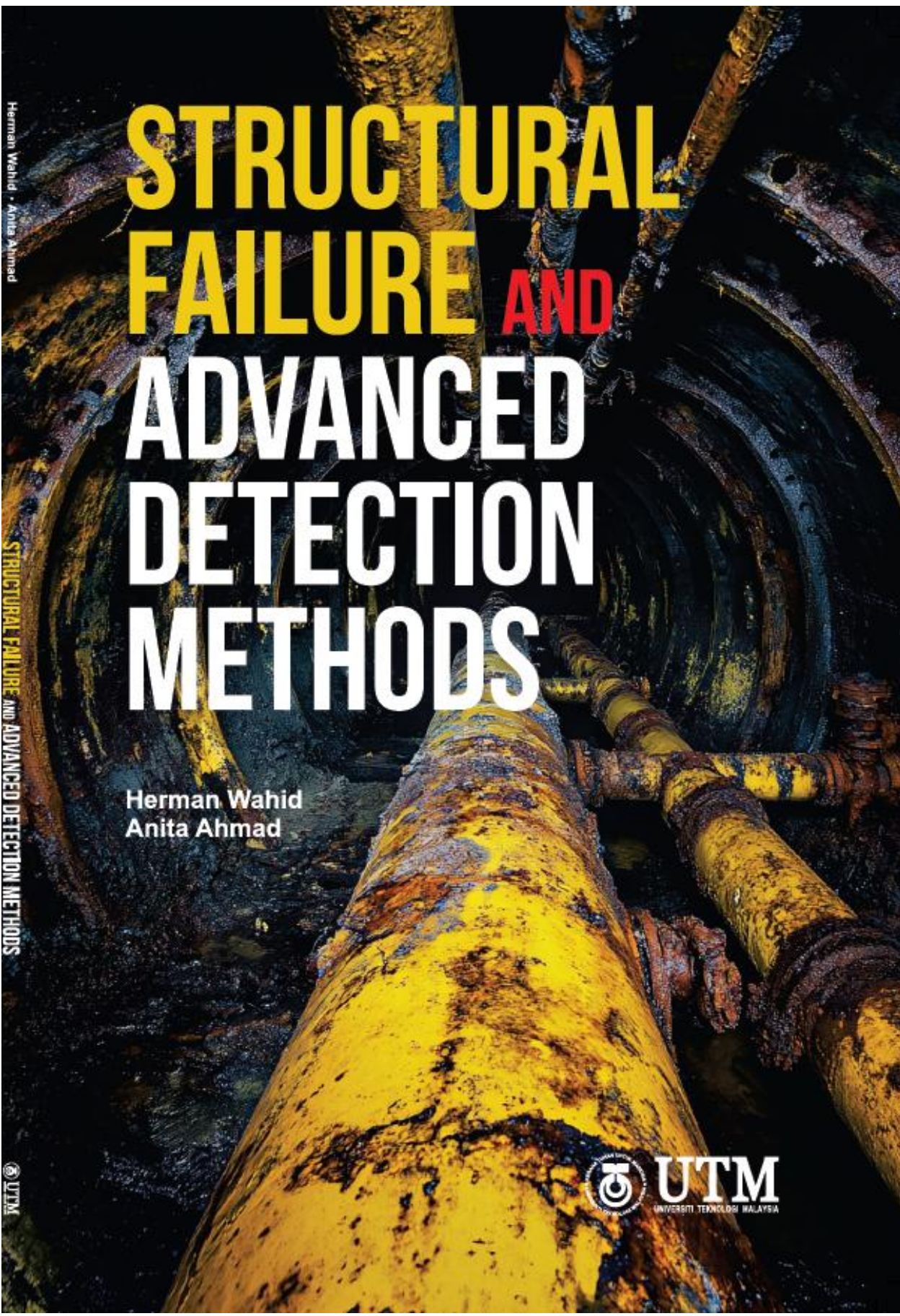

STRUCTURAL
FAILURE AND
ADVANCED
DETECTION
METHODS
Herman Wahid
Anita Ahmad
UTM
UNIVERSITI TEKNOLOGI MALAYSIA
Herman Wahid · Anita Ahmad
STRUCTURAL FAILURE AND ADVANCED DETECTION METHODS
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STRUCTURAL FAILURE AND ADVANCED DETECTION METHODS

