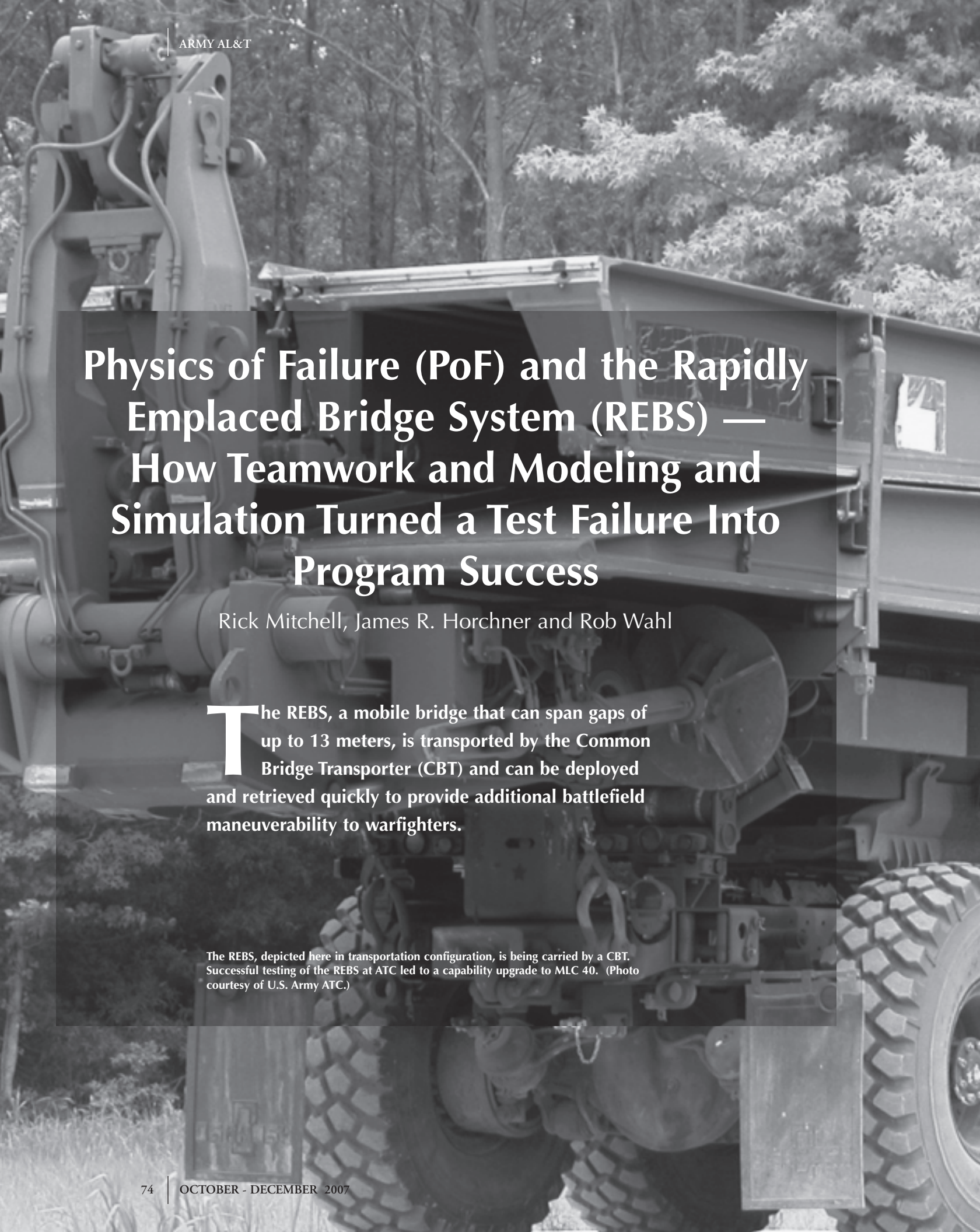

Physics of Failure (PoF) and the Rapidly Emplaced Bridge System (REBS) — How Teamwork and Modeling and Simulation Turned a Test Failure Into Program Success

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The REBS, a mobile bridge that can span gaps of up to 13 meters, is transported by the Common Bridge Transporter (CBT) and can be deployed and retrieved quickly to provide additional battlefield maneuverability to warfighters.

The REBS, depicted here in transportation configuration, is being carried by a CBT. Successful testing of the REBS at ATC led to a capability upgrade to MLC 40. (Photo courtesy of U.S. Army ATC.)

Initial REBS requirements envisioned a basic load-carrying capacity of Military Load Class (MLC) 30 (approximately 30 tons for a tracked vehicle). An acquisition based on the MLC 30 requirement was undertaken, and production qualification testing at Aberdeen Test Center (ATC), MD, was initiated. Historically, the cost and time associated with conducting large-scale bridge crossing tests precluded full testing of the requirement to levels of statistical confidence. To solve this problem, ATC developed the Bridge Crossing Simulator (BCS) device, which physically simulates the loads imposed by a crossing vehicle on a bridge under test, allowing durability testing to be conducted quickly and economically.

