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Press Information

Special use for hydraulic cylinders: The bridge crushers

Nussbaumen (Switzerland), September 2017 – Researchers at the Technical University (TU) of Munich have developed a new test stand for concrete bridge beams. In order to better calculate the load-carrying capacity of these beams in the future, six hydraulic cylinders from Liebherr Components are used to press down with full force on the element until it breaks. The collected data helps in developing new, leaner constructions from ultra-high-performance concrete. Yet, above all, it could also help rescue thousands of existing bridges.

Researchers from the Department of Solid Construction of the Technical University of Munich have made it possible to gain new insights into the calculation of bridges. In order to provide a detailed calculation basis for the statics of preloaded bridge beams, the extremely heavy constructions must first be tested under load until they fail. This is no easy task for beams measuring 20 m and more in length. "The mere handling of such concrete beams is complex, not to mention the costs. For this reason, in the past, testing was mostly carried out on reduced-scale models with a cross-section height of 20 - 30 cm. Very little testing is done on realistic section heights," explains Nicholas Schramm, research assistant at TU Munich, who for the last year and a half has been responsible for the construction of a new test facility. In Munich, they are pursuing a new approach based on what is called the "substructure principle". Instead of using a complete concrete bridge beam, only the subsections in which the construction is prone to failure are examined, whilst maintaining the cross-section height. As a result, the dimensions of the test specimens can be reduced by approximately three-quarters. In the case of a bridge beam with a length of 20 m, this means a section measuring 5 m in length. This method makes manufacturing, transport, handling and disposal easier and, of course, greatly reduces the costs. The goal is to carry out as many tests as possible at a reasonable cost.

Keep pressing until it cracks

For the experimental investigation, the team led by Prof. Oliver Fischer designed and built a special test bench which provides the necessary forces. Configured to handle a maximum cross-section height for the individual sections of 1.8 m and a width of 1.3 m,

it enables a load force of 3.3 MNm to be exerted for the maximum bending moment and 3.2 MN for the maximum shear force. At the core of the system are six dual-action hydraulic cylinders, which provide the constantly increasing massive pressure. "Each of these cylinders provides a maximum compressive force of up to 1.6 MN and a maximum traction force of 1.1 MN, making it particularly efficient for its size," says Sven Weckwerth, sales manager for hydraulic cylinders at Liebherr-Components Kirchdorf GmbH. The company annually develops and manufactures around 50,000 hydraulic cylinders, shock absorbers and hydraulic systems. "For test benches, it is always about meeting individual demands, which requires specific application know-how. Other important factors in the cylinder design are the available installation space, the desired stroke and the requisite power. From TU Munich we received especially well-defined specifications, and on this basis we were able to adapt an existing cylinder," says Mr Weckwerth.

The basic prerequisite for success is the smooth coordination of special projects. "Through intensive exchange, the special features of the design and mechanical interfaces were clarified in conjunction with Liebherr, and it all worked out perfectly despite the time pressures", says Nicholas Schramm. To which Sven Weckwerth adds: "It was a great collaborative effort from the start, with us also being able to contribute our know-how in order to come up with the best possible tailor-made solution." Subsequently, there was also contact with Liebherr-Mischtechnik, since for the first concreting with ultra-high-performance concrete in a precast factory, a pan mixer with very high mixing energy was needed.

Realistic basics to rescue existing bridges

Three research projects investigating the shear load resistance of prestressed bridge beams are currently taking place at the Department of Solid Construction of the Technical University of Munich. On the one hand, the researchers want to obtain greater insight into the design of novel beams made out of ultra-high-performance fibre-reinforced concrete. On the other hand, there is an acute need to refine the measurement approaches for calculation of existing bridges. Nicholas Schramm describes the problem: "For many older bridges from the '60s and '70s, we need to adapt the underlying calculation methods and models. Designed for the traffic and loads of the day, today they no longer correspond to the increased requirements. We also know, however, that the static calculations in the '60s were made using simplified calculation approaches,

meaning that often there is a lot in reserve, so that the bridges are capable of withstanding far more." In many cases, a considerably higher reliable load level can be confirmed through detailed and well-founded retrospective calculation, thereby avoiding expensive demolition and rebuilding, or the costly restoration of the structure. For this, however, additional realistic data from component testing is necessary. The savings potential is enormous: the federal highways alone in Germany comprise around 39,000 bridges, representing investment assets of around €45 billion. A large proportion of them are more than 50 years old.

Impressive lab tests

Therefore, at TU Munich, sections with obsolete structural development will be replicated and then tested in the new test stand. In the current tests the shear force amounts to around 700 kN, corresponding to around 70 tons, and thereby to a realistic load of, say, a super lorry. The sections are 3.5 m long, with a cross-section height of 80 cm, equating to a total beam length of 12 m. For this, four horizontal and two vertical hydraulic cylinders act with constantly increasing force on the test piece until the structure of the concrete beam ruptures. The combination of all six servo-hydraulically controllable cylinders offers a hitherto unique flexibility. The variable control of the dual-action cylinders allows the concrete element to be tested both for bending and shear force, along two axes if required, and for torsion. With the aid of the hydraulic equipment, cyclic load application and relaxation is also possible, and should expand the examination potential in the field of extended time and fatigue testing in the future. "Our hydraulic cylinders are ideally suited to this, since they can provide constant and precisely-adjustable force through to rupture," Sven Weckwerth declares. These measurements take place during operation, with Liebherr supplying the appropriate position transducer systems. Along with the commonly used strain gauges, lots of high-tech measurement technology is also deployed. One such example is the fibre-optic sensors that are otherwise predominantly used in the automobile industry. These enable the continual measurement of strain, and therefore provide data on load and deformation behaviour.

Since May 2017, prestressed concrete bridge beams have been examined weekly on the test stand at TU Munich. The acquired data enable better comprehension of the realistic load-bearing behaviour of the beams for the future improvement and expansion of the calculation modules. There is certainly a lot of testing to be done: for the coming

year, sections with cross-section heights of 1.2 m are already being lined up. These beams would then have a regular length of around 20 m, which would mean considerable extra expense using traditional testing procedures. Tests are also being carried out on ultra-high-performance, fibre-reinforced concrete. This is three to five times stronger than traditional concrete, which means that, in the future, based on the data required, considerably leaner constructions may be produced.

Captions

servo-hydraulically-controlled-cylinders.jpg
Servo-hydraulically controlled cylinders by Liebherr.

test-stand-for-concrete-bridge-beams.jpg
A new test stand for concrete bridge beams.

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