ram reports in applied measurement

BELFA load application vehicle – measurement and loading techniques for the structural evaluation of bridges and sewers

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Fig. 1: Load testing with the aid of loading frames at Dassow, Germany (1993)

Introduction

To demolish and rebuild road bridges that have been found by calculation to be unable to support heavy loads consumes resources and disrupts traffic. With the aim of economizing on materials, and in order to rationally perform loading experiments using the experimental load-bearing method known as EXTRA on bridge structures and sewers, a group of researchers at the Universities of Bremen (team leaders), TU Dresden, HTWK Leipzig and the Bauhaus University of Weimar worked with the Eggers group and other companies to develop a special vehicle that could be used in flexible ways to apply loads to structures. Known as BELFA, its name is an acronym from the German word for this type of vehicle ("Belastungsfahrzeug").

Background

The national and local road networks in Germany include more than 80,000 bridges of various kinds and some 300,000 km of sewers of widely differing ages, some of which are in doubtful condition. By way of comparison, there are around 760,000 bridges throughout Europe. About 90 % of the bridges are solid structures, and around 70 % of these have single spans of less than 18 meters [1]. A broad estimate of the total cost of currently outstanding repairs and maintenance to bridges and sewers runs into double-figure billions of euros.

The investment required to replace these structures with new ones can only be brought down to a sustainable level by successfully extending their useful life to a significant degree despite further increases in traffic volumes. This can only be achieved with objective, experimental proof of adequate load-bearing capacity, especially in the case of load-bearing structures that are already damaged or have been singled out for some other reason, followed up as necessary with long-term observation and monitoring.

The main ground rules for the experimental analysis of present load-bearing performance were acquired in recent years by cooperation between the organizations mentioned above in developing and testing the EXTRA method on more than 300 bridges, major constructions and sewers [2 ... 5]. The method con-

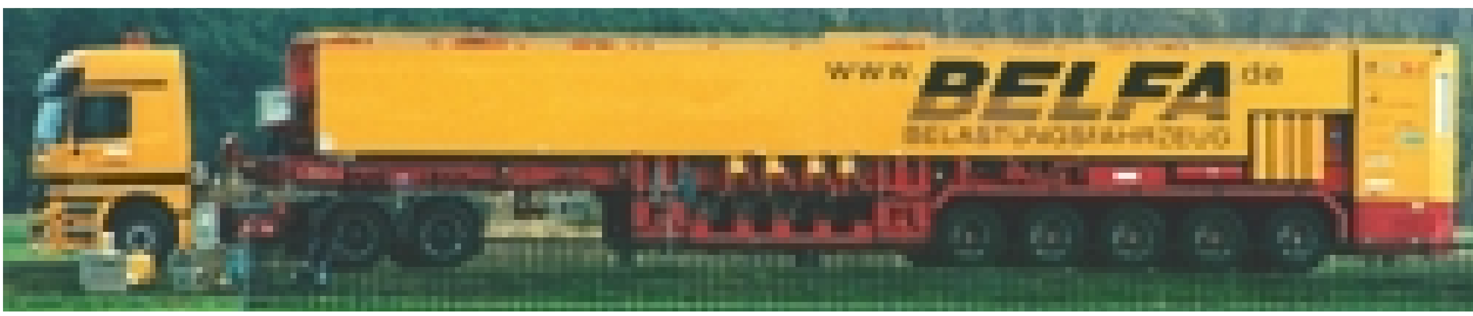

Fig. 2: BELFA on the road

cerned has since been given legal status in the form of a guideline [6].

The experience gained from many of the objects investigated made it clear that the time required for preparatory work and related phases of the experiments, such as setting up and dismantling the load application engineering, represented some 70 % of the total time needed for a typical object and was an obstacle to wider application of the method.

In the case of bridges there was the associated factor of relatively lengthy disruption to traffic (**Fig. 1**). The development, construction and testing of the BELFA prototype is intended to meet the need to reduce investigation costs and bring the disruption from road works down to one or two days.

Fig. 3: BELFA at its premiere in Neu Kalиß, Germany

Specifications

Constructing the load application vehicle involved a number of complex engineering requirements, the most important of which were the following:

- **Ability to carry out loading investigations using the EXTRA method in one lane of bridge classes 12 to 60 as defined in DIN 1072 (12.85); up to bridge class 30 this would involve not using a back tie, that is not drilling through the waterproof layer to install tie rods, and for bridge class 60 two back tie rods would be installed per abutment**
- **Ability to operate as a special vehicle without significantly restricting traffic (all-up weight 80 tonnes, axle loads ≤10.5 tonnes, turning circle D = 22 meters)**
- **Largely autonomous compliance with all requirements relating to the loading procedure and operating safety in the course of preparing and executing the investigation**
- **Use of the self-locking loading principle when using hydraulic force generation in connection with a rigid version of the BELFA's main chassis (max. f = 25 mm at a maximum test loading of 1.5 MN)**
- **Variable span adaptation where l = 4.00 to 18.00 meters by means of infinitely variable telescopic action**
- **Ballasting with 20 tonnes of mass with the aid of flexible water tanks**
- **Axle loads on towing vehicle to be kept down to ΣF = 230 kN when crossing class 12 bridges**

Following restricted tendering, the order for construction including a target time for planning and construction (9 months) was awarded to Eggers Fahrzeugbau GmbH, vehicle-builders, in 28816 Stuhr, Germany.

