茅以升科技文选

——纪念茅以升先生诞辰100周年

《茅以升科技文选》编辑委员会　编

中　国　铁　道　出　版　社

1995年·北京

力学及基础工程协会，对这一学科在我国的发展起了巨大的推动作用。

四、工程教育　茅老对于工程教育，主张制度改革，如“习而后学”，持论独辟蹊径，成一家之言。解放后，鉴于新中国经济发展迅猛，而生产各层次的文化技术水平，相对落后，曾对业余教育、半工半读等教学方法，提出不少建议，具见于《茅以升文集》（科学普及出版社 1984 年 2 月第一版）中。又多年来大力普及科学，指导青少年爱科学、学科学的社会性活动，属望之殷，溢于言表，可与本文集选文四篇，互相参证。

五、科学研究　茅老主持铁道科学研究院工作逾 30 年，是新中国铁道科学研究事业的创业人之一，深受广大科技工作者的爱戴。本文所收专题五篇，具有总结性特点，当为关心我国铁道科研事业者所乐闻。

六、科学技术史　这部分多为 60 年代作品。古代桥梁技术史这一新课题，属于茅老晚年著述。他受到同学兼挚友李俨、罗英两位先生的影响。这两位一是由铁路工程而转入古代科技史的研究；一是由兴建公路而进入古代石桥的探讨。彼时英国李约瑟教授撰写的中国科技史传入国内，影响颇大。茅老认为中国应有自己撰写的桥梁史，遂与建筑学家梁思成教授联名倡议，受到有关部门的重视和支持，在科学总结祖国几千年桥梁技术成就的基础上，完成了《中国古桥技术史》一书。这一时期，茅老研读了大量古籍文献，还写了不少有关古代桥梁的文章，提倡保管好古文物，以便鉴古知今，古为今用。

本世纪后期，新兴科学发展迅猛，技术日新月异。我国老一辈科学工作者所展现的精勤不懈、孜孜不倦的治学精神，正激励后学继武前进。作为本世纪初处于积弱落后的旧中国负笈求学的老一代留学生，自律之严，立志之坚，不负历史使命，不愧为新中国建设大军之先驱者。今天我们重理遗著，如对严师，景仰之情，不已于怀。谨赘数语，以就正于海内外读者。

《茅以升科技文选》编辑委员会

1995 年 5 月 1 日于北京

（京）新登字 063 号

内 容 简 介

为纪念茅以升先生诞辰 100 周年，《茅以升科技文选》编辑委员会历时数载编成本书。

本文选主要包括：学位论文、桥梁工程、土力学及基础工程、工程教育、科学研究、科学技术史、其他及附录，反映了茅以升先生为了祖国的繁荣昌盛和科学技术的发展，耕耘一生、奉献一生的概要。

读者对象：海内外学者，科学技术和文化教育工作者，高等院校师生。

茅以升科技文选
——纪念茅以升先生诞辰 100 周年
《茅以升科技文选》编辑委员会　编
*
中国铁道出版社出版发行
（北京市东单三条 14 号）
责任编辑　刘启山　封面设计　赵敬宇
北京市燕山联营印刷厂印刷

开本：787×1092 毫米 1/16　印张：23.75　彩插：10　字数：351 千字
1995 年 12 月　第 1 版　第 1 次印刷
印数：1—1000 册

ISBN7-113-02159-X/G・49　定价：100 元

《茅以升科技文选》
编辑委员会及编辑组成员名单

一、编辑委员会

主任委员：张　维

副主任委员：黄文熙　程庆国　曾　威

委　员：万明坤　王序森　卢肇钧　许宏儒
刘曾达　沈大元　何广乾　张　维
张　琳　林秉南　周　镜　钱冬生
姚明初　唐寰澄　黄文熙　黄　棠
程庆国　曾　威　潘际炎　戴　竞

二、编 辑 组

组　长：刘启山

成　员：王能远　许宏儒　茅玉麟　郑淑涓　强士中　程季青

（均以姓氏笔画为序）

序

1996年1月，欣逢茅以升先生百年诞辰。茅老是本世纪著名的桥梁专家、工程教育家、社会活动家。有关人士合议辑成《茅以升科技文选》，要我为这本富有纪念意义、印刷精美的文集写篇序文，我与茅老共事久，相知深，又同属老一辈科学工作者，感到义不容辞。

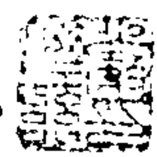
20世纪是近代史上极不平凡的100年。在“四海翻腾云水怒，五洲震荡风雷激”的翻天覆地的时代里，作为积弱落后中国的爱国青年、知识分子，为了奋发图强，走自己成功的道路，是很不容易的。

