# AN EXPERIMENTAL STUDY OF FLY ASH

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# An Experimental Study of Fly Ash

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The ancient Romans knew that volanic ash mixed with lime produced a hydraulic cement. The Romans used this for years on buildings and roads.

A fly ash with low carbon content and high fineness may prove to be a artificial puzzalonic material. The ash is generally spherical shape and extremely fine, and may produce a portland-puzzolon-cement of superior properties.

Fly ash is a residue from the burning of p owered coal. The powered coal is passed through the boiler and the carbon is burned. The residue remains in suspension in the form of fused particles. The particles are still in suspension and are carried to a low temperature where they solidify to form fly ash. The ash is then passed into the stacks. The ash is caught by precipitators before it has left the stacks.

The chemical composition for the ash will depend on the type of coal used. The more common compounds are silica, alumina, iron,oxide and lime. Silica makes up the greatest part of the ash and there is a small amount of carbon in the ash. Fly ashes are characterized by the extreme fineness. All the ash used in this experiment would pass a 200 mesh sieve.

Two different cements were used, the first was a Valtes cement and second was a peerless cement. All the cement used had passed a 20 mesh sieve.

Standard Ottawa sand was used for all mixes, which is sieved to pass a No. 20 sieve and retained on a No. 30 sieve. The condition which fly ash is produced are similar to those of volcanic ash.

<u>Chemical Analysis of Fly Ash</u>

| | |
|---|---|
| Carbon | 11.53 |
| SiO2 | 45.46 |
| Al2O3 | 28.87 |
| FeO | 1.51 |
| Fe2O3 | 6.55 |
| CaO | 2.04 |
| MgO | .28 |
| SO3 | .89 |
| Ignition loss 1800 degrees F | 11.78 |
| Na2O + K2O | .96 |
| Insoluable Res | 88.83 |
| Free Lime | 0.00 |
| Water soluble alkalies or sulphates | .27 |
| Total water soluble | 1.90 |

All the fly ash used in this experiment was obtained from the Detroit Edison Co., and came from their Trenton Channel plant.

## Fineness and Specific Gravity of Fly Ash

Carbon ............. ......... 12%

Specific Gravity ............. 2.16%

**Percent Passing Sieve Dry**

No.200 (74 microns) ......... 89.7

No.325 (44 " ) ......... 86.1

**Percent Finer Than**

10 microns .......... ...... 38.0

1 micron ................. 0.0

**Specific Surface, Sq. Cm/Gram** 3220

The following tests were made: tensile, compression and duribility.

The samples were made up in the following manner:

| Sample | Part Cement | Part Ash |
|---|---|---|
| A | 10 | 0 |
| B | 9 | 1 |
| C | 8 | 2 |
| D | 7 | 3 |
| E | 6 | 4 |
| F | 5 | 5 |

| Sample | Part Cement | Part Ash |
|---|---|---|
| G | 4 | 6 |
| H | 3 | 7 |
| I | 2 | 8 |
| J | 1 | 9 |

Determination of Normal Consistency of Portland Cement and Ash.

The cement and ash was mixed as explained and a consistency test was made on each sample.

This test was to determine the amount of water for normal consistency. A 500 grain sample was made for each test and mixed with different percentages of water. The material mixed, reacts normal consistency when the plunger of the vicat apparatus settles 10mm in 30 seconds. Several trials for each sample were made. The percentage of water for the samples ran from 25.5 to 38.5.

The following test were made with each mix.

A mixture

Test 1 - 500g Cement, 120cc H20

24% H20

30 sec. - 3 mm..

Test 2 - 135 cc H20 or 27%

30 sec. - 15 mm..

Test 3 - 125 cc $H_2O$ or 25.5%

30 sec. - 10 mm..

B mixture

Test 1 - 450g cement - 50 g Ash

125cc $H_2O$ - 25%

30 sec - 3 mm..

Test 2 - 135cc $H_2O$ or 27%

30 sec. - 10 mm..

