IMPACT PROPERTIES OF CIRCULAR BEAM UNDER LATERAL LOADING

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Dedicated to my beloved family
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ABSTRACT

Beam elements present simple damage mechanisms when they reach collapse configuration. The deformation characteristics of simply supported circular beams subjected to lateral impact are studied. Such loads tend to lead to large changes in geometry which are accommodated by plastic bending and shearing within regions of the beams. The study is concerned with the quasi-static bending of various diameter beams by cylindrical-nosed impactors for a variety of support spans. The objective of the present work includes the evaluation of the energy absorbing capacity of beam structures under impact loads. The range of energy-deformation curves and modes of deformation are described. Theoretical models are useful when designing energy-absorbing systems. The influence of material strain-rate sensitivity and system inertia in changing the quasi-static characteristic are discussed. The analytical results are discussed and compared with the experimental results.
ABSTRAK

# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>CHAPTER</th>
<th>TITLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>DECLARATION</td>
<td></td>
<td>iii</td>
</tr>
<tr>
<td>DEDICATION</td>
<td></td>
<td>iv</td>
</tr>
<tr>
<td>ACKNOWLEDGEMENTS</td>
<td></td>
<td>v</td>
</tr>
<tr>
<td>ABSTRACT</td>
<td></td>
<td>vi</td>
</tr>
<tr>
<td>ABSTRAK</td>
<td></td>
<td>vii</td>
</tr>
<tr>
<td>TABLE OF CONTENTS</td>
<td></td>
<td>viii</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td></td>
<td>xi</td>
</tr>
<tr>
<td>LIST OF SYMBOLS</td>
<td></td>
<td>xvi</td>
</tr>
<tr>
<td>1 INTRODUCTION</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>1.1 Overview of Impact Analysis</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>1.2 Problem Statement</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>1.3 Objectives</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>1.4 Scope of Study</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>1.5 Methodology</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>2 LITERATURE REVIEW</td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>3 STRAIN RATE BEHAVIOUR</td>
<td></td>
<td>10</td>
</tr>
<tr>
<td>3.1 Strain Rate Effects</td>
<td></td>
<td>11</td>
</tr>
<tr>
<td>3.2 Strength Models</td>
<td></td>
<td>14</td>
</tr>
<tr>
<td>3.3 Failure Modes</td>
<td></td>
<td>14</td>
</tr>
<tr>
<td>4 IMPACT MECHANICS</td>
<td></td>
<td>20</td>
</tr>
</tbody>
</table>
4.1 Analysis of Low Speed Impact 21
4.2 Theories of Low Speed Impact 22

5 COLLISION AGAINST FLEXIBLE STRUCTURES 23
5.1 Transverse Impact on Flexible Structures 23
5.2 Transverse Impact on Elastic Beams 24
  5.2.1 Impact Response – Parametric Study 25
  5.2.2 Effect of Mass and Velocity 26
  5.2.3 Constant Energy 26
  5.2.4 Constant Mass 27
  5.2.5 Constant Velocity 28
5.3 Impact of Perfectly Rigid Impactor 29
5.4 Effect of Local Compliance in Structural Response to Impact 29