20世纪初期，我们这一代人正面临着时代更新，思想更新，知识更新的一系列新课题。20年代前后，是我国负笈学子，远涉重洋，学成归国，受到重视的年代。茅老于1920年在美国获得工学博士学位，并在美国桥梁公司进行实习，由他的母校交通大学唐山工学院聘为教授。从此，历任东南、河海、北洋大学教席14年，又成功地主持建成了钱塘江大桥，有名于世。经过8年抗日战火的洗礼，明辨向背，在上海迎接解放，步入了为人民服务的实践与考验。直至90高龄，以坚定的步伐，不倦的努力，不负初衷，无愧衾影，不愧为进步知识分子的楷模。从这一角度出发，理解茅老的一生和发生的作用，对当代我们的同行——广大的科学工作者说来，是十分有意义的。

回忆新中国建立后，当时我们的科学、工程、教育队伍，人单力薄，确是一场严峻的考验。我们都是这一实践中的亲身经历者，都经

过一段由困惑到理解，从不自如到完全适应的过程；而茅老在这一过程中，也是一个达到满分者。他原与铁道系统渊源较深，尤其是在桥梁工程方面，培育了有用人才，但他所承担的任务，远远不限于此。40年来，他在科研、科普、对外交流、宣传新中国建设的巨大成就等方面取得了丰硕成果，足涉亚、欧、美三洲。尤其是耄耋之年，一再向国外华裔知识界人士，提出报国有门的热望。这一系列的辛勤劳动以及所发生的影响，在老一辈科学工作者的行列中，也是相当突出的，因而受到当代学者的景仰与怀念，是可以理解的。

人生百年，自强不息，其流风遗韵，是值得珍视的。茅老知交遍宇内，这册纪念文集，好似一叶扬帆的小舟，驶入科技知识界的广阔水域，希望能得到科技知识界的喜爱。我在这篇短短的序文里，希望能将我所了解的茅老一生介绍给后之来者，以表达我个人的怀念与追思，并就正于读者。

嚴濟慈 

1995 年 4 月写于北京

前　言

我国著名科学家、工程教育家茅以升先生自幼年目睹国事日非、外侮日深、慨然发愤读书，欲与有志之士，共求救国之策。逮学成归国，投身教育、建设事业，不遑宁处。新中国建立，喜国威日隆，凡有倚任，胥皆尽心力以赴之。年登耄耋，老不知倦，为我国经济建设与发展，科技繁荣与进步，贡献了毕生精力；体现了老一辈科学家爱祖国、爱人民的高尚品德，以及献身、求实、创新、协作的科学精神，受到国内外科技知识界广大人士的一致推重。1996年1月9日为茅老百年诞辰，有关人士合议编辑《茅以升科技文选》以资纪念。

茅老著作甚丰，晚年曾将生平著述，亲自整理。除专著五种外，历年发表于国内外报刊上的文章，已由有关出版社出版了三种文集，国内多有流传。

本文选以介绍茅老学术思想和建树业绩为主，按其内容分为七部分，选收了茅老在各时期的有关论述，使读者得以窥见其治学治事之风范和毕生的追求与贡献。

一、学位论文　这里选收了茅老的硕士及博士论文部分内容，由西南交通大学钱冬生教授根据原文节录而成。

二、桥梁工程　这里选收了茅老亲自主持设计、施工的钱塘江桥工程纪要及有关文献。他将现代科学理论与我国悠久文化融汇贯通于胸中，提出了有中国特色的精辟论点。当谈到中国的土木工程、建筑工程和水利工程时，以万里长城、南北大运河、赵州桥、都江堰等为例，有力地指出“……这些工程，有的规模庞大，有的结构奇巧，不但施工组织和材料工具都不简单，即从设计能力来说，也确是惊人的。可以说：中国历史上有过不少土水、建筑、水利工程其设计和施工是具有科学性的。”这一论点与当代英国著名学者李约瑟对中国古代科技的评价不谋而合。早在解放前夕，茅老曾有感而言：“今之谈工程者往往侈谈欧美巨构，认为建设新中国，非将新式工程整个移植不可，与误认为科学之为纯粹西方物产者，其错误正复相同。”正是这种实事求是的唯物史观以及爱国主义和民族自豪感，贯串于茅老一生的言行中。

三、土力学及基础工程　土力学是30年代新兴的学科之一，茅老洞察这一新学科对我国工程建设的重要性，给予大力支持。本文集所选三篇论文是他对土力学的早期研究工作。1957年茅老在北京创建了我国土力学及基础工程学术委员会，促进了全国土力学工作者的学术交流与发展提高，并代表我国参加了国际土

目　　录

（封面照片为莫敌同志提供）

一、学位论文

硕士论文《The Design of a Two-hinged Spandrel-braced Arch bridge with an Investigation of its Secondary Stresses》节选（1917）

