STRESS-STRAIN CHARACTERISTICS OF BRICK MASONRY PREPARED WITH POND ASH IN CEMENT MORTAR UNDER UNIAXIAL COMPRESSIVE STRENGTH

Dhirajkumar Lal,[a] Aniruddha Chatterjee[b]* and Arunkumar Dwivedi[c]**

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The waste from coal-based thermal power plants in the form of pond ash is utilized in making of environment-friendly cement mortar with using sand and cement. The mechanical properties like compressive strength under uniaxial stress of brick masonry and cement mortars prepared with the incorporation of pond ash into the cement mortar at various mixing ratios have been determined. The mathematical relationship of compressive stress values and the composition of brick, mortar and masonry have been developed. The compressive stress, strain and Young's modulus values and their relationships have been determined. Using pond ash lead to an increase in the strength of the mortar and brick masonry prism prepared.

Corresponding Authors
E-Mail:* aniruddha.chatterjee@mit.asia;
** deanace@sandipuniversity.edu.in
[a] Kavayitri Bahinabai Chaudhari North Maharashtra University, Jalgaon-425001, India
[b] Department of Plastic and Polymer Engineering, Maharashtra Institute of Technology, Aurangabad-431010, India
[c] Civil Engineering Department, School of Engineering and Technology, Sandip University, Nasik-422002, India

Introduction

The usefulness of ash in building materials and civil engineering application has been known for a long time.[1,2] There are attempts to utilize pond ash in cement mortar in the brick masonry with replacement of cement and sand with various ratios as per IS 1905,[3] IS 2250,[4] Eurocode EC 6 and EN 1996-1-1.[5] Mathematical models were also developed to characterize the relationships between the compressive strength and modulus of elasticity of brick, mortar and masonry mortar contains alternative replacement materials.[6-14.]

The present work includes the results about compression tests for masonry prisms prepared using reference mortar and pond ash modified mortar and the evaluation of relationships between the values of Young's modulus of elasticity (E) and the compressive strength for mortars prepared with various curing methods.

Experimentals

The locally available burnt clay brick, cement mortar with 1:4 proportion (contained one par cement and four parts sand) and brick masonry prism specimen were prepared. The samples of clay brick, mortar cubes and brick masonry prism were cured at 3, 7 and 28 days period. For the preparation of modified mortars, ordinary Portland cement (53 grade), river sand (locally available) and pond ash (sample collected from Thermal Power Plant, Bhusawal, Dist Jalgaon, Maharashtra) were used. Pond ash samples were dried after collection from disposal sites. The ratio between binder and filler used in the experiments was 1:4. The filler means river sand is first replaced with pond ash with a percentage level of replacement from no replacement to fifty percentage (abbreviation used as: SR_{0-50}). Replacement of cement at the same level named as CR_{0-50}. The mortar sample was prepared and cured at 7 and 28 d periods before testing. The compression test set up with a capacity of 400 kN was used to determine compressive strength and value of strain for burnt clay brick, cement mortar cube and brick masonry prism prepared using pond ash partially replaced with cement and sand. The samples were tested for their ultimate load carrying capacity. Stress and strain values were obtained and recorded. Test set up for brick masonry prism and cement mortar specimen can be seen in the Electronic Supplementary Information (ESI Fig.1.).

Result and discussion

Compressive strength values were measured and given in Table 1 and 2. The compressive strength values for pond ash modified products, the values decrease with increasing the replacement level for both CR_{5-40} and SR_{30-50} samples. The values of compressive strength for pond ash modified mortar exceeds the control in case of SR_{5-35} samples. These values can be used to determine the elasticity modulus (E).

