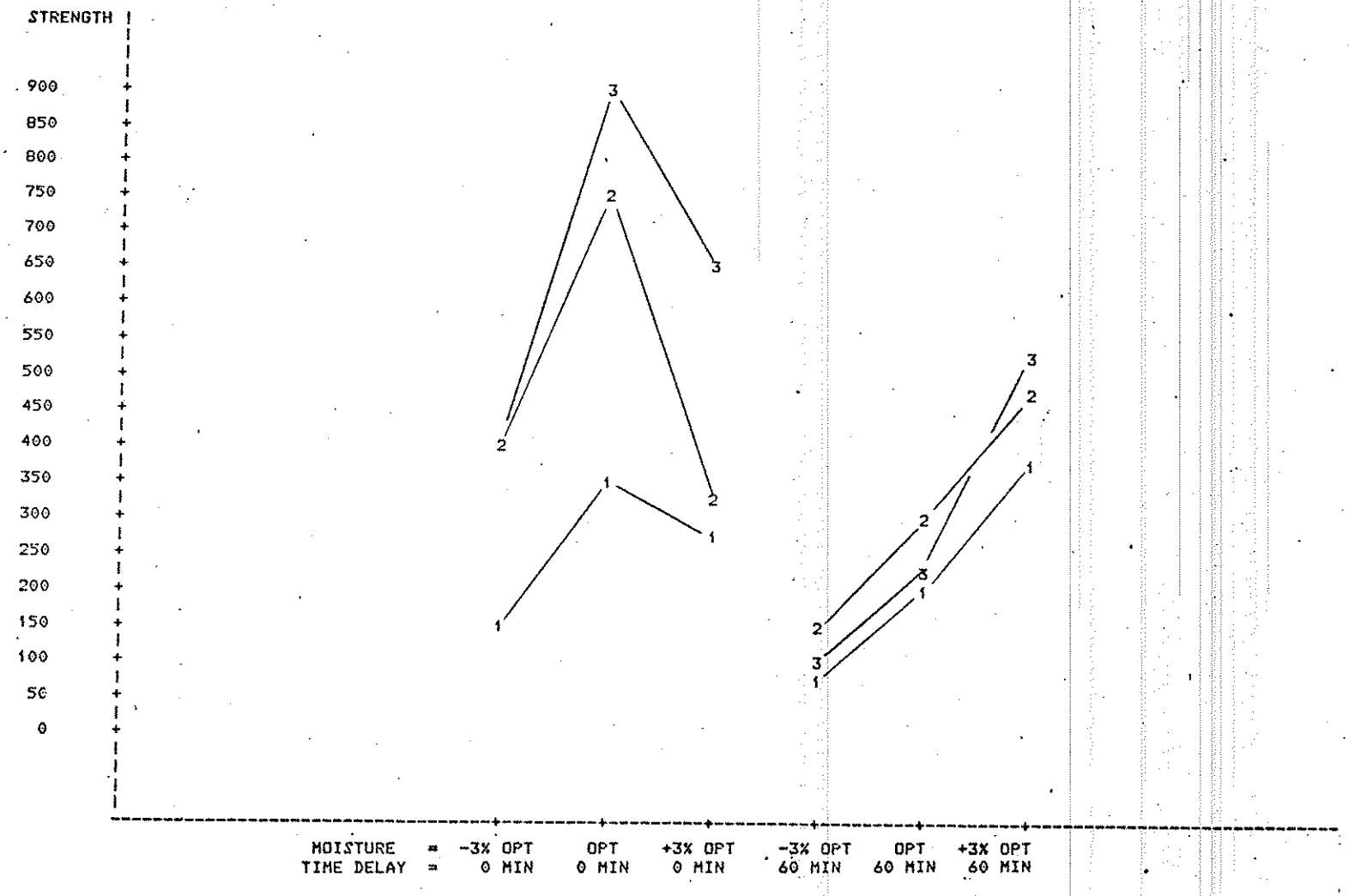


FIGURE 9

COUNCIL BLUFFS ASH AND BLOW SAND

COMPRESSIVE STRENGTH (PSI) AS A FUNCTION OF FLYASH % & TREATMENT
1 = 16% ASH 2 = 20% ASH 3 = 25% ASH

28 DAY CURE



Analysis of the data obtained shows that loess-fly ash mixtures failed to reach 300 psi regardless of moisture content, compaction delay time, fly ash content or being allowed to cure for 28 days (Figures 2 thru 5).

The results of the blow sand-fly ash testing (Figures 6 thru 9) indicate that the 300 psi limit can be exceeded by utilizing a high percentage of Council Bluffs ash and a moisture content that varies depending upon the compaction delay time. The interrelationships between moisture content and delay time were studied further in the retarder phase.

