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Method Development for Compression Testing of Synthetic Ballistic Gelatine

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Abstract

The aim of this project was to use DIC to investigate the mechanical behaviour of ballistic gelatine in quasi-static compression. Specimen prep was refined to increase the repeatability of results and developed further to allow the use of Digital Image Correlation (DIC). Quasi-static compression tests were carried out with the addition of high-resolution stereo cameras to obtain the out-of-plane motion of the ballistic gelatine.

The displacement data was used to investigate the volume change of the specimen and determine Bulk Modulus (K) and Poisson's ratio (v). These are key parameters that will help provide baseline data for the development of a numerical model for human tissue for protective design against explosions.

Specimen manufacture

Ballistic gelatine specimens were manufactured using a purpose built aluminium mould detailed below. The gelatine was weighed out into the mould and placed in the oven at 125C for 4 hours, to allow for bubbles to dissipate. Once cooled the top part of the mould was removed and the gelatine was cut flat using a hot wire cutter.

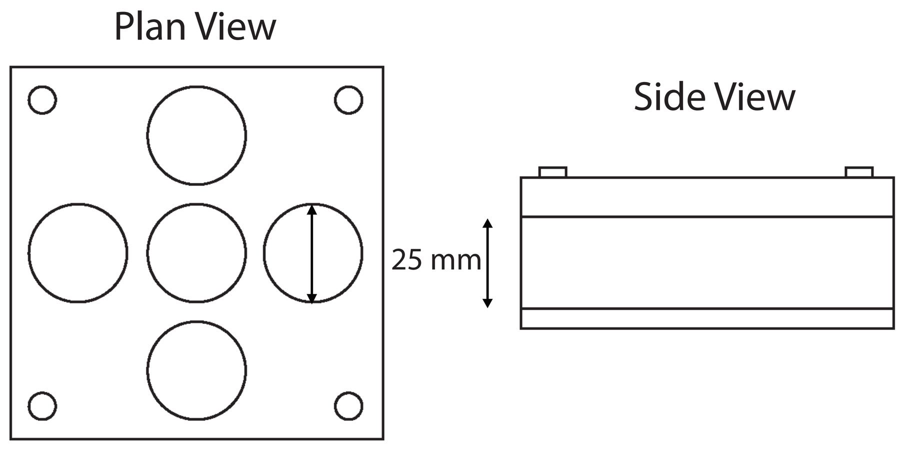

Figure 1 - Aluminium mould for casting gelatine specimens

Cutting the top surface of the gelatine with a hot wire cutter proved difficult and left a range of flat and rough finishes, examples of these can be see below. The effect this had on stress-strain results can be seen in Figure 3 where the rough specimens show large variability and highlights the need for good specimen manufacture.

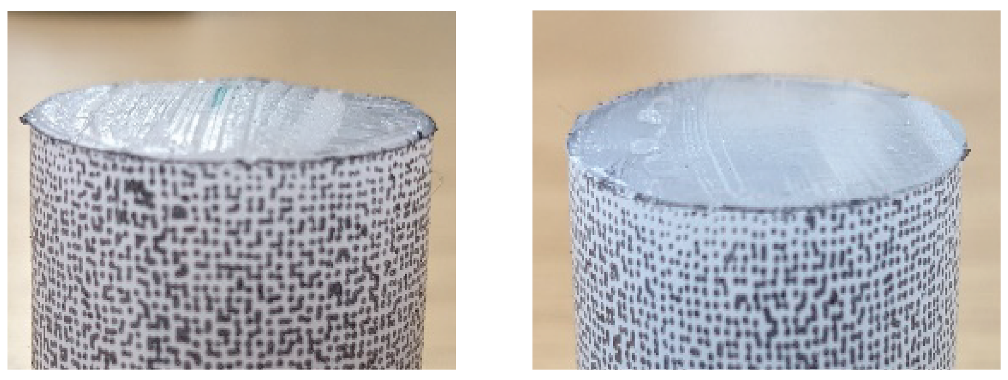

Figure 2 - Example of a rough finish (left) and flat finish (right).