C Mixture

Test 1 - 400g cement - 100g ash

145cc $H_2O$ or 29%

30 sec. - 7.5 mm

Test 2 - 154 cc $H_2O$ - 31%

30 sec. - 10 mm.

D Mixture

Test 1 - 350g cement - 150g ash

160cc $H_2O$ or 32%

30 sec - 10 mm

E Mixture

Test 1 - 300g Cement - 200 g Ash

162.5cc $H_2O$ or 32.5%

30 sex. - 10mm

There was some error in this test and it can not be used.

F Mixture

Test 1 - 250g cement - 250 g ash

170cc H20 or 35%

30 sec. - 8.5 mm

Test 2 - 177.5cc H20 or 35.5%

30 sec. - 10 mm

G Mixture

Test 1 - 200 g Cement - 300 g Ash

185 cc H20 - 37%

30 sec. - 12 mm

Test 2 - 182.5 cc H20 - 36.5%

30 sec. - 10 mm

H Mixture

Test 1 - 100 g Cement - 400 g Ash

190 cc H20 - 38%

30 sec. - 7 mm

Test 2 - 192.5 cc H20 or 38.5%

30 sec. - 10 mm

From these values a graph was drawn which is No. 1. Finding the slope of the curve and applying this to the water ratio of cement only, I obtained the value of 10.75%. This value is based on the weight of cement, sand and ash.

Tensil Strength.

All mixes were based on the standard mortar of one part cement and three parts sand. For normal consistency, 10.75% of water was used. The one part of cement was broken down for each mix as:

A mixture

235 g cement

705 g sand

101 g water

705 g sand

B mixture

211.5 g. cement

23.5 g. ash

101. g. water

705 g. sand

C mixture

188 g. cement

47 g. ash

101 g. water

705 g. sand

D mixture

164.5 g. cement

70.5 g. ash

101.9 g. water

705 g. sand

E mixture

141 g. cement

94 g. ash

101 g. water

705 g. sand

F mixture

117.5 g. cement

117.5 g. ash

101. g. water

705 g. sand

G mixture

100 g. cement

150 g. ash

107.5 g. water

750 g. sand

H mixture

75 g. cement

175 g. ash

107.5 g. water

750 g. sand

I mixture

50 g. cement

200 g. ash

107.5 g. water

750 g. sand

J mixture

25 g. cement

225 g. ash

107.5 g/water

750 g. sand

These samples were cured and tested at the end of seven days and twenty-eight days. The results are as follows:

Tensile Strength p.s.i.

| Sample | 7 days | 28 days | % ash |
|---|---|---|---|
| A | 260 | 340 | 0 |
| B | 254 | 339 | 10 |
| C | 234 | 330 | 20 |
| D | 200 | 275 | 30 |
| E | 163 | 240 | 40 |
| F | 155 | 228 | 50 |
| G | 108 | 190 | 60 |
| H | 100 | 170 | 70 |
| I | 90 | 150 | 80 |
| J | 75 | 135 | 90 |

The adding fly ash in place of cement did not increase the tensile strength at seven or twenty-eight days. The samples of ten percent and twenty percent was increasing with strength at a more rapid rate of speed than the sample with only cement in it. I believe that at the end of six months the samples of ten and twenty percent ash will have more strength than the one with only cement. The samples beyond fifty percent ash had no value being used as tensile strength. These values are much to small and if the value would rise in six months, it would not equal the sample with cement only.

Table No. 2 will show the curve for these values.

Compression.

