Dynamic diagnosis of structures using a modal hammer and a dynamic inertance function

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ABSTRACT

As engineers, we do expertises on structural condition of structures, when damages occur on them. Simple look at a damaged pattern allows us some times to evaluate safety of it and detect reasons of observed damages and deformations. In most cases, especially related to historical structures, simple optical survey and engineering experience is not enough. We have to use more or less complicated diagnosis tools (laboratory and in situ test on material properties, geometry survey, dynamic and foundation investigation or analysis of numerical models) and to engage a large team of various experts (in very complex cases). Additionally in historical structures, knowledge about past reconstructions and structural interventions is required, where an expert has to behave like a detective to discover real danger and needs requiring a proper structural intervention. Often, a bad structural condition of an analysed structure is unknown and sudden collapse without any warning happens, as in the case of the Pavia Civil Tower in Italy.

Presently, quick development of diagnostic methods and measurement systems allows us to do very sophisticated diagnosis but it is rather costly, complex and in some cases impossible action. Being on site, an expert need simple and handy tool, offering in analysis wide spectrum of useful information. Dynamic modal analysis of structures allows engineers for powerful diagnosis, when proper methods are used. One of such powerful method is analysis of dynamic inertance and compliance functions, determined with a modal hammer. This simple tool can be easily used on site for testing of structures and structural elements. Acquired data can be analysed in laboratory and elaborated results allow detecting changes in eigen-frequency and thus in global or local structural stiffness. This information is significant when structural eigen-frequencies start to be close to the dominant frequency band characteristic for a seismic area. Threatened of resonance, assessed during dynamic monitoring of a structure, should trigger structural intervention process to avoid sudden collapse of urban and heritage structures during next earthquake. The presented diagnostic methodology allows also determining damping of the structure, which both with eigen-frequencies can be useful for validation of numerical models of structures. Properly validated numerical models allow engineers to assess more easy vulnerability and toughness of analysed structures. This diagnosis methodology is presented on structural examples, examined also on a shake table.

Assessment of heritage structures using a modal hammer and dynamic inertance and compliance functions allow for periodic control (monitoring) of changing structural properties, which can be used in an object passport collecting proper information for authorities and owners.

Highlights

- Diagnosis method simple in use on site
- Detection of stiffness changes of a damaged (cracked) structure
- Determination of dynamic properties of structures
- Evaluation method suitable for structures in seismic areas.

CURRICULUM VITAE

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Status: Married
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Employment: since 2015: Professor of CUT at the Cracow University of Technology,
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since 2013: Associate Professor at the Cracow University of Technology,
Department of Civil Engineering, Institute of Structural Mechanics
since 2002: Assistant Professor at the Cracow University of Technology,
Department of Civil Engineering, Institute of Structural Mechanics
1995 – 2002: Scientific-didactic assistant at the Cracow University of Technology,
Department of Civil Engineering, Institute of Structural Mechanics
1994 – 1995: internship at the Cracow University of Technology, Department of Civil
Engineering, Institute of Structural Mechanics

Qualifications: 2013: graduated D. Sc. in Civil Engineering, Cracow University of Technology

2013: graduated CTT PK Course “Rules of obtaining funds for the commercialization of research results”
2010: graduated ZWICK Course on operation of Universal Testing Machine ZWICK
2009: graduated CTT PK Course “Workshop on MS-Project”
2008: graduated CTT PK Course “Entrepreneur Researcher”
2008: graduated CTT PK Course “Protection tools of intellectual property rights”
2007: graduated IBDiM Course “Structural Strengthening by Bonding of Reinforcements
Made of FRP Composite Materials”
2004: graduated ICMS Course “Surface Waves in Geomechanics” in Udine
2002: graduated Ph.D. in Civil Engineering, Cracow University of Technology
(with the best grade)
1998: Postgraduate Diploma in Pedagogic
1995: graduated M.Sc. C.Eng. in Civil Engineering, Cracow University of Technology
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1985 – 1990: Structural Engineering Technician, Secondary School of Structural
Engineering

Work experience: since 2020: Member of the Interdisciplinary Committee for repair of historical masonry arch viaduct in Cracow.

2019-20: Task coordinator in the project INMASPOL "INfills and MASonry structures protected by deformable POLyurethanes in seismic areas" realized in frame of the SERA — H2020-INFRAIA-2016-2017/H2020-INFRAIA-2016-1 "Seismology and Earthquake Engineering Research Infrastructure Alliance for Europe"

2017-20: Member of the POIR.04.01.02-00-0016/17-00 project (EU funds) "Innovative technology of vibro-acoustic insulation of floors"

2017-19: R&D Head of the POIR.01.01.01-00-0828/16 project (EU funds) "Development of innovative modular construction technology, prefabricated on the basis of timber by PalettenWerk Kozik Spółka Jawna"

