Glass Powder as a Partial Replacement of Cement in Cement Concrete for Green Building

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Abstract- Cement is the chief, expensive and most important ingredient of the concrete mix, while concrete is the second most consumed substance in the world after water. Cement has huge carbon footprint. In production of one ton of cement, approximately one ton of carbon dioxide is released. Global warming and climate change are the major environmental issues raised due to emission of carbon dioxide. The construction industries have a great impact on the environment that contributes to a major part of carbon dioxide emission. . Cement industry is very slow to new thing. A lot of researches are continuously going on the search of new materials that can fully or partially replace cement. Supplementary cementitious materials like fly ash, GGBS, metakaolin, rice husk ash, and silica fume are in the prime focus from last decade. One such abundantly available material is waste glass that can be used in replacement to cement. Reutilization of various wastes resolves the landfill problem and at the same time provides a potential way for use of such materials in construction sector. Glasses are varying in properties so it is difficult to recycle each and every type of waste glass. Only a small fraction of waste glass is reused in production of new glass and the remaining glass are disposed due impurities or color or because of cost .The prime aim of this study is to investigate feasibility of glass powder as partial replacement of cement in cement concrete. M-15 and M-25 grades of concrete were made by partially replacing cement by glass powder in the fraction 0%, 5%, 10%, and 15% and characteristic compressive strength were evaluated. Optimum results were seen at 10% cement replacement with glass powder.

Index Terms: Cement, Cementitious Properties, Compressive Strength, Glass Powder, Recycle, Waste Glass.

1.0 INTRODUCTION

In the present era concrete is the most common material which is abundantly used in the construction sector [1]. The carbon footprint of cement is very high. In the process of production of one ton of cement, approximately one ton of carbon dioxide is released [2]. Nearly 400 Million Tonnes of concrete are consumed per year and in the next decade it is expected to reach to 1000 Million Tonnes [3]. The cement production from various major and smaller manufacturers is anticipated to increase upto 421 Million Tonnes till 2017 and is expected to rise in the production to 550-600 Million Tonnes by the year 2025 [4]. The production of cement for construction industry results in an increase in the emission of the carbon dioxide, this can be minimized by use of various supplementary cementitious materials [5]. A lot of researches are continuously going on the search of new materials that can fully or partially replace the cement [6]. Supplementary cementitious materials like fly-ash, GGBS, rice husk, metakaolin and the silica fume are in the prime focus from last decade [7], [8], [9], [10]. One such abundantly available material is waste glass that can be used in replacement to cement. Only a small fraction of waste glass is reused in production of new glass and the remaining glass are disposed due impurities or color or because of cost [8]. The recycling ratio of waste glass is very low as compared to the production of waste glass [11]. Crushed waste glass are having a variety of properties like large percentage of silicon and calcium which has amorphous structure. Thus waste glasses are having cementitious properties which can be used as partial replacement of cement. Studies in past has observed that the chemical composition of glass depends on application of the waste glass other than colour and its origin of the glass. Glasses on the other hand are classified in 32 types [12], but are primarily characterized as lead, vitreous silica, alkali silicates, soda-lime, borosilicates, aluminosilicate and barium glasses. During production of glasses, additives are chiefly used to get the variant color and properties. Among them the most common is soda-lime glasses which are used in production of float, sheet and containers. The percentage of SiO_2(73%), Na_2O(13%), and CaO(10%) in soda lime glass makes it a pozzolanic cementitious material and can be suitably used in the concrete. At the same time lead glass can also be used but the only disadvantage of the lead glass is that it has the presence of lead in it which is quite unsuitable for cement and the concrete [13]. Thus we can see the glasses are varying in properties so it is difficult to recycle each and every type of waste glass. Due to the addition of glass powder to concrete, tri-calcium silicate increases and lowers the quantity of di-calcium silicate and the tri-calcium aluminate [14]. Glass powder is both pozzolonaic and cementitious in character, this is mainly because of silica and calcium which is present in the waste glass. Also mixing waste glass will fully utilize the amount of energy imparted to the glass making process [15].

2.0 RESEARCH SIGNIFICANCE

The main aim of this research is to explore the utilization of waste glass powder. During the process of production of cement, huge quantity of carbon-dioxide is released into atmosphere. By partial reduction of cement by glass powder will help in reducing the carbon dioxide production. This study is conducted to accomplish some predefined objectives that is to study the compressive strength of concrete using glass powder. In this study glass powder was partially replaced as 0%, 5%, 10% and 15% in place of cement in cement concrete for M-15 and M-25 mix.

