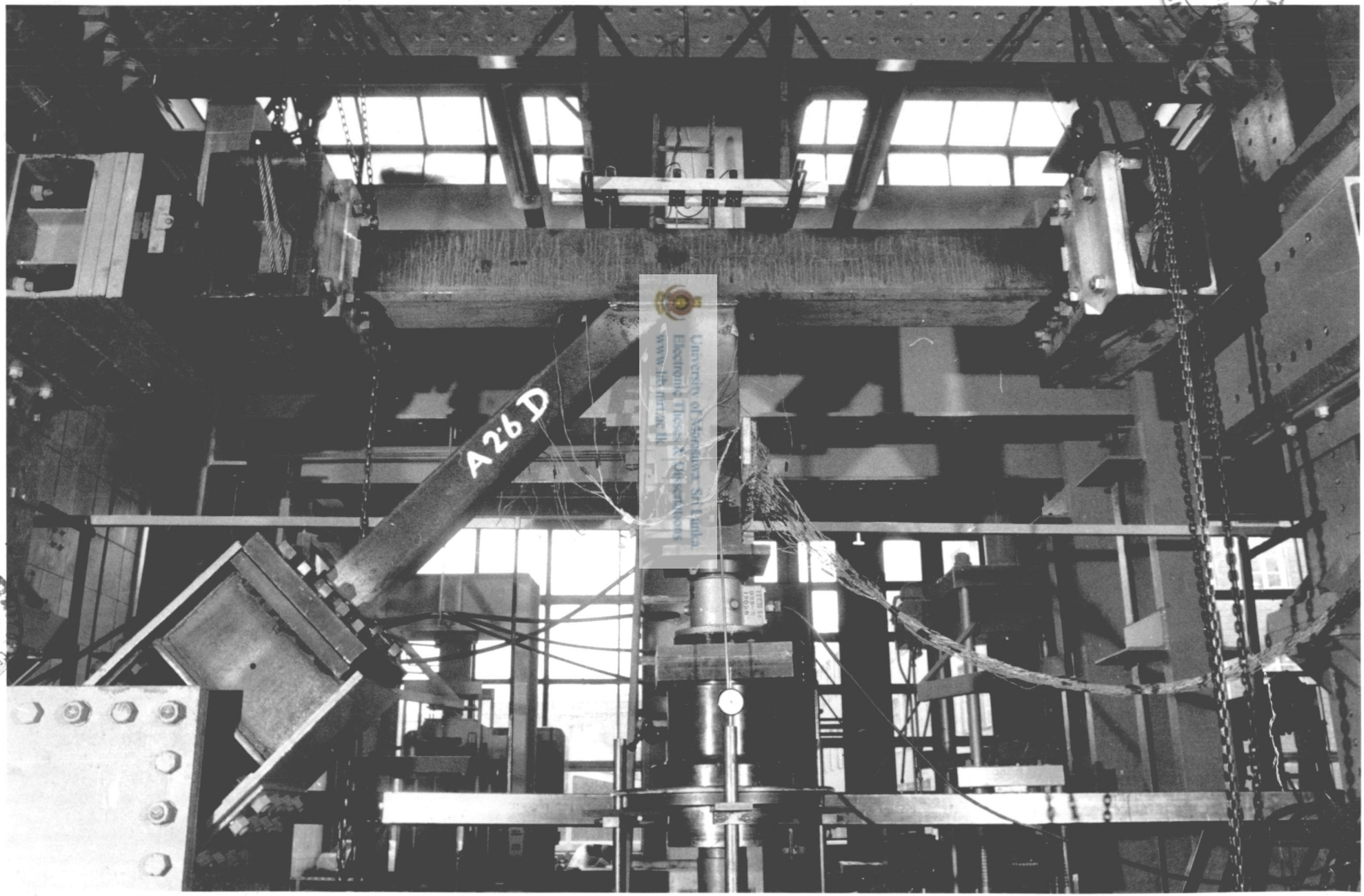

STRUCTURAL BEHAVIOUR RELATED TO STRESS ANALYSIS OF JOINTS IN COLD-FORMED SQUARE HOLLOW SECTIONS

Thesis submitted to the University of Sheffield for the Degree of Doctor of Philosophy in the Department of Civil and Structural Engineering of the Faculty of Engineering

by

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To my mother, RUPAWATHIE, and my sister, SRIYA, whose love and understanding have brought me happiness beyond all expectations.

"It is not until we attempt to bring the theoretical part of our training into contact with the practical that we begin to experience the full effect of what Faraday has called 'mental inertia' - not only the difficulty of recognizing, among the objects before us, the abstract relations which we have learned from the books, but the distracting pain of wrenching the mind away from the symbols to the objects, and from the objects back to the symbols. This, however, is the price we have to pay for new ideas".

James Clerk Maxwell, 1871.

SUMMARY

Tubular sections possess great intrinsic advantages for structural application but exploitation of these has been hampered, initially by the lack of an efficient joining method and subsequently, after the adoption of welding, by lack of knowledge concerning joint performance.

An extensive investigation of hot-formed tubular joints has recently been carried out at Sheffield. The current investigation extends the study to include cold-formed steel sections, fabricated into N-joints.

To investigate the trends in experimental research, a comprehensive survey of previous work was conducted. Drawing on this experience, an experimental investigation was designed, testing 47 specimens over a range of geometrical parameters and using material from four different manufacturers. All tests were fully instrumented and automatically recorded for computer data processing. As well as giving an overall assessment of joint performance, the experimentation was able to identify and analyse the basic modes of load transfer and ultimate failure.

An extensive investigation of the material properties of the cold-formed SHS was conducted, consisting of over 650 tensile tests, 160 hardness tests, 78 Charpy impact tests and 8 residual stress determinations. A particular feature studied was the variation of properties around the section perimeter. Tests showed that the material covered a wide range of stress-strain characteristics. Residual stresses were high. Ductility was low, but adequate, and there was no evidence of notch sensitivity at room temperature.

Previous theoretical research was reviewed, and a fundamental theoretical study was commenced, employing finite element techniques as the most suitable approach to the problem. Effort was concentrated on developing a folded plate / shell analysis program to describe the

elastic behaviour, as a starting point for a future investigation.

In the practical context, current design methods were critically reviewed. Selecting the ultimate load approach as most satisfactory, a regression analysis of all available data was used to formulate the proposed provisional design recommendations.

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I am truly thankful to all those mentioned and it is my earnest hope that what I have produced will go some way towards thanking all of them.

CONTENTS

CHAPTER 4 - Continued

CHAPTER 4 - Contimued

CHAPTER 6 - Continued

CHAPTER 7 - Continued

CHAPTER 9 - Continued

LIST OF FIGURES

Page

NOTATION

d_1 - Width of the chord member

d_2 - Width of the compression branch member (vertical)

d_3 - Width of the tension branch member (diagonal)

t_1 - Thickness of the chord member

t_2 - Thickness of the compression branch member (vertical)

t_3 - Thickness of the tension branch member (diagonal)

F_{y_1} - Yield stress of the chord member

F_{y_2} - Yield stress of the compression branch member (vertical)

F_{y_3} - Yield stress of the tension branch member (diagonal)

g - Width of the gap of separation between the vertical and the diagonal

Prel. - Pre-load of the chord member

P - Ultimate load of the joint

E - Modulus of elasticity

L/R - Slenderness ratio

I - Second moment of area of cross-section about the neutral axis

ν - Poisson's ratio

ABBREVIATIONS

SHS - Structural hollow section

CHS - Circular hollow section

RHS - Rectangular hollow section

RSJ - Rolled steel joists