

**BLENDING OF FLY-ASHES TO REDUCE THE EFFECT OF
THEIR VARIABILITY ON THE PERFORMANCE OF
CONCRETE**

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**DEPARTMENT OF CIVIL ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY DELHI
MARCH 2018**

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by

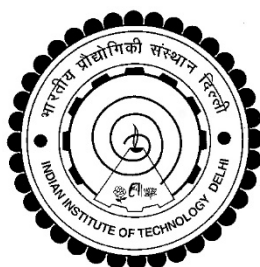
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Submitted

in fulfillment of the requirements of the degree of Doctor of Philosophy

to the



INDIAN INSTITUTE OF TECHNOLOGY DELHI

HAUZ KHAS, NEW DELHI-110016, INDIA

MAR 2018

Certificate

This is to certify that the thesis entitled “BLENDING OF FLY-ASHES TO REDUCE THE EFFECT OF THEIR VARIABILITY ON THE PERFORMANCE OF CONCRETE”, being submitted by Mr. Satya Chaitanya Medepalli, to the Indian Institute of Technology Delhi, for the award of ‘Doctor of Philosophy’ in Department of Civil Engineering is a record of the bonafide research work carried out by him under our supervision and guidance. He has fulfilled the requirements for submission of this thesis, which to the best of our knowledge has reached the requisite standard.

The material contained in the thesis has not been submitted in part or full to any other University or Institute for the award of any other degree or diploma.

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Acknowledgements

First, I would like to thank my supervisor, Dr. Shasahank Bishnoi for his esteemed guidance in carrying out the research work and continued belief in me through all the tough times. I would also like to thank Science and Engineering Research Board, Department of Science and Technology, Govt. of India for their generous support for this project (SERB/F/2766/2012-13). I am grateful to my research committee members Prof. B.Bhattacharjee, Prof. K. G. Sharma and Prof. B.P. Patel for participating in my research presentations and giving valuable insights into my work.

I am thankful to all my colleagues, Amarpreet, Arun, Meenakshi, Malaya, Aneeta and Shiju who were part of my Ph.D. journey. I am deeply thankful for the contribution of my friends Vineet, Sreejith, and Anuj, who were always willing to help and have never said no to any help in laboratory or otherwise;

Thanks to TARA (Technology and Action for Rural Advancement) for their help and allowing me to work in their laboratory and use the TGA machine. I would also like to thank the lab staff, Bir Singh, Lal Singh and Gowtam Barai especially support staff, Deepak, Manoj, Krishna and Vinesh who were very helpful to assist me during the experiments.

I would be always indebted to my family for their love and support throughout my Ph.D.

Abstract

Fly ash is the most widely used supplementary cementitious material in India owing to the abundant quantity of coal reserves across the country. Still, large quantities of the material cannot be used due to their mixed quality. Additionally, the variation in fly ash properties due to the variation in its generation and handling can cause significant variation in the properties of the resulting concrete. If unutilized, the fly ash is dumped in ash ponds filling up space and polluting the environment. This work aims to reduce the variation in the property of concrete arising from the variation in the characteristics of fly ash and to allow the utilization of lower quality fly ashes by blending them with higher quality ones.

Twelve ashes, including 4 pond ashes and 2 processed ashes were obtained and characterized for their physical and chemical properties. Their oxide contents were measured using X-ray fluorescence and crystalline contents were measured using X-ray diffraction. The specific gravity, Blaine's fineness, and particle size distribution were also measured. The morphology of the fly ashes was observed using scanning electron microscopy. Pastes, mortars and concretes, at a fly ash substitution level of 30%, were produced and their hydration characteristics, phase assemblage, and compressive strengths were studied. Hydration was studied using isothermal calorimetry and chemical shrinkage and phase assemblage using X-ray diffraction and thermogravimetric analysis. The influence of individual physical and chemical characteristics of fly ash could be studied by using a combination of the techniques used. It was found that although it is difficult to relate the performance of the mixes to any particular characteristic of the fly ash, fineness, silica content and alumina content appear to have the most important influence. In order to homogenize these characteristics, blends of fly ashes having widely different characteristics were prepared. It was found that even when fly ashes with very different properties were blended together to homogenize these three properties, the variation in the heat of hydration and compressive strength reduced drastically. The blending of the fly ashes based on the homogenization of one parameter allowed an easier understanding of the influence of the other parameters on performance.

