A study of ultimate load of a beam under bending

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ABSTRACT – Bending of beams is a frequently encountered loading situation in practice. A slender member subject to traverse loads is termed as a beam under bending. At any cross-section, the traverse loads generate shear and bending moment to maintain equilibrium. One of the common principles used to determine the loading capacity of a structure is the first yield criterion which assumes that the maximum load is reached when the stress in the extreme fabric reaches yield stress. However, the design based on this rule is not economical for a beam carrying static load, and a substantial reserve of the strength is disregarded. In order to make use of the material strength fully, the possibilities of loading the beam into the plastic region can be explored. Then, the experiment is carried out to study the ultimate load of a beam under bending. Thus, we can conclude that the solid cross section beam was the strongest and the hollow cross section beam was the weakest.

1. INTRODUCTION

Many structures can be approximated as a straight beam or as a collection of straight beams [1].The bending moment, which causes the maximum stress in the beam to equal the yield stress, is known as the moment for first yield [2]. However, this is not the ultimate moment that the structural beam can sustain. This is because there is still a large elastic core capable of supporting higher loads (moments). When the stress in the entire section has reached the yield stress limit, the structure will fail. The moment, which causes this stress distribution, is the ultimate moment or the moment for full plasticity. Using this ultimate moment (ultimate load) as the design parameter, a more cost-effective and efficient design can be accomplished. The Shape Factor, which is the ratio of ultimate moment to the moment for first yield, provides an indication of the design efficiency [3]. Assume the elastic perfectly plastic material, the limit load of beams with any cross-section can be readily calculated.

One of the common principles used to determine the loading capacity of a structure is the first yield criterion which assumes that the maximum load is reached when the stress in the extreme fabric reaches yield stress [4]. While this criterion is easy to apply and safe to use, the design based on this rule is not economical for a beam carrying static load. According to the elastic flexure formula, the stress in a beam is proportional to the distance from the neutral axis [5]. When a beam is made to carry a moment causing the extreme fabric to yield, the material below this layer will still be elastic and is capable to carry further load [6]. Therefore, if the first yield criterion is applied, a substantial reserve of the strength is disregarded. In order to make use of the material strength fully, the possibilities of loading the beam into the plastic region can be explored.

2. METHODOLOGY

This paper focused on the analysis of stresses in beam bending, and was carried out using various loading beams, namely 2 C-channels (thick and thin), a box beam and 2 rectangular cross-section beams. Theoretical analysis and experiments were carried out to determine the strength and stiffness of the beams, which were simply supported at 2 ends with a central load. A C-beam was chosen and a reinforcement scheme was done to prevent buckling and to increase the strength of the beam. Figure 2.1 shows the flow chart of the bending moment analysis.

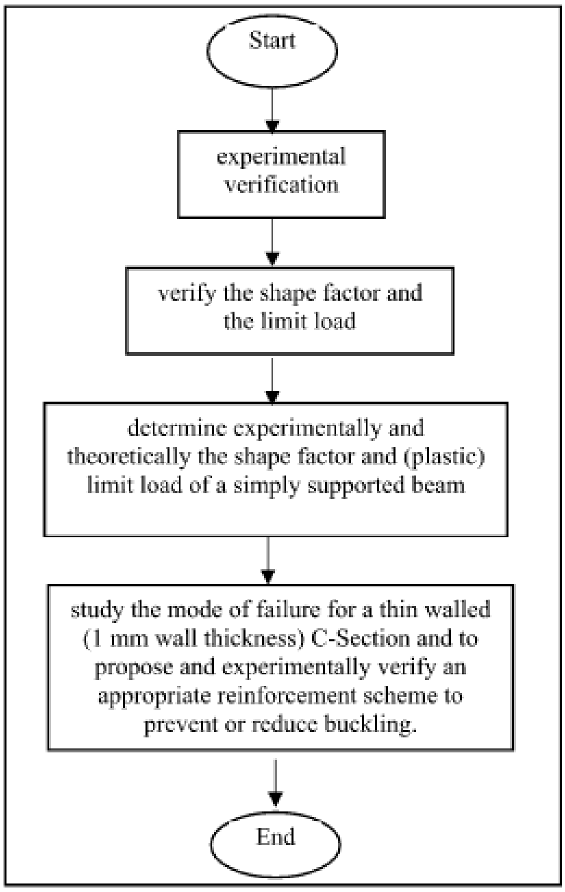

Figure 2.1 Flow chart of the bending moment analysis

3. RESULTS AND DISCUSSION

Table 3.1 shows the values of the theoretical shape factors, as well as the theoretical and experimental ultimate loads experienced by beams of various cross-sections. It was observed that the experimental ultimate load was lower than that of the theoretical load, for each of the cross sections tested. One of the possible reasons for this was that failure in each of these beams occurs by other modes rather than the pure bending process stipulated. In the case of the thin C-channel, buckling and warpage of the channel occurred shortly after the application of the load force. These have resulted in the material failing, and hence the ultimate experimental load attained was lower than the theoretical calculated value. In the case of the beam with the rectangular hollow cross-section, it was observed that a region of bending occurs in the region where the roller support was placed. The deformation in that region has caused the material to fail.

Table 3.1 Result of theoretical and experimental of ultimate loads experienced by beam

X-section	Theoretical Ultimate Load (N)	Experimental Ultimate Load (N)	Experimental Load of First Yield (N)	Theoretical Shape Factor	Experimental Shape Factor
Solid cross-section	6564	4722	3888.9	1.5	1.21
Thin C-channel	1519.25	1379.7	1207.55	1.72	1.14
Thick C-channel	5336.6	4216.9	2452.3	1.79	1.72
Hollow rectangular cross-section	7437.04	2200	1764.7	1.178	1.25

4. CONCLUSIONS

Based on this study, various types of reinforcement schemes have been suggested. One of the suggestions is to use riveting joints. Theoretically, when the distance between rivets is small, the resultant stress concentration ratio is relatively small as the rivet can be taken to be over a large area. However, introducing rivets will result in stress concentration at the riveting points and this may result in material failure. Thus the modification was carried out on the thin wall C channel to reinforce the sides of the C Channel using strips bent into s-shape and adhesive bonding.

Bending of beams is a frequently encountered situation in practice. The experiment conducted was to study the ultimate load of a beam under bending. For this experiment, specimens were made of aluminum, which was a nonferrous metal; its properties differed from ferrous metals, which was iron based. As most high stressed structures were made of ferrous metals, the correlation of the experimental results and observations were needed. Judging from the results, the solid cross section beam was the strongest and the hollow cross section beam was the weakest, which verified the theoretical calculations.

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