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Strength Assessment of Fly Ash Concrete with Water Containing Sodium Hydroxide

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***Abstract:* -** This paper presents the effect of sodium hydroxide (NaOH) present in the curing water on the strength of fly ash cement concrete. The concrete is produced by mixing of % replacement of cement by fly ash and curing water containing NaOH of 5% concentration with constant dosages. This research work describes the feasibility of using the fly ash (Class-F) in concrete production as partial replacement of cement by weight. The cement has been replaced by fly ash accordingly in the range of 0% (without fly ash), 10%, 20%, 30% and 40% by weight of cement for M-40 mix. The compressive strengths were evaluated for 56 days of normal curing and 28 days normal + 28 days 5% NaOH contain water curing. The results show that, the compressive strength of fly ash cement concrete has come down with an increase in the % replacement of cement by fly ash with constant dosages of 5% concentrated NaOH solution at 56 days. Compressive strengths of fly ash Cement Concrete have decreased in the range of 8.22 to 36.11%, when compared with the control specimens. By using Regression Models we can predict the compressive strength value and the ratio with predicted values.

***Keywords:* -** *Fly Ash Cement Concrete, Compressive Strength, Regression Models, Sodium Hydroxide*

I. INTRODUCTION

Concrete is the most widely consumed material in the world, after water. Nowadays, most of the construction of buildings and infrastructures are using concrete as a construction material. It is a construction material composed of cement as well as other cementations materials such as slag cement, aggregate, water, and chemical admixtures. Concrete solidifies and hardens after mixing with water and placement due to a chemical process known as hydration. The water reacts with the cement, which bonds the other components together, eventually creating a stone-like material. As it gives benefit to the construction field, it's also given environmental problem. The cement industry is one of the primary producers of carbon dioxide (CO_2), cement kiln CO2 is released from calcinations of limestone (±50%) and from the combustion of fuels (±50%), and cement production accounts for approximately 5% of the global CO_2 emissions.

The durability of concrete can be defined as the ability to perform satisfactorily in the exposure condition to which it is subjected over an intended period of time with minimum of maintenance. Durability problems related to environmental causes include the following: steel corrosion, delamination, cracking, carbonation, sulfate attack, chemical attack, scaling, spalling, abrasion and cavitation.

Water is an important ingredient of concrete, which is not only actively participates in the hydration of cement but also contributes to the workability of fresh concrete and durability of hardened concrete. Cement is a mixture of complex compounds, the reaction of cement with water leads to setting and hardening. Since water helps to form the strength giving cement gel, the quality of water is to be critically monitored and controlled during the process of concrete making. In practice, very often, great control on the properties of cement and aggregate is exercised but the control on the quality of water is often neglected.

II. MATERIALS AND METHODS

a) Supplementary Cementitious Material: Fly Ash

Fly ash is composed of the non-combustible mineral portion of coal. Particles are glassy, spherical 'ball bearings' finer than cement particles. Sizes of particle are 0.1µm-150 µm. It is a pozzolonic material which reacts with the free lime in the presence of water, converted into calcium silicate hydrate (C-S-H) which is the strongest and durable portion of the post in concrete. The fly ash is procured from Maize Products (A division of Sayaji Industries Ltd) Power plant. This plant is located near Kathwada in Ahmedabad District in Gujarat State.

b) Ordinary Portland Cement

The most common cement used is an Ordinary Portland Cement (OPC). The Ordinary Portland Cement of 53 grades conforming to IS:8112-1989 is used. Many tests were conducted on cement; some of them are specific gravity, consistency tests, setting time tests, compressive strengths, etc. The Physical properties of cement present in the cements are presented in Table 1.

TABLE 1 PROPERTIES OF ORDINARY PORTLAND CEMENT 53 GRADES

Sr. No.	Physical properties of cement	Result	Requirements as per IS:8112-1989
1	Specific gravity	3.15	3.10-3.15
2	Standard consistency (%)	28%	30-35
3	Initial setting time (hours, min)	35 min	30 minimum
4	Final setting time (hours, min)	178 min	600 maximum
5	Compressive strength- 7 days	38.49 N/mm^2	43 N/mm^2
6	Compressive strength- 28 days	52.31 N/mm^2	53 N/mm^2

Chemical Properties of Ordinary Portland Cement (OPC) and Fly Ash (F-Class) as listed in Table 2.