The K, α and β values as constants for model Eqn. 1 were determined with fitting the experimental values.

$$f_k = \mathrm{K}\, f_{\mathrm{b}}^{\mathbf{a}}\, f_{\mathrm{m}}^{\mathbf{b}} \qquad (1)$$

where,

f_{k} = characteristic strength of masonry prism (N mm^{-2})

f_{b} = Compressive strength of brick (N mm^{-2})

f_m= Compressive strength of mortar (N mm^{-2})

K=0.365

α=0.455 and

β=0.4

Table 1. Compressive strength values of prism, brick and mortar, along with a comparison of F_k (experimental and values obtained from Eqn. 2) for CR_{0-50}

Pond ash replacement	f_k experimental N mm^{-2}	Constant *K*	F_b N mm^{-2}	*α*	F_m N mm^{-2}	*β*	f_k from Eqn.2 N mm^{-2}	% Error
CR-0	2.61	0.365	4.19	0.455	24.53	0.4	2.52	3.36
CR-5	2.72	0.365	4.19	0.455	22.16	0.4	2.42	11.08
CR-10	2.28	0.365	4.19	0.455	19.81	0.4	2.31	-1.27
CR-15	2.42	0.365	4.19	0.455	15.89	0.4	2.12	12.47
CR-20	2.56	0.365	4.19	0.455	19.62	0.4	2.30	9.84
CR-25	2.22	0.365	4.19	0.455	19.36	0.4	2.29	-3.45
CR-30	1.88	0.365	4.19	0.455	19.11	0.4	2.28	-21.55
CR-35	1.79	0.365	4.19	0.455	16.99	0.4	2.17	-21.63
CR-40	1.70	0.365	4.19	0.455	14.87	0.4	2.06	-21.25
CR-45	1.47	0.365	4.19	0.455	13.14	0.4	1.96	-33.19
CR-50	1.42	0.365	4.19	0.455	10.56	0.4	1.80	-26.95

Table 2. Compressive strength values of prism, brick and mortar, along with a comparison of F_k (experimental and values obtained from Eqn. 2) for SR_{0-50}

Pond ash replacement	f_k experimental N mm^{-2}	Constant *K*	F_b N mm^{-2}	*α*	F_m N mm^{-2}	*β*	f_k from Eqn.2 N mm^{-2}	% Error
SR-0	**2.61**	**0.365**	**4.19**	**0.455**	**24.53**	**0.4**	**2.52**	**3.36**
SR-5	**3.15**	**0.365**	**4.19**	**0.455**	**26.91**	**0.4**	**2.61**	**16.96**
SR-10	**3.14**	**0.365**	**4.19**	**0.455**	**29.31**	**0.4**	**2.71**	**13.83**
SR-15	**3.19**	**0.365**	**4.19**	**0.455**	**31.69**	**0.4**	**2.79**	**12.51**
SR-20	**3.61**	**0.365**	**4.19**	**0.455**	**34.06**	**0.4**	**2.87**	**20.42**
SR-25	**3.63**	**0.365**	**4.19**	**0.455**	**39.14**	**0.4**	**3.04**	**16.45**
SR-30	**3.25**	**0.365**	**4.19**	**0.455**	**44.22**	**0.4**	**3.19**	**2.02**
SR-35	**3.06**	**0.365**	**4.19**	**0.455**	**38.21**	**0.4**	**3.01**	**1.71**
SR-40	**2.87**	**0.365**	**4.19**	**0.455**	**32.20**	**0.4**	**2.81**	**1.97**
SR-45	**2.63**	**0.365**	**4.19**	**0.455**	**29.44**	**0.4**	**2.71**	**-3.12**
SR-50	**2.41**	**0.365**	**4.19**	**0.455**	**25.70**	**0.4**	**2.57**	**-6.32**