6 ENERGY ABSORPTION 33
6.1 Energy Absorption by Structural Deformation 33

7 EXPERIMENTAL PROCEDURES 35
7.1 Tensile Test 35
7.2 Impact Test 37

8 RESULTS AND DISCUSSIONS 47
8.1 Tensile Test 47
8.2 Strain Rate Effects 49
8.3 Impact Test 51
8.4 Transverse Shear 54

9 CONCLUSION 85

10 RECOMMENDATION FOR FUTURE WORKS 87

REFERENCES 88
# List of Tables

<table>
<thead>
<tr>
<th>TABLE NO.</th>
<th>TITLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.1</td>
<td>Composition of the specimen material.</td>
<td>36</td>
</tr>
<tr>
<td>8.1</td>
<td>Elastic modulus, yield stress and ultimate stress at various strain rates</td>
<td>48</td>
</tr>
<tr>
<td>8.2</td>
<td>Calculation for values of $q$ and $D$ in Cowper-Symonds equation.</td>
<td>50</td>
</tr>
<tr>
<td>8.3</td>
<td>Theoretical strain energy absorbed, with and without strain rate effects.</td>
<td>53</td>
</tr>
<tr>
<td>8.4</td>
<td>Impact analysis on circular steel beam – absorbed energy due to flexural and transverse shear deformation</td>
<td>57</td>
</tr>
<tr>
<td>8.5 (a,b,c,d,e,f)</td>
<td>Deformation of beams of diameters 2.6, 4 and 6.5 mm with impactors of mass 0.825 and 1.7 kg when dropped from heights 0.5, 1.0, 1.5 and 2.0 m.</td>
<td>59</td>
</tr>
<tr>
<td>8.6</td>
<td>Effect of diameter and mass of impactor on deformation. Span=100 mm. Height=2 m</td>
<td>60</td>
</tr>
<tr>
<td>8.7</td>
<td>Effect of beam span, impactor mass and height on the flexural and transverse shear deformations of 4 mm-diameter beam.</td>
<td>60</td>
</tr>
<tr>
<td>8.8</td>
<td>Effect of beam span and mass of impactor on energy absorbed by 4 mm diameter beam when impactor dropped from 1.5 m height.</td>
<td>62</td>
</tr>
<tr>
<td>8.9</td>
<td>Effect of diameter on flexural and shear deformation. Mass=0.825 and 1.7 kg. Span=100 mm. Height=2 m.</td>
<td>82</td>
</tr>
</tbody>
</table>
## LIST OF FIGURES

<table>
<thead>
<tr>
<th>FIGURE NO.</th>
<th>TITLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.1 (a,b)</td>
<td>Impact force and displacement histories in linear analysis</td>
<td>25</td>
</tr>
<tr>
<td>5.2 (a,b)</td>
<td>Impact force and displacement histories in nonlinear analysis</td>
<td>26</td>
</tr>
<tr>
<td>5.3 (a,b)</td>
<td>Resultant force and centre displacement histories at constant impact energy, using nonlinear analysis</td>
<td>26</td>
</tr>
<tr>
<td>5.4</td>
<td>Numerical analysis of impact force history, at constant mass.</td>
<td>28</td>
</tr>
<tr>
<td>5.5</td>
<td>Resultant force and centre displacement histories at constant velocity and varying mass.</td>
<td>28</td>
</tr>
<tr>
<td>5.6</td>
<td>Local indentation $\delta(t) = u(t) - w(x_o,t)$ during collision between a sphere and an initially stationary beam. The displacements of contact points on the mass $u(t)$ and beam $w(x_o,t)$ do not include displacement due to local deformation.</td>
<td>30</td>
</tr>
<tr>
<td>5.7</td>
<td>Contact force $F(t)$, beam displacement $w(x_o,t)$ and sphere displacement $u(t)$ for single degree of freedom. Transverse impact of steel sphere, with radius $R' = 0.01$ m, at midspan of simply supported steel beam, $b=h = 0.01$ m, $L = 0.1535$ m which gives mass ratio $\alpha = 0.55$. Incident speed of sphere, $0.01$ ms$^{-1}$, yields solely elastic deformation. (from Timoshenko)</td>
<td>31</td>
</tr>
<tr>
<td>6.1</td>
<td>Typical impact load-deflection curve</td>
<td>34</td>
</tr>
<tr>
<td>7.1</td>
<td>Dimensions of sheet-type tensile test specimens</td>
<td>35</td>
</tr>
</tbody>
</table>
7.2 (a-c)
Tensile test set-up and specimens 36

7.3. Different diameters beams 38

7.4. Diameter 2.6 mm beams with different spans 38

7.5. Diameter 4 mm beams with different spans 38

7.6. Diameter 6.5 mm beams with different spans 38

7.7 (a,b)
Impact test rig 39

7.8 (a,b)
The impact test 39

7.9 (a,b)
The impact test and the deformed beams and impactor 40

7.10. Flexural and transverse shear deformation of 2.6 mm
diameter beam. Mass=1.7 kg. Span=30 mm. Height=1.5 m. 40

7.11. Complete shear fracture of 2.6 mm diameter beam.
Mass=1.7 kg. Span=30 mm. Height=1.0 m. 41

7.12. Flexural and transverse shear deformation of 4 mm
diameter beam. Mass=1.7 kg. Height=2 m.
Span=30, 40 and 50 mm 41

7.13. Close-up view of flexural and transverse shear
deformation of 4 mm diameter beam.
Mass=1.7 kg. Height=2 m. Span=30 mm 42

7.14. Flexural and transverse shear deformation of 2.6 mm
diameter beam. Mass=0.825 kg. Height=2 m.
Span=30, 40 and 50 mm 42

7.15. Flexural and transverse shear deformation of 2.6 mm
diameter beam. Mass=1.7 kg. Height=2 m.
Span=30 and 50 mm 43

7.16. Flexural and transverse shear deformation of 4 mm
diameter beam. Mass=1.7 kg. Span=20 mm.
Heights=0.5, 1.0, 1.5 and 2 m. 43

