PROCEEDINGS OF FLEXIBLE ANTI-COLLISION DEVICE USED FOR DEFENDING SHIP-BRIDGE COLLISION

防御船舶撞击桥梁的柔性防撞装置论文集

陈国虞　王礼立　杨黎明　陈明栋　倪步友等　著

上海科学技术文献出版社
Shanghai Scientific and Technological Literature Press

防御船舶撞击桥梁的柔性防撞装置论文集

Proceedings of Flexible Anti-collision Device Used for Defending Ship-Bridge Collision

CHEN Guoyu WANG Lili YANG Liming CHEN Mingdong NI Buyou etc.
陈国虞　王礼立　杨黎明　陈明栋　倪步友等

上海科学技术文献出版社
Shanghai Scientific and Technological Literature Press

图书在版编目（CIP）数据

防御船舶撞击桥梁的柔性防撞装置论文集 / 陈国虞等著．—上海：上海科学技术文献出版社，2015.11

ISBN 978-7-5439-6793-9

Ⅰ．①防… Ⅱ．①陈… Ⅲ．①桥梁工程—防撞—文集 Ⅳ．①U443.8-53

中国版本图书馆 CIP 数据核字（2015）第 187709 号

责任编辑：祝静怡　王茗斐
封面设计：许　菲

防御船舶撞击桥梁的柔性防撞装置论文集
陈国虞　王礼立　杨黎明　陈明栋　倪步友等　著
出版发行：上海科学技术文献出版社
地　　址：上海市长乐路 746 号
邮政编码：200040
经　　销：全国新华书店
印　　刷：上海市印刷七厂有限公司
开　　本：787×1092　1/16
印　　张：20.25
字　　数：467 000
版　　次：2015 年 11 月第 1 版　2015 年 11 月第 1 次印刷
书　　号：ISBN 978-7-5439-6793-9
定　　价：78.00 元
http://www.sstlp.com

序 言 1

我国桥梁防船撞装置的实践,确切地说应该是在建设黄石长江公路大桥时才开始的。由于该桥桥型采用了主跨245 m的五跨预应力混凝土连续刚构,设有双薄壁墩及群桩基础,桥位又处在$R=30\,000$ m的弯河道上,通行5 000 t的船只及驳船队,而当时规范采用的船撞力明显偏少,因此开展了防撞装置的研究,最终采用了以钢刚架为主,加护舷的浮式弹塑性耗能的防撞装置。

十几年后,在21世纪初建设湛江海湾大桥,要通行50 000 t船只。由于桥位处10 m等深线宽约800 m,只有解决50 000 t船只的防撞问题,才有可能选用主跨小于此宽度的较经济桥型方案。在设计投标方案比选中,由于采用了黏滞性防撞圈为主的柔性防撞装置方案,完善地解决了突出的防撞问题,使主跨480 m的双塔混合梁斜拉桥方案中标并建成。

这种柔性防撞装置经专家会议鉴定是世界首创。与过去的装置相比,标志着防撞装置已进入了新的一代:

从理念上,已由过去的单纯防止桥梁破坏,发展到"三不坏"的理念,即桥梁不坏,船只不坏,防撞装置不坏;

从措施上,采取了拨转船头,带走大部分动能,以及用耗能效果良好的多层黏滞性钢丝绳胶圈,大大减小了船舶撞击力;

从计算理论和方法上,依托宁波大学,采用冲击动力学、黏弹性的本构模型以及相应的有限元方法,引入了应力波和波阻抗的概念,并应用实测的钢丝绳胶圈参数,使计算更符合实际。为了证明计算理论和这种装置的有效性,还在宁波象山港大桥,由宁波高指、宁波大学和上海海洋钢结构研究所一起作了实船实桥的撞击试验,即用实船撞击装有柔性防撞装置的桥墩,取得了满意的结果。

在上述工作的基础上,上海海洋钢结构研究所还制定了《桥墩的船撞力计算及柔性防撞装置设计指南》的企业标准。

在柔性防撞装置的研究和建造中,陈国虞教授在桥梁防撞这一学科中,作出了重要的、开拓性的贡献。与有关大学与产业部门共同协作,不断探索、不断实践,为一系列桥梁设计和建造了柔性防撞装置,并总结提高,共同编写了《船撞桥及其防御》及《桥梁防撞理论和防撞装置设计》两本专著,并在杂志和国际国内专业会议上发表了大量有关论文。现

