高校土木工程专业规划教材
GAOXIAO TUMU GONGCHENG ZHUANYE GUIHUA JIAOCAI

木结构设计

Timber Engineering

何敏娟　Frank LAM　杨军　张盛东　编著

MUJIEGOUSHEJI

中国建筑工业出版社

高校土木工程专业规划教材

木结构设计

Timber Engineering

何敏娟　Frank LAM　杨军　张盛东　编著

中国建筑工业出版社

图书在版编目（CIP）数据

木结构设计/何敏娟等编著．—北京：中国建筑工业出版社，2008

高校土木工程专业规划教材

ISBN 978-7-112-09345-8

Ⅰ．木…　Ⅱ．何…　Ⅲ．木结构-结构设计-高等学校-教材　Ⅳ．TU366.204

中国版本图书馆 CIP 数据核字（2008）第 009022 号

本书涵盖了木结构设计的主要内容，对近年建造较多的轻型木结构建筑进行了较为详细的介绍，内容符合现行《木结构设计规范》（2005 年版）GB 50005 的具体规定。本书共分 6 章，主要介绍了国内外木结构的发展状况、木结构中常用的结构用材和性能、木结构主要构件及连接的形式和计算方法、最为常用的两种木结构体系的基本设计方法以及木结构的防护等。

本书每章末均附有相关英文阅读文献，既让读者了解了一些北美现代木结构的知识，又满足了中国高校双语教学的发展需求，增加了学生原版专业资料的阅读量。

本书可作为土木工程等相关本科专业的教材，也可作为从事木结构设计、制作、安装等的工程技术人员学习的参考书。

* * *

责任编辑：吉万旺　王　梅

责任设计：赵明霞

责任校对：陈晶晶　安　东

高校土木工程专业规划教材

木结构设计

Timber Engineering

何敏娟　Frank LAM　杨军　张盛东　编著

*

中国建筑工业出版社出版、发行（北京西郊百万庄）

各地新华书店、建筑书店经销

北京密云红光制版公司制版

北京富生印刷厂印刷

*

开本：787×1092 毫米　1/16　印张：11　字数：268 千字

2008 年 3 月第一版　2008 年 3 月第一次印刷

印数：1—3000 册　定价：**20.00** 元

ISBN 978-7-112-09345-8

（16009）

前 言

木结构是中国最为传统的一种结构形式，远溯3500年前，就基本形成了榫卯、斗拱等中国传统的木结构体系。宋代《营造法式》从建筑、结构到施工全面系统地反映了中国古代木结构建筑的体系。中国拥有建成数百年甚至上千年的古代木结构，如建于公元1056年的应县木塔、建于公元857年的山西佛光寺大殿都历经战争、自然灾害而至今依然巍然屹立，充分展示了中国古代木结构高超的建造技术水平。解放初期，由于木结构建造容易而大量使用，致使结构用材过度砍伐；之后由于木材资源的缺乏，木材在建筑业中的使用受到限制。

近年来，由于中国林业技术的发展和国外进口结构木材的增多，现代木结构在我国又得以复苏。木材资源易于再生、绿色环保，木结构保温隔热、抗震性能好等优越性越来越被认识，木结构知识又受到了建筑设计、施工单位的关心，木结构教育也受到了高等教育的关注。同济大学自2003年起恢复了木结构课程教学，作为选修课向土木工程本科专业开设，几年来已有数百名本科生选修，也陆续培养了数届与木结构研究相关的硕士研究生。本书就是在前几年教学实践的基础上编写的。

本书共分6章，主要介绍了国内外木结构的发展状况、木结构中常用的结构用材和性能、木结构主要构件及连接的形式和计算方法、最为常用的两种木结构体系的基本设计方法以及木结构的防护等。本书涵盖了木结构设计的主要内容，对近年建造较多的轻型木结构建筑进行了较为详细的介绍，内容符合现行《木结构设计规范》（2005年版）GB50005的具体规定。本书可作为土木工程等相关本科专业的教材，也可作为从事木结构设计、制作、安装等的工程技术人员学习的参考书。

