

**Load identification  
and structural damage  
detection of bridges**

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Thesis submitted in fulfilment of the requirements for  
the degree of

**Doctor of Philosophy**

under the supervision of A/Prof Xinqun Zhu

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# Certificate of Original Authorship

I, Bing Zhang declare that this thesis, is submitted in fulfilment of the requirements for the award of Doctor of Philosophy, in the School of Civil and Environmental Engineering, Faculty of Engineering and Information Technology at the University of Technology Sydney.

This thesis is wholly my own work unless otherwise referenced or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

This document has not been submitted for qualifications at any other academic institution.

This research is supported by the Australian Government Research Training Program.

Signature

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# List of publications

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# Table of Contents

Certificate of Original Authorship .....	i
Acknowledgement .....	ii
List of publications .....	iii
Table of Contents .....	iv
List of Figures .....	viii
List of Tables .....	xiii
Abstract .....	xv
Chapter 1    Introduction .....	1
1.1 Background .....	1
1.2 Research objectives .....	3
1.3 Significance .....	4
1.4 Structure of the thesis .....	4
Chapter 2    Literature Review .....	7
2.1 Overview .....	7
2.2 Load identification .....	7
2.2.1 Load identification methods .....	7
2.2.2 Impact load identification .....	12
2.2.3 Moving load identification .....	15
2.3 VBI based structural damage detection .....	16
2.3.1 Damage detection based on bridge responses .....	16
2.3.2 Damage detection based on vehicle responses .....	20
2.3.3 Damage detection based on both vehicle and bridge responses .....	22
2.4 Bridge local damage detection .....	23
2.4.1 Composite beam shear connector damage detection .....	23
2.4.2 Bridge cable damage detection .....	25
2.5 Simultaneous identification of structural load and damage .....	27

	2.6 Summary .....	30
Chapter 3	Impact force identification based on truncated transfer matrix.....	32
	3.1 Overview .....	32
	3.2 Theory .....	32
	3.2.1 Impact force identification.....	32
	3.2.2 Impact force localization .....	35
	3.3 Regularisation model for impact force identification .....	37
	3.3.1 $l_2$ -norm Regularisation.....	38
	3.3.2 $l_1$ -norm Regularisation.....	38
	3.3.3 Truncated transfer matrix-based method for impact force identification .....	39
	3.4 Numerical study .....	40
	3.4.1 Identification of impact forces on a simple supported beam.....	40
	3.4.2 Single impact force identification.....	42
	3.4.3 Multiple impact force identification .....	47
	3.5 Experimental validation .....	48
	3.5.1 Experimental setup .....	48
	3.5.2 Finite element model validation .....	50
	3.5.3 Impact force identification.....	52
	3.6 Summary .....	57
Chapter 4	Low-rank transfer submatrix based group sparse regularisation for impact force localization and reconstruction .....	58
	4.1 Overview .....	58
	4.2 Theory .....	59
	4.2.1 Force identification.....	59
	4.2.2 Impact force identification using one single sensor .....	61
	4.3 Impact force identification using group sparse regularisation .....	62
	4.4 Numerical study .....	63
	4.4.1 Simple supported beam .....	63
	4.4.2 Determination of the low-rank matrix for impact force identification .....	65
	4.4.3 Effect of measurement noise .....	69

4.4.4 Multiple impact force identification with one single sensor .....	72
4.5 Experimental validation .....	77
4.5.1 Experimental setup .....	77
4.5.2 Results and discussion .....	77
4.6 Summary .....	80
Chapter 5 Moving force identification via equivalent nodal force based on group weighted regularisation.....	81
5.1 Overview.....	81
5.2 Governing equation of moving force identification via equivalent nodal force .....	81
5.3 Group weighted regularisation model for equivalent force identification.	83
5.4 Numerical study .....	85
5.4.1 Simulation parameters .....	85
5.4.2 The effect of the number of measurements .....	87
5.4.3 The effect of the number of equivalent nodal force .....	91
5.5 Summary .....	94
Chapter 6 Interface monitoring in steel-concrete composite beams with a novel slip sensor .....	95
6.1 Overview.....	95
6.2 Experimental study .....	95
6.2.1 Interface monitoring system .....	95
6.2.2 Experiment setup .....	98
6.2.3 Experimental procedure.....	99
6.2.4 Test results and discussion .....	100
6.3 Finite element model.....	101
6.3.1 General.....	101
6.3.2 FE model Validation.....	102
6.4 Numerical study .....	103
6.4.1 Influence of damage severities .....	104
6.4.2 Influence of multiple damage severities and multiple damage locations .....	106
6.4.3 Influence of damage locations with one damage severity .....	108