THE DESIGN OF A
TWO-HINGED SPANDREL-BRACED ARCH BRIDGE
WITH AN INVESTIGATION OF ITS
SECONDARY STRESSES

THESIS

Presented to the
Faculty of the Graduate School
Cornell University
for the degree of
Master of Civil Engineering

BY

THOMSON MAO

Associate of the Tanshan Engineering College

June，1917。

THE DESIGN OF A TWO-HINGED SPANDREL-BRACED ARCH BRIDGE WITH AN INVESTIGATION OF ITS SECONDARY STRESSES

PREFACE

The object of the present thesis, as the title indicates, is to design a double-track railway arch bridge of the Two-hinged Spandrel-braced type. While the main part of the work is to give numerical computations and designs of the arch under consideration, equal effort is given to the theory and principles which control the design, and of the same time special attention has been paid to those things which affect the adaptability and utility of the arch. It is the aim of the writer to give critical study to the relative merits of arches and other kinds of bridges having equal chances of adoption; between two-hinged and three-hinged arches ; between spandrel-braced trusses and arch ribs either with solid or open webbing; and finally between two-hinged spandrel-braced arches with and without cantilever arms. The study is not complete on account of the limited time available, but it disposes the facts and conclusions arrived at in a straightforward manner.

To obtain rigidity in a two-hinged arch and to do away with the uncertainty of stress distribution after erection, an expedient is resorted to which makes the arch a comhination type, so called because it possesses the advantages of both two-and three-hinged arches. The arrangement is such that the dead lood stresses follow the law of the three-hinged arch while those due to live load, impact, wind, temperature and braking forces are controlled by the theory of the two-hinged arch.

Much has been said relating to the strength and stiffness of two and three-hinged arches, both in engineering literature and theses of graduate students in the College of Civil Engineering of Cornell University. As the amount of investigation has been large it seems advisable to collect all the conclusions and results obtained so that it may be in good sbape for immediate reference. The present thesis does this summarising in a very brief form but nothing of importance has been lost sight of.

Perhaps none of the works mentioned above have touched the problem of secondary stresses in arches. It might be interesting to see how these stresses act in arches of the two-hinged, spandrel-braced type and how they affect the design. For this reason about thirty per cent of the present work has been devoted to the calculations of these stresses and to conclusions drawn therefrom. This is a painstaking task as the span is long and influence lines are to be constructed.

As the greater part of the work in calculating stresses in two-hinged arches is required to find the horizontal component of the reaction, a portion of the following pages will be directed to the various methods used in the past, both analytic and graphic, exact and approximate. The relative merits of each will be discussed and the best ones adopted.

The principal dimensions of the arch are proportioned to conform to the best modern practice with respect to aesthetic and economic effects. Since the only argument against the appearance of spandrel-braced arches has been its abrupt termination with a shallow approach span, the present arch will have two cantilever arms supporting two approach simple spans trussed like a portion of the arch.

In regard to the design and detailing of the arch, it may suffice to say that it has been done with great care to follow the most modern practice. Specifications of American Railway Engineering Association were adopted.

In preparation for the writing of this thesis a vast amount of material has been collected from books, theses and journals. Instead of giving the references separately, each will appear where it is used. Things that are common to all books will not be referenced because only features which differ materially from others merit a reference to its source so that the original article may be consulted for further study.

Attention is called to the following schemes which were developed hy the writer: Approximate method of constructing the influence line for horizontal thrust (p. 90); dead load stresses for unequal panel loads (p. 119); method of increasing the accuracy of displacement diagrams (p. 157); and finally the arrangement of table for the solution of equations in calculating secondary stresses (p. 432).

In conclusion the writer wishes to express his indebtedness to Professor H. S. Jacoby under whose directions the present work is undertaken.

CONTENTS

第一章部分内容：

PART I. INTRODUCTORY CHAPTERS

CHAPTER I. HISTORICAL NOTES

Masonry arch is one of the oldest types of extant bridges and was probably originated in China.① Through gradual changes in the art of bridge building and to meet the demand of heavy structures for railway traffic, metallic arches of solid rib type were invented, the first cast iron arch being built at Coalbrookdale, England in 1776.② In 1867 there appeared a foot bridge over the Bollat Fall at Hohenschwangan, which was the first arch of the spandrel-braced type.②

Perhaps the oldest two- hinged spandrel- braced arch is in America, the one at Corondelet Park, St. Louis, built in 1887. The arch crossing Noce Schluct was built three years later, in 1890. In the year of 1897, the well known suspension bridge at Niagara Falls was replaced by Niagara Falls arch of 550 feet span, then the longest two- hinged spandrel- braced arch in the world. In the same year, Mill street bridge at Watertown, N. Y., was completed. Next on the list comes the one in Germany built in 1899 crossing the Rhine River. The arch of Maine St., Waterport, N. Y., was completed in 1900 and that of Costa Rica, in 1902. In the year of 1905, another monumental arch of the two-hinged spandrel-braced type was built in Africa, the Zambesi bridge crossing Victoria Falls. The first arch of the combination type was completed in the year of 1911, the bridge over Crooked River designed by Modjeski. The arch over St. John River, Canada, was built in 1914, which having a span of 565 feet is the longest two-hinged spandrel-braced arch in existence at the present time.