In order to better understand the influence of this homogenization on hydration and strength, numerical modeling of the microstructural development of fly ash pastes was carried out. It was found that the amorphous content and particle size distribution of the fly ashes could be used to obtain a good prediction of the strength development in mortars and concretes. This implies that these two factors have the largest influence on strength development. The results from modeling also allowed a better understanding of the rate of hydration of fly ash particles, which are otherwise difficult to measure. Additionally, it was found that modeling could be used to predict the variation in the heat of hydration and compressive strength arising from the variation in the properties of fly ash. The values of the parameters, once determined for one fly ash, could be used without any modification for the other fly ashes.

Overall, it was found that the measurement of Blaine's fineness can be used as a simple and effective means of assessing the proportions in which various fly ashes must be mixed in order to reduce the variability in concrete performance. Although other properties also play an important role, the control of fineness alone can significantly reduce the variation in heat of hydration and strength of concrete.

Keywords: Cement hydration, Fly ash, Blending, Modeling, Calorimetry, Chemical shrinkage, XRD, TGA

सार

फ्लाई ऐश देश भर में प्रचुर मात्रा में कोयले के भंडार के कारण भारत में सबसे अधिक व्यापक रूप से इस्तेमाल किया जाने वाला पूरक कनिष्ठ सामग्री है। फिर भी, उनकी मिश्रित गुणवत्ता के कारण सामग्री का बड़ी मात्रा में उपयोग नहीं किया जा सकता। अतिरिक्त, फ्लाई ऐश प्रॉपर्टी में अंतर इसकी पीढ़ी और हैंडलिंग में भिन्नता परिणामी कंक्रीट के गुणों में महत्वपूर्ण भिन्नता का कारण हो सकती है। यदि अप्रयुक्त किया जाता है, तो फ्लाई ऐश को राख तहखाने में जगह में भर दिया जाता है और वातावरण को प्रदूषित करता है। यह काम कंक्रीट की संपत्ति में बदलाव को कम करने का है। फ्लाई ऐश की विशेषताओं में भिन्नता से उत्पन्न होने और कम गुणवत्ता वाले मक्खी राख के उपयोग को उच्च गुणवत्ता वाले लोगों के साथ मिश्रण करने की अनुमति देने के लिए।

4 तालाब राख और 2 संसाधित राख सहित बारह राख, विशिष्ट गुरुत्व प्राप्त किया गया और उनके भौतिक और रासायनिक गुणों के लिए होती है। उनकी ऑक्साइड सामग्री एक्स-रे प्रतिदीप्ति का उपयोग कर नापा गया और क्रिस्टलीय सामग्री एक्सरे विवर्तन का उपयोग कर मापी जाती थी।, ब्लेन की उत्कृष्टता, और कण आकार वितरण भी नापा गया। मक्खी राख की आकारिकी, स्कैनिंग इलेक्ट्रॉन माइक्रोस्कोपी। चिपकाता है, मोर्टार और concretes का उपयोग कर 30% की फ्लाई ऐश प्रतिस्थापन स्तर पर मनाया गया, उत्पादन किया है और उनके जल-योजन विशेषताओं, चरण संयोजन, और संपीड़न ताकत गया अध्ययन किया गया। हाइड्रेशन समतापीय उष्मागति और रासायनिक संकोचन और चरण संयोजन का उपयोग कर एक्सरे विवर्तन और तेर्मोग्राविमेट्रिक विश्लेषण का उपयोग कर अध्ययन किया गया। फ्लाई ऐश का व्यक्ति भौतिक और रासायनिक विशेषताओं के प्रभाव का अध्ययन किया जा सकता है इस्तेमाल तकनीक के संयोजन का उपयोग करके। यह पाया गया कि हालांकि मक्खी राख के प्रदर्शन को फ्लाई ऐश, शुभकामना, सिलिका सामग्री और एल्यूमिना सामग्री के किसी भी विशेष लक्षण के साथ जोड़ना मुश्किल है, यह सबसे महत्वपूर्ण प्रभाव होता है। इन विशेषताओं होमेगेनीज़ करने के लिए, व्यापक रूप से विभिन्न विशेषताओं वाले मक्खी राख के मिश्रणों तैयार थे। यह पाया गया कि यहां तक कि जब बहुत से मक्खी राख विभिन्न गुणों को एक साथ मिश्रित कर रहे थे इन तीन गुण होमेगेनीज़ करने के लिए, जलयोजन और संपीड़न ताकत की गर्मी में बदलाव काफी कम। मक्खी एक पैरामीटर के एकरूपता के आधार पर राख के सम्मिश्रण के प्रदर्शन पर अन्य पैरामीटर के प्रभाव का एक आसान समझ की अनुमति दी ।

