UNIVERSITI TEKNOLOGI MARA

BENDING COLLAPSE AND ENERGY ABSORPTION OF CONVENTIONAL AND INSERT-REINFORCED CLOSED-HAT-SECTION BEAMS

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of the requirements for the degree of
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AUTHOR'S DECLARATION

I declare that the work in this thesis was carried out in accordance with the regulations of Universiti Teknologi MARA. It is original and is the results of my own work, unless otherwise indicated or acknowledged as referenced work. This thesis has not been submitted to any other academic institution or non-academic institution for any degree or qualification.

I, hereby, acknowledge that I have been supplied with the Academic Rules and Regulations for Post Graduate, Universiti Teknologi MARA, regulating the conduct of my study and research.

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ABSTRACT

Closed-hat-sections are a generic form of structural profiles used in vehicular structures. The bending behavior of a closed-hat-section beam is largely dependent on its section shape, dimension, and material. Despite being used widely in many applications, extensive study on design development and research information are still lacking. Introducing the insert-reinforcement into conventional design of closed-hat-section beam offers possibility of improving the bending resistant as well as energy absorption performance such as SEA, CFE, and DAF for energy absorber application. The primary aim of this thesis was to generate research and design information on the collapse mechanism, impact, and energy absorption characteristics of conventional and insert-reinforced closed-hat-section beams in order to facilitate their application in energy absorbing systems. A series of validation procedures of FE models through experiment and remodel were described. The validated FE models were used in parametric study of quasi-static and impact bending. To further analyze their collapse mechanism and analytical solution, two established analytical models for pure bending and one for three-point bending condition were modified and validated via FE simulation. Both analytical models for pure bending were derived using energy method and the three-point bending was derived using force-moment equilibrium method. Research findings show that the energy absorption response can be controlled by varying some of the geometries and number of insert. The wall thickness, web, and flange width can be used as parameters to control the amount of absorbed energy. However, the greatest effect on absorbed energy is the wall thickness. It was also evident that insert reinforcement can enhance the energy absorption capacity and reduces the inertia effect sensitivity by providing more plastic deformation during bending. Nevertheless, as far as energy absorption performance is concerned, higher number of insert seems to have a lower or similar performance with fewer insert reinforcement or even with conventional beam. Here, the use of ultra light-weight insert such as Magnesium and hybrid composite is desirable. The modified analytical models for pure bending have resulted in complex limit equations and were solved using numerical approach. Moment-rotation relationships acquired from both solutions showed good agreement with simulation. Another analytical solution has successfully predicted the pattern of load-deflection relationship under point bending. Useful empirical models to simplify the lengthy analytical solutions were also developed to predict the moment-rotation curves of conventional and insert-reinforced closed-hat-section beams as described in this thesis.

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CHAPTER ONE
INTRODUCTION

1.1 INTRODUCTION

Global deaths and injuries resulting from road traffic crashes are a major and growing public health problem. Worldwide, the number of people killed in road traffic crashes each year is estimated around 1.2 million, while the number injured is about 50 million which is the combined population of five of the world's large cities [1]. One of the major road safety problems worldwide are the impacts between vehicles leaving the road and solid roadside objects such as trees, poles, and road signs [2]. Thus, a device which can be used to prevent vehicle from making contact with all the fixed objects is essential to be installed at the high risk spot. Road environments also need to be designed so as to eliminate head-on collision at high speeds, where the car itself cannot offer sufficient protection. Cars, roads, and other aspect of the traffic system must be designed in a mutually-linked way [3].

As the result, the general public now is becoming increasingly aware of the cost of vehicle accidents in terms of human suffering as well as the financial burden on society and individual families and is sensitive to the fact that much more could be done to alleviate the problem. In Malaysia, road accidents are considered one of the top three public health problems [4, 5]. Despite the best efforts, nothing much has changed for the containment of the epidemic. According to the 'Investigation and Reconstruction Report 2012', which is an annual statistic record from 2007 to 2010 that was issued by Malaysia Institute of Road Safety Research (MIROS), it was showed that rollover crashes have the highest 'Killed and Severely Injured' (KSI) index by 6.06 and head-on crashes have the highest fatality index of 3.06 compared to other type of crashes.

In the light of these detrimental effects, continuous effort is ongoing to overcome this significant problem. Over the past several decades, there has been a continuous increased in the use of energy absorbers and their research interest [6, 7]. The energy absorption capacity of vehicles and protective structures has become more important due to ever stringent safety requirements. As an example, increasing focus