SYSTEM IDENTIFICATION OF CRACK-DAMAGE IN REIFORCED CONCRETE STRUCTURES

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SUMMARY

Damage of concrete structures (cracks, for instance) can be defined as stiffness reduction of one (or more) elements of the structure, which means a change in the dynamic behaviour. If these changes could be measured, it would be possible to assess the success of rehabilitation measures, using analysis and system identification techniques. But at this time it is not possible to determine the damage locations using dynamic analysis. Every building has a spectrum of infinit eigenfrequencies and associated eigenvectors, which depend on the geometry of the building, the distribution of mass and stiffness and on the boundary conditions. With these geometric and mechanical parameters it is possible to model the building.

Keywords: System identification, dynamics, cracks

1. INTRODUCTION

In order to erect a building that satisfies the high expectations of *stability* and *serviceability* including *durability*, strict requirements are placed on the quality control of reinforced concrete and steel materials.

Stresses will result not only from unavoidable deformations of the building due to loads and/or temperature changes, but also due to planning errors or human error while constructing the building. When the tensile stress in concrete exceeds the tensile strength, a crack will occur. If the crack width exceeds a defined limit, the structural system or durability of the building is in danger.

Each building has an infinite spectrum of eigenfrequencies and associated eigenvectors, which depend on the geometry of the building, the distribution of mass and stiffness and on the boundary conditions. With these geometric and mechanical parameters it is possible to model the building. Using these models it is possible to determine all system response quantities, such as building movements.

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Damage (cracks, for instance) can be defined as stiffness reduction of one (or more) elements of the structure, which means a change in the dynamic behaviour. If this change could be measured, it would be possible to assess the success of rehabilitation measures, using dynamic analysis, for example. But it is not yet possible to determine the damage locations using dynamic analysis.

2. A LAYERED MODEL / SYSTEM IDENTIFICATION

There are two different categories of models to simulate a crack area:

- The discrete model which is built by splitting a FE-node into two separate nodes. With each iteration step (changing of the crack area) the FE-mesh is generated new and the number of unknowns increases. The advantage of this model is that bond effects can be considered.
- The smeared model is the most frequently used one. Cracks are 'smeared' over the whole crack area by reducing the material stiffness (Young's and shear modulus).

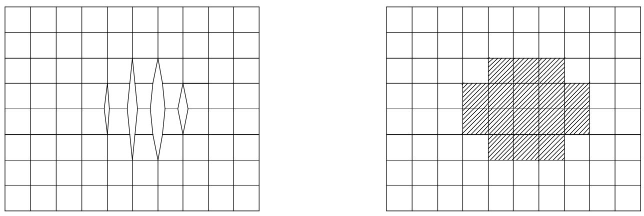

Figure 1: Discrete and smeared crack approaches

Using system identification, two researchers from the University of Kassel have used a quadratic parabola to idealize the crack damage area caused by pure bending in a reinforced concrete beam, and modelled with isoparametric elements [Jahn, 96; Eilbracht, 96].

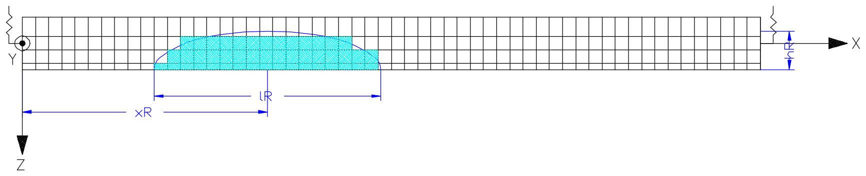

Figure 2: Beam with parabolic crack area

Based on this results, another possibility of modelling beam structures to identify these crack areas will be tested. This method is based on a layered model.

In this model a plane-shell element with layers (concrete and reinforced concrete layers) is used. To simulate a crack damage, the element stiffness will be reduced layer by layer.