在又把这些论文经过优选精编，出版这本《防御船舶撞击桥梁的柔性防撞装置论文集》，内容丰富、翔实、全面。对于从事桥梁防撞的广大工程技术人员，这是一个大好消息，可以提供他们阅读、应用和钻研，也有利于桥梁防撞学科的进一步发展提高。

交通运输部公路科学研究院　研究员

2015 年 4 月 18 日

Preface 1

To be precise, the practice of the Chinese bridge anti-collision device began at when Huangshi Yangtze river highway bridge constructed. Since this bridge adopted the bridge-type of five spans prestressed concrete continuous rigid frame with 245 m mainspan, and the substructure adopted double-walled pier and group piles foundation, and also the bridge was at $R = 30\ 000$ m curved river. At that time, the builder required 5 000 t ship and barge train to go through, nerveless the ship crash force of the design specification was obviously lower. For this reason, the investigation of anti-collision device was carried out. Finally the floating elastic-plastic energy dissipation anti-collision device which was composed of steel frame and fender was used.

After ten years, construction of Zhanjiang bay bridge in the early 21st century, 50 000 t ship needed go through. If they wanted to choose the economic bridge scheme with mainspan of less than 800 m, they must solve the anti-collision problem of 50 000 t ship, because the bridge location in 10 m isobath was about 800 m wide. In the selection of the design bidding scheme, as the scheme of the flexible anti-collision device that was using viscosity steel wire rings would perfectly solve this problem, and finally this device helped the twin towers hybrid girder cable-stayed bridge with 480 m mainspan win the biding and construction.

The flexible anti-collision device via expert meeting appraisal was word's first. Compared with the past device, it marked the anti-collision device has entered a new generation:

In concept, it has developed the anti-collision concept from purely preventing bridge damage in the past to ' three-uninjured ', that is bridge uninjured, ship uninjured and anti-collision device uninjured.

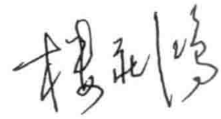
In measurement, it employs v-shape to change the bow's direction and brings lots of kinetic energy. It also uses the high energy absorption element of layers viscosity steel wire rings to greatly reduce the impact force of the ship.

In computation theory and method, relying on the Ningbo University, it adopts impact dynamics, visco-elastic constitutive model and the corresponding finite element method, and introduces the concept of stress wave and the wave impedance, and uses the test parameters of steel wire ring to agree the results.

In order to validate the calculation theory and the effectiveness of the device, they, Ningbo highway headquarters, Ningbo University and Shanghai Marine Steel & Structure Research

Institute (SMSSRI), did a real impact test between ship and bridge at Ningbo Xiangshan bay bridge, that is a ship crash with bridge added flexible anti-collision device. The test is with satisfactory results being attained.

On the basis of the above work, SMSSRI also set an enterprise standard of Impact force calculation for bridge and flexible anti-collision device design guide. In the research and construction of the flexible anti-collision device, Professor CHEN Guoyu has made an important and pioneering contribution in the area of anti-collision discipline for bridge. He Works together with the university and industry departments, continues to explore and practice. Flexible anti-collision device were designed and constructed for a series of bridge. He summarized and wrote two monographs of ship-bridge collision and its defense and Theory and design of crashworthy device against ship-bridge collision, and also published a large number of relevant papers in the magazine and the international/domestic professional meeting. Now he puts these papers through optimizing choreography and publishes this book Proceedings of Anti-collision device used for defending ship-bridge collision, this book is rich in content, detailed and comprehensive. This is big good news for general engineers who engage in bridge anti-collision areas. This book should be useful, therefore, as a textbook to read, apply and investigate. And it is also beneficial to the further development to improve bridge anti-collision discipline.



