Advancing Structural Engineering at the Built Environment and Structural System Center of The Hashemite University

by Ahmad Tarawneh and Ahmad Mhanna

Structural engineering stands at the forefront of innovation, shaping the built environment we inhabit. It involves developing innovative structural systems and materials that can withstand various loads while ensuring the safety of buildings, bridges, and other structures. At The Hashemite University in Zarqa, the Hashemite Kingdom of Jordan, the Built Environment and Structural System Center (BESSC) is a beacon of progress in this field in the Middle East. Established with a vision to elevate structural engineering, concrete innovation, and educational processes, BESSC serves as a hub for structural and material testing and expert consultations (Fig. 1).

About the Center

With a built area of 3600 m^2 (38,750 ft^2), BESSC is more than just a research facility—it is a catalyst for change in the structural engineering landscape in Jordan and the Middle East. The primary goal is to enhance structural engineering practices through rigorous experimentation, developing adaptable structural systems, and collaboration with the concrete industry. The center is actively seeking academic and research partnerships with scientific institutions and industrial companies, fostering a culture of collaboration and knowledge exchange. Moreover, BESSC is deeply committed to fulfilling the university's broader objectives in higher education, scientific research, and community service. More than 40 graduate-level students are currently engaged in research at the center.

Testing Equipment

Central to BESSC's success is its state-of-the-art equipment, meticulously curated to support cutting-edge

Fig. 1: The Built Environment and Structural System Center (BESSC)

research and experimentation. The testing area, covering 300 m^2 (2330 ft^2), is equipped with an L-shaped reaction wall 20 m (66 ft) long and 8 m (26 ft) high, served by two 20 ton (18 tonne) overhead cranes (Fig. 2). This robust facility houses an array of tools, including two portable moment frames, MTS® actuators of varying capacities, hydraulic pumps, and customizable supports. These resources empower researchers to conduct different setups of experiments for testing of beams, slabs, columns, and walls under monotonic and cyclic loading.

The material testing area showcases BESSC's commitment to understanding the performance of structures in various environments. The Center boasts freezing-and-thawing chambers, large-scale environmental chambers, MTS Criterion testing machines, convection ovens, and concrete compression testing machines. These facilities enable researchers to simulate diverse weather conditions, which is crucial for understanding structural performance in different environments. Additionally, BESSC's extensive collection of measurement equipment, including linear variable differential transformers, strain gauges, crack width sensors, accelerometers, load cells, data acquisition systems, and others, ensures comprehensive data capture and analysis. Of particular note is the facility's advanced digital image correlation (DIC) system for strain measurement, a cutting-edge tool that enables nondestructive, high-resolution strain monitoring in structural components (Fig. 3). The DIC system:

- Captures minute deformations in materials under load and converts them into quantifiable strain data;
- Requires no mechanical connection to the test object surface, imposes no mechanical limitations (such as fixed gauge lengths) or constraints on test speed, and collects data over its entire field of view; and
- Can be used to monitor the propagation of cracks in structural components, such as slabs, beams, columns, and shear walls.

At BESSC, the DIC system is being leveraged in numerous research projects to advance the understanding of concrete behavior under different loading conditions.

With its MTS bidirectional shake table, BESSC provides invaluable resources for engineers and researchers working to improve the seismic performance of structures, a critical component of achieving seismic resilience.

Finally, BESSC's workshop area provides students with hands-on experience, allowing them to craft wood and steel parts for experimental testing.

Current Activities/Research Projects

With BESSC, research isn't confined to the theoretical realm; it's a hands-on endeavor driven by passionate students and faculty. Currently, graduate and undergraduate structural engineering students are engaged in many research projects spanning various disciplines (Fig. 4).

One such project has focused on introducing hooked-end steel fibers to enhance shear resistance in lightweight concrete beams without stirrups (LC-BWS). Key objectives included evaluating the effectiveness of steel