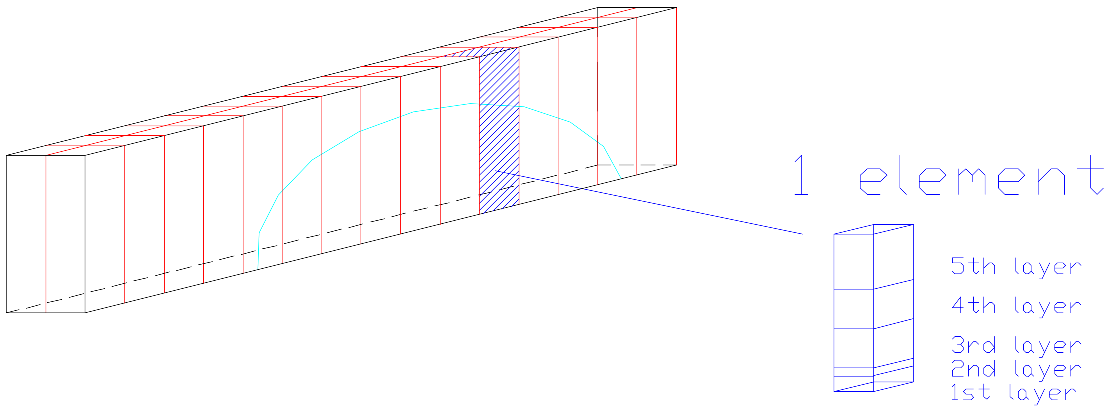

Figure 3: Layered model of a beam

After successful verification of this method, it will be extended to identify existing cracks in reinforced concrete <u>slab</u> structures (with smeared reinforcement).

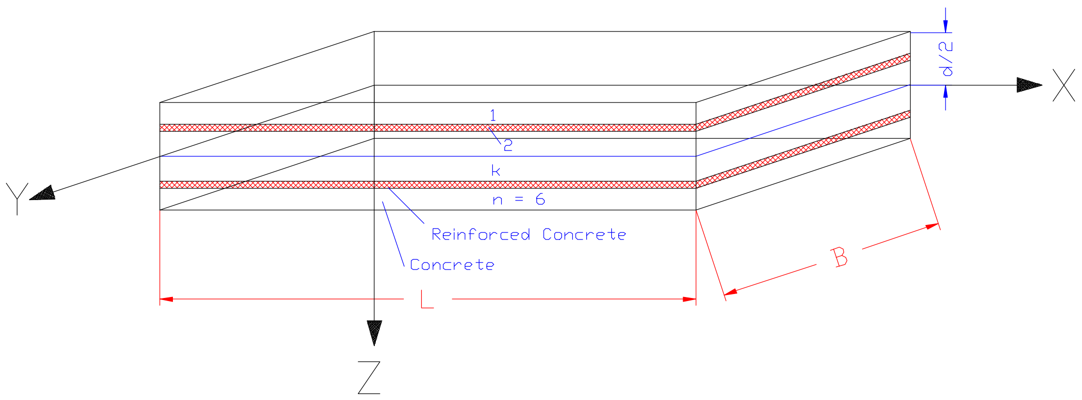

Figure 4: Layered slab element

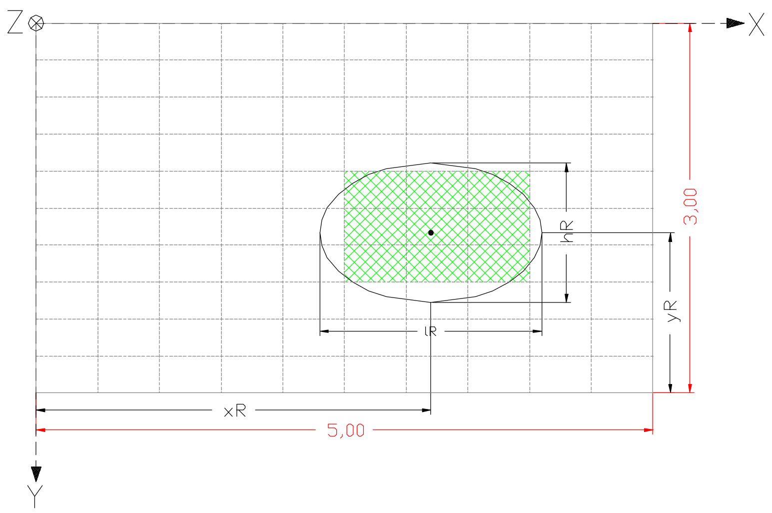

Figure 5: Slab with an elliptical crack area

The parameter identification is an inverse problem. With the modal data obtained from physical experimentation, the correction-model is fitted until a precision criterion is reached. The sequence of identification steps is shown in figure 6. More details of these parameter corrections can be found in the article by *Jahn* in these proceedings.