3.0 EXPERIMENTAL INVESTIGATION

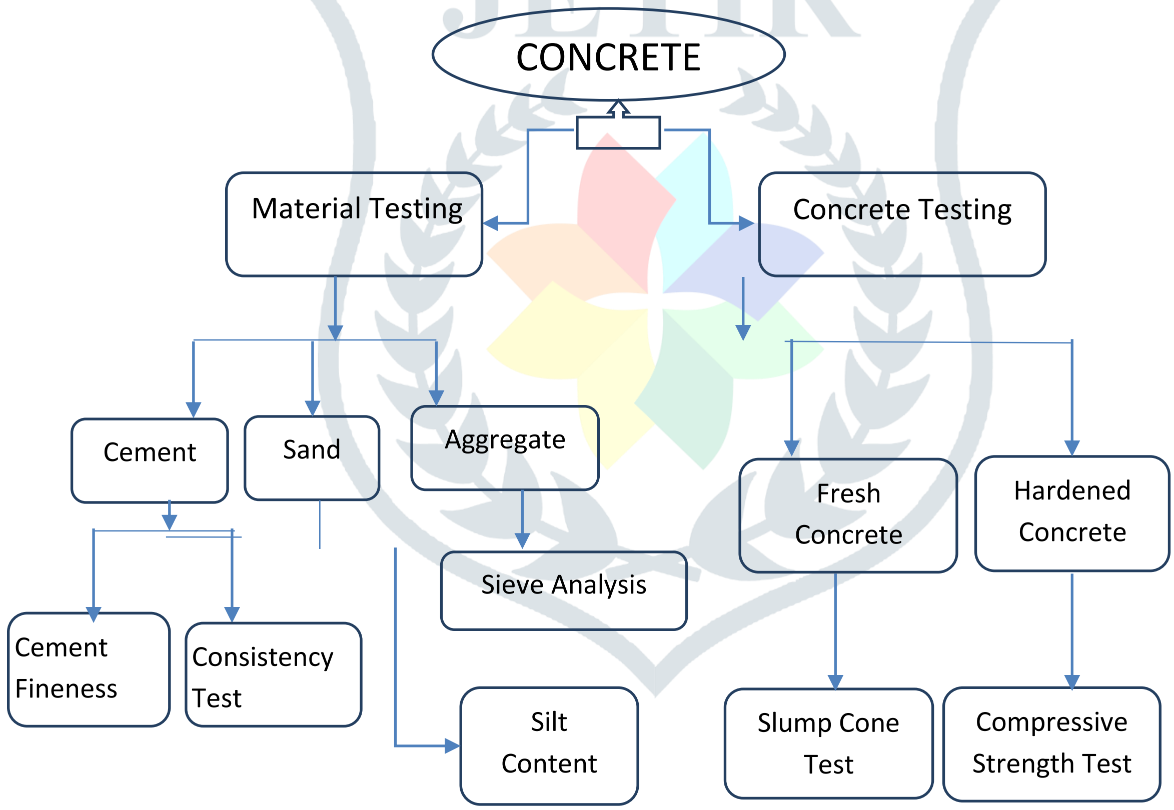
The properties of materials used for making concrete mix are determined in laboratory as per the relevant codes of practice. Test specimens of size 150×150×150 mm were prepared for testing the compressive strength of concrete. In the concrete mixes cement was replaced with varying percentages (0%, 5%, 10% and 15%) of glass powder. Variables include the type of cement (Ordinary Portland Cement, cement replaced with glass powder), coarse aggregate, sand, glass powder and water-cement ratio. The compressive strength increases or decreases as compared to control mix as the percentage of glass powder is increased in the mix.

3.1 MATERIALS USED

- Ordinary Portland Cement (OPC) of grade-43 conforming to IS: 8112-2013 was taken.
- Glass was grinded into powder form collected from Bhopal city, India.
- In all the concrete mix for fine aggregate normal river sand conforming to zone-III (IS: 385-1970) were used.
- Coarse aggregate of size 20mm and size 10mm were used.
- Potable water was used for making concrete. It was free from any detrimental contaminants and was good potable quality.

