

# **NON-STRUCTURAL CONCRETE UTILIZING FLY ASH, MARBLE POWDER AND FOAM**

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**DEPARTMENT OF CIVIL ENGINEERING  
INDIAN INSTITUTE OF TECHNOLOGY DELHI  
FEBRUARY 2020**

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by

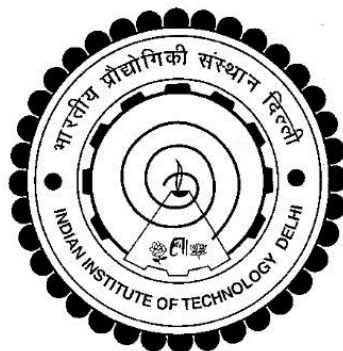
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Submitted

in fulfilment of the requirements for the degree of Doctor of Philosophy

to the



**INDIAN INSTITUTE OF TECHNOLOGY DELHI**

**FEBRUARY 2020**

# Certificate

This is to certify that the thesis entitled “**Non-Structural Concrete Utilizing Fly Ash, Marble Powder and Foam**” submitted by **Miss Meera** to the Indian Institute of Technology Delhi for the award of the degree of **Doctor of Philosophy** in Civil Engineering is a bonafide record of research work carried out by him under my supervision. The thesis work, in my opinion, has reached the requisite standard of fulfilling the requirements for the degree of Doctor of Philosophy.

The results contained in this thesis have not been submitted, in part or full, to any other university or institute for the award of any degree or diploma.

Date: 24/02/2020

Place: New Delhi

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# Acknowledgements

ॐ असतो मा सद्गमय ।  
तमसो मा ज्योतिर्गमय ।  
मृत्योर्मा अमृतं गमय ।  
ॐ शान्तिः शान्तिः शान्तिः ॥

*I am extremely thankful to the Almighty God for his grace and answering my above prayer by providing an opportunity in Indian Institute of Technology Delhi, for pursuing my research interest. I shall use the knowledge and skill gained through the research to serve humanity.*

*I acknowledge the MHRD Institute Fellowship which enabled me to read what I want, think great thoughts and have few publications to earn my keep.*

*I express my sincere gratitude to Dr. Supratic Gupta for his creative ideas, amazing insights and philosophical talks throughout the period of this research. Without his immense guidance painstaking efforts and support, the thesis would not have been possible.*

*I am grateful to the Student Research Committee (SRC) members, IIT Delhi– Prof. B.J Alappat, Prof. Ashok N. Bhaskarwar and Dr. Shashank Bishnoi for valuable suggestions and constructive criticism. Sincere thanks to Prof. Gurmail S Benipal for his encouragement and for contributing time in proofreading of the thesis.*

*I am deeply indebted to Prof. Vasant Matsagar, Dr. J Uma Maheswari and Dr. Hariprasad P. for adding feathers to my wings and inspiring me to take up new challenges. Without you, the sojourn was never possible. Sincere thanks to Dr. Neeraj Kumar Chaurasia for helping in library-related concerns whenever I needed.*

*I would like to thank my colleagues, Dr. Anuj Maheshwari, Dr. Khuito Murumi, Dr. Ashish Kumar Dash and Mr. Kumar Supravin for motivating me with their words of wisdom and ideas. I always enjoyed brainstorming sessions with them. I acknowledge laboratory staffs, namely Mr. Pradeep Singh Negi and Mr. Biri Singh and other attendants for their dutifulness and assistance in my experimental work. I am also thankful to departmental office staffs for helping me deal with the institute bureaucracy.*

*My sincere thanks to staffs of Kailash hostel, IIT Delhi hospital, and Security unit. I express my heartfelt thanks to awesome friends Mulubrhan, Werku, Tesfaye, Fitsum, Sudhir, Subodh, Tanwee, Eliza, Khair Ahmad, Mamata, Snigdha, Madhulika, Subarni, Monalisha, Rashmi, Roman, Shubham, Shiva, Janmejaya, Prashad, Rajesh, Saugat, Dr Lily, Dr Sachi and Dr Jeevan who made IIT Delhi a great place to be in. Thanks for the unforgettable time! Balaji; words are not enough to thank him so I will not try. Apologies to any of the people I may have inadvertently overlooked. I thank all friends, well-wishers at home, and elsewhere for your good thoughts.*