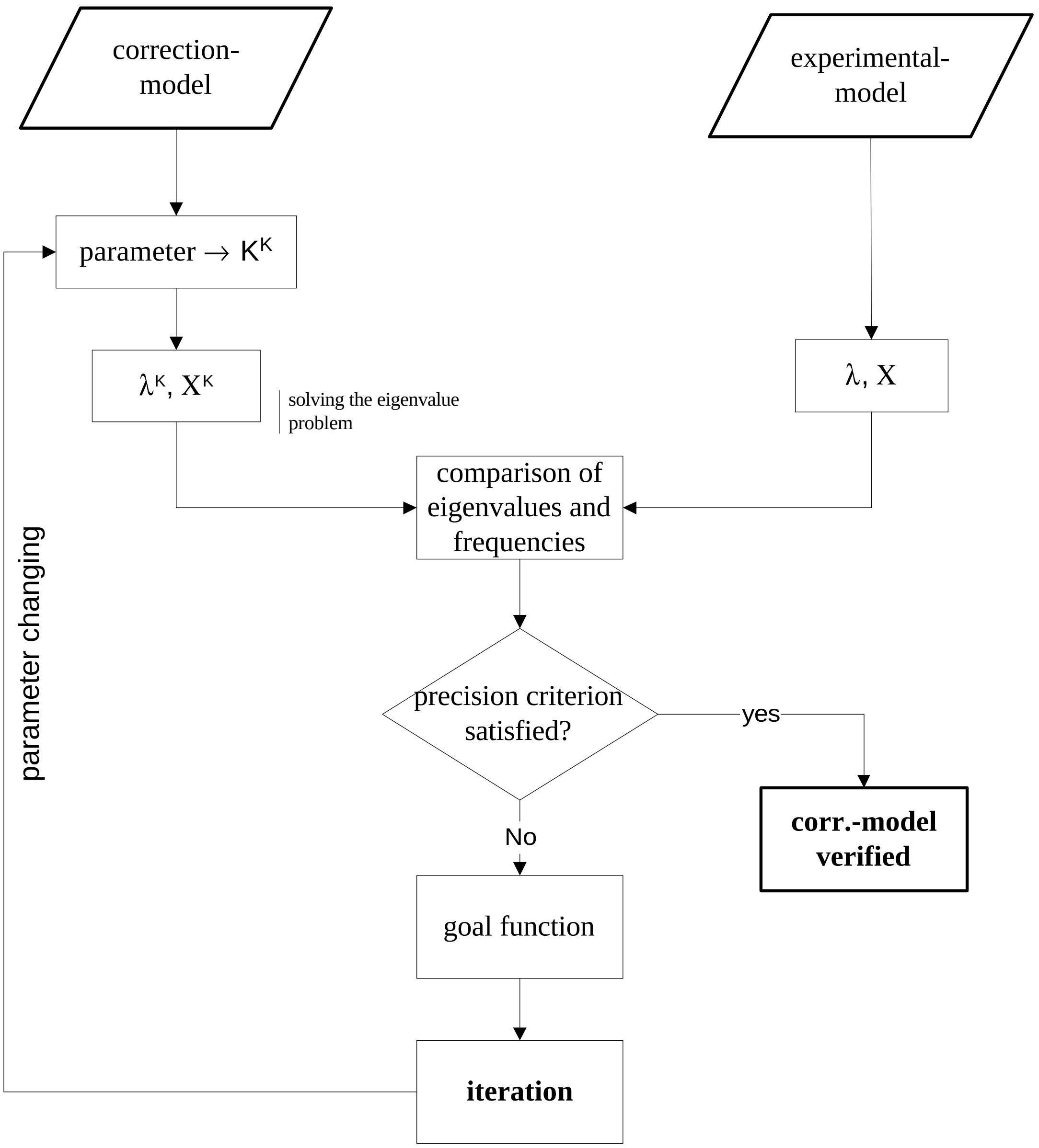

Figure 6: Sequence of identification steps

3. PHYSICAL EXPERIMENTS

The aim of the physical experiments is to check the theoretical results and to show, that this technology could be used in practice. It is intended to test two different types of slabs for this purpose: three rectangular slabs with the dimension of 3,00 * 5,00 * 0,15 m and three skewed slabs with dimensions of 3,00 * 3,00 * 0,15 m.

