Structural Assessment using identified Bending Stiffness

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Summary

All Engineering structures are subjected to time dependent degradation processes. In order to allow a cost effective maintenance planning, it is necessary first to determine a structure's condition and reliability profile respectively and second to extrapolate the acquired assessment indices into the future. Based on this information maintenance planning then can be optimized. This contribution will deal with a practically feasible approach to the assessment of existing structures based on different methods for the determination of the 'real' bending stiffness distribution.

Keywords: reinforced concrete, damage identification, stiffness identification, dynamics, structural assessment, reliability index

1. Introduction

During the last decades a high number of structures have been built. Nowadays an increasing demand for more efficient ways to determine the structures' condition can be observed since every operator is obliged by law and codes to ensure save usage of all structures. This encompasses especially guaranteeing a sufficiently high reliability level with respect to the ultimate limit state (ULS), the serviceability limit state (SLS) und the durability limit state (DLS). Furthermore in case of bridges traffic safety has to be considered.

Visual inspection is currently the tool of choice in most countries regarding the inspection of bridges, as is it in Austria. However regardless of the extent of visual inspection results are always limited to what can be detected on the surface. Consequently operators are highly interesting in the application of more sophisticated tools which allow for an assessment of parts of the bearing structure which are covered for instance by pavement, insulation or cladding and thus not easily accessible. These include local testing through ultrasound, thermal imagery or radar surveillance as well as approaches based on global characteristics like bending lines, eigenfrequencies, mode shapes or influence lines for bearing reactions. The main demands for practically feasible inspection tools are easy application, low costs and objectivity. Consequently the structural characteristics used should be easy to capture and the analysis needs to be highly automated lacking the need for a lot of engineering effort or an expert operator. Although using experts with a lot of experience has a lot of benefits the resulting condition rating is subjective and hardly allows comparison between different structures. The quantification of a structures condition with respect to reliability levels defined by international codes on the other hand is independent of the engineer, type of structure and environmental conditions present.

2. Identification and Assessment

Most types of damage relevant to structural response affect the bending stiffness of the cross section. Especially cracking in non-pre-stressed reinforced concrete leads to significant losses of up to 75%. Consequently this parameter is suited to be used for the identification, localization and even to a certain extent quantification of damage. Since the distribution of bending stiffness EI(x) along a structure influences structural response – modal characteristics, deflection lines and bearing

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reactions in hyperstatic structures – the measured response can be used inversely to determine the actually present bending stiffness distribution.

Current practice mainly includes visual inspection which has the benefit to include expert knowledge in the assessment. However many areas of interest can not be inspected visually and visually obtained ratings are to a certain extent subjective. The identification techniques presented allow for inspection of the entire structure even in areas which are not easily accessible using global characteristics. Unfortunately the determined stiffness distribution is of little immediate use to the operator who calls for assessment with respect to codes. Consequently the resulting stiffness distributions have to be evaluated regarding the failure probabilities specified for instance in the Eurocode and/ or correlated to classical condition ratings. In order to guarantee the proper usage of a structure/ serviceability mainly the deflection and crack width are to be limited. Both parameters can be calculated using the ‘real’ identified bending stiffness in a linear elastic model of the structure thus leading to a fairly good estimation of the reliability since serviceability relevant loads are mainly limited to the linear branch of the load deflection line. The estimation of the reliability level regarding the ULS using a linear model is only possible if the stiffness loss already is fully developed. However the introduction of the identified ‘real’ stiffness distribution in a non-linear fracture mechanics FEM will allow for better assessment of the remaining bearing capacity.

3. Application

After all identification techniques had been tested and verified in laboratory tests plans for a field test were derived both to test several of the identification tools under real conditions in order to evaluate their practical applicability and to apply the proposed assessment strategies. In November 2007 a field test was conducted at an overpass of the Austrian railroad line Vienna – Laa. The structure chosen (see Figure 1) is a simple three span reinforced concrete plate, with defined boundary conditions and shows no curvature or oblique crossing angles. Furthermore it is part of a road of minor importance and is easily accessible, which allowed inspection and interventions including temporary closings of the bridge. The spans are 10.0 m, 13.0 m and 10.0 m and the cross-section of the plate is 9.55 m by 0.60 m. At the abutments the structure is supported by elastomeric bearings and above the pillars by rocker bearings.

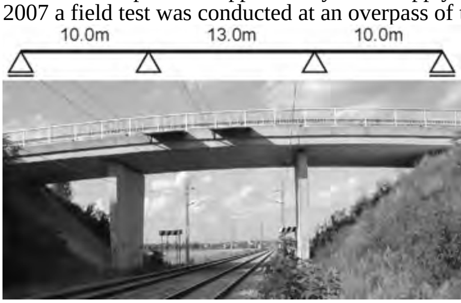

Fig. 1: Overpass Vienna - Laa

Although significant cracking was documented already 17 years ago no signs of corrosion or spalling could be detected during inspection in 2007. Since almost all cracks had a width of less than 0.3 mm and the condition of the bridge equipment was good a condition rating of 1-2 could be assigned.

Considering the crack pattern in the main span corresponding to 25% loss of stiffness and a decrease in stiffness of up to 50% above both pillars leads to the conclusion that cracks surpassing 0.3 mm exist in those areas, which are not visible. Taking the additional information provided by the identified stiffness distribution on a qualitative level into account the rating has to be modified because a problem with respect to the serviceability or durability may develop. Thus the condition rating is reduced to class 2.

In a further step the stiffness distribution can be used to determine the reliability level regarding both SLS and ULS. Apart from the dead load an equally distributed load $q_{vehicle}$ over the entire bridge deck and two vehicles positioned exactly in the middle of the main span with two axles each were considered. The calculation of the maximum deflection using a linear finite element tool implemented in MATLAB resulted in an average displacement of 7.7 mm with a coefficient of variation of 10% following a three parametric gamma distribution. The comparison with L/250 = 52 mm led to a failure probability of far less than the demanded value of 10^{-3} per year thus confirming the condition rating of 1-2, which was also supported by the analysis regarding the ULS.