*My sincere love and gratitude to my parents: Mrs. Phularani Behera and Mr. Pitambar Behera and brother Arabinda Behera for always being there with me! Everything I am, I owe to them and I dedicate this work to them.*

*Miss Meera  
February 2020*

# Abstract

Concrete is the most widely used construction material in the construction industry. A large volume of concrete is used for non-structural applications. These applications are mostly with low strength concrete, assumed to be unimportant and investigations on this are neglected. A comparatively large volume of concrete is consumed in these applications and its study can provide ample scope for material optimization and waste utilization in concrete. In this research, utilization of marble powder and fly ash in conventional concrete and foam concrete is presented.

For the study of non-structural concrete, effective w/c ratio of 0.5 – 1.15 is adopted. Mix design of control concrete in these higher effective w/c is difficult due to paste deficiency. Guidance is taken from Table 9 of IS 456: 2000, which is applicable to nominal mixes. A new approach is presented to design control mixes without using 20mm coarse aggregate and assuming  $s/a = 0.5$ . The obtained strength-w/c ratio relation is used for strength prediction in the entire research.

As strength decreases, higher fly ash percentage can be used to minimize cement consumption. Hence, the determination of the efficiency factor for the higher percentage of fly ash is done through experiments essential for mix design. Experiments were carried out to optimize and study the properties of concrete mixes using this derived k-factor.

Designing of concrete with marble powder ought to be carried out with proper water correction for its water absorption at surface saturated dry (SSD) condition. Determination of accurate water absorption at the SSD condition of marble powder is important and is determined experimentally. The obtained moisture content (MC) is used to design mixes for optimization of marble powder concrete, and to conduct a comparative study between marble powder with fly ash concrete. Marble powder can be utilized effectively up to total powder content of

950 kg/m<sup>3</sup>, and with 0% or 15% fly ash. Use of 15% fly ash would provide optimum benefit in cement saving. It does not significantly affect the cost but saves a huge amount of aggregates while providing good cohesivity. Experiments were also carried out on concrete mixes for paver blocks, using fly ash and marble powder.

Strength of foam concrete is presented to be the function of density or porosity in literature. Prediction of porosity is difficult, while the dependence of strength with density is not appropriate. In this research, a novel formulation is proposed for designing and strength prediction for foam concrete. Excess of water that used for hydration of cement leads to pores. Foam that is incorporated into the mortar to also create pores. Hence, in the proposed formulation the volume of foam equivalent to water is added with water in the numerator of the effective water-cement ratio. This proposed model is validated with results presented in literature and through experiments utilizing fly ash and marble powder.

Finally, an Integrated theory was proposed for any concrete mix for designing and strength prediction. An example of 10 MPa concrete is illustrated using the proposed theory.

This thesis provides a clear view of efficient utilization of fly ash and marble powder for the production of non-structural cement and mortar based products promoting economy, sustainability and scope of entrepreneurship to youths in developing countries like India by saving of natural resources through savings in cement and aggregate consumption is important.

***Keywords: Efficiency Factor; Fly Ash; Marble powder; Optimisation; foam concrete***

# सार

निर्माण उद्योग में कंक्रीट सबसे व्यापक रूप से इस्तेमाल की जाने वाली निर्माण सामग्री है। कंक्रीट की एक बड़ी मात्रा का उपयोग गैरसंरचनात्मक अनुप्रयोगों के लिए भी किया जाता है। ये अनुप्रयोग ज्यादातर कम ताकत वाले कंक्रीट के साथ हैं, जिन्हें महत्वहीन माना जाता है और इस पर जांच उपेक्षित है। इन अनुप्रयोगों में कंक्रीट की तुलनात्मक रूप से बड़ी मात्रा में निर्माण सामग्री की खपत होती है। इसका अध्ययन कंक्रीट में सामग्री अनुकूलन और अपशिष्ट उपयोग के लिए पर्याप्त गुंजाइश प्रदान कर सकता है। इस शोध में, पारंपरिक कंक्रीट और फोम कंक्रीट में संगमरमर पाउडर और फ्लाई ऐश का उपयोग प्रस्तुत किया गया है।

