LATERAL COMPRESSION OF SQUARE TUBES AND THEIR CROSS LAYERED SYSTEMS

By

SANTOSH KUMAR SINHA

Submitted
in fulfilment of the requirements
of the degree of

DOCTOR OF PHILOSOPHY

Department of Applied Mechanics
INDIAN INSTITUTE OF TECHNOLOGY, DELHI

JUNE 1988

CERTIFICATE

This is to certify that the thesis entitled "Lateral Compression of Square Tubes and their Cross Layered Systems" by Sri Santosh Kumar Sinha has been prepared under my supervision and has attained a standard required for a Ph.D. degree of the Institute. The thesis is a record of bonafide research work carried out by him and its contents have not been submitted to any other University or Institute for the award of any degree or diploma.

11.6.88

(N.K. GUPTA)
Professor,
Applied Mechanics Department,
Indian Institute of Technology, Delhi.

ACKNOWLEDGEMENTS

I am extremely grateful to Professor N.K. Gupta, Department of Applied Mechanics, Indian Institute of Technology, Delhi, for his inspiring guidance and encouragement throughout this work.

I am grateful to the staff of the Strength of Materials Laboratory and the Departmental Workshop for their co-operation and assistance.

I am indebted to Mr. A.D. Pavate and Mr. R.Pangasa for their help and encouragement.

I am thankful to my young friends, Rajiv, Sanjay, Anil and Dipak for their help.

Finally, I express my deepest sense of gratitude to my wife, Jharna, without whose inspiration, encouragement and forbearance, this work would not have been completed.

S.K. SINHA

LATERAL COMPRESSION OF SQUARE TUBES AND THEIR CROSS LAYERED SYSTEMS

ABSTRACT

Mechanical devices or systems for dissipating kinetic energy in a controlled manner or at a predetermined rate are of importance particularly in situations related to the collision of vehicles of various sorts, wherein it is important for the safety of the occupants and the structure that an excessively high rate of retardation is prevented. Devices normally used for this purpose are such items that under the situation of collision, may undergo large plastic deformation in a specified and predictable manner without restitution while absorbing the kinetic energy of the collision. Once subjected to the load and plastically deformed, these items are discarded and replaced. Simple structure elements like wires, bars, frames and tubes form components in such devices because of their capacity to undergo large plastic deformations. It is therefore important to study large deformation plasto-mechanics of these simple elements, the essential requirements being that the devices should be able to dissipate energy irreversibly and possess a more or less rectangular force displacement characteristics.

The present work consists of an experimental study of the quasi-static deformation of single square tubes and

their cross-layered combinations when subjected to lateral compression. The tubes were made of aluminium and mild steel and were tested in as received as well as in annealed conditions. The experiments were generally performed on an Instron machine. The indenters used in the experiments were wedge shaped or flat surfaced. The dimension of the tubes as well as the angle or width of indenters were varied in different experiments. The single tubes were subjected to lateral compression under pairs of identical or non-identical indenters. In cross layered systems both number of tubes in a layer and number of layers were varied. These were sandwiched and compressed between two rigid platens and their deformation behaviour has been studied. The experimental results of the deformation history, the load deformation characteristics and the energy absorbed are presented both for single tubes and their cross layered combinations. Attempt has been made to study the behaviour of single tubes with different combinations of indenters and relate it to the behaviour of cross-layered systems. The analysis presented has been based on plastic hinge formation, with associated assumptions and results thus obtained are compared with the experimental results.

TABLE OF CONTENTS

	CERTIFICATE	(i)
	ACKNOWLEDGEMENTS	(ii)
	ABSTRACT	(iii)
	TABLE OF CONTENTS	(v)
	LIST OF FIGURES	(vii)
	LIST OF TABLES	(xiii)
	NOTATIONS	(xiv)
CHAPTERS		Page No.
1.	INTRODUCTION	1
	1.1 Introduction	1
	1.2 Review of Literature	4
	1.3 The Present Attempt	13
2.	LATERAL COMPRESSION OF A SINGLE TUBE BETWEEN SYMMETRICAL INDENTERS	17
	2.1 Introduction	17
	2.2 Experimental Procedure	2Ø
	2.3 Compression between two platens	23
	2.4 Compression between wedges or short flat platens	33
	2.5 Analysis	45
3.	LATERAL COMPRESSION OF A SINGLE TUBE RESTING ON A FLAT BASE BY AN INDENTER OF SHORT WIDTH.	
	3.1 Introduction	55
	3.2 Experimental Procedure	58

3.3 Lateral compression between a wedge and a platen 59

3.4 Compression of a tube resting on a flat base by a 4 mm wide indenter. 63

3.5 Compression between a platen and a short flat indenter. 65

3.6 Analysis 70

4. COMPRESSION OF CROSSED LAYERS OF TUBES

4.1 Introduction 80

4.2 Experimental Procedure 82

4.3 Lateral compression of 1X1 tube system 84

4.4 On prediction of P-δ curve for lateral compression of 1x1 system. 94

4.5 Lateral compression of two orthogonal crossed layers. 96

4.6 Lateral compression of three layered tube system with one or two tubes in each layer. 102

5. CONCLUSIONS 112

REFERENCES 119

BIO DATA OF THE AUTHOR 123