TABLE 2 CHEMICAL PROPERTIES OF OPC AND FLY ASH (F-CLASS)

Chemical Properties	Ordinary Portland Cement (OPC) (Percent by mass)	Fly Ash (F-Class) (Percent by mass)
Silicon Dioxide (SiO_2)	21.77%	62.22%
Calcium Oxide (CaO)	57.02%	5.30%
Magnesium Oxide (MgO)	2.71%	6.09%
Sulphur Trioxide (SO_3)	2.41%	3.00%
Aluminium Oxide (Al_2O_3)	2.59%	7.63%
Ferric Oxide (Fe_2O_3)	0.65%	0.13%
Loss on Ignition	2.82%	9.98%

c) Fine Aggregate

Those fractions from 4.75 mm to 150 microns are termed as fine aggregate. The river sand and crushed sand are used in combination as fine aggregate conforming to the requirements of IS: 383. The river sand is washed and screened, to eliminate deleterious materials and oversize particles.

d) Coarse Aggregate

The fractions from 20 mm to 4.75 mm are used as coarse aggregate. The Coarse Aggregates from crushed Basalt rock, conforming to IS: 383 are used. The Flakiness Index and Elongation Index were maintained well below 15%.

e) Water

Curing water containing 5% concentrated NaOH solution with constant dosages is used.

III. DESIGN MIX METHODOLOGY

a) Design Mix

A mix M40 grade were designed as per IS 10262:2009 and the same was used to prepare the test samples. The design mix proportion is shown in Table 3

TABLE 3 CONCRETE DESIGN MIX PROPORTIONS

Sr. No.	Concrete Mix	Concrete Design Mix Proportion (By Weight in kg)				% Replacement of Cement by Fly ash
		Water/Cement Ratio	Cement	Fine Aggregate	Coarse Aggregate	
1	A2	0.38	473.68	341.91	1419.30	0% (0 kg)
2	B5	0.38	426.31	341.91	1419.30	10% (47.37 kg)
3	B6	0.38	378.94	341.91	1419.30	20% (94.74 kg)
4	B7	0.38	331.58	341.91	1419.30	30% (142.10 kg)
5	B8	0.38	284.21	341.91	1419.30	40% (189.47 kg)

Test samples are prepared with the range of 0% (without fly ash), 10%, 20%, 30% and 40% by weight of cement for the M-40 mix.

b) Alkali Attack Test

This test was carried out on the specimens of 100 mm diameter and 200 mm height. Total 30 cylinders were cast and demoulded after 24 hours. 15 cylinders are tested at the ends of 56 days of the normal curing period. 15 cylinders are tested at the ends of 56 days (28 days normal + 28 days 5% NaOH contain) water curing period. The specimens were taken out from the curing tank and initial weight was taken.

The concentration of the solution was maintained throughout this period by changing the solution periodically. The surface of the cylinders was cleaned, weighed and then tested on the compressive testing machine under the uniform rate of loading of 120 kg/cm2/min. The changes in strength of the concrete cylinders were calculated as per IS: 516-1959.

Figure: 1 Test Setup for Alkali Attack

IV. RESULTS AND DISCUSSION

a) Effect on weight of Fly Ash Cement Concrete

The effect of NaOH on weight of fly ash cement concrete is shown in Table 4, from which it is observed that with increases in % replacement of cement by fly ash, the % loss in weight also increases.

TABLE 4 EFFECT ON WEIGHT OF FLY ASH CEMENT CONCRETE

Sr. No.	Concrete Mix	% Replacement of Cement by Fly ash	Oven Dry Weight in Grams (W1)	Wet Weight in Grams (W2)	Loss in Weight % age
1	A2	0 %	3.937	3.930	- 0.17
2	B5	10 %	3.648	3.641	- 0.19
3	B6	20 %	3.603	3.595	- 0.20
4	B7	30 %	3.623	3.614	- 0.24
5	B8	40 %	3.645	3.635	- 0.27