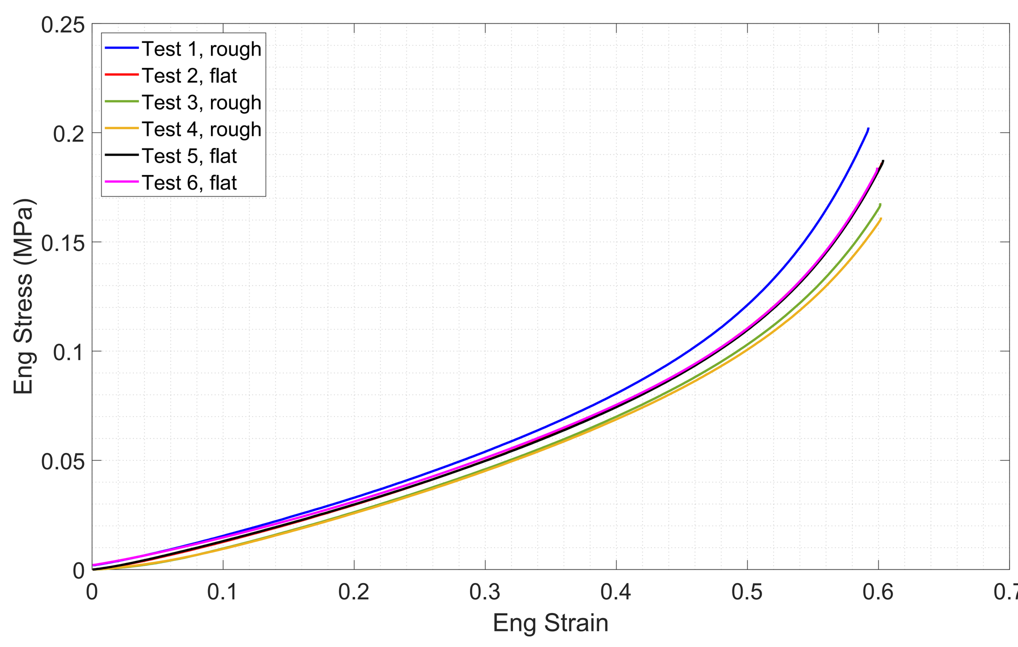

Figure 3 - Engineering stress-strain graph of gelatine detailing the varibility caused by specimen manufacture.

Digital Image Correlation (DIC)

Two high-resolution 5Mpx cameras were used to capture the full view of motion of quasi-static compression tests. A speckle pattern was applied to the gelatine, so the movement of the gelatine could be measured. To achieve a speckle pattern on ballistic gelatine that is a transparent material, firstly an opaque finish was required. Highly flexible body paint, tattoo paper and dye were trialled.

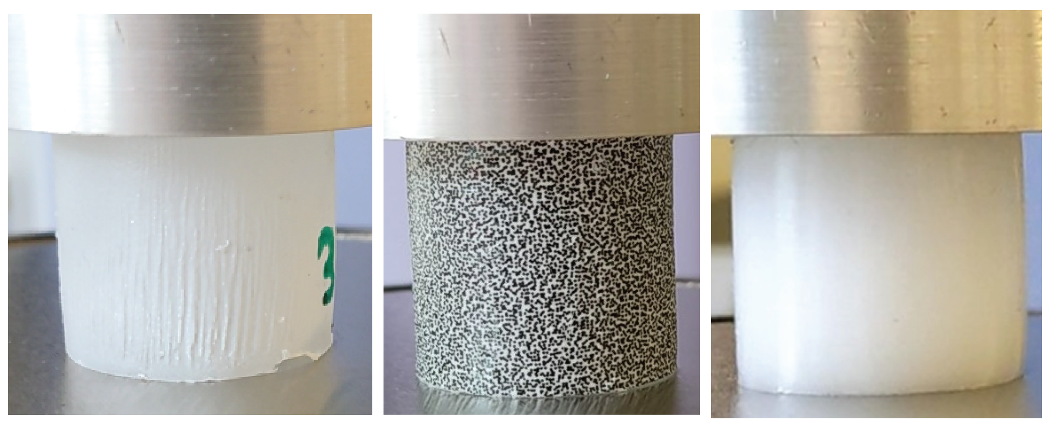

Figure 4 - Painted (left), tattoo paper (middle) and dyed (right) gelatine.