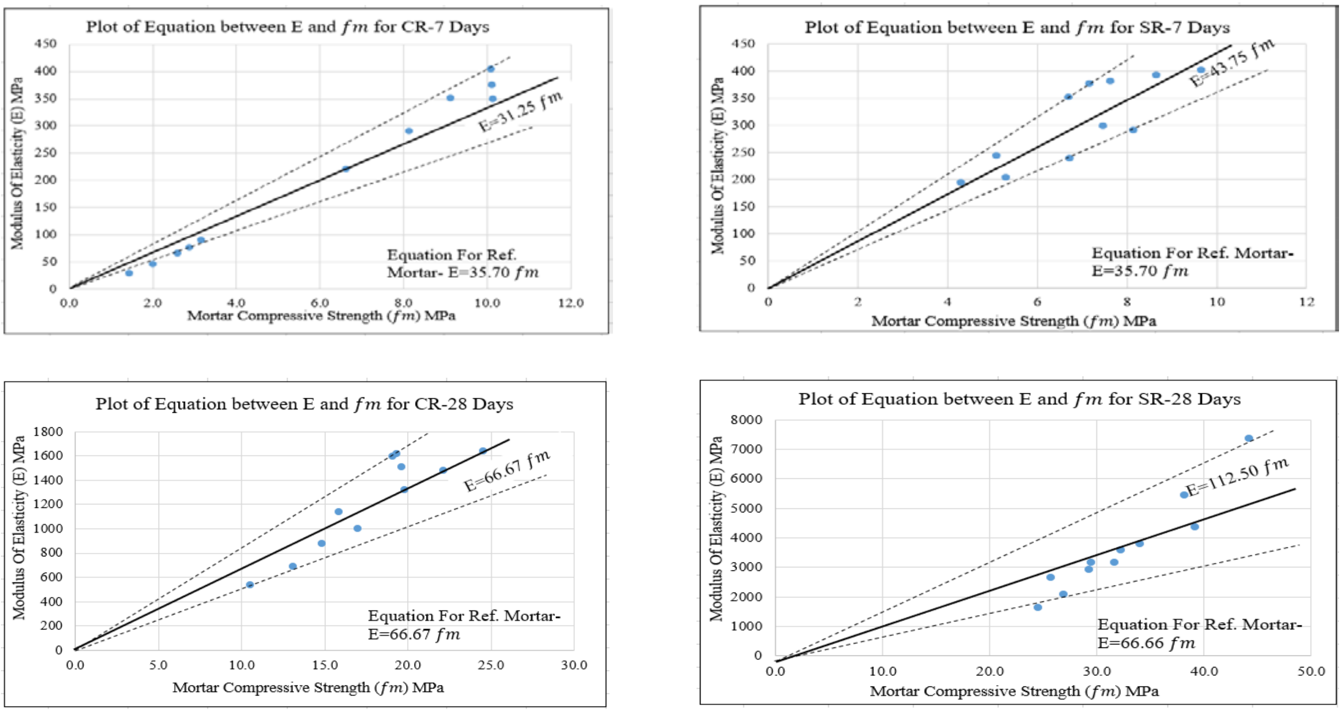

Figure 3. The plot of the equation between *E* and f_m for pond ash modified mortar for 7 and 28 days curing

The strength of brick prism is associated with the strengths of mortar and brick

The relations between elasticity modulus and strength for reference mortar/prism and pond ash modified mortar/prisms can be used for further analysis of masonry structures. The equations for 7 and 28 d curing period for reference and pond ash modified mortar/ prism samples are shown in Table 3-4.

Table 3. The equation for the relation between elasticity modulus (E) and Compressive strength (f_m) for cement mortar

Mortar mix	Reference mortar	Pond ash modified mortar
CR 7 Days	E=35.70 f_m	E=31.25 f_m
SR 7 Days	E=35.70 f_m	E=43.75 f_m
CR 28 Days	E=66.67 f_m	E=66.67 f_m
SR 28 Days	E=66.67 f_m	E=112.50 f_m

Table 4. The equation for the relation between elasticity modulus (E) and compressive strength (f_k) for brick masonry prisms

Mortar mix	Reference mortar	Pond ash modified mortar
CR 7 Days	E=83f_k	E=108 f_k
SR 7 Days	E=83 f_k	E=160 f_k
CR 28 Days	E=264f_k	E=266.67 f_k
SR 28 Days	E=264f_k	E=320 f_k

If the strength of mortar prism is known, the values for elasticity modulus can be calculated by using these equations available in Tables 3 and 4.