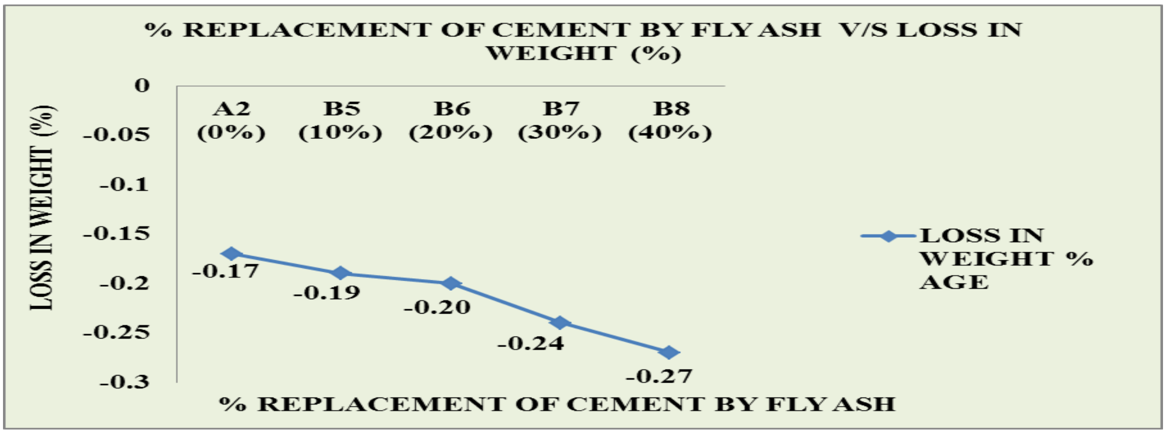

Figure: 2 % Replacement of Cement by Fly Ash v/s Loss in Weight (%)

b) Effect on Compressive Strength of Fly Ash Cement Concrete

The effect of NaOH concentration on the compressive strength Fly Ash Cement Concrete is presented in Table 5.

TABLE 5 Compressive Strength of Fly Ash Cement Concrete Corresponding To Naoh Contain Curing

Sr. No	Concrete Mix	% Replacement of Cement by Fly ash	Fly Ash Cement Concrete			% Change in Compressive Strength	
			Compressive Strength N/mm^2 (P1) 100X200	Compressive Strength N/mm^2 (P2) 100 X200	Loss in Compressive Strength % age (P2-P1/P1) x 100	Compressive Strength N/mm^2 (P1) 100X200	Compressive Strength N/mm^2 (P2) 100 X200
			With normal curing of 56 days	With 28 days normal curing and 28 days NaOH contain curing		With normal curing of 56 days	With 28 days normal curing and 28 days NaOH contain curing
1	A2	0 %	31.00	30.57	- 1.39	0	0
2	B5	10 %	33.55	27.18	- 18.99	8.22	- 11.08
3	B6	20 %	30.57	26.33	- 13.87	- 1.38	- 13.86
4	B7	30 %	28.87	20.38	- 29.41	- 6.87	- 33.33
5	B8	40 %	27.18	19.53	- 28.15	- 12.32	- 36.11