Operating principle

The vehicle is 2.75 meters wide and 3.50 meters high. It consists of a towing vehicle, a welded main chassis comprising two longitudinal and 16 transverse girders, ballast water tanks, and a deck crane with adjustable extension and height (**Fig. 3** to **5**).

Four hydraulically movable feet positioned over the neutral abutments/pillars are used to align the vehicle horizontally and vertically. Five test rams with fittings on extending slides generate the test loads. The rear-mounted control cabin and associated diesel-electric drive for the soundproofed hydraulic motor complete the list of main elements. Before the BELFA can be placed in the test position it has to be pulled forward by the towing vehicle until it is over the load-bearing structure that is intended to be examined (**Fig. 4 to 5**). In this situation the towing machine load can be reduced to the minimum 23 tonnes by temporarily removing ballast so that it is even possible to cross load-bearing structures on class 12 bridges. The heavy five-axle trailer vehicle at that point remains outside the test area. On reaching the test position the vehicle is

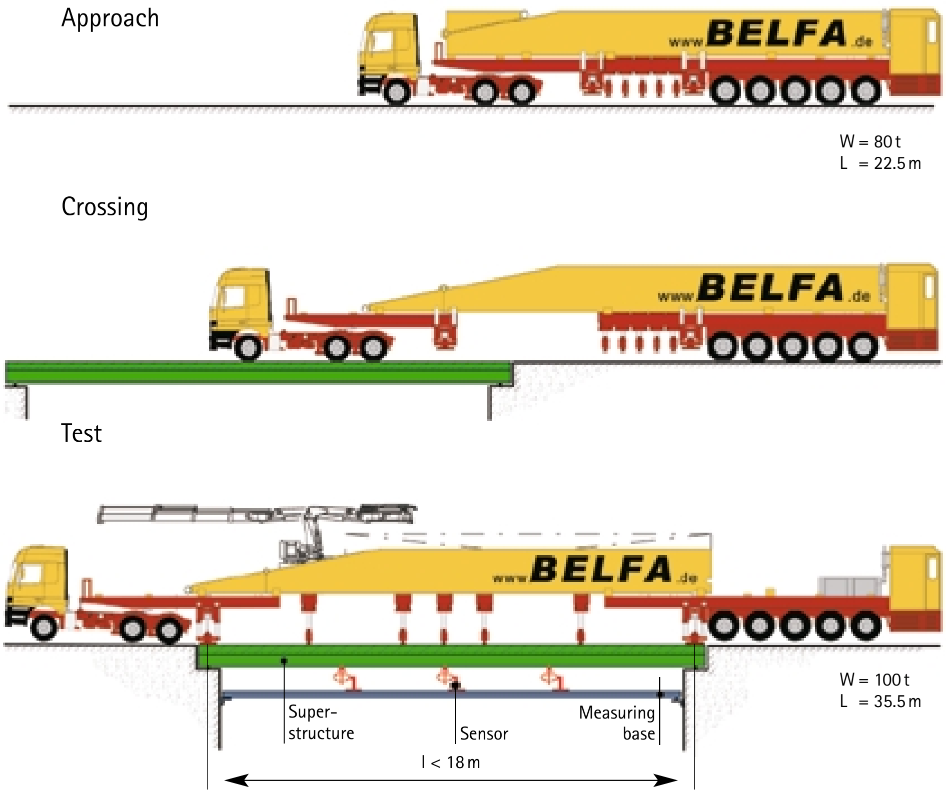

Fig. 4, above:
Extending the frame increases the usable length to 18 meters

Fig. 5, left:
Views of the BELFA;
above: in traffic; below:
in test position

chocked and aligned vertically in the transverse direction. The towing vehicle and trailer are raised and trimmed with the aid of the ballast, increasing the available test dead weight to 80 tonnes (or 100 tons using the water ballast). The weight is equally distributed over the feet (**Fig. 5 – 6**).