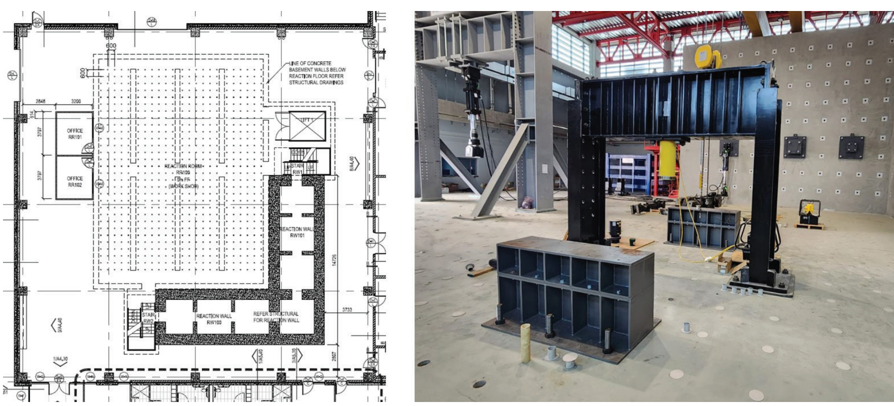

Fig. 2: Testing area in BESSC

Fig. 3: Testing equipment in BESSC

Fig. 4: Research conducted at BESSC

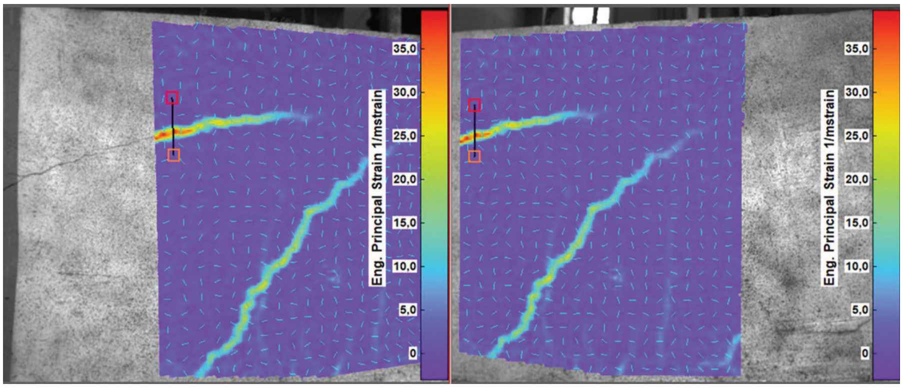

Fig. 5: Crack propagation in a tested specimen

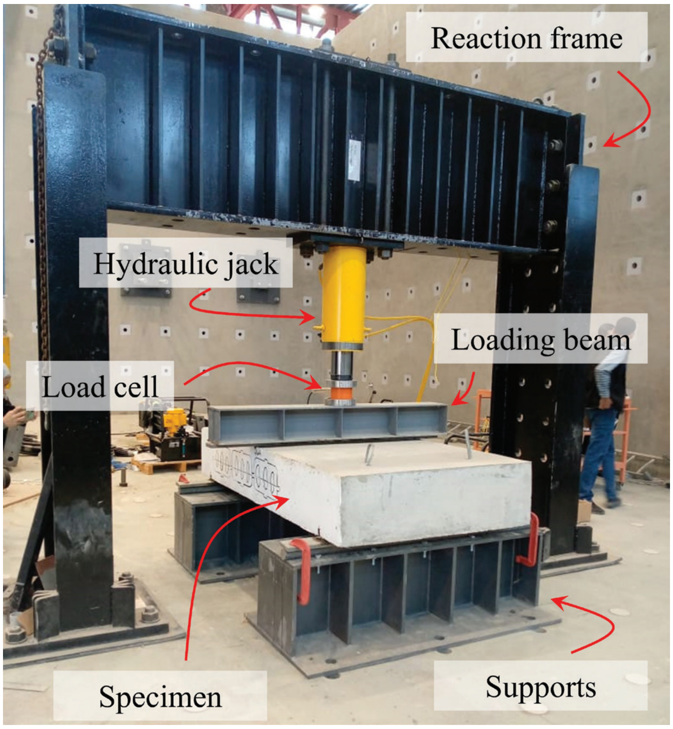

Fig. 6: Testing voided slabs

fibers as the minimum shear reinforcement in LC-BWS and assessing the influence of the beam depth on the shear capacity of such beams. Specimens were fabricated using mixtures with 0.5% fiber content by volume. Specimen depths ranged from 300 to 900 mm (12 to 36 in.), and the longitudinal reinforcement ratio was either 1 or 1.5%. The shear span-to-effective depth ratio was 3.5 for every specimen.

The DIC system was used to evaluate crack propagation (Fig. 5). The test results indicated the normalized shear stress at failure decreased with increasing specimen total depth, suggesting a size effect for LC-BWS specimens. However, adding steel fibers into the concrete matrix significantly augmented shear capacity compared to ACI CODE-318-19 predictions for RC members without steel fibers.

Another cutting-edge research initiative at BESSC is an investigation of the shear behavior of voided slab systems (Fig. 6). Current design standards do not include provisions accounting for the reduced shear capacity of voided flat plates. Using data from tests of one-way voided slabs, a capacity reduction factor λ_{void} has been proposed as a function of the ratio of void height to the slab thickness. The proposed factor has been calibrated to the ACI CODE-318-19 shear model, using a strength reduction factor (ϕ) of 0.75. The factor allows for section optimization by selecting the height of the void former based on the required shear strength.

Ongoing research delves into punching shear in flat slabs with drop panels, addressing critical challenges in modern construction practices (Fig. 4). Moreover, BESSC is at the forefront of material testing, particularly in the realm of composite materials with natural fibers. One project, for example, is focused on evaluating concrete's mechanical properties and durability with chemically treated grape bark fibers (Fig. 7), aiming to unlock new possibilities for sustainable construction practices. The evaluation has included testing the effect of fiber content and length on the density, compressive strength, tensile strength, and flexural strength of concrete specimens. Additional specimens have been tested to evaluate such mixtures for resistance to cyclic freezing and thawing.

Potential International Collaborations

While BESSC's achievements are rooted in local expertise, the center recognizes the value of global collaboration in

Fig. 7: Grape bark

advancing structural engineering. The center therefore actively seeks and supports international partnerships with scientific and academic institutions, envisioning a future of shared knowledge and mutual growth. Through international collaboration, BESSC aims to broaden its horizons, leveraging diverse perspectives and resources to tackle large projects. BESSC welcomes opportunities for cross-border collaboration.

Conclusions

The Built Environment and Structural System Center at The Hashemite University is a symbol of the power of innovation, collaboration, and the pursuit of knowledge in advancing the field of structural engineering. With cutting-edge equipment, groundbreaking research projects, and a commitment to international collaboration, BESSC is poised to shape the future of the built environment in Jordan, the Middle East, and around the world.

As we continue our journey of discovery and innovation, we invite fellow researchers, institutions, and industry partners to join us in this pursuit. Together, we can push the boundaries of structural engineering, building a safer, more resilient world for generations to come.

Selected for reader interest by the editors.

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