DEVELOPMENT OF INTERLOCKING BLOCK MASONRY SYSTEM AND AN EXPERIMENTAL INVESTIGATION ON ITS BEHAVIOUR UNDER UNIAXIAL REPEATED LOADING

by

BINOD KUMAR SINGH
DEPARTMENT OF CIVIL ENGINEERING

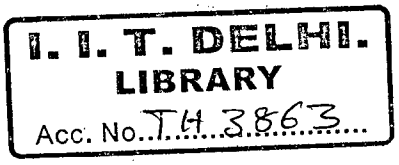
Submitted in fulfillment of the requirements of the degree of
DOCTOR OF PHILOSOPHY

to the

INDIAN INSTITUTE OF TECHNOLOGY, DELHI
NEW DELHI – 110016
INDIA

December, 2008

Interlocking block/brick masonry;
Architecture — Masonry.



Dedicated to the loving memory of my
Mother and Grandfather

CERTIFICATE

This is to certify that the thesis entitled, **"DEVELOPMENT OF INTERLOCKING BLOCK MASONRY SYSTEM AND AN EXPERIMENTAL INVESTIGATION ON ITS BEHAVIOUR UNDER UNIAXIAL REPEATED LOADING"**, being submitted by **Binod Kumar Singh** to the Indian Institute of Technology, Delhi for the award of the Degree of Philosophy in Civil Engineering, to the best of our knowledge, is a record of bonafide research work carried out by him.

This thesis, or any part thereof, has not been submitted to any other University or Institute for award of any degree or diploma.

Prof. K.G. Sharma Prof. Ashok Gupta Prof. A.K. Gosain

Notional Supervisors
Civil Engineering Department
Indian Institute of Technology, Delhi
New Delhi- 110016, India

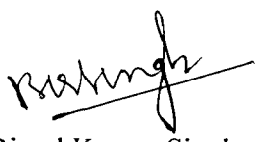
ACKNOWLEDGEMENT

I am gratefully indebted to Prof. K.G. Sharma, Prof. Ashok Gupta and Prof. A.K. Gosain for their advice, encouragement and support as the Notional Supervisors. I am also grateful to Prof. S.N. Sinha for his guidance during the course of research work. Special thanks are expressed to the Director, Dean (PGS & R), Head (Civil Engineering) and other faculty members of the Civil Engineering Department, particularly Prof. T.K. Datta, Prof. A.K. Jain, Prof. B. Bhattacharjee, Dr. G.S. Benipal and Dr. Alok Madan for their constructive criticisms and comments at several stages of the research work.

I am thankful for the assistance and support extended to me by the staff members of the Office, Structural Engineering Laboratory, Civil Engineering Workshop, Computational Laboratory and Rock and Soil Mechanics Laboratory, particularly Shri Ram Kumar, Shri Badan Singh, Shri G.D. Tiwari, Shri Badale Ram, Shri Gosain, Shri K.K. Bali, Shri N.R. Gehlot, Shri Amit Bundela and Shri Bikram Chand.

My sincere appreciation is also due to the authorities of Vastu Kala Academy College of Architecture, New Delhi for their resource; to Dr. Manohar Prasad, Ex-Professor, IIT, Kanpur, for his expert advice, and to my colleagues Dr. Sandeep Chaudhary, Dr. N.S. Maurya, Dr. Kumar Niraj Jha and Shri Umesh Pendarkar whose cooperation was morale boosting throughout the research work. I also thank Shri M. Suresh Kumar for his constructive suggestions.

I also express my appreciation for the support, patience and understanding extended by my father, wife, daughter, in-laws and other members of the family.



Binod Kumar Singh

ABSTRACT

In the present study, an attempt has been made to improve the efficiency and performance of the masonry through the development of two types of interlocking grouted masonry systems – one for unreinforced masonry constructions and other for unreinforced, reinforced and prestressed masonry constructions – which are simple in shape, less workmanship dependant and accelerate the construction process. To increase the economical viability and sustainability of the product, simple apparatus and processes that use locally available men and materials for manufacturing its units have been developed. Experimental investigations on the behaviour of the unreinforced interlocking grouted stabilized mud brick and block masonry panels, and interlocking grouted concrete brick and block masonry panels under uniaxial repeated compressive loading in the direction perpendicular and parallel to the bed joints have been conducted. The unreinforced interlocking grouted masonry system exhibited almost double the masonry efficiency (strength of masonry to strength of masonry unit) of conventional masonry. The embodied energy of unreinforced interlocking grouted stabilized mud block masonry and interlocking grouted concrete block masonry with 15 percent cement and 25 percent fly ash was 1884 MJ/m^3 and 2082 MJ/m^3, respectively which is less than the embodied energy of conventional burnt brick masonry (2653 MJ/m^3). The mean compressive strength of the unreinforced interlocking grouted stabilized mud block and unreinforced interlocking grouted concrete block was 16.63 N/mm^2 and 32.76 N/mm^2, respectively.

The interlocking masonry systems developed are a set of solid masonry units of precise height and width that interlock securely due to interlocking or interfitting male projections on the one face and female depressions on the opposite face, and are self-

aligned and self-adjustable. It has predetermined horizontal and vertical gaps of 3 mm thickness at the joints on stacking. Special grooves are made for containment reinforcement or tendons. Perfect bonding is achieved by interlocking and grouting of the joints. For manufacturing of these interlocking bricks/blocks, a semi-automatic portable hydraulic press has been developed. The press uses the principle of compaction through ramming action.

The unreinforced interlocking grouted masonry brick and block panels of size 600 mm × 100 mm × 700 mm and 600 mm × 100 mm × 750 mm respectively were tested under uniaxial repeated compressive loading in the direction perpendicular and parallel to the bed joints. Three types of tests have been conducted for each loading case: (i) Monotonic test (ii) Common point test and (iii) Stability point test. Seven masonry specimens for each type of masonry panel and direction of loading were tested.

A single mathematical formulation is proposed for determination of envelope, common point and stability point curves for loading perpendicular and parallel to the bed joint for unreinforced interlocking grouted brick/block masonry. A general polynomial equation of single term is proposed to predict residual strain curves. An empirical expression is also suggested for the variation of energy dissipation ratio with the envelope strain and the residual strain. A mathematical model is presented to predict reloading-unloading curves at any given residual strain. The mathematical model prediction compares well with the experimentally obtained stress-strain curves under repeated loading.

TABLE OF CONTENTS