While the REBS was under test on the BCS, a problem developed. Specifically, the bridge center coupler connection failed before the bridge had reached its required durability life. Army Materiel Systems Analysis Activity (AMSAA) engineers used a physics-based computer modeling analysis technique — PoF — to identify the root causes of the REBS failure and to recommend a design improvement.

The recommendation suggested adding structural angle sections to connect the center couplings of the bridge to the vertical webs, which

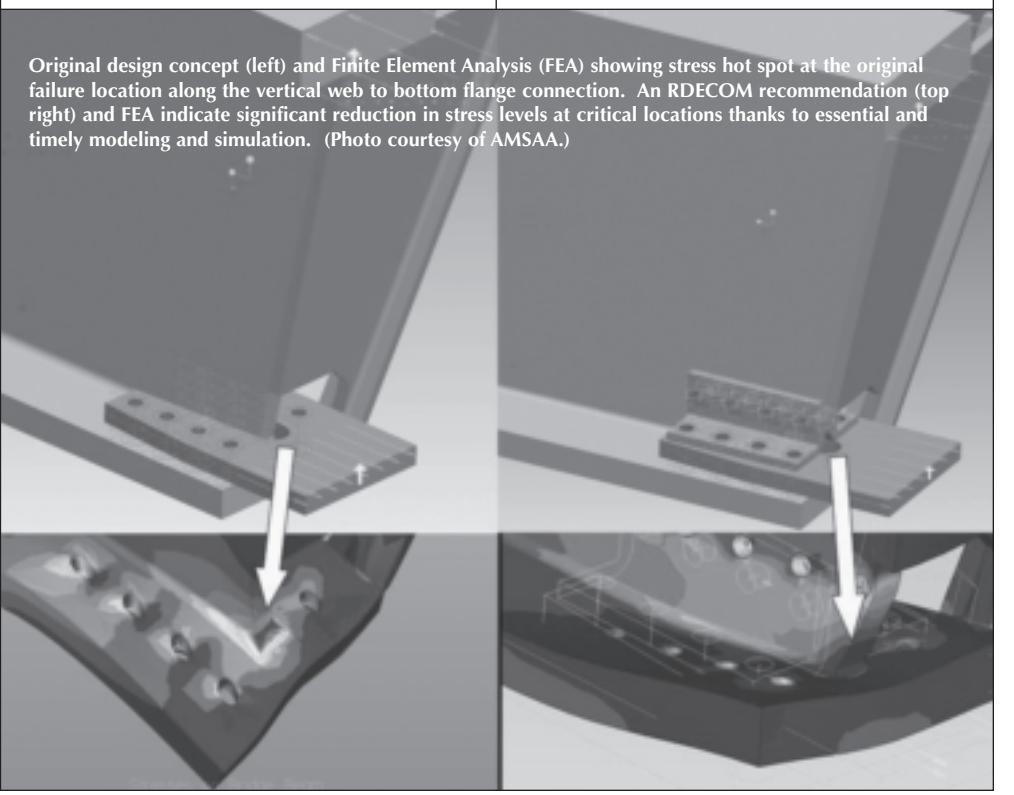
The REBS undergoes testing on the BCS device developed by ATC. (Photo courtesy of U.S. Army ATC.)

would create a much stronger double-shear connection. The new design proposal eliminated the hot spot in the weld between the bridge bottom flange and vertical web where the previous failure had originated.

U.S. Army Tank Automotive Research, Development and Engineering Center (TARDEC) engineers, along with the Product Manager (PM) Assured Mobility Systems, reviewed the results of an MLC 40 upgrade feasibility study performed by the REBS prime contractor to address increased requirements. They determined that the suggested design improvement might not only fix the immediate problem, but also provide the additional margin needed to upgrade the bridge's load capacity. The PM Bridging, located in the Program Management Office Force Projection, capitalized on the confluence of events and moved forward to upgrade the bridge. TARDEC and the REBS contractor worked to implement the AMSAA recommendation and to add other enhancements to ensure that REBS would meet the new, tougher requirements. A new plan was developed to test the bridge durability at the MLC 40 level.

There was high confidence as the test began. The PoF fatigue analysis predicted that the redesigned center coupler region — the previous failure location — would survive 100,000 MLC 40 crossings. The new test demanded that the bridge survive 19,000 MLC 40 crossings to prove its requirement to a high degree of statistical confidence. The question on everyone's mind was, "Would some 'new' weak link emerge as the test progressed?" The answer turned out to be both, "Yes" and "No."

After 16,584 simulated crossings, a crack was discovered at a new location on the bridge. The question was, "What to do now?" The crack initiated in a replaceable component, and so the failure of such a component by definition was not a durability failure.