本书主要由中国同济大学和加拿大不列颠哥伦比亚大学（University of British Columbia）合作完成，中国清华大学也参加了部分内容的编写。主要分工为：何敏娟——第1章、第2章、第3章、第4章及5.1和5.3等中文章节，Frank LAM——除第6章外的所有英文内容，杨军——第6章，张盛东——5.2节。值得一提的是，加拿大不列颠哥伦比亚大学Frank LAM教授英文阅读文献的融入，既让读者了解了一些北美现代木结构的知识，又满足中国高校双语教学的发展需求，增加了学生原版专业资料的阅读量。

本书编写过程中得到同济大学建筑工程系高耸结构研究室诸多研究生的帮助，如孙永良先生参加了本书例题的计算，周丽娜、阎祥梅等参加了文字的输入，在此表示感谢。课程开设受到了加拿大木业协会的大力资助、受到加拿大不列颠哥伦比亚大学Frank LAM等多位教授的鼎力支持，教材编写得到同济大学本科教材出版基金的资助，在此一并表示衷心地感谢。限于作者水平，书中谬误之处在所难免，敬请读者指正。

何敏娟

2008年元旦于同济园

Preface

Timber is the only major natural renewable building material. The sustainable use of this resource through responsible for forestry practice allows wood to be recognized worldwide as a green and environmentally friendly building material.

Although timber is a traditional building material in China, its structural use has been curtailed since the 1960s because of limited availability of the resource. As China steps into the 21st century, its phenomenal growth during the past decades provided exciting opportunities to rebuild and create cities with world class architecture. Eventhough timber is available from the maturing of China' s plantation forest and import, so far concrete and steel are the building material of choice. The possibility to increase the structural use of timber, in sync with the "green" building concept, is somewhat limited because of a lack of formal education at the university level, modern teaching text in Chinese, and experts/designers on timber engineering.

This book "Timber Engineering" is a cooperative effort between Tongji University, Tsinghua University, and the University of British Columbia to address the need of a modern Chinese text in Timber Engineering. The material covers fundamental topics including the structural properties of wood, modern engineered wood products, behaviour of timber members, connection behaviour, design of timber structures, fire protection, and durability issues. The book also links with the Chinese timber structure design code (GB 50005) and can be use as a useful reference text by design engineers who are interested in the subject. As a oversee Chinese I am particularly pleased to be able to cooperate with my Chinese colleagues in this effort and help rejuvenate the interest of Timber engineering in Major Chinese Universities.

Frank Lam (林中法)
University of British Columbia
February 2008.

目　录

1 绪 论

1.1 木结构的特点

木结构是指以木材为主要受力体系的工程结构。木结构在房屋建筑、桥梁、道路等方面都有应用。在房屋建筑方面，木结构除大量用于住宅、学校和办公楼等中低层建筑之外，也大量存在于大跨度建筑，如体育场、机场、展览馆、图书馆、会议中心、商场和厂房等。与其他材料建造的结构相比，木结构具有资源再生、绿色环保、保温隔热、轻质、美观、建造方便、抗震和耐久等许多优点。

（1）木材资源再生产容易。木材依靠太阳能而周期性地自然生长，只要合理种植、开采，相对于其他建筑材料如砖石、混凝土和钢材等，木材最易再生产，一般周期为50～100年；随着林业、木材加工业的发展，很多速生材也可用于建筑结构中，这样大大缩短了林业资源的再生产周期。

（2）木材是一种绿色环保材料。对分别以木材、钢材和混凝土为主要结构材料的面积约200m^{2}的一幢住宅建筑进行比较，结果表明：木结构建筑消耗的能量是混凝土建筑的45%、是钢结构建筑的66%；木结构建筑排放使全球具有变暖趋势的等效二氧化碳最少，是混凝土建筑的66%、是钢结构建筑的81%；木结构建筑的空气污染指数最低，是混凝土建筑的46%、是钢结构建筑的57%；木结构建筑的水污染指数最低，是混凝土建筑的47%、是钢结构建筑的29%；木结构建筑的生态资源耗用指数最低，是混凝土建筑的52%、是钢结构建筑的88%，林业生产虽损失大片林区，但这一影响只是短暂的，树木再植、森林资源的可持续管理将生态资源影响降低到最低程度；木结构建筑的固体废物是混凝土建筑的76%，但比钢结构建筑略多，为1.21倍。因此，综合考虑能耗、等效二氧化碳、空气污染、水污染、生态资源耗用和固体废弃物等因素，木材最为绿色环保。