2018: ISCARSAH Expert for assessment of structural condition of heritage structures in Iran

since 1996: over 200 publications and conference presentations (in English and Polish)

since 2004: 3 patents, 4 patent claims and 5 utility models registered in the Polish Patent
Department (on applications of polymer flexible joints)

since 2016: Chief Executive Officer of FlexAndRobust Systems Ltd. (spin-off company)

since 2007: Promoter and co-worker of the Science-Industry Consortium PK-NTB
(organized at the Technology Transfer Centre of the Cracow University of Technology, to
commercialize results of research on polymer flexible joints)

2014-15: Member of the Organizing Committee of the 70th Anniversary of the Cracow University of Technology (Forum: *Science and Economy*; Anniversary Scientific Conference: *Practical applications of innovative solutions resulting from scientific research*)

2012: Member of the Organizing Committee of SAHC2012

2010 – 2012: A head of the scientific research program on polymer flexible joints in
civil engineering and model aspects of innovation solutions in engineering practice – Grant
N N506 071438 ordered by Polish Scientific Research Committee
2004 – 2007: A head of the scientific research program on the elasto-plastic methods of
protection and repair of structures working under static, dynamic and thermal loads – Grant
PB 1529/T07/2004/27 ordered by Polish Scientific Research Committee
2002 – 2003: Internship in HOCHTIEF Poland - Division KPIS Cracovia
2000 – 2001: Management of the scientific research program on the dynamic behaviour of
the concrete wall embedded in soil – Grant KBN 7T-07E009-19 ordered by Polish
Scientific Research Committee
1997 – 1999: Management of the scientific research program on the in situ vibration
propagation shallow underground – Grant KBN 7T-07G007-12 ordered by

Polish
Scientific Research Committee
1996 – 2020: Several dozen expert opinions on the construction condition of buildings and
on the behaviour of structures under static and dynamic excitations
1996 – 2005: Projects of strengthening of historical masonry building in Cracow - including FRP materials (the first strengthening project of the brick arches in Poland /in 1998/ with realization in 2002)
1997 – 2012: Calculations of concrete chimneys
1999: Member of the Organizing Committee the 19th International Meeting in Cracow of the International Association of Spatial Structures
since 1993: Working with computer programs: MS Office (Word, Excel, Power Point),
AUTOCAD, MATHCAD, other engineering programs.

Awards:

- 2018: JM Rector CUT Award for the RILEM publications
- 2018: JM Rector CUT Award for scientific activity in the Leader competition
- 2018: JM Rector CUT Award for the publication and scientific activity
- 2017:Gold Medal of the Cracow University of Technology

2015: Scientific Award of the IV Technical Science Department of the Polish Science
Academy
2015: JM Rector CUT Award for the team work for organization of the 70th Anniversary of the Cracow University of Technology
2010: Honorary Distinction of the Cracow University of Technology
2003: Ministry of Spatial Management and Building Engineering Award for the best Ph.D. work
2003: JM Rector CUT Award for the best Ph.D. work
2002: JM Rector CUT Award for the team work for publications on research on dynamic
influences on buildings
2001: JM Rector CUT Award for the team work for didactic activity
2000: JM Rector CUT Award for the team work for monograph
1996: Ministry of Spatial Management and Building Engineering Prize for the best graduation work
1996: Izydor Stella-Sawicki Award of the Polish Society of Building Engineers and
Technician for the best graduation work

Other experience:

in 2018: Lecture during the International Workshop on Restoration and Strengthening of Historical Structures (Tehran Workshop) and Expert Visits on Iranian heritage structures
since 2018: Expert Member of the International Scientific Committee on the Analysis and Restoration of Structures of Architectural Heritage (ISCARSAH)
since 2016: Member of the Management Committee and Core Group COST Action CA15202 Self-healing As preventive Repair of COncrete Structures
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Design Guidelines for Composites in Construction
since 2012: Member of the International Institute for FRP in Construction (IIFC)
since 2012: Member of the Section of Material and Structural Mechanics of the Polish
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since 2012: Senior Member of the RILEM Technical Committee CSM Composites for
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2009-2011: Member of the Development Committee of Department of Civil Engineering
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since 2008: Senior Member of the RILEM Technical Committee 223 MSC Masonry
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Selected publications:

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Kwiecień A., Zając B.: Is it Possible to Repair Detached Composites Effectively after Failure of Masonry Strengthening? Key Engineering Materials, 624 (2015), Trans Tech Publications, Switzerland, pp. 518-525.
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Kwiecień A.: Flexible polymers using in repair of cracked masonry walls as a composite material. MuRiCo3 Mechanics of masonry structures strengthened with composite materials, AICO, Venice 2009, pp. 325-332.
Kwiecień A., Zając B., Jankowski R.: Static and dynamic properties of a flexible joint working in cracked historical masonries. Structural Analysis of Historic Construction Preserving Safety and Significance – D'Ayala & Fodde (eds), Taylor & Francis Group, London 2008, pp. 931-939.
Kwiecień A., Zając B., Kubica J.: Repair of cracked historical masonry structures by use of the Flexible Joint Method (FJM) – laboratory tests. Structural Analysis of Historical Constructions, P.B. Lourenço, P. Roca, C. Modena, S. Agrawal (Eds.), Published by: Macmillan India Ltd, New Delhi 2006, pp. 1447-1454.
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