Original design concept (left) and Finite Element Analysis (FEA) showing stress hot spot at the original failure location along the vertical web to bottom flange connection. An RDECOM recommendation (top right) and FEA indicate significant reduction in stress levels at critical locations thanks to essential and timely modeling and simulation. (Photo courtesy of AMSAA.)

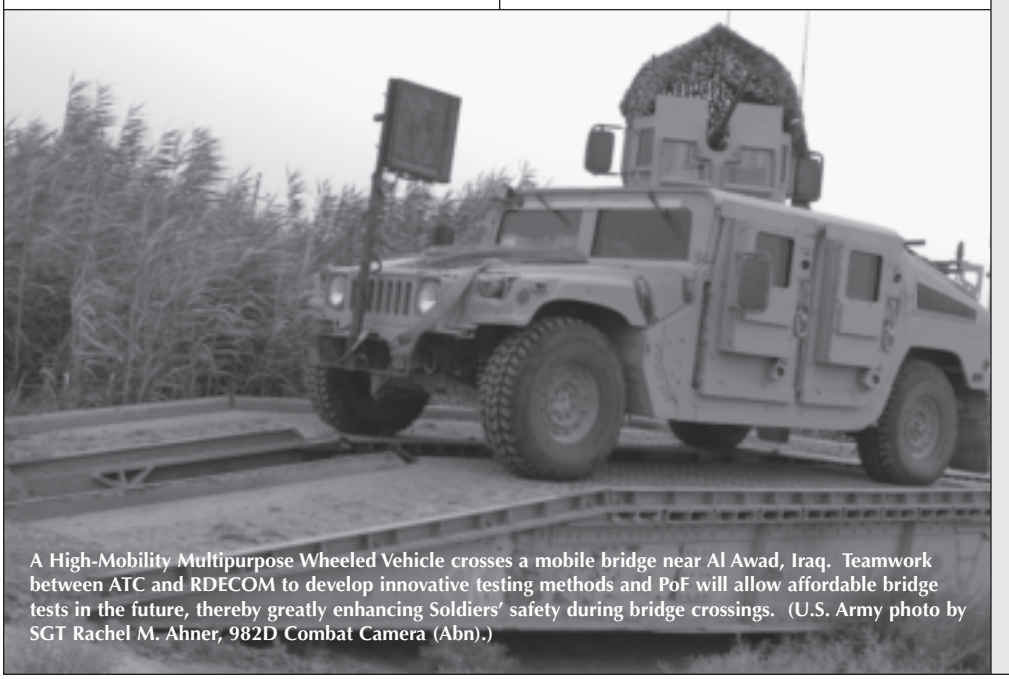
A U.S. Army Soldier drives a Bradley Fighting Vehicle over a mobile bridge near Al Awad, Iraq. A recently tested REBS mobile bridge, by ATC, that's capable of being deployed and retrieved quickly, will provide additional battlefield maneuverability to warfighters. (U.S. Army photo by SGT Rachel M. Ahner, 982D Combat Camera Airborne (Abn).)

If the part was replaced, the test could continue. REBS would have almost certainly continued on to pass its durability test. But, what if the crack developed during a mission? How fast would it grow? Could the REBS still carry its crossing load? Would Soldiers be able to complete their mission before failure? It was important to know this information for the future safety of our warfighters.

After considering the options, a decision to continue the test without repair was made. Amazingly, the REBS continued to carry its full load — 100, 200, 300 … crossings. The crack in the bridge grew, easily reaching sizes that would be spotted in routine preventive maintenance checks and service (PMCS) — 500, 600, 700. ... The test went on at maximum MLC 40 load. Finally, after an additional 748 crossings, a grand total of 17,322 crossings, the test was stopped. The REBS was durable, and when it failed, it did so with warning. The operators would have ample opportunity to discover the damage during the preventative maintenance checks and services and before a new mission. The REBS had proven "damage tolerance," a hallmark of a creditable bridge design.

The REBS is the most tested bridge in recent U.S. Army history. Prior to BCS introduction by ATC, large-scale durability testing was cost prohibitive and, as a result, past production decisions were made with incomplete information and at increased risk. Now, the U.S. Army can affordably test bridges to high levels of statistical confidence and verify the damage tolerance, thereby greatly enhancing Soldier safety.

The REBS program is a good example of Army organizations working together for success. ATC's innovative testing methods, the U.S. Army Research, Development and Engineering Command's (RDECOM's) PoF analysis and the PM's determination to provide warfighters with the best possible tools made this program a success.



A High-Mobility Multipurpose Wheeled Vehicle crosses a mobile bridge near Al Awad, Iraq. Teamwork between ATC and RDECOM to develop innovative testing methods and PoF will allow affordable bridge tests in the future, thereby greatly enhancing Soldiers' safety during bridge crossings. (U.S. Army photo by SGT Rachel M. Ahner, 982D Combat Camera (Abn).)

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