6.5 Summary .....	109
Chapter 7 Cable damage detection of a bridge under traffic loading from bridge deck strain measurements using SVM based classification and regression .....	111
7.1 Overview .....	111
7.2 Damage identification approach .....	111
7.2.1 The cable-stayed bridge .....	111
7.2.2 The relationship between the cable force and the bending strains of the bridge deck .....	113
7.2.3 Damage identification approach .....	117
7.3 The cable-stayed bridge SHM system and FEM .....	120
7.3.1 Description of the cable-stayed bridge SHM system .....	120
7.3.2 FEM of the cable-stayed bridge .....	123
7.3.3 Calibration of the FEM .....	124
7.4 Single cable damage identification .....	128
7.4.1 The damage identification indexes .....	128
7.4.2 Training datasets and testing datasets .....	132
7.4.3 Damage cable identification .....	134
7.4.4 Damage degree identification .....	136
7.5 Double damage cables identification .....	138
7.5.1 The double damage cables identification datasets .....	138
7.5.2 The double damage cables identification .....	141
7.6 Summary .....	143
Chapter 8 Conclusions and recommendations .....	144
8.1 Conclusions .....	144
8.2 Recommendations .....	147
References .....	149



# List of Figures

Figure 1.1 Bridge damage cause catastrophic accidents.....	2
Figure 3.1 Discrete form of the impact force identification .....	39
Figure 3.2 (a) Time history of impact force and relevant dynamic response; (b) Truncated transfer matrix.....	40
Figure 3.3 Numerical model of simply supported beam.....	41
Figure 3.4 Modal parameters for the single force identification .....	42
Figure 3.5 Identified impact force with measurements of nine sensors considering 10% noise level.....	44
Figure 3.6 Effect of measurement noise on impact force identification.....	45
Figure 3.7 Force identification results with different number of modes .....	46
Figure 3.8 The force identification results with different number of sensors.....	47
Figure 3.9 Modal parameters for two impact force identification.....	48
Figure 3.10 Identification of two impact forces.....	48
Figure 3.11 Experimental setup .....	49
Figure 3.12 Arrangement of the accelerometers.....	50
Figure 3.13 Finite element model .....	51
Figure 3.14 First 6 modal shape comparison between experimental model and FE model ....	52
Figure 3.15 Predefined possible load position in the experiment model.....	53
Figure 3.16. Time history of the impact force at S4 and the acceleration response at A2 .....	53
Figure 3.17 Impact force at S4 location identification results in 4 modes, 6 modes, 8 modes and 10 modes.....	54
Figure 3.18 Impact force identification with different number of sensors and modes .....	55
Figure 3.19 Impact forces at S4, S6 and the acceleration response at A2 .....	55
Figure 3.20 Identification of the impact force at S4 with different number of modes .....	56

Figure 3.21 Identification of the impact force at S6 with different number of modes .....	56
Figure 3.22 Two impact force identification with 10 modes & 3 sensors .....	56
Figure 4.1 Simply supported beam subjected to impact forces .....	59
Figure 4.2 The discrete format of Eq. (4.8) .....	61
Figure 4.3 The discrete form using the submatrix with one single sensor .....	62
Figure 4.4 Impact excitation interval determination from acceleration responses .....	65
Figure 4.5 The identification index results under different range of partial matrix .....	66
Figure 4.6 Identified force vector divided into predefined groups .....	69
Figure 4.7 The results of impact force identification with the submatrix of $m=5$ : the localization index results .....	69
Figure 4.8 The results of impact force identification under different noise effect. ....	71
Figure 4.9 Acceleration time history response for estimation of two intervals related to impact forces.....	72
Figure 4.10 Identified force vector for double impact divided into predefined groups.....	73
Figure 4.11 The results of double impact force identification.....	74
Figure 4.12 Acceleration time history for triple excitations interval determination.....	74
Figure 4.13 Identified force vector for triple impacts divided into predefined groups.....	75
Figure 4.14 The results of triple impact force identification .....	75
Figure 4.16 Predefined possible load position in the experiment model.....	77
Figure 4.17 Experimental results of single impact force identification at location S4.....	78
Figure 4.18 Experimental results of double impact force identification .....	79
Figure 5.1 Simply supported beam subjected to equivalent nodal force transferred from one moving force .....	82
Figure 5.2 Equivalent nodal force features .....	84
Figure 5.3 Identified equivalent loads .....	88