3.2 TEST CONDUCTED ON MATERIALS

The experimental work were performed individually on the following materials and their codal recommendations are mentioned respectively



3.2.1 Cement

The tests conducted on the cement (OPC-43 Grade) are Fineness, Consistency, Initial and Final setting time, Compressive strength on 7 and 28 days.

Fineness test- performed by Blaine's air permeability apparatus as per IS 4031 (Part II): 1488 and its value should not be more than 10%.

Consistency, Initial setting time, Final setting time – performed by Vicat's apparatus as per IS 4391 (Part V): 1988 and the initial and final setting time values should not be less than 30 minutes and should not be more than 600 minutes respectively.

Compressive strength test- performed on three specimen cubes each having a surface area of 50cm^2 and its values as per the code should be around 33MPa and 43MPa at 7 days and 28 days respectively.

3.2.2 Fine Aggregate (Sand)

Silt Content- performed as per IS 2386 (Part III): 1963 and limiting percentage of silt in sand is 8%.

Sieve Analysis- performed as per IS 2386 (Part I): 1963 to find particle size distribution and its fineness modulus limiting percentage value is 15.

3.2.3 Coarse Aggregate

The test which are conducted for coarse aggregates are Impact test, Shape test like Flakiness Index test and Elongation Index test, and Sieve analysis for 20mm and 10mm aggregates.

Impact test- performed as per IS:2386 (Part IV)- 1963

Shape test- performed as per IS:2386 (Part I)- 1963. The shape test is performed by two methods one is **flakiness index method** and the other is **elongation index method**. In both methods, the test are not performed for size smaller than 6.3mm.

Sieve Analysis- performed as per IS 2386 (Part I): 1963 to find particle size distribution and its fineness modulus limiting percentage value is 15. In this investigation sieve analysis on coarse aggregate are performed on sizes of 20mm and 10mm aggregates respectively.

3.2.4 Water

Other than the pH test, no such specific tests were conducted on water. Regular tap water was used for mixing.

3.3 TEST CONDUCTED ON CONCRETE

The experimental works were performed on both fresh and hardened concrete.

Slump test are performed for fresh concrete but in this investigation slump value was fixed and it was between 25mm to 50mm.

The **compressive strength test** was performed on the hardened concrete. Two different grades of concrete M15 and M25 were taken for study. The specimen of sizes 150mm×150mm×150mm were cast as per codal provision of IS: 516-1959. The natural river sand of Zone III were used for the preparation of the concrete mix. Specimens were cured and tested at 7 and 28 days. Water curing was done at relative humidity of 90% and at the temperature of 27±2 ºC. Averages of the three specimens were considered as the representative compressive strength.

4.0 RESULT AND DISCUSSION

Final results of the individual test conducted on materials as per Indian codal specifications are mentioned below

4.1Cement

S.NO.	TEST	RESULT
1	Fineness test	6.03%
2	Consistency	31%
3	Initial setting time	45 minutes
4	Final setting time	530 minutes
5	7 days strength	34.4 MPa
6	28 days strength	45.2 MPa

4.2 Fine Aggregate (Sand)

S.NO.	TEST	RESULT
1	Silt Content	3.18%
2	Sieve Analysis (Fineness Modulus)	2.41%

4.3 Coarse Aggregate

S.NO	TEST	RESULT
1	Impact Value Test	-
2	Flakiness Index Test	-
3	Elongation Index Test	-
4	Sieve Analysis (Fineness Modulus) of 20mm size	6.98%
5	Sieve Analysis (Fineness Modulus) of 10mm size	6.25%

4.4 Water

It was ensured that water used for mixing should be free from alkali and pH of water used should not be less than 6 as recommended by Indian codal specification. Regular tap water was used in the mixing process.