Researcher of Research Institute of Highway Ministry of Transport

2015 年 4 月 18 日

序 言 2

铁路的新建直接影响到国民经济的顺利发展,尤其是高速铁路建设已是当今国家的战略重点,铁路桥梁是铁路的重要组成部分。研究探讨我国铁路桥梁的发展历史及其经验教训,为从事铁路桥梁建设和养护工作者提供有益借鉴。原铁道部领导吕正操、刘建章、李颉伯等同志曾多次倡议编写中国铁路桥梁史。1980 年 4 月,铁道部和铁道兵联合组成了中国铁路桥梁史编辑委员会及其办公室。中国第一座长江大桥——武汉长江大桥的总设计师、第一届中国工程设计大师王序森先生和大桥局第一任局长彭敏同志为首席顾问等 66 位领导和专家组成的编辑委员会,于 1980 年 4 月—1987 年 10 月,历时 7 年多编辑出版的《中国铁路桥梁史》。其中的第五章:“中华人民共和国成立以来铁路桥梁重大灾害”第三节第四部分专论“船舶碰撞桥梁事故”。不仅详细介绍了我国通航河流上的铁路桥梁被船舶或漂流物碰撞造成灾害的事故情况和原因,并且特别提出了最早的:“漂浮式或固定式的缓冲装置,除具有吸收撞击的动能外,还有调整改变船舶的偏航方向和撞击速度的作用……”。向后人提示了既保护桥也能保护船的“双保护”的先进设计思想。然而我们一些铁路大桥建养部门,迄今自以为铁路桥梁桥墩的设计的安全系数较大,长江上的几座公铁两用大桥虽经多次碰撞,仍安然无恙,所以对船撞桥及其防御的问题不够重视。但“人无远虑,必有近忧”,事物必然会发展变化的规律是千万不能忽视的。我国在防灾、减灾、免灾的国策中,保护人的生命总是摆在第一位的,绝不能按西方用工程投资大小与人的生命价值的比值公式来考虑问题。而应从以人为本科学发展的观点来处理当今船撞桥及其防御的难题。就以笔者亲历参与修建的四座长江大桥,从 1959 年至 1984 年统计:共发生碰撞桥梁事故 62 次,其中武汉大桥 45 次,南京大桥 12 次,枝城大桥 3 次,九江大桥 2 次。62 次事故中,碰撞桥墩的占 60 次,碰撞钢梁的占 2 次。有的严重事故造成船沉、人亡、物损的惨状,令人目不忍睹。1986 年有代表向全国人大提出议案,要求解决船舶碰撞桥梁采取有效的措施问题。但始终未得到解决。从 1994 年起,以陈国虞先生等多位老专家,他们先后花了 8 年时间从调查研究和收集国内外的有关船撞桥及其防御措施的资料,进行了分析,坚持走中国自己的路,通过多学科的理论研究和力学论证并通过模型试验制造出黏滞性防撞圈。2001 年得到宁波大学王礼立副校长等多位教授负责仿真数值分析;2011 年由宁波高指牵头,杨黎明教授等在象山港进行了实船撞墩实验。使得理论分析、实验验证和数值计算等三种方法结合起来,共同创造了国际领先的柔性、吸

能、缓冲的“三不坏”防撞装置。这种装置设计思想的机理是非常先进的，利用黏弹性防撞元件抓住了刚柔相结合的技术关键，将发生的船舶冲击集中动能转化为分散的环带受力圈，因而使桥墩受到的水平力至少降低50 %以上，换言之，也就是使桥墩防撞的安全系数提高了一倍。无疑这种安全、实用、经济、耐久的先进装置已完成了桥梁界先辈们的期望，而且进一步将两保护（保护桥梁同时保护船的安全）飞跃发展成了三保护（防撞装置不坏）。现在荟萃了历年来多种期刊的精辟文章，汇编成这部《防御船舶撞击桥梁的柔性防撞装置论文集》，是一本难得的新书，无疑会对今后这方面工作的进一步创新和发展起到推波助澜、画龙点睛的作用。

