NUMERICAL AND PHYSICAL MODELLING OF CRACKS IN MASONRY WALLS DUE TO THERMAL MOVEMENTS OF AN OVERLYING SLAB

By

K G S Dilrukshi

The thesis was submitted to the Department of Civil Engineering of the University of Moratuwa in partial fulfillment of the requirements for the Degree of Doctor of Philosophy

Research supervised

By

Professor W P S Dias

DEPARTMENT OF CIVIL ENGINEERING

UNIVERSITY OF MORA TUWA

MORATUWA

SRI LANKA

2008

ABSTRACT

Concrete slabs exposed to direct sunlight experience temperature related horizontal movements. In addition, temperatures on the top surface will be higher than those on the underside of the slab, causing an upward deflection of the slab during heating. In a typical building, masonry and concrete elements are connected to each other at their common interfaces. Therefore, significant movements may be generated on the masonry walls due to the movement of the roof slab. These movements can result in overstressing and cracking in masonry. These cracks may not be structurally serious, but may lead to ingress of moisture and in any case are not acceptable especially where good finish is desired.

In this study, the behaviour of these cracks was studied based on surveys of buildings where such cracks have formed. Also typical structural arrangements were numerically modelled to investigate the stresses developing in walls due to the movement of the overlying slab and consequent cracking. Using these numerical models, the effect of the aspect ratio of the wall, structural form of the wall and presence of other structural features such as openings and lintels on the formation of these cracks was studied. These results were compared with the information obtained from the field survey and also with a few physical models which were constructed to the scale of 1/3 of the prototype. The formation of cracks was observed and the strains generated on walls and the temperature variations of the assemblies were monitored. These observations enabled qualitative validation of the numerical models.

Numerical modelling was initially done as a linear elastic un-coupled analysis. A commercially available structural analysis software SAP2000 was used for the study. Locations and directions where cracking would occur were identified using the principal stresses developed in the finite element model and a failure criterion developed based on modified Von-Mises theory. Using detailed numerical modelling (i.e. non-linear structural-thermal coupled analysis), the development of cracks in walls under the time varying thermal load was studied. Modelling was done using a

commercially available finite element code ANSYS 11.0. The model was also used to study the effectiveness of various remedial measures for the problem of thermal cracks in concrete framed walls.

It was found that concrete framed walls could exhibit horizontal cracking under the beam and inclined cracking (at 45^0 to the horizontal) near the ends of walls. For load bearing walls the inclined cracking at wall ends had an inclination to the horizontal of around 60^0, while vertical cracking near the wall mid length was also a possibility.

Linear elastic analysis will give a reasonably good idea of crack locations in solid walls. However non-linear analysis would be required for predicting crack locations in walls with openings.

The results of detailed numerical modelling illustrate that the use of a lintel in a concrete framed wall is not an effective solution to the problem of thermal cracking in walls. However, separating the wall from the concrete frame at the wall-beam interface and wall-column interface (for a depth of 1/3 of the wall height from the beam soffit level) seems to be an effective solution.

ACKNOWLEDGMENT

I offer my most heartfelt gratitude to my supervisor Professor W P S Dias, Head of the Department of Civil Engineering, University of Moratuwa, Sri Lanka for his kindness, generosity, encouragement, invaluable advices and perfect guidance held upon my research. I also would like to acknowledge the National Science Foundation of Sri Lanka for their financial support and encouragement during the period of this research.

In particular, I am grateful to Professor Nimal Rajapakse, and the Department of Mechanical Engineering, University of British Columbia, Canada for the collaboration with their expensive resources and guidance.

Within the department of Civil Engineering, University of Moratuwa the author wishes to thank the technical staff of the structural testing laboratory and the building materials laboratory for their help with the experiments. My sincere gratitude is also offered to Dr. Ranjith Dissanayake and the rest of the technical staff of the structural testing laboratory, University of Peradeniya for their support on experimental study. Thanks are also due to Mr. C Mallikarachchi, Mr. C Edirisinghe, Miss. N Satanarachchi and Mr. H Yapa, fellow post graduate students for their help on several occasions.

I would also like to thank the Vice Chancellor, Dean of the Engineering Faculty, the Senate Research committee, Head of the Department of Civil Engineering and the Director, Postgraduate Studies of University of Moratuwa for crating a good research environment

Finally my warm gratitude is for my husband who always stood by me during difficult moments and for nourishing my mind with hope and courage.

DECLARATION

This thesis is a report of research carried out in the Department of Civil Engineering, University of Moratuwa, between February 2004 and May 2008. Except where references are made to other work, the contents of this thesis are original and have been carried out by the undersigned. The work has not been submitted in part or whole to any other university.

Dilaranagoda

K G S Dilrukshi
Department of Civil Engineering
University of Moratuwa
Sri Lanka

UOM Verified Signature

Supervisor
Prof. W P S Dias
Department of Civil Engineering
University of Moratuwa
Sri Lanka

CONTENTS

LIST OF FIGURES

LIST OF TABLES