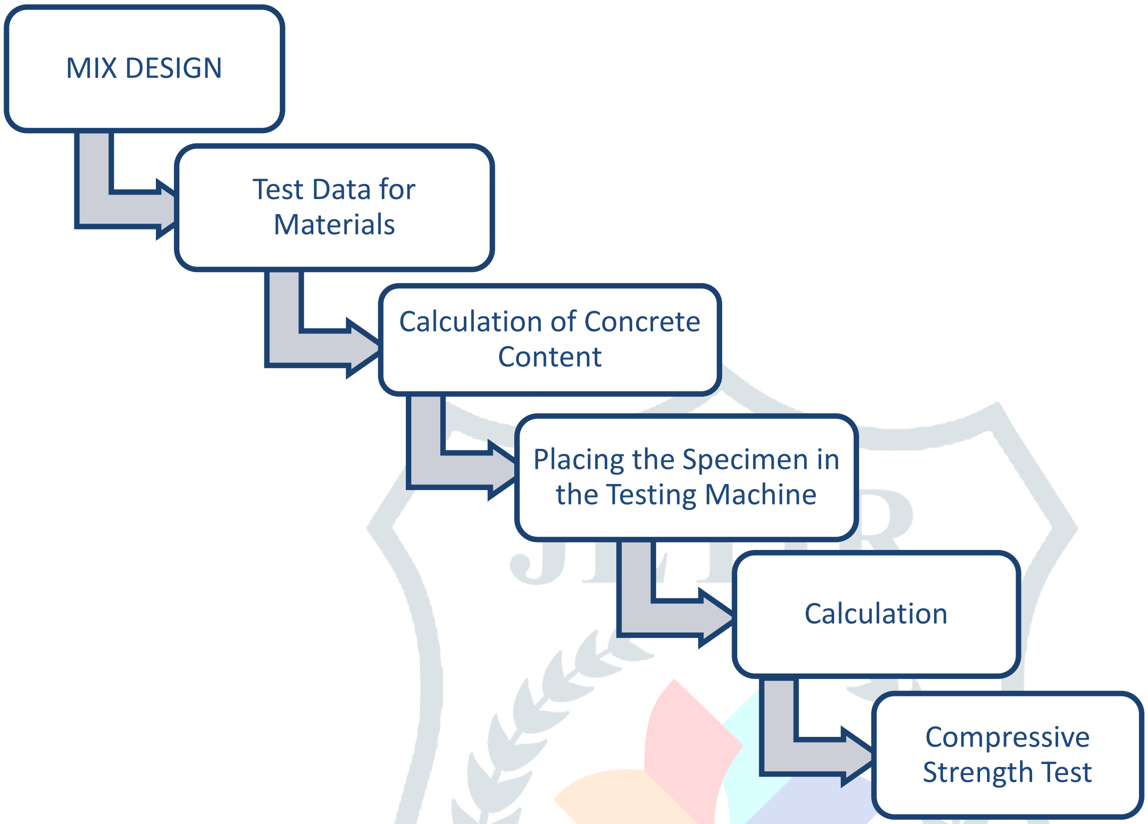
Along with the individual test conducted on materials, some tests were performed on concrete in both fresh and hardened state.

4.5 Workability test

In this investigation, the slump range was fixed and it was between 25mm-50mm.

4.6 Compressive strength test

For performing this test, first quantities were calculated as per the mix design



Mix design chart

4.6.1 Quantities per cubic meter for trial mixes (M15)

Mix	w/c Ratio	Glass powder %	Glass powder (kg/m^3)	Cement (kg/m^3)	Fine Aggregates (kg/m^3)	Coarse Aggregates (kg/m^3)	Water (l/m^3)
M1	0.55	0	0	338	749.7	1142.4	186
M2	0.55	5	16.9	321.1	749.7	1142.4	186
M3	0.55	10	33.8	304.2	749.7	1142.4	186
M4	0.55	15	50.7	287.3	749.7	1142.4	186