गैर-संरचनात्मक कंक्रीट के अध्ययन के लिए 0.5 - 1.15 के प्रभावी  $w/c$  अनुपात को अपनाया जाता है। इन उच्च प्रभावी  $w/c$  में नियंत्रण कंक्रीट का मिक्स डिज़ाइन पेस्ट की कमी के कारण मुश्किल है। IS 456: 2000 की तालिका 9 से मार्गदर्शन लिया जाता है, जो नाममात्र मिश्रणों पर लागू होता है। एक नया दृष्टिकोण 20 mm रोड़ी बिना और  $s/a = 0.5$  का उपयोग किए नियंत्रण मिश्रणों को डिजाइन करने के लिए प्रस्तुत किया गया है। प्राप्त शक्ति  $w/c$  अनुपात संबंध पूरे अनुसंधान में ताकत भविष्यवाणी के लिए उपयोग किया गया है।

जैसे ही ताकत कम होती है, सीमेंट की खपत को कम करने के लिए उच्च प्रतिशत फ्लाई ऐश का उपयोग किया जा सकता है। इसलिए, फ्लाई ऐश के उच्च प्रतिशत के लिए दक्षता कारक का निर्धारण किया जाता है। इस व्युत्पन्न  $k$ - कारक संबंध का उपयोग करके कंक्रीट मिक्स के गुणों का अनुकूलन और अध्ययन करने के लिए प्रयोग किए गए थे।

संतृप्त सतह शुष्क (SSD) स्थिति में इसके जल अवशोषण के लिए समुचित जल सुधार के साथ संगमरमर के पाउडर के साथ कंक्रीट की डिजाइनिंग की जानी चाहिए। संगमरमर पाउडर की SSD स्थिति में सटीक जल अवशोषण का निर्धारण महत्वपूर्ण है और प्रयोगात्मक रूप से निर्धारित किया जाता है। प्राप्त नमी सामग्री का उपयोग संगमरमर पाउडर कंक्रीट के अनुकूलन के लिए मिक्स डिजाइन करने के लिए किया जाता है, और फ्लाई ऐश कंक्रीट के साथ संगमरमर पाउडर के बीच तुलनात्मक अध्ययन करने के लिए। संगमरमर पाउडर को कुल पाउडर सामग्री  $950 \text{ kg/m}^3$  तक, और 0% या 15% फ्लाई ऐश के साथ प्रभावी ढंग से उपयोग किया जा सकता है। 15% फ्लाई ऐश का उपयोग सीमेंट बचत और संगमरमर पाउडर के उपयोग में इष्टतम लाभ प्रदान करेगा। यह लागत को महत्वपूर्ण रूप से प्रभावित नहीं करता है लेकिन अच्छा सामंजस्यपूर्ण मिश्रण प्रदान करते हुए कुल के उपयोग को कम करने में योगदान देगा। फ्लाई ऐश और संगमरमर के पाउडर के उपयोग से पेवर ब्लॉक के लिए कंक्रीट मिक्स पर भी प्रयोग किए गए हैं।