The test rams are then moved into their intended positions and vertically aligned if necessary. Three of the five rams represent the three axles of a heavy goods vehicle (HGV) as defined in DIN 1072, while the two outer rams are used to apply a loading to the remaining surfaces fore and aft of the HGV area.Each of the last two rams mentioned can also be used in a separate test for determining bearing strength in the event of lateral forces in the vicinity of the support structure. If the available dead weight of the BELFA is insufficient, pre-tensionable back ties must be installed in the abutment area using tie bolts fixed in the abutment itself. The dead weight and pre-tensioning of the back ties then form a total available test load capacity of 1,500 kN, which is adequate for g-fold loads up to bridge class 60.

Hydraulic loading unit and associated monitoring equipment

The hydraulic loading unit in the strictest sense consists of five test rams, the hydraulic motor complete with power generator and the associated programmable controller. This unit alone is responsible for the controlled generation of the test load. All other essential hydraulic functions, such as extending the four feet, are specific to the motor vehicle and are perceived by the various separate modules as being independent of the loading unit.

Each test ram is linked to the main chassis of the BELFA by an extensible positioning slide in such a way that its axis is rigid in the transverse direction and jointed in the longitudinal direction, though lockable (**Fig. 6**). Not only do the hydraulic rams each have a nominal force of 500/250 kN (compression/traction) but each ram is fitted with a 500 kN tensile/compressive force transducer at the end of its piston rod.

All data streams, whether from the transducers installed on the load-bearing structures under investigation or from the force and tilt

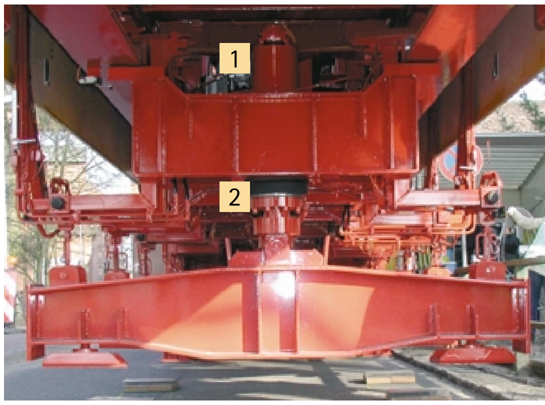

Fig. 6:
Test ram with extensible positioning slide, force transducers and cross-beam

1 *Integrated force measurement*
2 *Hydraulic ram*

measurements performed by the load application vehicle, are brought together in the rear test control point. The latter has a dynaSax II PLC for analyzing the measurement signals and a PC controlled UPM 100 multipoint measuring device from HBM (**Fig. 7**). When a test is in progress the PLC passes the current force values from all test cylinders to the multipoint measuring device. A downstream analysis program provides an online

Fig. 7, left:
19” rack with PC, monitor and controller for load application and vehicle hydraulics, together with UPM100 multipoint measurement amplifier from HBM

Fig. 8: Extensible positioning slides

display of the independently measured deformations of the load-bearing structure and the force/deformation functions. The test supervisor and a metrologist in the control cabin are provided with all the information they need relating to the test in order to operate the BELFA.

For the sake of maintaining operating safety the PLC monitors the behavior of the vehicle throughout the test loading procedures. Not only the forces acting upon the supports but also the longitudinal and transverse tilt at both ends of the main chassis are continuously recorded and compared with threshold criteria (**Fig. 9**). If a warning is ignored and an abort threshold is exceeded, the hydraulic motor automatically cuts out. The test load is reduced in the shortest possible time. In the process the system monitors both absolute and relative values.

A test procedure is aborted in the following circumstances:

- A defined minimum force is not present in one of the supports (lifting/slipping due to excessive longitudinal tilt)
- A defined longitudinal or transverse tilt is exceeded
- There is too great a difference between each of the supports in a pair (right and left)
- The total load acting upon all supports is too low (lifting/slipping)

The PLC automatically reduces threshold values in accordance with the situation of the superstructure, for instance in the event of pronounced longitudinal tilt.

Experiences during initial implementation

Since BELFA first entered service in March 2001, it has been used to examine the structures of a total of eleven bridges in five German federal states. Thanks to the experimental analysis carried out on the load-bearing structures with the aid of BELFA, it was possible to reclassify all these bridges at least one class higher than would have been possible using conventional calculation methods. Thus these structures meet the requirements out of today’s traffic revenue and they were able to be cleared for higher loads. The cost saving due to economizing on materials and continued use when compared with new replacement structures was declared by those in charge of construction to be between € 250,000 and € 1 million. Disruption on the bridges amounted to one or two days or less, no more than half the amount of time specified.

Prospects

Once the research project is complete it is intended to set up a scientifically-based scheme to offer the services of the BELFA load application vehicle. Current information can be obtained from the web site www.belfa.de.

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Fig. 9:
One of the two front supports with integrated force measurement

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