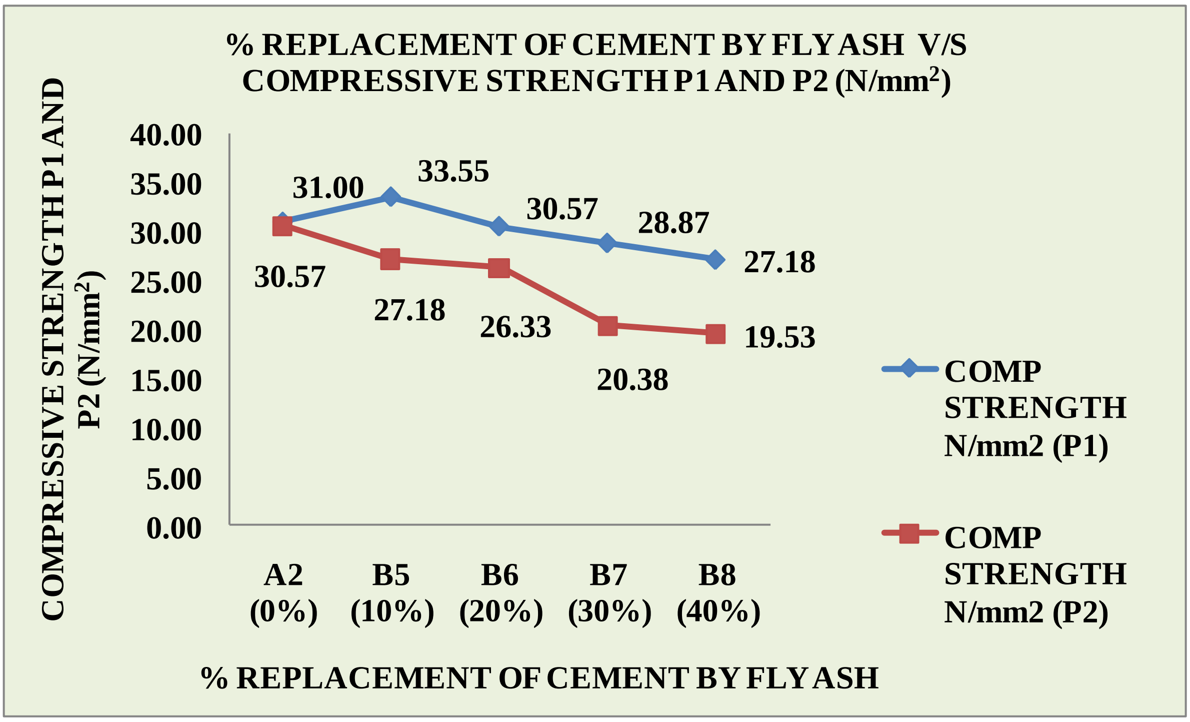

Figure: 3 % Replacement of Cement by Fly Ash V/S Compressive Strength (N/mm^2) P1 and P2

Decrease in compressive strength of specimens cured with NaOH solution is observed. The rate of decrease in compressive strength also gradually increases with an increase in the % of fly ash in the concrete. With the % replacement of cement by fly ash 0 %, 10%, 20%, 30% and 40% with normal curing after 56 days the compressive strength of cylinders is decreased but parallel the compressive strength with 56 days (28 days normal + 28 days 5% NaOH contain) curing also deceased. The decrease in compressive strength is 36.11% for 56 day concrete

It was also observed that the fly ash cement concrete shown a noteworthy resistance vis-a-vis the plain concrete. Similar observations were also noticed in the present experimental investigation.

c) REGRESSION MODELS

To estimate the compressive strength of fly ash cement concrete exposed to NaOH, two regression models have been developed one each for 56 days M40. The regression models are given below.

$fck56_1$ = 32.698 - 0.1232 x C-------------------Equation (1)
$Fck56_2$ = 30.574 - 0.2888 x C-------------------Equation (2)

Where,
$f_{ck}56_1$= Compressive strength of Fly Ash Concrete in N/mm^2 with normal curing of 56 days
$F_{ck}56_2$ = Compressive strength of Fly Ash Concrete in N/mm^2 with 28 days curing + 28 days 5% NaOH contain curing
C = % replacement of cement by fly ash

The coefficient of co-relation factor for regression equations 1 and 2 is **0.6633** and **0.9413** respectively. The performance of regression models is presented in Table 6.

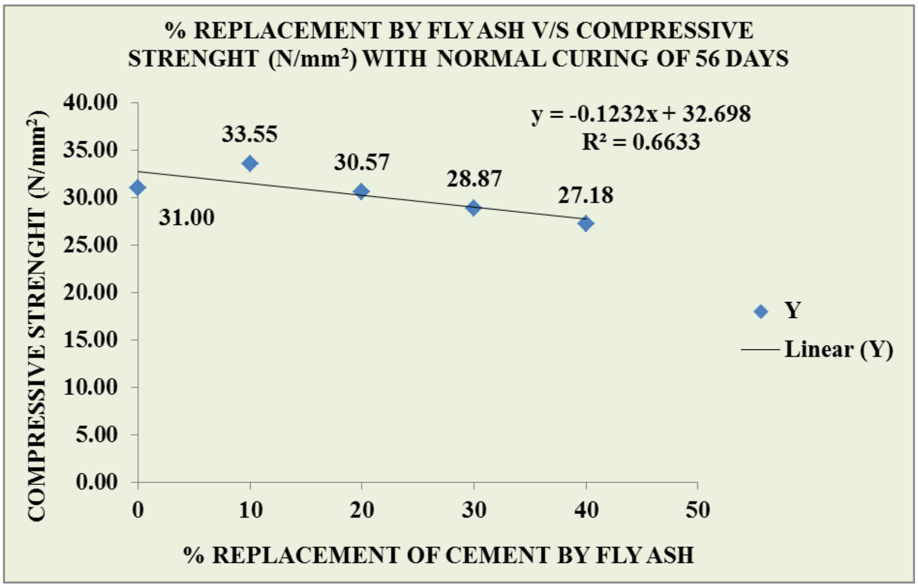

Figure: 4 % Replacement of Cement by Fly Ash V/S Compressive Strength (N/mm^2) Normal Curing of 56 Days