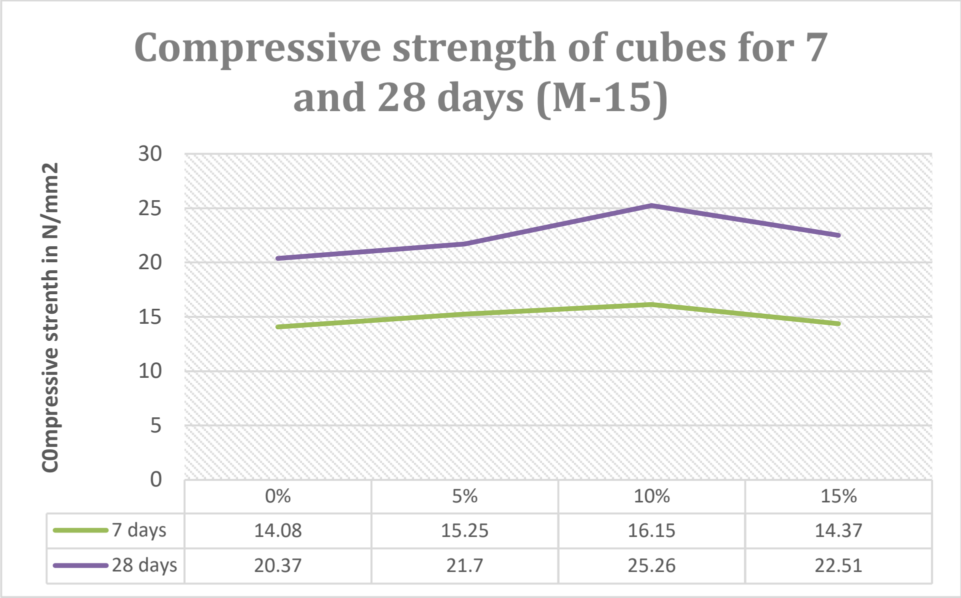
4.6.2 Quantities per cubic meter for trial mixes (M25)

Mix	w/c Ratio	Glass powder %	Glass powder (kg/m^3)	Cement (kg/m^3)	Fine Aggregates (kg/m^3)	Coarse Aggregates (kg/m^3)	Water (l/m^3)
M1	0.45	0	0	413.33	662.38	1101.28	186
M2	0.45	5	20.67	392.67	662.08	1100.77	186
M3	0.45	10	41.33	372	661.78	1100.27	186
M4	0.45	15	62	351.33	661.47	1099.76	186

The result of the compressive strength test for M15 for different percentages of glass powder for 7 days and 28 days are tabulated below

S. No.	% of Glass Powder	Compressive Strength (N/mm^2)	
		7 days	28 days
1	0	14.08	20.37
2	5	15.25	21.70
3	10	16.15	25.26
4	15	14.37	22.51

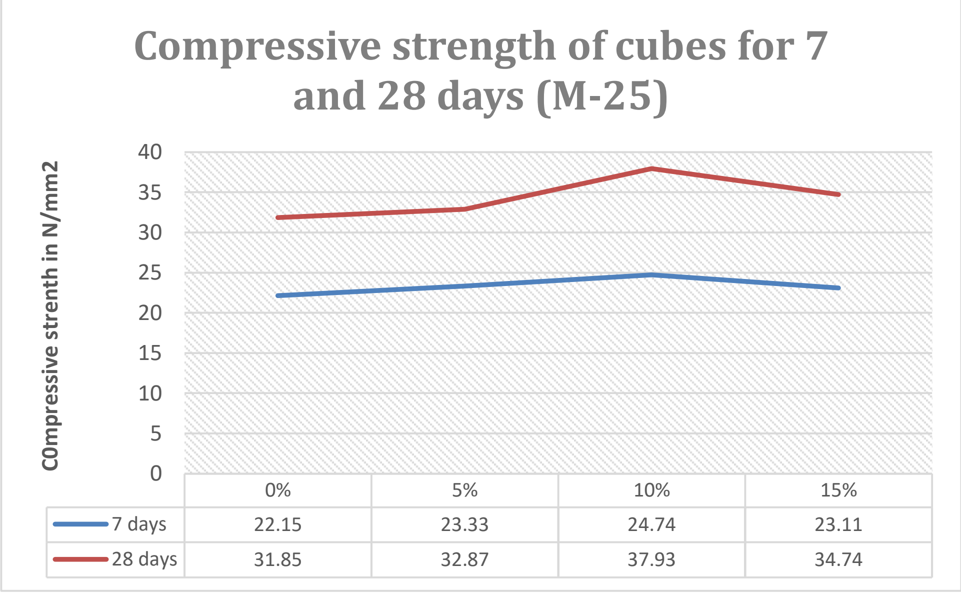
Fig. No.4.1 Effect of partial replacement of cement on different percentages of glass powder on compressive strength of M15.



The result of the compressive strength test for M25 for different percentages of glass powder for 7 days and 28 days are tabulated below

S. No.	% of Glass Powder	Compressive Strength (N/mm^2)	
		7 days	28 days
1	0	22.15	31.85
2	5	23.33	32.87
3	10	24.74	37.93
4	15	23.11	34.74

Fig. No. 4.2 Effect of partial replacement of cement on different percentages of glass powder on compressive strength of M25.