The compressive strength for pond ash modified mortar is higher for SR_{5-40} than CR_{5-50}. The relation between elasticity modulus and compressive strength is obtained for 7 and 28 days are curing periods for brick masonry and mortar for reference and pond ash modified mortar. The new mathematical model obtained in accordance with Eurocode EC 6 and EN 1996-1-1 related to pond ash modified mortars for brick masonry prism.

References

[1]Jaturapitakkul, C. and Cheerarot, R., Development of Bottom Ash as Pozzolanic Material, *J. Mater. Civil Eng*., ASCE, **2003**, 48-53. https://doi.org/10.1061/(ASCE)0899-1561(2003)15:1(48)

[2]Bang R.S., Pateria I. K. and Chitlange M. R., "Use of pond ash as the fine aggregate-Experimental study"*, J. Civil Eng. Construct. Rev.*, **2009**, *22(1),* 48-51.

[3]IS 1905 *Code of Practice for structural use of unreinforced masonry, Bureau of Indian Standards*, New Delhi, India**. 1995**.

[4]IS 2250 *Code of Practice for preparation and use of masonry mortar, Bureau of Indian Standards*, New Delhi, India, **2000**.

[5]Eurocode EC 6 and BS EN 1996-1-1:2005 *Design of masonry structure.*

[6]Kaushik, H. B., Rai, D. C. and Jain, S. K., "Stress-strain characteristics of clay brick masonry under uniaxial compression", *J. Material Civil Eng., Am. Soc. Civil Eng.*, **2007**, *19*, 723-739. **DOI:** 10.1061/_ASCE_0899-1561_2007_19:9_728_

[7]Costigan, A., Pavia, S., Kinnane, O. "An experimental evaluation of prediction models for the mechanical behavior of unreinforced, lime-mortar masonry under compression", *J. Building Eng.*, **2015**, *4*, 283-294. DOI: 10.1016/j.jobe.2015.10.001

[8]Narayanan, S. and Sirajuddin, M., "Properties of Brick Masonry for FE modeling", *Am. J. Eng. Res., (AJER)***, 2013**, *1*, 6-11.

[9]Nagarajan, T., Viswanathan, S., Ravi, S., Srinivas, V. and Narayana, P., "Experimental Approach to Investigate the Behaviour of Brick Masonry for Different Mortar Ratios", *Int. Conf. Adv. Eng. Technol., (ICAET'2014),* March 29-30, **2014** Singapore. http://dx.doi.org/10.15242/IIE.E0314167.

[10]Basaran, H., Demir, A. and Bagci, M.,"The Behavior of Masonry Walls with Reinforced Plaster Mortar", *Adv. Mater. Sci. Eng.*, **2013**, 1-9. http://dx.doi.org/10.1155/2013/436946

[11]Gehlot, T., Sankhla, S. S., Saini, K. K., "Study of the Compressive Strength of Brick Prism of Normal Red Brick with Variation in Percentage of Recron Fibre with Cement Mortar of 1:6 And 1:8 Ratio", *J. Architect. Civil Eng*., **2016**, *3(1),* 1-6.

[12]Sharma, S., Purohit, S., "Behavior of Red Clay and Fly Ash Bricks under Uniaxial Compression", *Int. Res. J. Eng. Technol. (IRJET)*, **2017**, *4(7),* 1380-1383.

[13]Slivinskas, T., Jonaitis, B., Marciukaitis, J. G., Zavalis, R., "Investigation of the Behavior of Hardening Masonry Exposed to Variable Stresses", *Materials*, **2018**, *11*, 697, 1-14. https://doi.org/10.3390/ma11050697

[14]Al-Ajmi, F., Abdalla, H., Abdelghaffar, M. and Almatawah, J., "Strength Behavior of Mud Brick in Building Construction", *Open J. Civil Eng.*, **2016**, *6*, 482-494. DOI: 10.4236/ojce.2016.63041

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