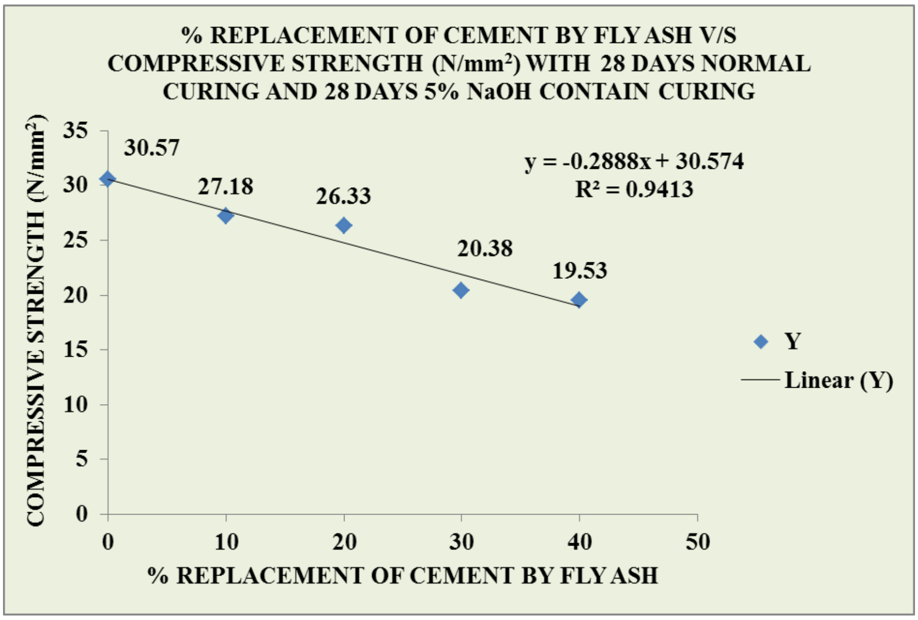

Figure: 5 % Replacement of Cement by Fly Ash V/S Compressive Strength (N/mm^2) with 28 Days Normal Curing and 28 Days 5% NaOH Contain Curing

TABLE 6 PERFORMANCE OF REGRESSION MODELS FOR COMPRESSIVE STRENGTH

Sr. No.	% Replacement of Cement by Fly ash	Compressive Strength of Fly Ash Concrete in Mpa with Normal Curing of 56 days			Compressive Strength of Fly Ash Concrete in MPa with 28 days Normal Curing and 28 days NaOH Solution Curing		
		Experimental (EXP)	Regression Model (RM)	R.M./ EXP	Experimental (EXP)	Regression Model (RM)	R.M./ EXP
1	0 %	28.03	32.70	1.05	25.05	30.57	1.00
2	10 %	27.18	31.47	0.94	24.20	27.69	1.02
3	20 %	25.90	30.23	0.99	20.81	24.80	0.94
4	30 %	23.35	29.00	1.00	17.41	21.91	1.08
5	40 %	20.81	27.77	1.02	16.56	19.02	0.97

From this table the ratios between experimental compressive strength value and the value predicted by the regression model for with normal curing of 56 days are about 0.94 to 1.05 and with 28 days normal curing and 28 days 5% NaOH solution curing are about 0.94 to 1.08 respectively. This implies the proposed models made a good agreement with experimental values.