Unfortunately, the paint and tattoo paper restricted the gelatine and resulted in a stiffer response. Also large cracks formed on the applied surface, making DIC impossible. However, the dye showed no significant impact on the deformation of the gelatine, with strong correlation seen between the stress-strain curves. A black speckle pattern was applied by rolling the gelatine on a premade DIC speckle stamp. The final gelatine specimen can be seen in Figure 6.

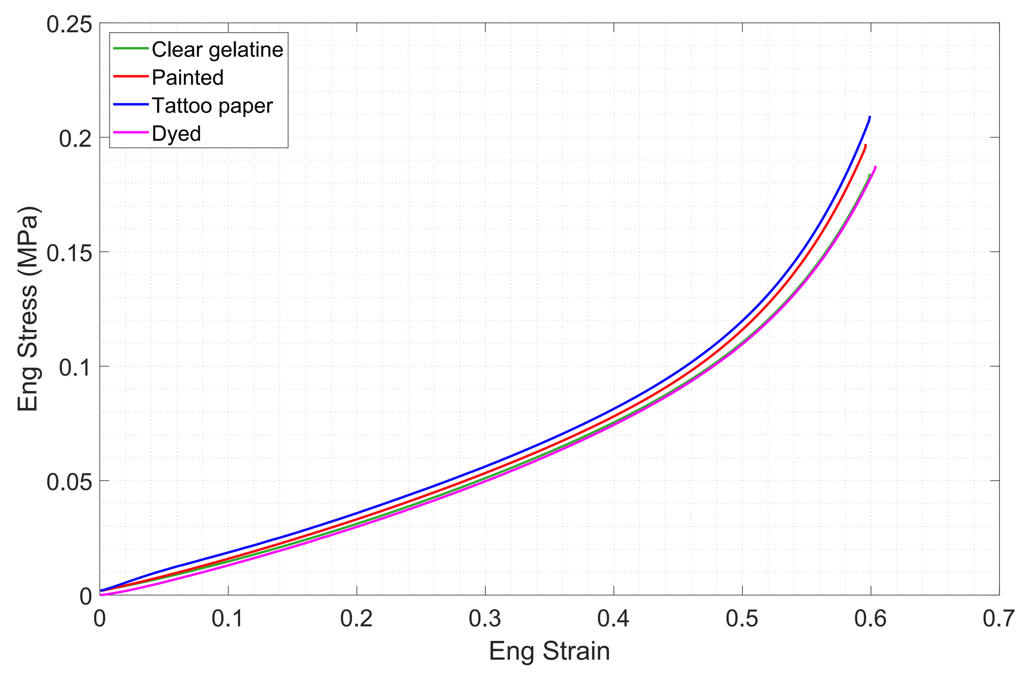

Figure 5 - Engineering stress-strain response of clear, painted, tattoo and dyed gelatine.