Figure 5.4 Identified moving force .....	90
Figure 5.5 Identified moving force under different number of equivalent loads.....	92
Figure 5.6 Identified moving force via different number of equivalent loads.....	93
Figure 6.1 UIPM slip displacement sensor .....	96
Figure 6.2 Schematic of slip sensor .....	96
Figure 6.3 Calibration apparatus.....	98
Figure 6.4 Sensor no. 1 calibration between relative displacement (slip) and voltage.....	98
Figure 6.5 Experimental bridge model .....	99
Figure 6.6 Bridge subjected to loads.....	100
Figure 6.7: The interlayer slip of composite beam without damage under loading .....	101
Figure 6.8. Finite element model .....	102
Figure 6.9 Interlayer slippage from finite element and experimental results .....	103
Figure 6.10 Results comparison in Case0, Case1,Case2 and Case3.....	104
Figure 6.11 Slippage comparison in Case0, Case1,Case2 and Case3 .....	105
Figure 6.12 Slippage divergence comparison in Case1, Case2 and Case3.....	106
Figure 6.13 Results comparison in Case0, Case4, Case5 and Case6.....	106
Figure 6.14 Slippage comparison in Case0, Case4, Case5 and Case6 .....	108
Figure 6.15 Slippage divergence comparison in Case4, Case5 and Case6.....	108
Figure 6.16 Results comparison in Case0, Case7,Case1,Case8 and Case9.....	109
Figure 7.1 The real cable-stayed bridge.....	112
Figure 7.2 Schematic view of the cable-stayed bridge .....	112
Figure 7.3 The cable-stayed bridge calculation diagram .....	114
Figure 7.4 The flow chart of cable damage identification of cable-stayed bridge .....	120
Figure 7.5 Illustration of the accelerometer sensor locations (A1:A24) on the cross girders (CGs) .....	122

Figure 7.6 Illustration of the strain gauges array .....	123
Figure 7.7 Illustration of 600 seconds response.....	123
Figure 7.8 The FEM of the cable-stayed bridge .....	124
Figure 7.9 The cross girder CG8 details .....	125
Figure 7.10 The 1st mode shape: (a) identified from test; (b) obtained from FEM .....	126
Figure 7.11 The first five mode shapes of the cable-stayed FEM .....	127
Figure 7.12 The test vehicle.....	127
Figure 7.13 The vehicle load on the FEM of the cable-stayed bridge.....	127
Figure 7.14 The measured strain response (black line) and the FEM strain response (red line) .....	127
Figure 7.15 Bending strain response under the cables 1-4 and cables 9-12, when the bridge is intact and the cable 4 damaged 30%.....	129
Figure 7.16 Bending strain response under the cables 1-4 and cables 9-12, when the bridge is intact and the cable 8 damaged 30%.....	129
Figure 7.17 The damage identification indexes poly line diagrams when the cables 1-8 cross sections are reduced 30%.....	130
Figure 7.18 The corresponding damage identification indexes poly line diagrams which are calculated by symmetry .....	131
Figure 7.19 The damage identification indexes poly line diagrams when the cable 4 cross section is reduced 10%, 20% and 30% .....	132
Figure 7.20 The identified damage cables and the actual damage cable .....	135
Figure 7.21 The comparison between the actual damage cable and the identified damage cable with different noise levels.....	135
Figure 7.22 The comparison between the actual damage degrees and the identified damage degrees of DDI.....	137