7.17. Close-up view of flexural and transverse shear deformation
of 4 mm diameter beam. Mass=1.7 kg.
7.18. Flexural and transverse shear deformation of 4 mm diameter beam. Mass=1.7 kg, Span=10 mm. Heights=0.5, 1.0, 1.5 and 2 m. 44
7.19. Flexural and transverse shear deformation of 4 mm diameter beam. Mass=1.7 kg, Span=20 mm, Height=2 m. 45
7.20. Flexural and transverse shear deformation of 4 mm diameter beam. Mass=1.7 kg, Span=10 mm, Height=2 m. 45
7.21 (a-f)
    Close-up views of beams deformed in bending and shear. 46
8.1 Tensile test results, at various strain rates. 47
8.2 Elastic regions of tensile tests. 48
8.3 Determination of slope and intercept of curve, for the calculation of q and D in Cowper-Symonds equation. 51
8.4 Theoretical absorbed energy vs. theoretical impact energy. 54
8.5 Comparison between total energy absorbed and energy absorbed due to flexural calculation only 58
8.6 Effect of span on theoretical energy absorbed. (through calculation of θ only). 63
8.7 Energy absorbed by beam. Diameter=2.6 mm, Mass=0.825 kg Span=150 mm 64
8.8 Energy absorbed by beam. Diameter=2.6 mm, Mass=0.825 kg Span=100 mm 65
8.9 Energy absorbed by beam. Diameter=2.6 mm, Mass=0.825 kg Span=50 mm 65
8.10 Energy absorbed by beam. Diameter=2.6 mm, Mass=0.825 kg Span=40 mm 66
8.11 Energy absorbed by beam. Diameter=2.6 mm, Mass=0.825 kg Span=30 mm 66
8.12 Energy absorbed by beam. Diameter=2.6 mm, Mass=1.7 kg Span=150 mm 67
8.13. Energy absorbed by beam. Diameter=2.6 mm. Mass=1.7 kg Span=100 mm
8.14. Energy absorbed by beam. Diameter=2.6 mm. Mass=1.7 kg Span=50 mm
8.15. Energy absorbed by beam. Diameter=2.6 mm. Mass=1.7 kg Span=40 mm
8.16. Energy absorbed by beam. Diameter=2.6 mm. Mass=1.7 kg Span=30 mm (Shear fracture occurs at height = 1 m)
8.17. Energy absorbed by beam. Diameter=4 mm. Mass=0.825 kg Span=150 mm
8.18. Energy absorbed by beam. Diameter=4 mm. Mass=0.825 kg Span=100 mm
8.19. Energy absorbed by beam. Diameter=4 mm. Mass=0.825 kg Span=50 mm
8.20. Energy absorbed by beam. Diameter=4 mm. Mass=0.825 kg Span=40 mm
8.21. Energy absorbed by beam. Diameter=4 mm. Mass=0.825 kg Span=30 mm
8.22. Energy absorbed by beam. Diameter=4 mm. Mass=1.7 kg Span=150 mm
8.23. Energy absorbed by beam. Diameter=4 mm. Mass=1.7 kg Span=100 mm
8.24. Energy absorbed by beam. Diameter=4 mm. Mass=1.7 kg
8.25. Energy absorbed by beam. Diameter=4 mm. Mass=1.7 kg Span=40 mm
8.26. Energy absorbed by beam. Diameter=4 mm. Mass=1.7 kg Span=30 mm
8.27. Energy absorbed by beam. Diameter=6.5 mm. Mass=0.825 kg Span=150 mm
8.28. Energy absorbed by beam. Diameter=6.5 mm. Mass=0.825 kg Span=100 mm
8.29. Energy absorbed by beam. Diameter=6.5 mm. Mass=0.825 kg Span=50 mm
8.30. Energy absorbed by beam. Diameter=6.5 mm. Mass=0.825 kg
8.31. Energy absorbed by beam. Diameter=6.5 mm. Mass=0.825 kg
    Span=30 mm
77
8.32. Energy absorbed by beam. Diameter=6.5 mm. Mass=1.7 kg
    Span=150 mm
78
8.33. Energy absorbed by beam. Diameter=6.5 mm. Mass=1.7 kg
    Span=100 mm
78
8.34. Energy absorbed by beam. Diameter=6.5 mm. Mass=1.7 kg
    Span=50 mm
79
8.35. Energy absorbed by beam. Diameter=6.5 mm. Mass=1.7 kg
    Span=40 mm
79
8.36. Energy absorbed by beam. Diameter=6.5 mm. Mass=1.7 kg
    Span=30 mm
80
8.37. Effect of diameter on flexural and shearing deformation.
    Mass=0.825 and 1.7 kg. Span=100 mm. Height=2m.  
83
LIST OF SYMBOLS