These samples were made up the same as the others with one part cement and three parts sand with a normal consistency. The size of molds were four inch cubes. The mixtures were as follows:

A Mixture

500 g. cement

1500 g. sand

215 cc water

B mixture

450 g. cement

1500 g. sand

50 g. ash

215 g. water

C mixture

400 g. cement

1500 g. sand

100 g. ash

215 g. water

D mixture

350 g. cement

1500 g. sand

150 g. ash

215 cc water

E Mixture

300 g cement

1500 g sand

200 g ash

215 cc water

F mixture

250 g. cement

1500 g. sand

250 g. ash

215 cc water

G mixture

200 g. cement

1500 g. sand

300 g. ash

215 g. water

H mixture

150 g. cement

1500 g. sand

350 g. ash

215 cc water

I mixture

100 g. cement

1500 g. sand

400 g. ash

215 cc water

J mixture

50 g. cement

1500 g. sand

450 g. ash

215 cc water

The results of the seven and twenty-eight days tests are:

Compression Test, Psi

| Samples | 7 days | 28 days | % ash |
|---|---|---|---|
| A | 1600 | 2170 | 0 |
| B | 1545 | 2145 | 10 |
| C | 1520 | 2120 | 20 |
| D | 1505 | 2075 | 30 |

| Samples | 7 days | 28 days | % ash |
|---|---|---|---|
| E | 1485 | 1885 | 40 |
| F | 1455 | 1760 | 50 |
| G | 1360 | 1555 | 60 |
| H | 900 | 1105 | 70 |
| I | 520 | 605 | 80 |
| J | 250 | 310 | 90 |

None of the samples with fly ash were equal to the sample with cement only at the end of twenty-eight days. The increase of strength between the 7 day test and 28 day test, showed that the samples of up to 50% fly ash increased at a more rapid speed than the sample with cement only. If this increase of strength will pep up for a period of 6 months the sample with 10% - 30% fly ash will surpass the sample of cement. The test made on 50% ash to 90% were of no value at all. These strengths have no use.

Curing and Durability.

The samples were placed in a water bath for a period of several days and then taken out and kept moist. The temperature was kept near 70 degrees F. at all time.

The time of setting depends on the amount of fly ash in the mixture. The greater the amount of ash the longer it will take to set up. These times are still within the standard specifications.

The strength of the fly ash samples at the end of 7 and 28 days was somewhat less than the cement. As has been pointed out, the increase of strength between 7 and 28 days for the 10% - 30% fly ash samples was greater than the cement samples. If there had been time to cure the samples longer, the ones with ash up to 30% would have had a greater strength. If any mixtures were to be used in construction, the fly ash could be used up to 20%.

If this test was to be run over I would use the fly ash in a much diffenent way. Instead of replacing part of the cement with fly ash I would use it in place of the sand or fine aggerate. Keeping the same amount of cement in each sample. From this you would get a much lighter concrete per cubic foot. The weight of the fly ash is much less than the sand. For buildings this would cut down on the amount of steel that

Due to a time element an accelerated test was used. Using 325 grams of anhydrous magnesium sulphate ($MgSo_4$) mixed with one liter of water, the samples are placed in this solution for 18 hours and then removed. They are then placed in an oven at 110 degrees F for 6 hours. Five cycles were ran. At the end of the five cycles there was no change in any of the samples with fly ash up to 60%. The samples from 60% to 90% ash had lost weight and had started to crack up.

Conclusion.

This experiment should be run over a much longer time than what has been done.

It was found that the first mixtures had too much water and were not workable. From about 30% ash to 50% ash the mixtures were workable, but from 50% on up the mixtures were again not workable. It was found that using fly ash the mixtures required a greater water ratio. For this type of experiment a different water ratio should be used for each mixture or some other method should be found for a water ratio that will apply to all the mixtures.

is needed.

There are many more tests that should be done. Some of these tests are autoclave expansion, volume changes and weathering resistances.

The cost of the fly ash should be very small. Many plants dump their fly ash in lakes and the ocean. The cost of the transportation would be the greatest part of the cost.

I do believe that a fair test should be made, such as a small section of road or building built with the use of fly ash.