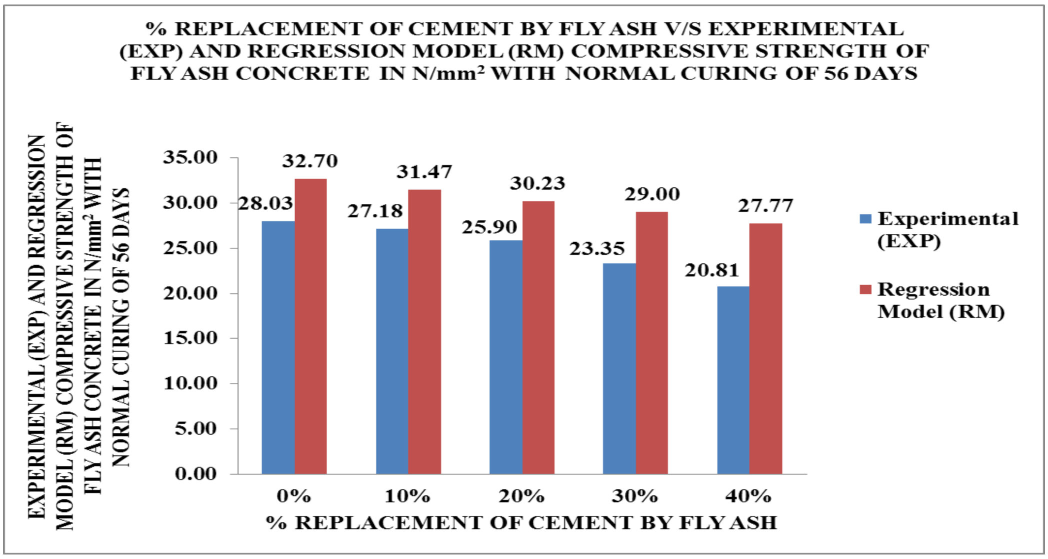

Figure: 6 % Replacement of Cement by Fly Ash V/S Experimental (EXP) and Regression Model (RM) Compressive Strength of Fly Ash Concrete in N/mm^2 with Normal Curing of 56 Days

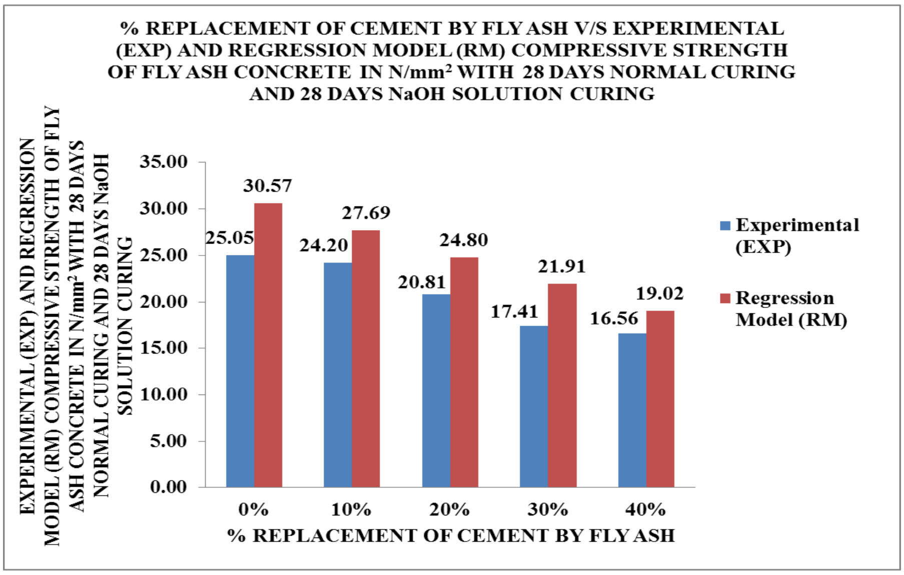

Figure: 7 % Replacement of Cement by Fly Ash V/S Experimental (EXP) and Regression Model (RM) Compressive Strength of Fly Ash Concrete in N/mm^2 with 28 days Normal Curing and 28 Days NaOH Solution Curing

V. CONCLUSIONS

The following conclusions were made from the experimental work.

1. Continuous loss in weight fly ash cement concrete specimens prepared with 0% to 40% replacement of fly ash by 0.17% to 0.27% .
2. Continuous decrease in compressive strength of fly ash cement concrete specimens prepared with 0% to 40% replacement of cement by fly ash when cured by % NaOH contain solution is 1.39% to 29.41%.
3. The proposed regression models shown good performance to predict the compressive strength.

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