It is thus seen that the development of two-hinged spandrel-braced arches has been very rapid in recent years. This is partly due to the fact that this structure is the most favorite type among arches for railway traffic,③ and partly due to the recent perfection of the theory of statically indeterminate structures.

---

① A Treatise on Arches, Howe, p. 1.

② History of Bridge Engineering, Tyrrell, p. 309.

③ Modern Framed Structures, Part III., p. 10.

第二章部分内容：

CHAPTER II. GENERAL COMPARISON OF STEEL ARCHES

Whether an arch bridge is preferable to others has long been a question in engineering profession. Not only there are different opinions between arches and other kinds of bridges, desultory controversies have been kept in arches themselves, among which the problem of the number of hinges is the most serious one. And yet the question is not settled even with the number of hinges known, as for each kind of arch there are different types of trussing and webbing, solid or open, spandrel-braced or braced rib. Undoubtedly to go deep into this prohlem would be beyond the scope of this thesis , the writer will therefore suggest to give the discussion as hrief as possible although it might not be so short as to fail to point out the adaptability of the arch wbich is going to be designed.

Art. 1. Relative Merits Between Arches and other kinds of Bridges

Steel arches have a rational application only where Nature has provided natural abutments. [①] In other cases unless the erection difficulties be large, other kinds of bridges are generally preferable. It is only where there are deep gorges or shallow streams with rocky bottom that arches are economical, [②] although sometimes they are huilt for aesthetic purposes. Mr. Grimm[③] considers the arch to be the only type suitable for long spans. He points out the objections of other kinds of hridges as follows: Cantilever bridge is not rigid, great deflection occurs at joint of spans, while its advantage of erection is shared equally well by arches. Continuous bridge has uncertainty of stress distrihution due to yielding of support and high secondary stresses. Suspension bridge is influenced by temperature and yielding of anchorage, and further it is not economical.

Art. 2. Relative Merits Between Two-hinged and Three-hinged Arches

"Three-hinged arch is statically determinate while two-hinged arch is stiff" is an expression so well known tbat there is no slightest doubt. The advantages

① Engineering Record, Vol. 68, p. 321.

② Bridge Engineering, Waddell, p. 618.

③ Transactions of A. S. C. E. Vol. 71, p. 233.

of three-hinged arches are: simplicity of computation and adjustment; absence of temperature stresses and adaptability to places with limited headroom due to the shallow depth at the crown.[1] The advantages of two-hinged arches are stiff, rigidity and absence of kink at center which is objectionable for railway traffic. It must be acknowledged that the disadvantages of each are shared by the other, although not in the same extent. For instance, the yielding of supports affects greatly two-hinged arch, but it also affects three-hinged arch in a small extent[2], while the sagging of lower chord of three-hinged arch due to temperature changes is also noticeable.[3]

In regard to the stiffness of two-hinged and three-hinged arches, a general conclusion reached is that the deflection in the center of the three-, two-, and no hinged arches from a load at center is about as 6 to 2 to 1.[4] The following investigations are made by the graduate students of Cornell University:

(1) Two-hinged arch deflects more at quarter point but less at center than the three-hinged arch for loads near the center.[5]

(2) The influence lines for deflections have the same general form for the two arches, the maximum deflection of any panel point due to a single load occurs when the load is over that point. The loading which produces the maximum deflection is not the same as the loading which produces the maximum stress in any part of the members.[6]

(3) The distribution of deflection has been such that a sag will be formed in the two-hinged arch between the quarter point and the center while the three-hinged arch will give a more uniform grade.[7]

There has been no decisive conclusion arrived as to the relative weights of two- and three-hinged arches. The analysis of Mr. Hudson showed that two-hinged is lighter than three-hinged[8], while that of Mr. Davis showed two-hinged is heavier than the three-hinged arch.[9]

Another advantage in favor of two-hinged arches is found in the fact that the

---

① Design of Steel Bridges, Kunz, p. 347.
② Bridge Engineering, Waddell, p. 618.
③ Higher Structures, Merriman & Jacoby, p. 218.
④ Design of Steel Bridges, Kunz, p. 119.
⑤ Thesis No. 728, p. 67. Thesis No. 42, p. 59.
⑥ Thesis No. 42, p. 67.
⑦ Thesis No. 42, p. 68.
⑧ Transactions of A. S. C. E. Vol. 43, p. 30.
⑨ Thesis No. 59, p. 42.