原中铁大桥局资深高级工程师（教授级）、工程测量专家

Preface 2

New railway construction directly affects the smooth development of the national economy, especially the high-speed railway construction is today's national strategic focus, railway bridge is an important part of railway. Research on the development history of railway bridges in China and its experience and lessons, it is beneficial reference for railway bridge construction and maintenance workers. The former leaders of MOR, Mr Lu Zhengcao, Mr Liu Jianzhang and Mr LI Jiebo etc. had repeatedly initiative to write Chinese railway bridge history. In April 1980, the MOR and railway corps merged to form the editorial board and office of China railway bridge history. The editorial board was composed of Mr Wang Xusen, China's first Yangtze river bridge — Wuhan Yangtze river bridge's chief designer, the first Chinese engineering design masters, and Mr PENG Min, the first director of Major Bridge Bureau, and other 66 leaders and experts. Mr WANG Xusen and Mr Peng Min were the principal consultant. From April 1980 to October 1980, China railway bridge history was edited and published which was lasted more than seven years. There is a monograph "Ship-bridge collision accident" in the fourth part of the 3rd quarter of chapter 5 of this book. The monograph not only introduced the accident caused by the collision between ship/waif and railway bridge pier on navigable rivers in China in detail and its reason, but also specially put forward the earliest demand: "Floating or fixed buffer device, besides absorb the impact kinetic energy, and also adjusts to change the yaw's direction and the impact speed ...". This prompted posterity to adopt the "dual protection" advanced design thought which is both protecting bridge and protecting ship. But the bridge construction and maintenance department always ignored the problem of ship-bridge collision, they thought that the railway bridge had bigger safety factor, and that was an example such as some highway-railway bridge on the Yangtze river. There is a Chinese proverb "Those who do not plan for the future will find trouble at their doorstep", The rule of things change is never ignored. In the national policy of disaster prevention and mitigation, protecting life comes first always. Using a ratio between project investment and value of human life to consider problems is not advisable. We should be in human science development view to deal with the problems of ship-bridge collision its defense. Take the four Yangtze river bridges of author personally participate in building as examples, the statistics data was from 1959 to 1984: there were 62 times accidents, such as 45 times at Wuhan bridge, 12 times at Nanjing bridge, 3 times at Zhicheng bridge, 2 times at Jiujiang bridge. In the 62 times accidents, 60 times collision with pier, 2 times collision with steel grider. There were miserable situations of ship sank, died and thing damage. In 1986, a representative brought a bill that ask to solve the problem of ship-bridge collision to NPC, but this still hasn't been solved.

Since 1994, Mr. Chen Guoyu and many aged experts took 8 years to investigate and collect material about ship-bridge collision from domestically and internationally. And they insisted on Chinese method, enentually fabricated the visoelastic anti-collision element by multi-disciplinary theory and mechanics knowlege. In 2001, Mr. Wang Lili, Ningbo university vice President, and other professors were responsible for the numerical simulation analysis; In 2011, led by ningbo highway headquarters, Pro. Yang Liming did a full-scale impact experiment at Xiangshan bay. They put theoretical analysis, experiments and numerical calculation together to create an internationally advanced flexible, energy absorption, buffer "three-uninjured" anti-collision device. The mechanism of the device design idea is very advanced, visoelastic anti-collision element was the key technology of rigid and soft. This technology can reduce 50% of impact force by steel ring outside the bridge pier. In other words, that makes the safety factor of the bridge pier anticollision doubled. The device, integrated with safety, practical, economic and durable, has finished the expectation of predecessors engaged in bridge engineering. And further they devolop two protection (protect bridges and ship together) into three protection (anti-collision device doesn't damage). Now the insightful articles of variety journals were gathered together to assembly the book *Proceedings of Anti-collision device used for defending ship-bridge collision*. This is a rare new book, and will be sure to help the further innovation and development.

ZHU Haitao

Former experienced senior engineer and engineering survey specialist of
China Railway Major Bridge Bureau

前　言

“船撞桥及其防御”是一个新兴的、交叉性综合性的、工程力学应用小学科。1983 年在北欧由国际桥梁和结构工程协会(IABSE)指定了该学科的分委员会,该分委会参考美国联邦公路局的公路规范和有关指南、丹麦海峡大桥和日本本州-四国联络桥等具体工程实例,提出了该分委会的“综述与指南”,1991 年于列宁格勒召开的年会上定稿。中国的上海海洋钢结构研究所也组织出版了:《船撞桥及其防御》(中国铁道出版社,2006)和《桥梁防撞理论和防撞装置设计》(北京:人民交通出版社,2013)等两本专著。可以说,中、外都同期到了这个小学科蓬勃发展的时期。