B  breadth of a beam with a rectangular cross section
H  height of a beam with a rectangular cross section
K  equation constant $1700 \text{ m}^{-2}$
L$_G$  gauge length
M$_o$  bending moment when complete plastic yielding of the material occurs
M$_y$  bending moment when plastic yielding of the material first occurs
m  mass
q  empirical constant used in the Cowper-Symonds equation
D  empirical constant used in the Cowper-Symonds equation
r  radius of circular beam cross-section
V$_o$  initial impact velocity
$\dot{\varepsilon}$  strain rate
$\theta$  bend or displacement angle
$\sigma_o, \sigma_y$  static material yield (flow) stress
$\sigma_{od}$  dynamic material yield (flow) stress
E$_I$  experimental impact energy
E$_T$  theoretical absorbed energy
h  drop height of impactor
CHAPTER 1

INTRODUCTION

1.1 Overview of Impact Analysis

In many engineering applications, a component is usually restricted to remain within the elastic limit of the material. However, at yielding the material is permanently deformed and energy is absorbed, and it is this phenomenon that forms the basis of design in structural crashworthiness analysis. Material stress-strain diagrams are obtained by loading a sample of the material under tension using a very slow-moving crosshead. However, the properties of some materials are dependent on the rate of deformation. This sensitivity can affect the material elastic modulus, yield stress, ultimate and rupture stresses. The relationship between the dynamic and static yield stress is expressed by Cowper-Symonds equation with empirical constants D and q, which are specific to each material. The study has large application in the dynamic response of underground structures, impact of nuclear fuel capsules, missile impact of nuclear power installations and the collision of transportation vehicles.

Consider a simply supported beam that is manufactured from a ductile material. Increasing the applied force at mid span will result in yielding to occur at the point of maximum bending moment, at the point furthest away from the neutral axis. If the load is increased further, then more of the material will yield in the cross-
section until the bending moment reaches the maximum collapse value. The energy is absorbed in this plastic hinge and can be evaluated. Impact test is of leading importance, once the dynamic resistance of the beam is assessed and evaluated. The impact beams are required to have large static strength and high impact energy absorption capability. Conventional metals seldom possess these properties simultaneously because usually metals with high strength have low toughness and vice versa.

The design of a motor vehicle includes structural elements that deform elastically in order to absorb the kinetic energy of a collision. Their function is to reduce the effects of a crash by limiting the impact force and acceleration. Many energy-absorbing elements are manufactured from ductile materials such as structural steel or aluminum. Normally, an engineer will design a structure to remain within the elastic limit of the material where deformations represent storage energy.

1.2 Problem Statement

If the load is applied dynamically then the collapse energy needs to be reevaluated considering the enhanced flow stress for the particular material. For dynamic applications, the impact test in structural parts is an essential procedure for their certification. In studying impact behaviour on structures, the difficulty lies in predicting energy absorbing capacity and impact behaviour of structural elements when various geometrical, dimensional, loading and constraint parameters interact.
1.3 Objectives

Hence, in order to address the difficulty faced in understanding the impact behaviour of structures, the study will attempt to evaluate the energy absorbing capacity of beam structures under impact loads and then predict the dynamic response of a simply supported circular beam when subjected to a mass impact at mid span of beam.

1.4 Scope of Study

The study on impact will involve the mechanics of collapse of beams under lateral impact. The beams are made of solid circular mild bars which are simply supported. Various masses of rigid impactor with cylindrical nose will be dropped from various drop heights.

1.5 Methodology

In this study, the static and dynamic tensile tests of the beam material were performed. At various straining rates the material properties were obtained. Beam with various diameters and span length, and impactors with various mass and drop heights were investigated using experimental method. The beams were impacted by the three-point impact bending test to evaluate their energy-absorbing performance. The three major phases in carrying out the project are introduction to the subject, experimental work and data analysis.
In the first phase, the background to the subject was studied to identify the problem, the objectives and the scope and to plan the experimental procedures so as to attain the objectives. Literature reviews are done on the topic through journals and electronic media to gauge the state of current research in the subject. The second phase of data collection is done through experimental method. The falling dart impact tests are done to obtain the impact energy and the energy absorbed by the beam. With a large amount of data obtained from a large range of beam and impactor parameters, it is possible to predict the energy-absorbing behaviour of similar structures when impacted transversely.