हाइड्रेशन और ताकत पर इस होमोजीनाइजेशन के प्रभाव को बेहतर ढंग से समझने के लिए, फ्लाइ ऐश पेस्ट के माइक्रोस्ट्रक्चरल विकास के संख्यात्मक मॉडलिंग को किया गया था। यह पाया गया कि फ्लाइ ऐश की अनाकार सामग्री और कण आकार वितरण का उपयोग करने के लिए इस्तेमाल किया जा सकता है मोर्टारों और कंक्रीट में ताकत के विकास से यह भविष्यवाणी। इसका मतलब यह है कि इन दो कारकों का ताकत विकास पर सबसे बड़ा प्रभाव है। मॉडलिंग के परिणामस्वरूप फ्लाइ ऐश कणों की हाइड्रेशन की दर को बेहतर समझने की अनुमति मिलती है, जो अन्यथा कठिन हैं अतिरिक्त, यह पाया गया कि मॉडलिंग का इस्तेमाल अग्निरोधी ताकत के तापमान में उभरने से उत्पन्न हाइड्रेशन की गर्मी और संकुचित शक्ति की भविष्यवाणी के लिए किया जा सकता है। एक बार फ्लाइ ऐश के लिए निर्धारित पैरामीटर के मानों का इस्तेमाल किया जा सकता है अन्य फ्लाइ ऐश के लिए किसी भी संशोधन के बिना

कुल मिलाकर, यह पाया गया कि ब्लेन की सुंदरता का माप को ठोस प्रदर्शन में परिवर्तनशीलता को कम करने के लिए थोड़ा अलग फ्लाइ ऐश में अनुपात का आकलन करने का एक सरल और प्रभावी साधन के रूप में इस्तेमाल किया जा सकता है जबकि अन्य गुण भी महत्वपूर्ण भूमिका निभाते हैं , अकेले सुंदरता का नियंत्रण केवल हाइड्रेशन और कंक्रीट की ताकत की गर्मी में परिवर्तन को कम कर सकता है।

कीवर्ड: सीमेंट हाइड्रेशन, फ्लाइ ऐश, ब्लेंडिंग, मॉडलिंग, कैलोरीमेट्री, केमिकल सिकुंज, एक्सआरडी, टीजीए

Glossary

OPC	Ordinary Portland cement
PPC	Portland pozzolana cement
SCM	Supplementary cementitious material
PFA	Pulverized fly ash
FA	Fly ash
BA	Bottom ash
PA	Pond ash
RHA	Rice husk ash
ESP	Electrostatic potential
SEM	Scanning electron microscopy
XRD	X-ray diffraction
QXRD	Quantitative X-ray diffraction
TGA	Thermogravimetric analysis
DTG	Differential thermogravimetry
PSD	Particle size distribution
CS	Chemical shrinkage
w/c	Water to cement ratio
w/b	Water to binder ratio (binder includes cement and SCM)
Aft	Ettringite
Afm	Monosulphate
DoH	Degree of hydration
CS	Chemical shrinkage
PAI	Pozzolanic activity index

Glossary

Cement chemistry notation

CaO	C
SiO ₂	S
Al ₂ O ₃	A
Fe ₂ O ₃	F
H ₂ O	H
SO ₃	$\bar{S}$
MgO	M
K ₂ O	K

<u>Name</u>	<u>Cement composition</u>	<u>Mineral name</u>
C ₃ S	3CaO.SiO ₂	Alite
C ₂ S	2CaO.SiO ₂	Belite
C ₃ A	3CaO.Al ₂ O ₃	Aluminate
C ₄ AF	4CaO.Al ₂ O ₃ .Fe ₂ O ₃	Ferrite/ Brownmillerite/ Ferrite solid solution
C $\bar{S}$ H ₂	CaSO ₄ .2H ₂ O	Gypsum

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