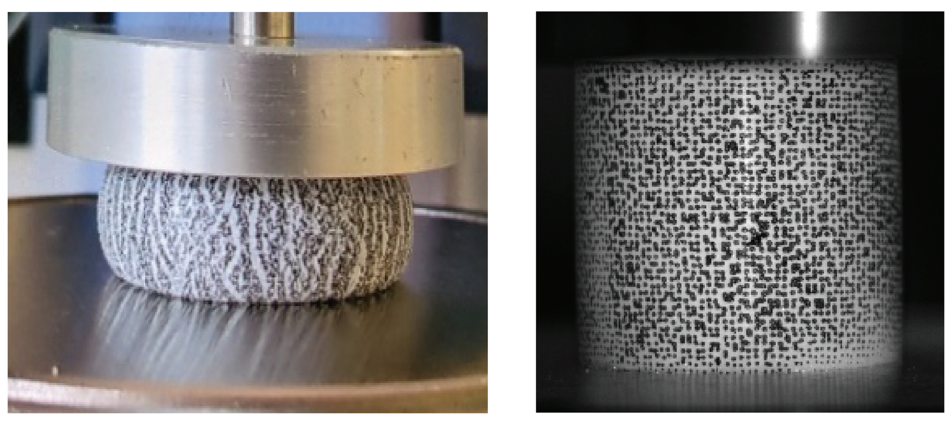

Figure 6 - Cracked tattoo paper (left) and final dyed gelatine with speckle pattern (right).

Results

The two high-resolution, 5Mpx stereo cameras were directed horizontally at the gelatine to record the movement. To help increase the clarity of the images, a polarized blue light was directed at the gelatine specimen. The cameras were also fitted with polarized lenses as this helped reduce the glare from the reflective gelatine surface. The figure below shows a still image taken from the DIC analysis, showing the vertical displacement of the gelatine specimen. The displacement data recorded through DIC was used to investigate the volume change of the specimen over the test.

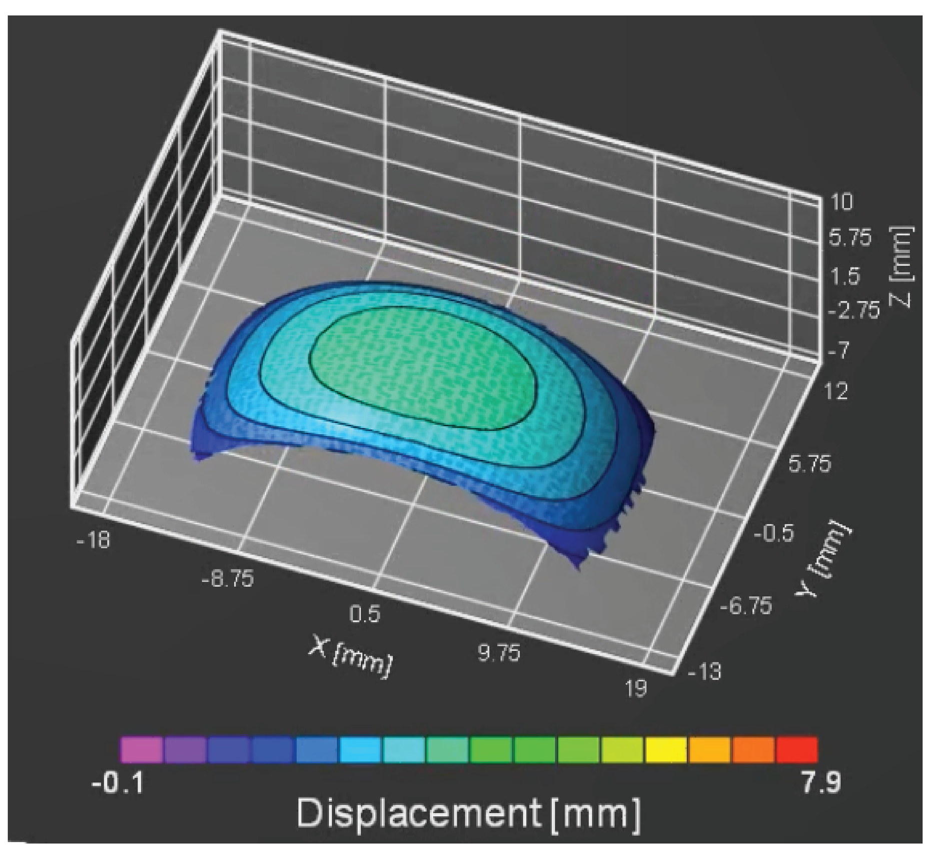

Figure 7 - Still image taken from the DIC displacement data.