现在,按照向航运界和桥梁界发送“三不坏”桥墩防撞装置的研究和工程进展资料的愿望,上海海洋钢结构研究所将其发表于各杂志的论文,依照论文性质分类汇印成册,在汇印时将图标和表头注上英文,便于更多的读者使用。原来发表的期刊和媒体,包括连续出版物:中国造船、中国水运、航海技术、航海科技动态、船舶工程、上海造船、广东造船、铁道标准设计、重庆交通大学学报、城市道路与防洪、桥梁、中国海洋产业海洋工程(国联资源直投媒体)、桥梁工程与技术(国联资源直投媒体)和海洋工程装备等;学会年会连续论文集包括:中国公路学会桥梁和结构工程分会全国桥梁学术会议论文集、中国土木工程学会桥梁及结构工程分会全国桥梁学术会议论文集、国际冲击工程学会论文集(ISIE Book of Proceedings)和国际自动化和工程控制会议论文集等;公开发行的单本论文集或专著有:科学中国人十年优秀论文选、应用力学进展(论文集)、桥梁船撞研究与工程应用(论文集)、船撞桥及其防御、桥梁防撞理论和防撞装置设计和国际船桥相撞及其防护学术研讨会论文集等;工程技术网站有:道客巴巴网www. doc88. com;豆丁网www. docin. com;中国桥梁网www. chinabridge. org. cn;桥梁工程与技术网www. bridge. ibicn. com;中国海洋产业海洋工程网www. coi. com. cn;共 29 家媒体。发表在不同的媒体是为了方便不同的读者群体,汇印在一起是为了使用者全面地了解这项技术的情况。

这本论文集从桥梁防船撞的要求、船对桥的撞击力、柔性防撞装置的设计等三方面展开论证,说明柔性防撞装置的必要性及可行性。通过冲击动力学理论、缓冲吸能元件实验和实船撞击实验等方法讨论该装置的科学性。同时采用数值分析的方法进一步验证防撞装置的设计方法及可行性。最后对设计中常见的具体问题进行解答,并对历史上、国内外一些防撞装置进行评价。使读者全面地了解该领域国内外的研究进展,深入系统地掌握

柔性防撞技术。

同时论文集体现了我国在桥梁防撞领域的若干进展,具体包括:

第一,着眼各类水域防撞问题,突破某些国家偏重于研究内河航运的局限性。我国现在于国、内外承建的桥梁,从上中游发展到下游、由内河走向港湾、由大陆通向离岸的岛屿、并且跨过海峡连接陆块、甚至承建洲际大桥。跨越航线的桥梁愈来愈多,桥下通过的船舶愈来愈大。所以我国防御船撞桥,一开始研究就不局限于内河。并指出从内河航运得来的结论,对我们有局限性,不适用。例如,驳船的情况,河渠化的航道,河道宽度在船长3倍以内的航速横向分布规律以及内河船与海船撞桥力估算的差别等。针对以上问题,我们都根据调查测定,作了具体分析,取代了曾经借用的外国假定。

第二,采用"应保尽保"及"三不坏"的先进设计理念。检阅了历年桥梁防撞研究的纪录,认为船撞桥的样本搜集比较少(与相邻的学科相比较,以及使用中由于样本少产生的误差等方面而言),因此使用"年撞塌概率"作为建与不建防撞装置的决定性指标,就不合适。提出了新的方法:"万一撞上也能保护桥梁、船舶和环境的安全"的原则。

第三、总结中外16种船撞力半经验公式。经过研究,指出他们都是同源的。由于在有了桥墩等设计图纸之后,可以用较精确的计算方法,所以半经验公式仅用在开始设计时对船撞力进行估算,在这个阶段对跨航线的桥梁决定桥型、桥跨和桥墩分布等都会有用。

第四、仿真分析与实船撞击试验。依托宁波大学引入通用有限元软件LS-DYNA辅助船撞桥问题研究及防撞装置的设计,并且使用材料动态受力变形时的性能指标(材料破坏临界值等),作为衡量构件失效的标准。我们专门设计实船撞墩试验,特别研制传感器系统,以测定力、变形、转角等的时程数值,检验软件程序的计算结果。