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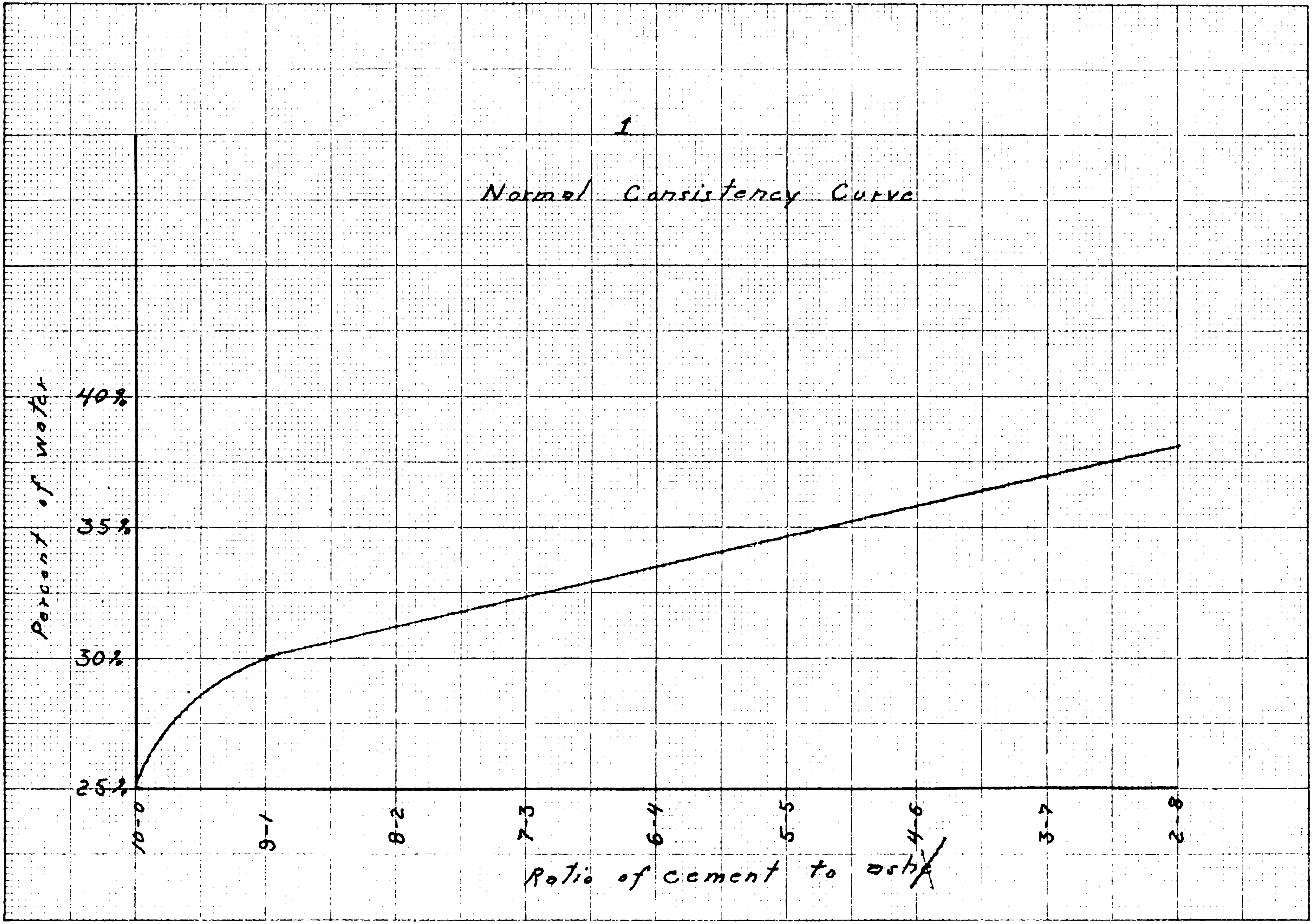
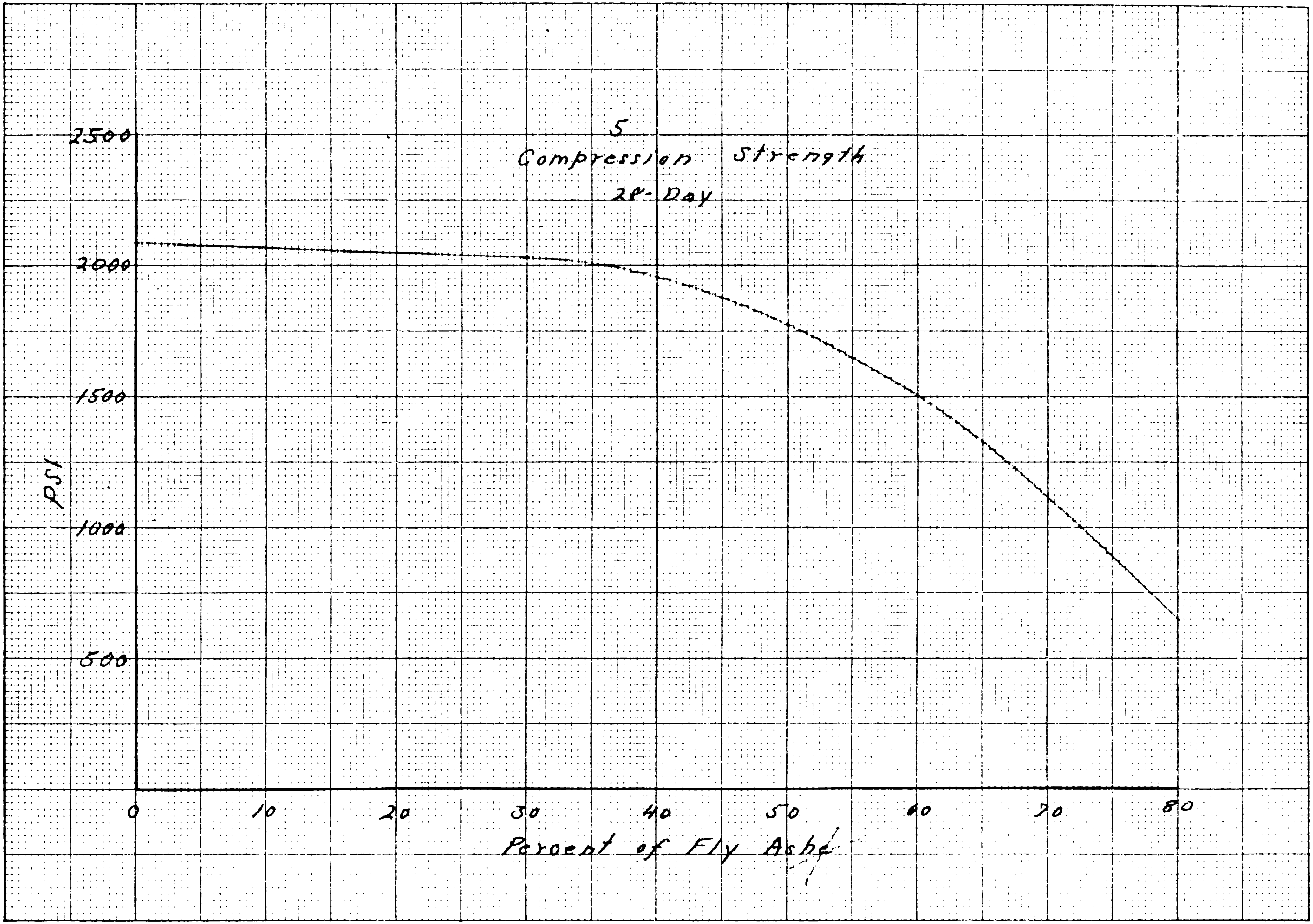

1
Normal Consistency Curve
40%
35%
30%
25%
Percent of water
10-0
9-1
8-2
7-3
6-4
5-5
4-6
3-7
2-8
Ratio of cement to ash


5
Compression Strength
28-Day
psi
2500
2000
1500
1000
500
0
10
20
30
40
50
60
70
80
Percent of Fly Ashe