This allowed us to calculate key parameters such as Bulk modulus and Poisson's ratio, Figure 8.

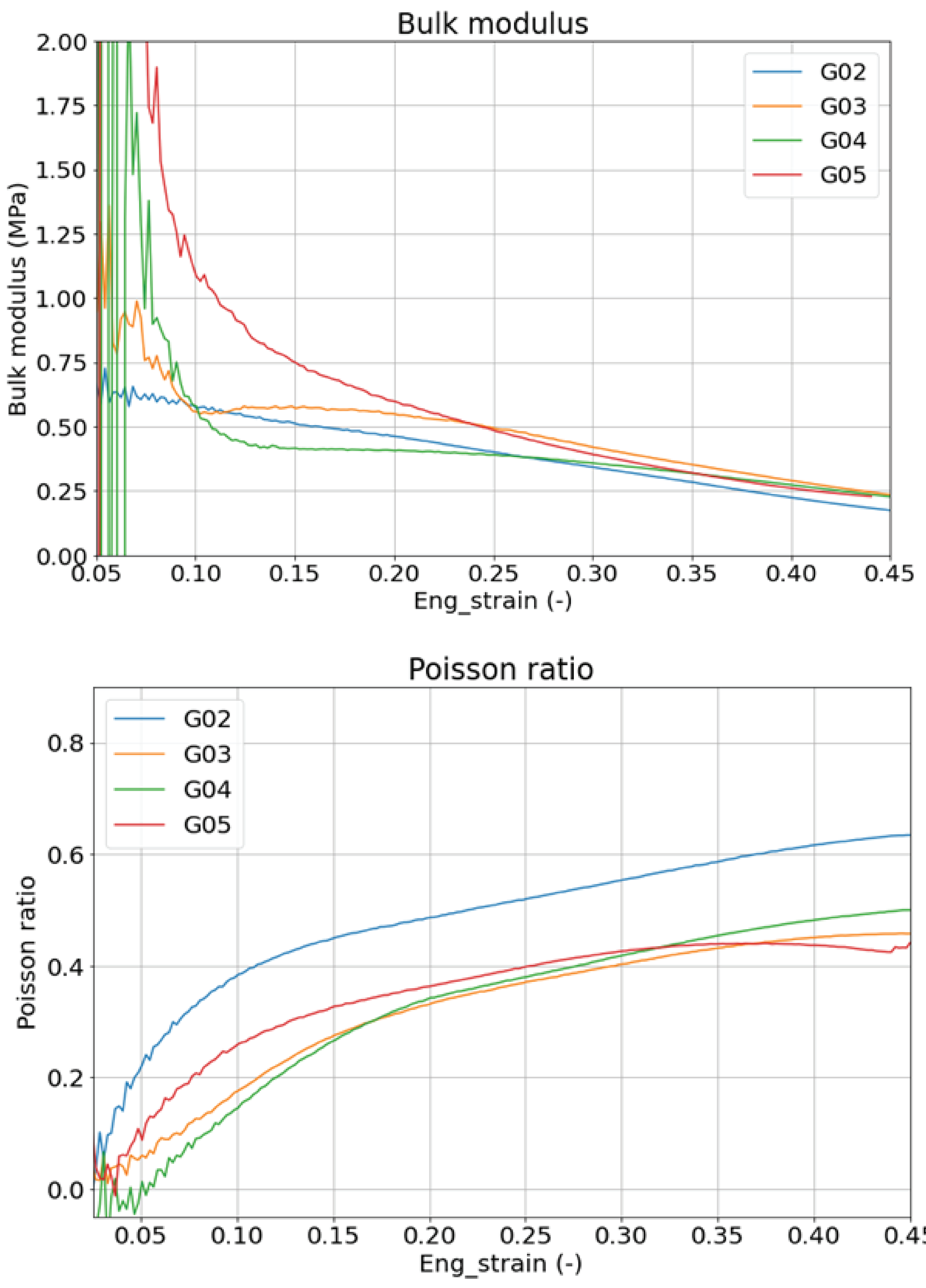

Figure 8 - Bulk modulus & Poisson's ratio for each specimen.