Figure 7.23 The comparison between the actual damage degrees and the identified damage degrees with different noise levels..... 137

Figure 7.24 The flow chart of calculate training datasets for double damage..... 139

Figure 7.25 The flow chart of calculate training datasets for double damage cables ..... 140

# List of Tables

Table 3.1 Predefined possible force locations .....	41
Table 3.2 Identified errors using different regularisation methods.....	43
Table 3.3 Identification accuracy index RE and PRE results .....	47
Table 3.4 Comparison of modal frequencies from the experiment testing and the updated FE model.....	51
Table 4.1 Predefined possible force locations .....	64
Table 4.2 The LOC values with different sizes of submatrices.....	67
Table 4.3 The RE and PRE values with different sizes of submatrices.....	67
Table 4.4 Localization index LOC results under different noise levels .....	70
Table 4.5 Identification accuracy index RE and PRE results under different noise levels .....	70
Table 4.6 Localization index LOC results for different number of impact force .....	76
Table 4.7 Identification accuracy index RE and PRE results for different number of impact force .....	76
Table 5.1 Cases for moving force identification.....	86
Table 5.2 Identification accuracy index RE (%) for each equivalent load .....	90
Table 5.3 Identification accuracy index GRE and MRE results under different number of sensors.....	91
Table 5.4 Identification accuracy index GRE and MRE results under different number of equivalent loads .....	92
Table 7.1 Frequencies from the finite element model and filed measurements .....	126
Table 7.2 The hypothetical damage scenarios .....	134
Table 7.3 The identified damage degrees of DDI.....	136
Table 7.4 The damage identified degrees error with different noise levels (unit: %) .....	137
Table 7.5 The hypothetical damage scenarios of double damage cables .....	140

Table 7.6 The double damage cables identification results .....	141
Table 7.7 The double damage cables damage degree identification results of damage scenarios .....	142

# Abstract

Load identification and structural damage detection are two important research areas in bridge structural health monitoring (SHM). In practice, the incomplete measurement information, variable service environments and other uncertainties make the structural load and damage identification difficult. Currently, many identification methods for load identification and bridge structural damage detection cannot effectively serve under operating conditions. Hence how to use the SHM data to accurately estimate the loads and evaluate the structural damage of the bridge has been a hot topic for researchers and engineers in the world. This study will focus on these two areas including the following contents.

Regarding the load identification, a truncated transfer matrix-based regularisation method is proposed for impact force identification. This method includes two steps. The first step is the force location identification. Once the location is determined, the transfer matrix for the force value identification could be constructed, then the force value identification could be conducted in the second step. To improve the impact force localization and value identification method, a low rank transfer submatrix-based group sparse regularisation method is proposed to localise and reconstruct the impact force simultaneously. The low rank transfer submatrix-based group sparse regularisation method is to construct a structured regularisation on the unknown forces, by binding the unknown amplitudes associated with different potential locations into separate groups and promoting the group-level sparsity among the potential locations. Similarly, the group sparse feature also exists in the equivalent nodal force which is transferred from the moving force. Based on this feature, a group weighted Tikhonov regularisation method is proposed for the moving force identification via the equivalent nodal force. These proposed methods for load identification are validated numerically and experimentally.



In terms of structural damage detection, a new interface slip monitoring system based on Ultra-flat Industrial Potentiometer Membrane (UIPM) sensor has been developed to directly measure the relative displacement between the concrete slab and steel girder and the integrity of the shear connectors has been assessed by the slip measurements. The finite element model has been developed to study the interface damage detection of the steel-concrete composite structure under the pseudo moving vehicular load. The results show that the slippage divergence ratio is very sensitive to the shear connector damage, which is a potential indicator for the damage of the shear connection system.

In practice, the cable force of the cable-stayed bridge is difficult to be monitored for its damage detection. Based on the relationship between the cable force and the strain of the bridge deck, a new method is proposed for the localization and servility identification of cable damage using the strain measurements on the bridge deck. Here the damage cable identification problem is treated as a multi-classification problem and the damage degree identification problem as a nonlinear regression problem using support vector machine. The results show that the proposed method has a strong anti-noise performance and can be easily adapted to the health monitoring system in the field.