The boundary conditions have a significant influence on the eigenvalues and -vectors, and they are not exactly known in practice. So it is another goal to identify them as well. It is planned to test three different boundary conditions: four point supports and two or four edge supports.

4. CONCLUSIONS

It was demonstrated that modal test data in conjunction with parameter identification can be used to identify / locate a crack area of a reinforced concrete slab. The finite element model utilizes a layerd plate-shell element with layerwise smeared cracks.

The next step is, to demonstrate that this theory can be used in practice. This should be realized with two different kinds of reinforced concrete slabs.

5. REFERENCES

[Altenbach/et al., 96]
Altenbach, H., Altenbach, J., Rikards, R.
Einführung in die Mechanik der Laminat- und Sandwichtragwerke,
Deutscher Verlag für Grundstoffindustrie, Stuttgart, 1990.

[Blum/Kerkhof, 87]
Blum, R., Kerkhof, K.
Bestimmung von Steifigkeitsveränderungen bei der Sanierung der Kloster-wegbrücke mit Hilfe der Schwingungsanalyse,
in: Bauingenieur 62 (1987),
Springer-Verlag, 1987, pp. 513-518.

[Doebling/et al., 96]
Doebling, S. W., Farrar, C. R., Prime, M. B., Shevitz, D. W.
Damage identification and health monitoring of structural and mechanical systems from changes in their vibration characteristics: a literature review,
Los Alamos National Laboratory Report LA-13070-MS, 1996.

[Eilbracht, 96]
Eilbracht, G.
Identifikation von Rißbereichen in Stahlbetonbalken mit Hilfe von Schwingungs-testdaten,
VDI Verlag, PhD. Thesis, Universität Gesamthochschule Kassel, 1996.

[Eschenauer/Schnell, 93]
Eschenauer, H., Schnell, W.
Elastizitätstheorie,
BI Wissenschaftsverlag, Mannheim Leipzig Wien Zürich, 1993.

[Friswell/Mothershead, 95]
Friswell, M. J., Mottershead, J. E.
Finite Element Model Updating in Structural Dynamics,
Kluwer Academic Publishers, Dordrecht, 1995.

[Jahn, 96]
Jahn, T.
Ein Beitrag zur Identifikation von Schädigungsparametern an Stahlbetonbauteilen,
PhD. Thesis, Universität Gesamthochschule Kassel, 1996.

[Link, 89]
Link, M.
Finite Elemente in der Statik und Dynamik, 2. Auflage,
Verlag B.G. Teubner, Stuttgart, 1989.

[MATFEM]
MATFEM,
Finite Element Programm,
FG Leichtbau, Universität Gesamthochschule Kassel, 1997.

[MATLAB]
Math Works Inc.
MATLAB,
Interaktives mathematisches Programm.

[Mehlhorn/Kollegger, 95]
Mehlhorn, G., Kollegger, J.
Anwendung der Finiten Elemente Methode im Stahlbetonbau,
in: Der Ingenieurbau - Grundwissen, Band: Rechnerorientierte Baumechanik,
Hrsg.: G. Mehlhorn, Verlag Ernst und Sohn, Berlin, 1995.

[Mehlhorn, 98]
Mehlhorn, G.
Bemessung im Betonbau,
in: Der Ingenieurbau - Grundwissen, Band: Bemessung,
Hrsg.: G. Mehlhorn, Verlag Ernst und Sohn, Berlin, 1998.

[Natke, 92]
Natke, H. G.
Einführung in Theorie und Praxis der Zeitreihen- und Modalanalyse,
3. Auflage, Vieweg Verlag, Braunschweig, 1992.

[Stempniewski/Eibl, 96]
Stempniewski, L., Eibl, J.
Finite Elemente im Stahlbetonbau,
in: Betonkalender 1996, Teil 2, Hrsg.: J. Eibl,
Verlag Ernst & Sohn, Berlin, 1996.

[Zou, 96]
Zou, Z.
Identifikation von Material- und Schädigungsparametern von Faserverbundstrukturen mit Hilfe von Schwingungstestdaten,
PhD. Thesis, Universität Gesamthochschule Kassel, Shaker Verlag, Aachen, 1996.