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77287 - Size Effect on Structural Strength of Lego Beams

LEGOs are one of the most popular toys and are known to be useful as instructional tools in STEM education. In this work we used LEGO structures to demonstrate the energetic size effect on structural strength. Many materials flexural strength decreases with increasing structural size. We seek to demonstrate this effect in LEGO beams.

Fracture experiments were performed using 3-point bend beams built of 2 X 4 LEGO blocks in a periodic staggered arrangement. LEGO wheels were used as rollers on either ends of the specimens which were weight compensated by adding counterweights. [1] Specimens were loaded by hanging weights at their midspan and the maximum sustained load was recorded. Specimens with a built-in defect (crack) of half specimen height were considered. Beam height was varied from two

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to 32 LEGO blocks while keeping the in-plane aspect ratio constant. The specimen thickness was kept constant at one LEGO block. Slow-motion videos and sound recordings of fractures were captured to determine how the fracture originated and propagated through the specimen. Flexural stress was calculated based on nominal specimen dimensions and fracture toughness was calculated following ASTM E-399 standard expressions from Srawley (1976). [2]

The results demonstrate that the LEGO beams indeed exhibit a size effect on strength. For smaller beams the flexural strength is higher than for larger beams. The dependence of strength on size is similar to that of Bažant's size effect law [3] . Initiation of failure occurs consistently at the built-in defect. The staggered arrangement causes persistent crack branching which is more pronounced in larger specimens. The results also show that the apparent fracture toughness increases as the specimen size decreases. Further ongoing investigations consider the effects of the initial crack length on the size effect and the fracture response.

The present work demonstrates that LEGO structures can serve as an instructional tool. We demonstrate principles of non-linear elastic fracture mechanics and highlight the importance of material microstructure (architecture) in fracture response. The experimental method is reproducible in a classroom setting without the need for complex facilities.

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[1] Khalilpour, S., BaniAsad, E., & Dehestani, M. (2019, April 11). A review on concrete fracture energy and effective parameters. Cement and Concrete Research. https://www.sciencedirect.com/science/article /pii/S0008884618310688.

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[3] Bažant, Zdeněk P. "Size effect on structural strength: a review." Archive of applied Mechanics 69, no. 9 (1999): 703-725

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