फोम कंक्रीट की ताकत को साहित्य में घनत्व या छिद्र का कार्य माना जाता है। छिद्र की भविष्यवाणी मुश्किल है, जबकि घनत्व के साथ ताकत की निर्भरता उचित नहीं है। इस शोध में, फोम कंक्रीट के लिए डिजाइनिंग और ताकत की भविष्यवाणी के लिए एक महत्वपूर्ण सूत्रीकरण प्रस्तावित है। जलयोजन के बाद बचा अतिरिक्त पानी कंक्रीट में छिद्र बनाता है। फोम जो मोर्टार में शामिल होता है वह भी छिद्र बनाता है। इसलिए, प्रस्तावित सूत्रीकरण में पानी के बराबर फोम की मात्रा को प्रभावी जल-सीमेंट अनुपात के अंश में पानी के साथ जोड़ा जाता है। यह प्रस्तावित मॉडल साहित्य में प्रस्तुत परिणामों के साथ और फ्लाइ एश और संगमरमर पाउडर के उपयोग के माध्यम से मान्य है।

अंत में, डिजाइनिंग और शक्ति भविष्यवाणी के लिए किसी भी ठोस मिश्रण के लिए एक एकीकृत सिद्धांत प्रस्तावित किया गया है। प्रस्तावित सिद्धांत का उपयोग करके 10 MPa कंक्रीट का उदाहरण दिया गया है।

यह थीसिस गैर-संरचनात्मक सीमेंट और मोर्टार आधारित उत्पादों के उत्पादन के लिए फ्लाइ एश और संगमरमर पाउडर के कुशल उपयोग का एक स्पष्ट दृष्टिकोण प्रदान करती है, जो भारत जैसे और विकासशील देशों में प्राकृतिक संसाधनों की बचत के माध्यम से उद्यमशीलता, स्थिरता और गुंजाइश को बढ़ावा देती है। सीमेंट और कुल खपत महत्वपूर्ण है।

**संकेतशब्द:** दक्षता कारक; फ्लाइ एश; संगमरमर का पाउडर; अनुकूलन; फोम कंक्रीट.

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# Abbreviations, Symbols and Notations

## Abbreviations

ACI	American Concrete Institute
ASTM	American Society for Testing and Materials
BIS	Bureau of Indian Standards
CA	Coarse aggregate
FA	Fly ash
GGBS	Ground granulated blast furnace slag
IIT	Indian Institute of Technology
IRC	Indian Roads Congress
IRS	Indian Railway Standard
IS	Indian Standard
MoRTH	Ministry of Road Transport and Highways
MP	Marble Powder
OPC	Ordinary Portland cement
PCC	Plain cement concrete
PCE	Polycarboxylate ether
PPC	Portland pozzolana cement (fly ash-based)
RCC	Reinforced cement concrete
SCC	Self-compacting concrete
SEM	Scanning electron microscope
Strength	Compressive strength of concrete at a particular age
SSD	Surface saturated dry

## Symbols and Notations

$\text{₹}$	Indian Rupee
$b$	Effective binder, that is, $c+kf$ ( $\text{kg/m}^3$ )
$c$	Ordinary Portland cement ( $\text{kg/m}^3$ ) unless otherwise stated
$C_7$	Compressive strength of concrete of 150 mm cubes at 7 days (MPa)
$C_{28}$	Compressive strength of concrete of 150 mm cubes at 28 days (MPa)
$cm$	Cementitious material, that is, the sum of cement and fly ash ( $\text{kg/m}^3$ )
$f$	Fly ash ( $\text{kg/m}^3$ )
$f\%$	Fly ash percentage (%), that is, $f/(c+f)$
$k_{28}$	Efficiency factor of fly ash at 28 days
$k_7$	Efficiency factor of fly ash at 7 days
$k$ -value	Efficiency factor of fly ash
$F$	Foam Volume
$p$	Powder content = the sum of cement and fly ash and Marble powder ( $\text{kg/m}^3$ )
$s$	Natural sand or fine aggregate ( $\text{kg/m}^3$ )
$s/a$	Sand to total aggregate ratio
$w$	Water ( $\text{kg/m}^3$ )
$\frac{w}{b} = \frac{w+\alpha F}{c+kf}$	Effective Water to cement ratio
min	Minute (time)

*Dedicated to*  
*My Beloved Parents*