5.0 CONCLUSION

Partial replacement of 10% of cement with glass powder gives the optimum results in both M15 and M25. 24% of increase in strength was observed in case of M15 and 19% of increase in strength was observed in case of M25 at curing period of 28 days. This can be clearly seen in the table given below

Compressive strength of cube for M-15 grade (10% glass powder)

S. No.	% of Glass Powder	Compressive strength (N/ m2)	
		7 days	28 days
1	0	14.08	20.37
2	10	16.15	25.26

Compressive strength of cube for M-25 grade (10 % glass powder)

S. No.	% of Glass Powder	Compressive strength (N/ m2)	
		7 days	28 days
1	0	22.15	31.85
2	10	24.74	37.93

6.0 REFERENCES

[1] N.Gautam, V.Krishna, A.Srivastava, Sustainability in the Concrete Construction, Int. J. of Environ. Res. Dev. 4 (2014) 81-90.
[2] R.D. Woodson, Concrete Materials, in Concrete Portable Handbook, Elsevier Inc., Oxford, 2012, pp. 5-18.
[3] P.P. Pathak, Inclusion of Portland and pozzolana (fly ash waste) cement in specifications, Ind. Highw. 37 (2009) 23-29.
[4] CPCB, Stat of solid waste generation, collection treatment and disposal in metrocities, series VUPS/16/1990-2000.
[5] K.H. Yang, Y.B. Jung, M.S. Cho, S.H. Tae, Effect of supplementary cementitious materials on reduction of CO2 emissions from concrete, J. Clean. Prod. 103 (2015) 774–783.
[6] M. Schneider, M. Romer, M. Tschudin, H. Bolio, Sustainable cement production—present and future, Cem. Concr. Res. 41 (2011) 642–650. doi:10.1016/j.cemconres.2011.03.019.
[7] T. Luukkonen, Z. Abdollahnejad, J. Yliniemi, P. Kinnunen, M. Illikainen, Comparison of alkali and silica sources in one-part alkali-activated blast furnace slag mortar, J. Clean. Prod. 187 (2018) 171–179. doi:10.1016/J.JCLEPRO.2018.03.202.
[8] D.K. Ashish, S.K. Verma, Determination of optimum mixture design method for self- compacting concrete: Validation of method with experimental results, Constr. Build. Mater. 217 (2019) 664–678. doi: 10.1016/j.conbuildmat.2019.05.034.790
[9] D.K. Ashish, Concrete made with waste marble powder and supplementary cementitious material for sustainable development, J. Clean. Prod. 211 (2019) 716–729. doi:10.1016/j.jclepro.2018.11.245.
[10] D.K. Ashish, S.K. Verma, Cementing efficiency of flash and rotary calcined metakaolin in 794 concrete, J. Mater. Civ. Eng. (2019). doi:10.1061/(ASCE)MT.1943-5533.0002953.
[11] P. Turgut, E.S. Yahlizade, Research into Concrete Blocks with Waste Glass, Int. J. Civ. Environ. Eng. 3 (2009) 186–192. https://waset.org/publications/6041/research-into- concrete-blocks-with-waste-glass (accessed April 28, 2019).
[12] G. Chen, H. Lee, K.L. Young, P.L. Yue, A. Wong, T. Tao, K.K. Choi, Glass recycling in cement production—an innovative approach, Waste Manag. 22 (2002) 747–753. doi:10.1016/S0956-053X(02)00047-8.
[13] C. Shi, K. Zheng, A review on the use of waste glasses in the production of cement and concrete, Resour. Conserv. Recycl. 52 (2007) 234–247. doi:10.1016/j.resconrec.2007.01.013.
[14] M. Belouadah, Z.E.A. Rahmouni, N. Tebbal, Effects of glass powder on the characteristics of concrete subjected to high temperatures, Adv. Concr. Constr. 6 (2018) 311–322. doi:10.12989/ACC.2018.6.3.311.
[15] T.D. Dyer, R.K. Dhir, Chemical Reactions of Glass Cullet Used as Cement Component, J. Mater. Civ. Eng. 13 (2001) 412–417. doi:10.1061/(ASCE)0899-1561(2001)13:6(412).