LS Dyna model development

An LS Dyna simulation of the quasi-static compression tests was performed. The gelatine was modelled as a simplified rubber/foam in LS-Dyna (MAT181). This material card was used by Singh and Bari [1] to model lower limb soft tissue under explosion loading and is used in the Total Human Model of Safety [2]. Stress-strain data and the Bulk modulus and Poisson's ratio calculated from the DIC were input into the model. Reasonable agreement was obtained between the stress-strain curves obtained from the simulations and our quasi-static compression test. Friction between the compression plates and the gelatine was not accounted for in the model. The shape of the curve gives confidence in the choice of MAT181 as a model for gelatine.

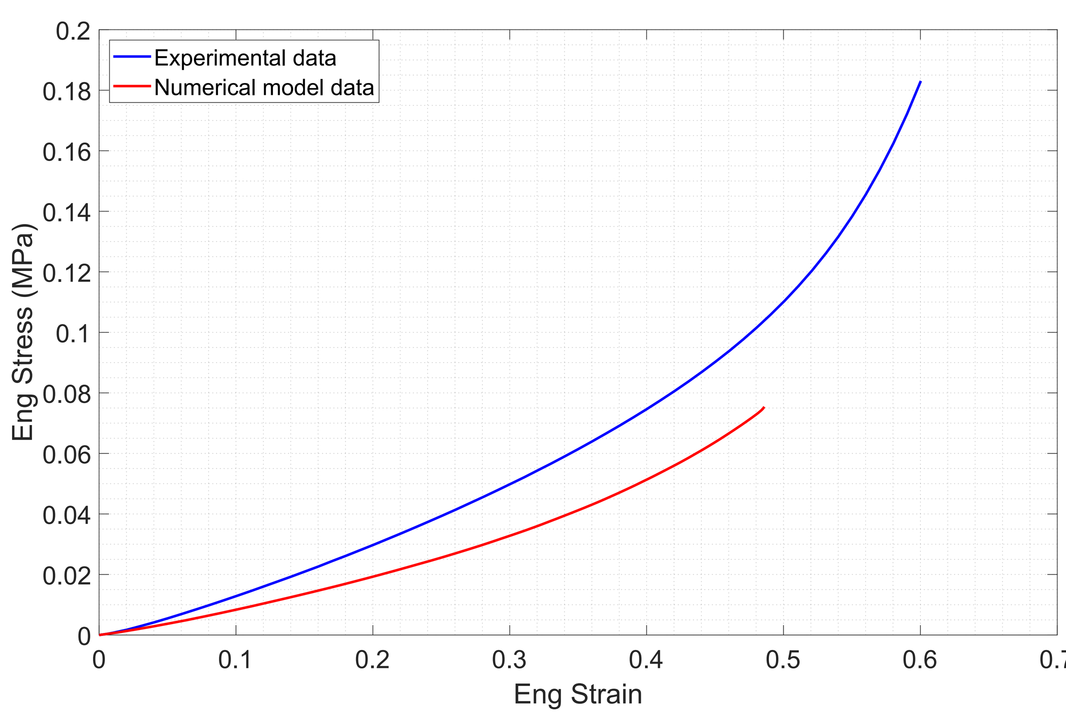

Figure 9 - Experimental vs numercial stress-strain results

References

[1] B. Singh and M.A. Basri, Human Factors & Mech. Engng for Defense & Safety,Vol. 6:14 (2022).
[2] Total Human Model for Safety (THUMS), Toyota. Online, available at: https://www.toyota.co.jp/thums/about/.

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