The distinction made by ASTM C618 between Class F and Class C ashes is based on the total amount of silicon dioxide plus aluminum oxide plus iron oxide present. Class F requires a minimum of 70% of the above oxides and Class C requires a minimum of 50%. The inference being that since Class C ashes contain less of the three listed oxides they contain more calcium oxides and therefore may be self-cementing. Although calcium oxide in itself is not responsible for the cementing action of a fly ash, it is an indicator of the presence and relative abundance of cementing compounds.

It would appear that the ASTM Class F and Class C characterization of an ash can be a first guide to its suitability as a soil additive to produce high strengths. As evidence of this, the Council Bluffs ash exhibits consistent chemical results that classify it as a Class C ash only. Neal No. 4 chemical results show variability to the point that it would have

FIGURE 10

RETARDER STUDY
COMPRESSIVE STRENGTH (PSI) AS FUNCTION OF ADDITIVE % & TREATMENT
BLOW SAND - 25% COUNCIL BLUFFS ASH - LIQUID RETARDER
E = NO ADDITIVE Q = 4 FL. OZ LIQUID RETARDER / CWT OF FLY ASH

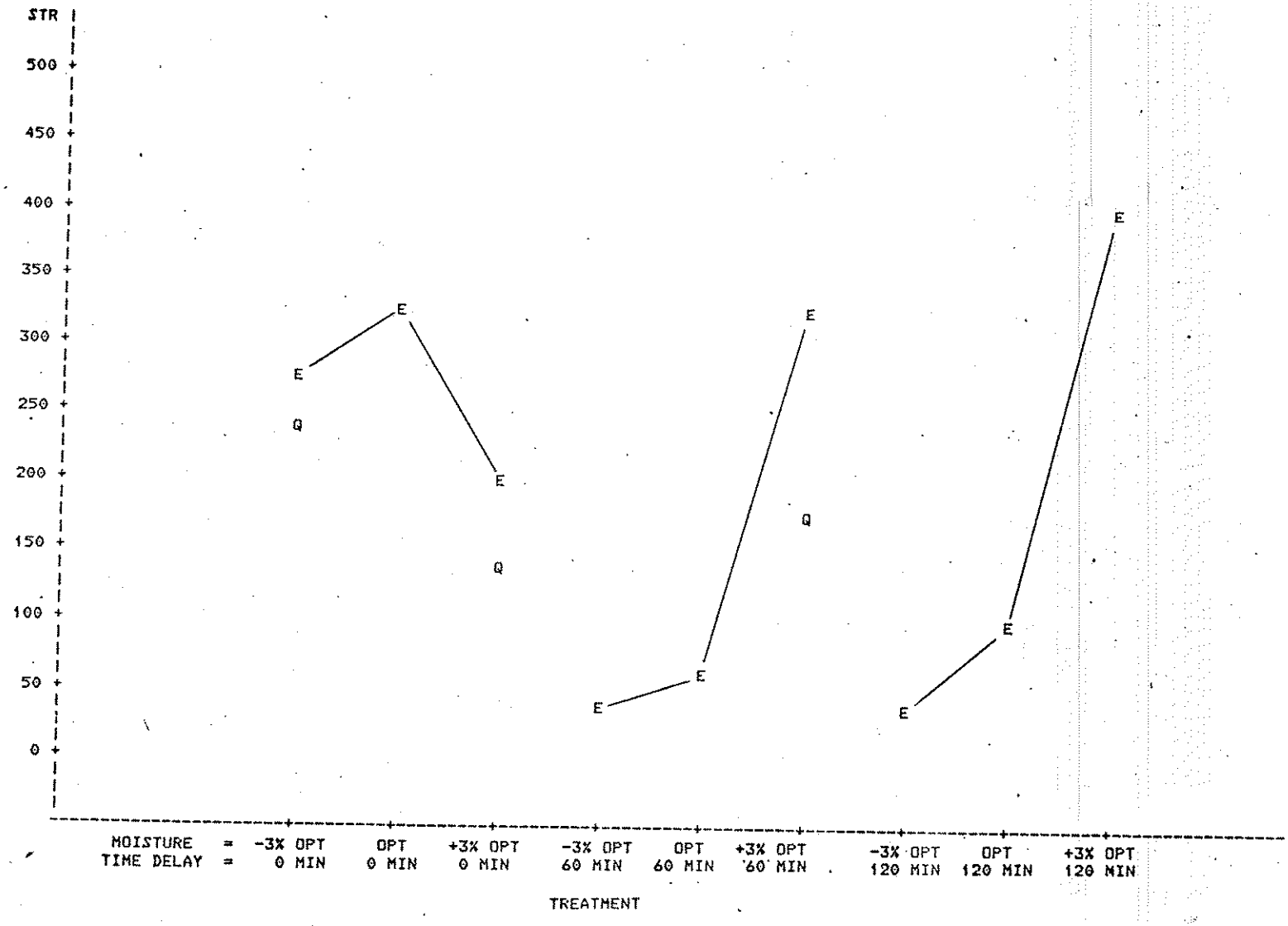


FIGURE 12

RETARDER STUDY
COMPRESSIVE STRENGTH (PSI) AS FUNCTION OF ADDITIVE % & TREATMENT
BLOW SAND - 16% COUNCIL BLUFFS ASH

A = NO ADDITIVE B = 0.5% BORAX G = 0.5% GYPSUM H = 1% GYPSUM

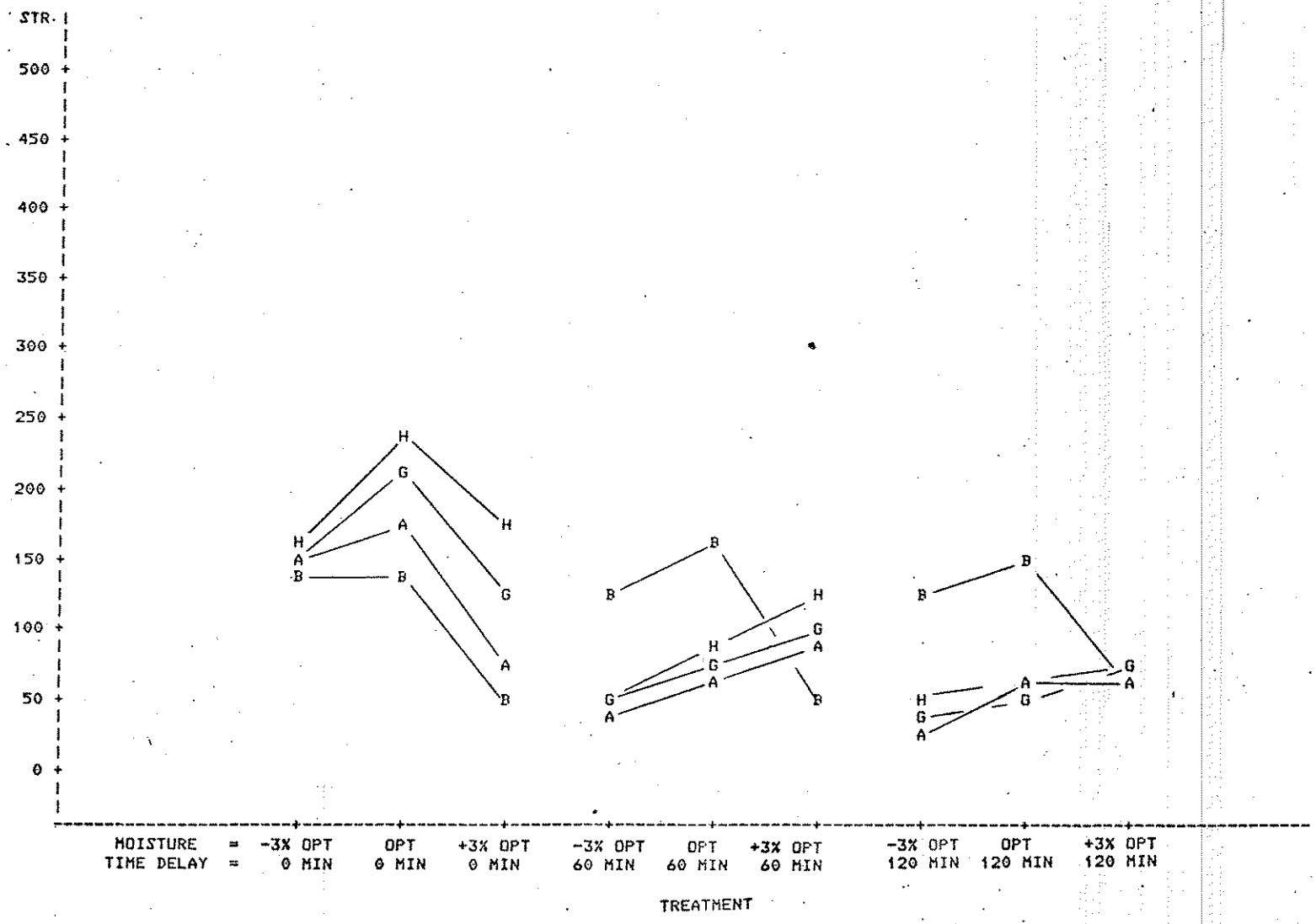


FIGURE 14

RETARDER STUDY
COMPRESSIVE STRENGTH (PSI) AS FUNCTION OF ADDITIVE X X TREATMENT
BLOW SAND - 25% COUNCIL BLUFFS ASH

E = NO ADDITIVE F = 0.5% BORAX K = 0.5% GYPSUM L = 1% GYPSUM