In a world where aging infrastructure threatens safety and sustainability, *Structural Failure and Advanced Detection Methods* unveil cutting-edge technologies revolutionizing how we safeguard our built environment. This groundbreaking book explores the invisible cracks, hidden voids, and silent corrosion that compromise bridges, buildings, and pipelines—flaws that, if undetected, can lead to catastrophic failures. From artificial intelligence (AI)-driven crack detection to robotic pipeline inspectors and advanced photoacoustic imaging, each chapter delves into innovative non-destructive testing (NDT) methods that blend engineering precision with futuristic innovation. Written by leading experts, this essential guide bridges academia and industry, offering engineers, researchers, and policymakers' actionable insights to prevent disasters before they strike. Whether you're diagnosing a crumbling bridge or securing a gas pipeline, *Structural Failure and Advanced Detection Methods* equips you with the tools to protect lives, preserve infrastructure, and pioneer the next era of structural health monitoring. The future of safety starts here.

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PREFACE

This book was written by leading experts to bridge the gap between cutting-edge academic research and real-world industrial application. The primary purpose of this book is to maintain a strict focus on actionable methodologies rather than theoretical deep dives, equipping engineering professionals with the knowledge to identify hidden flaws before they escalate into catastrophes. By providing practical insights into advanced non-destructive testing systems, this book aims to make structural monitoring smarter, more accessible, and highly effective. Ultimately, this text serves as both a practical guide and a call to action to protect lives, preserve vital civil infrastructure, optimise maintenance expenditures, and pioneer the next era of structural health monitoring.

The background of this book lies in the constant wear and tear of natural elements on aging infrastructure, where critical systems like buildings, bridges, and pipelines face degradation that compromises public safety. Hidden structural anomalies such as invisible cracks, air voids, internal corrosion, and silent leaks often develop deep beneath the surface and go entirely unnoticed by the naked eye. Recent history serves as a stark, tragic reminder of what happens when structural integrity is compromised, exemplified by catastrophic events like the Tacoma Narrows Bridge collapse in 1940, the Sampoong Department Store collapse in 1995, the Morandi Bridge failure in 2020, and the Champlain Towers South collapse in 2022. These events highlight a critical need to transition modern engineering toward advanced failure detection, positioning non-destructive testing (NDT) technologies as essential, life-saving tools. By allowing thorough internal assessments without causing further structural damage, modern NDT techniques

bridge the gap between academic innovation and field application to stop disasters before they strike.

The scope of this book covers a comprehensive spectrum of structural problems and the technological innovations revolutionising how we safeguard our built environment. It addresses common structural defects found in construction materials and pipelines, such as concrete voids, structural cracking, reinforcement metal corrosion, and hazardous gas leaks. To tackle these issues, the scope details traditional and emerging non-destructive modalities, including acoustic wave propagation, traditional ultrasonic testing, electrical resistivity tomography (ERT), and infrared thermography. Furthermore, the book encompasses futuristic automated technologies, exploring real-world applications of distributed gas sensor arrays, advanced robotic pipeline inspectors, and computer vision integrated with artificial intelligence (AI) and machine learning algorithms.

This book is an essential reference designed for a broad audience across both technical and management sectors. It is primarily tailored for civil and electrical engineers, infrastructure specialists, academic researchers, and students who require a blend of technical rigour and real-world case studies. Beyond technical practitioners, property owners, managers, and policymakers will find this book equally valuable. By explaining complex engineering concepts in accessible language, it empowers non-technical stakeholders to recognise early structural warning signs, understand expert assessments, and make well-informed decisions regarding maintenance priorities and safety regulations.

The book systematically guides readers through a logical, structured progression from foundational structural engineering principles to highly specialised, cutting-edge monitoring technologies across seven focused chapters. The journey begins in Chapter 1 by laying the essential groundwork regarding failure mechanisms such as material degradation, design flaws, and environmental impacts and introducing core NDT methodologies. The subsequent sections delve into advanced concrete assessment modalities, detailing innovative optical-acoustic hybrid imaging via photoacoustic tomography in Chapter 2 and the

subsurface physics of electrical resistivity tomography in Chapter 3. It then transitions into targeted, real-world structural systems by exploring portable gas leak detection sensors and networks in Chapter 4 followed by the mechanical and software integration of autonomous pipeline evaluation systems using the "FLEX-INSPECT" robotic crawler in Chapter 5. Finally, the text introduces modern artificial intelligence and machine learning paradigms to the field, outlining automated crack detection using Python and the YOLOv8 object recognition algorithm in Chapter 6 before concluding in Chapter 7 with quantitative concrete evaluation, signal processing amplification, and data-driven classification using machine learning decision trees.

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