第五、充分利用桥梁自身抗力,节约资源。现行设计有一种倾向是不愿利用桥墩和桥梁其他构件的水平抗力,而要"御敌于国门之外"。换言之,只要间接式防撞装置,不愿设计直接式防撞装置。我们通过严谨的理论推导和实验验证,证明合理利用桥墩自身抗力进行防护装置设计是可行的,并且具有尺寸小,性价比高的特点。

第六、防御船撞桥的设计指南是给谁用的?现实往往和人们想的不一样,粗略一看防御船撞桥应该是桥梁设计的一部分,但是从上世纪80年代开始传入的文献看,研究防御船撞桥的人除了桥梁设计者之外,还有一部分力学家。而文献内容中大量引用船的资料。我国最先引进防御船撞桥文章的是桥梁专家,但1994年交通部科技司(委)将一项防撞装置任务下达给部属船舶运输研究所和交通院校。不久在桥梁界出现了一个意见:"研究船撞桥的人以船舶和水运工作者比较合适",于是在上海、重庆、黑龙江和武汉出现了一批船舶和水运专业的研究者;在宁波和重庆出现了研究力学和材料的研究者参加进来。现在形成的认识是:研究防御船撞桥必须结合船舶和桥梁两个方面的专业知识,研究的方法是工程力学的三种方法(理论分析、数值计算和实验验证)。因此设计指南应该是提供给

设计桥梁的人使用的。而桥梁设计和防御装置、设施设计的人,不可能从事很多船撞桥方面的理论研究和进行现场实验等工作,因此指南需要简单明了、可供桥梁设计者使用。

在本书中,以上几点是新论,是骨架,专业人士只要阅读这些内容就可以了。但是为了更多的人认识“防御船撞桥”,文章中就写进很多科普性的介绍和系统性的内容。对于青年学生和非本专业读者,是一本比较全面而有用的参考书。

执笔　陈国虞　英文翻译　赵振宇

2015 年 5 月 10 日

Foreword

"Ship-bridge collision and its defense" is a new, overlapping, comprehensive and small discipline of engineering mechanics. The subcommittee of this discipline was assigned by the international association of bridge and structural engineering (IABSE) at Northern Europe in 1983. The subcommittee raised "Review and Guide" referencing the guide of FHWA and anti-collision engineering of Denmark Strait bridge and Japan Honshu-Shikokurode contact bridge. And that book was finalized at the meeting of Leningrad in 1991. Shanghai Marine Steel and Structure Research Institute (SMSSRI), China, also published, *ship-bridge collision and its defense*, (China railway publishing house, Beijing, 2006), and *Theory and design of crashworthy device against ship-bridge collision*, (People's traffic press, Beijing, 2013). That is to say, we enter the booming period of the small subject at the same time.

Now, According to wish of sending research progress of "three-uninjured" anti-collision device to shipping interests and bridge interests. SMSSRI published the paper that was published at various magazines by paper properties classification. In order to facilitate more readers to use, figures and table title were translated to English. The 14 journals and media, including continued publication, are, China Shipbuilding, China Water Transport, Marine Technical, Marine Technical News & Trends, Shipping Engineer, Shanghai Shipbuilding, Guangdong Shipbuilding, Railway Standard Design, Journal of Chongqing Jiaotong University, Urban Roads Bridges & Flood Control, Bridge, China's Marine Industry and Marine engineering (direct investment media resources), Bridge engineering and technology (direct investment media resources), Marine engineering equipment and so on. Conference proceedings including continuously, Proceedings of Bridge Conference of Bridge and Structure subcommittee of China Highway and Transportation Society, Proceedings of Bridge Conference of Bridge and Structure subcommittee of China Civil Engineering Society, ISIE Book of Proceedings and Proceedings of Conference of International automation and engineering control. Single proceedings and books of public offering, the excellent paper anthology of *Scientific Chinese* in the past ten years, Advances in Applied Mechanics, research on ship-bridge collision and its engineering application, ship-bridge collision and its defense, Theory and design of crashworthy device against ship-bridge collision, Proceedings of International Symposium on Ship-Bridge Collision and Its Protection. 5 engineering websites, www. doc88. com, www. docin. com, www. chinabridge. org. cn, www. bridge. ibicn. com, www. coi. com. cn. There are 29 media agencies in all. Publishing in different media is for the convenience of different reader groups, printing together is for users to fully understand the situation of this technology.

