Experimental analysis of specimens with micro-structure

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EXPERIMENTAL ANALYSIS OF SPECIMENS WITH MICRO-STRUCTURE

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1. Introduction

The classical Cauchy's continuum theory successfully reproduces numerous experimental results on many different materials such as steel and aluminum. However, in many cases there is a significant difference between experimental and theoretical results. When the microstructure scale becomes significantly large when compared to overall scale, representation based on classical theory fails and this was shown in the past researches including granular or fibrous structure [1] . So called size effect was observed in such materials where this specimens show stiffer behavior than the thick ones, which cannot be modelled using classical continuum theory. These experimental results can be reproduced using alternative continuum theories such as Cosserat's micropolar theory [2] .

In order to understand the behavior of the materials with microstructure better, a set of experiments was conducted including four-point bending of specimens of different sample sizes and patterns of microstructure. Microstructure of the material was formed by introducing an array of circular holes into a homogenous material (aluminum), inspired by the work of Beveridge, Wheel and Nash [3] .

2. Experimental setup

For the set of experiments conducted on metal specimens, an array of regularly spaced holes was drilled in the aluminum beams of four different sizes. Beam dimensions are given in *Fig. 1* and *Table 1*.

Table 1. Beam dimensions of test pieces.

Beam	b [mm]	h [mm]	L [mm]	a [mm]	c [mm]
B1	12.7	12.7	150	5	35
B2	12.7	25.4	280	10	66
B3	12.7	38.1	400	10	66
B4	12.7	50.8	530	10	66

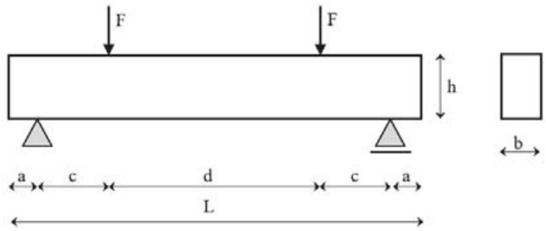

Fig. 1. Test beam in four-point bending.

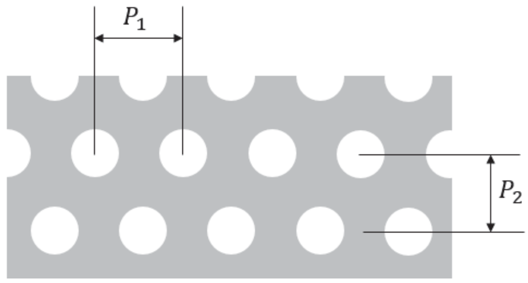

Fig. 2. Specimens' internal structure.

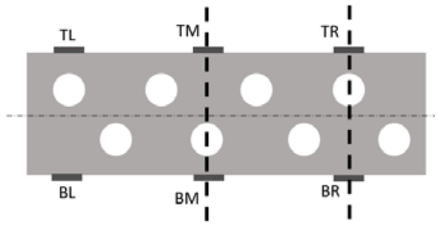

Fig. 3. Position of the strain gauges on B2 sample in pure bending zone.

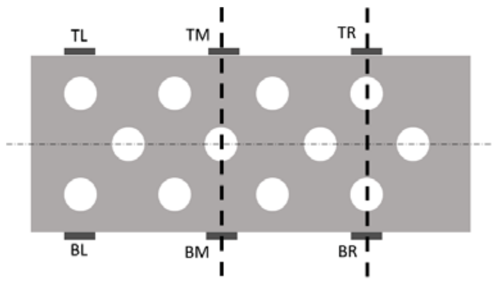

Fig. 4. Position of the strain gauges on B3 sample in pure bending zone.

Specimens' internal structure is defined by values P_1=16 mm and P_2= 12.7 mm, with the radius of voids 3.5 mm as shown in *Fig. 2*.

The pure bending region of each specimen has been monitored for strain evolution in a slow-rate load application in four-point bending. The top and the bottom edge od this region has been carefully cleaned and prepared for the application of two (the smallest specimens) or three quality strain gauges on both edges (total of four or six strain gauges per sample). To account for any strain localization effects in samples with micro-structure, the strain gauges have been positioned such that on each edge of the region at least one strain gauge is closest to a hole or mid-way between the two holes near each edge as shown in Fig. 3 and Fig. 4. In these figures abbreviations stand for *TL=Top left*, *TM=Top middle*, *TR=Top right*, *BL=Bottom left*, *BM=Bottom middle, BR=Bottom right*.

3. Measurements

Specimens prepared in this way were exposed to four-point bending on the Controls hydraulic testing machine. For the smallest samples B1, the testing was performed on a Shimadzu Autograph AGS-X micro-tensile machine.

The total force of *2F* at the load jacks has been applied at the rate od *10N/s* up to a maximum value of *1.5 kN*, *2.8 kN*, *4 kN* and *5 kN* for *B1*, *B2*, *B3* and *B4* specimens respectively.

The strain evolution at the monitored position in time is shown in *Fig. 5* and *Fig. 6* for B2 and B3 specimens.

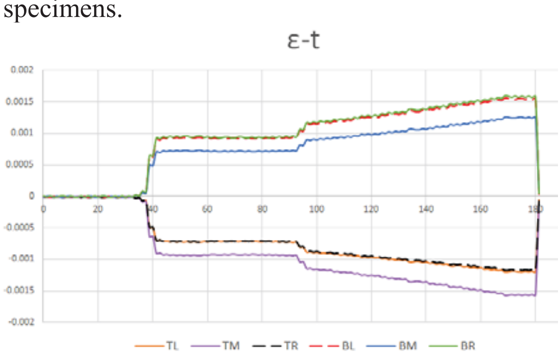

Fig. 5. Strain measurements for B2 sample.

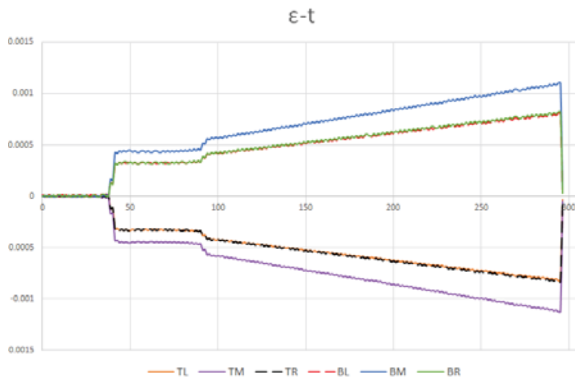

Fig. 6. Strain measurements for B3 sample.

In these figures, several loading phases may be clearly identified: (i) no deformation before the load jack has come in contact with the specimen, (ii) adjustment to the position in which the specimen resistance is clearly identified for some initial loading, (iii) temporary termination of load increase needed to initiate the strain monitoring procedure, (iv) strain increase, (v) load termination before unloading and (vi) load release. All the graphs show that the readings of the strain gauges placed between the two holes are higher than the ones placed right above/below the hole. This is in contrast with the expectation that the deformations will be higher in the position where there is less material.

These results should be confirmed by numerical analysis and a deeper analysis will be conducted.

Acknowledgements

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References

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[3] Beveridge, A. J, Wheel, M. A., Nash, D. H., The micropolar elastic behavior of model macroscopically heterogeneous materials. *International Journal of Solids and Structures, 2013, 50, 246-255.*