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

Anggota bercirikan rasuk memberikan mekanisme kerosakan mudah apabila mereka menghampiri keadaan runtuh. Ciri-ciri deformasi rasuk silinder bulat yang disokong mudah adalah menjadi kajian apabila struktur-struktur ini dikenakan hentaman melintang. Bebanan sedemikian selalunya akan menyebabkan deformasi kepada geometri rasuk akibat lenturan dan ricihan plastik pada rasuk tersebut. Kajian ini mengutamakan lenturan kuasi-statik rasuk yang mempunyai berbagai nilai diameter yang dihentam dengan penghentam muncung berbentuk silinder. Kesan jarak rentang juga dikaji. Objektif kajian ini melibatkan penilaian keupayaan struktur berbentuk rasuk dalam penyerapan tenaga hentaman. Julat lengkung tenaga-deformasi rasuk serta mod deformasi akan dihuraikan. Model-model dari teori sangat berguna dalam merekabentuk sistem yang berupaya menyerap tenaga. Kesan sensitiviti perkadaran masa terikan and inersia terhadap ciri-ciri kuasi-statik akan dibincangkan. Keputusan analitikal akan dibincang dan dibandingkan dengan keputusan dari eksperimental.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

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 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
$\acute{\varepsilon}$	strain rate
θ	bend or displacement angle
σ_o, σ_y	static material yield (flow) stress
σ_{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.