The demand of ship-bridge collision, the impact force between ship and bridge and the design of anti-collision device were discussed in this book, and that indicates the necessity and feasibility of flexible anti-collision device. Scientificity of this device was proved by the theory of impact dynamics, experiments of buffer energy-absorption element and full-scale test. The design method and feasibility were further verified by numerical analysis. At last, we answered some question about ship-bridge collision technology, appraised some other devices at home and abroad in history. Give readers a comprehensive understanding of the field research progress both at home and abroad, systematically master flexible anti-collision technology deeply.

While this book embodies some progress in the field of bridge anti-collision in our country, specific include:

First, collision problem with all kinds of waters, the breakthrough in some countries those focus on research limitations of inland waterway transport. Now in our country the bridges construction of domestic and international are from the upper and middle reaches to downstream, from inland to harbor, from mainland to the offshore islands and across the strait connecting landmass, even intercontinental bridge construction. The more bridges across lane, the bigger ships which go under bridge. So the study on defending collision in our country is not limited with inland waterway. And points out that the conclusion from the inland waterway transport, we have limitations, do not apply. For example, the condition of the barge, the speed transverse distribution in watercourse which has 3 times length of ship width and the difference impact force between inland vessel and seagoing vessel. To solve above problems, we are all according to the survey, made a concrete analysis, replaced the foreign assumption that we used ago.

Second, the advanced design concept of "must be where should be" and "three-uninjured". We surveyed the record of bridge anti-collision research for many years, and we deemed that the sample was less than that in other disciplines. So the probability of collapse per year is not suitable to do the qualitative index of choosing anti-collision device. We put forward a new concept that is, "the safety of ship, bridge and environment should be protected in the collision."

Third, 16 empirical formulas of impact force were summarized. We pointed out they are isogeny after we studied. As the exact calculating method is used after design, so empirical formula is used to estimate the impact force before design. In the period, impact force is useful for choosing bridge type, bridge spans and the distribution of bridge pier.

Forth, simulation analysis and full-scale experiment. The finite element software LS-DYNA was firstly used to assist ship-bridge collision research and design of anti-collision device supporting by Ningbo University. And we used the performance parameters (such as damage threshold) of material's dynamic deformation to measure component failure. Full-scale experiment was being designed, in specialty; sensor system was being developed to measure the history data of force, deformation and angle of rotation. Result by software was validated by experiment.

Fifth, make full use of the bridge itself resistance, save resources. There is a trend of device design that doesn't use the resistance of bridge itself. In other words, they only choose the indirect type device, don't choose direct type. We demonstrated that making full use of the bridge itself resistance to design device was feasibility by rigorous theoretical derivation and experimental verification, and the device had the characteristics of small-size and high cost performance.

Sixth, who will use this guide? Reality often is not the same as people think, at first glance, defending ship-bridge collision is part of bridge design, nevertheless, Judging from the literature of beginning in the 1980s, there were also mechanical who researched on it. And a lot of ship information reference was in literature content. In our country, who introduced firstly the article of defending collision was bridge expert, but a mission of anti-collision device was being given to shipping research institute and traffic colleges. In the near future, an opinion was appeared in bridge interests, "people who research on ship-bridge collision are better with ship and water transport workers". So there are some researchers major in shipping and water transport in Shanghai, Chongqing, Heilongjiang and Wuhan. There are some researchers major in mechanics and material in Ningbo and Chongqing. Now the formation understanding is that people who research on ship-bridge collision must have ship and bridge professional knowledge at the same time, and use the study method of theoretical analysis, numerical calculation and experimental verification. So the design guide should be provided to people who design bridges. But these people have little knowledge of ship-bridge collision and full-scale experiment, so the guide should be simple to bridge designer.

In the book, above is new and skeleton, professionals just read the content. But in order to let more people to know ship-bridge collision, the science popularization introduction and the content of systemic are been written. It is a more comprehensive and useful reference book for young students and non-professional reader.

When the proceedings were collected, PhD student ZHAO Zhenyu of XJTU was in charge of sorting and supplements translation, and Pro. CHEN Guoyu revised.

Actual writing: CHEN Guoyu; English Translation: ZHAO Zhenyu

2015 - 05 - 10