（3）木材具有较好的保温隔热性能。由于木材本身构造的特点，细胞内有空腔，形成了天然的中空材料，使得热传导速度慢，保温、隔热性能好，所以木结构有冬暖夏凉之美称。

（4）木结构建筑重量较轻。木材密度比传统建筑材料都小。木材的强度与荷载作用方式、荷载与木纹的方向等因素有关，但只要设计合理，木材的顺纹抗压、抗弯强度还是比较高的。因此合理设计的木结构建筑总体上重量较轻。

（5）木结构建筑美观。木结构建筑的纹理自然，与人有很强的亲和力。住在木结构的建筑中使人有一种回归自然的感觉。

（6）木结构建筑建造方便。木材加工容易，可锯切成各种形状。木结构构件相对轻巧，运输和安装都较容易，尤其对于轻型木结构建筑安装无需大型设备，3～4个月就能完成一幢独立别墅的建造。

（7）木结构建筑具有较好的抗震性能。结构物上的地震作用与结构质量有关，木结构

质量轻，产生的地震作用当然也小；由于木结构质量轻，地震致使房屋倒塌时对人产生的伤害也要比其他建筑材料小。另外，木结构的整体结构体系一般具有较好的塑性、韧性，因此在国内外历次强震中木结构都表现出较好的抗震性能。

（8）木结构具有一定的耐久性。如果木结构设计合理，具有较好的防潮构造、合理的防火措施，则其耐久性也较好。如现存的我国五台山南禅寺大殿和佛光寺大殿都已有1200年左右的历史。挪威一座建于12世纪的木结构教堂，由于其出色的设计和精心的保养，历经800年的风雨依然完好如初。无数北美和欧洲的19世纪建造的木结构建筑物，都证明了木结构能够经受得起时间的考验。

木结构也有一些缺点，这些缺点有时会影响木结构的应用，因此需合理设计，避免这些缺点对使用的影响。

（1）木材各向异性。树木自然生长，断面上有显示生长周期的年轮；树木沿纵向随其纤维长度的生长而增高。因此从外观上看，木材沿纵向、横向完全不同，而从力学性能上说为各向异性体。木材强度按作用力性质、作用力方向与木纹方向的关系一般可分为：顺纹抗压及承压、横纹抗压、斜纹抗压、顺纹抗拉、横纹抗拉、抗弯、顺纹抗剪、横纹抗剪、抗扭等，各种强度差别相当大，其中顺纹抗压、抗弯的强度较高。因此木结构设计最好尽可能使构件承受压力，避免承受拉力，尤其要绝对避免横纹受拉。

（2）木材容易腐蚀。木材腐蚀主要是由附着于木材上的木腐菌的生长和传播引起，但木腐菌生长需要有一定的温度、湿度条件。木腐菌最适宜的生长温度约为20℃左右，这也是人类生活的舒适温度，因此无法通过控制温度来抑制木腐菌生长，而控制湿度是唯一办法。使用干燥的木材，做好建筑物的通风、防潮，都是避免木材腐蚀的有效措施；当然长期可能受到潮气侵入的地方，如与基础连接的木构件、直接暴露于风雨中的构件等，可采用具有天然防腐性的木材或对木材进行防腐蚀处理。

（3）木材易于受虫害侵蚀。侵害木材的虫类很多，如白蚁、甲虫等，品种因地而异。切实做好木材防潮是减少或避免虫害的主要措施；在房屋建造前，对建筑场地及四周土壤清理树根、腐木，设置土壤化学屏障等也是预防虫害的一种措施；木结构一旦遭受虫害，需及时用药物处理。

（4）木材易于燃烧。对于房屋的使用者而言，火灾是随时存在的危险，但研究和事实表明：房屋的防火安全性与建筑物使用的结构材料的可燃性之间并无太多关联，很大程度上取决于使用者对火灾的防范意识、室内装饰材料的可燃性以及防火措施的得当与否。因此，木结构按防火规范做好防火设计很有必要，适当的防火间距、安全疏散通道、烟感报警装置的设置等都是防止火灾的必要措施。

1.2 国内外木结构的发展状况

1.2.1 木结构在国外的应用

欧美许多国家，木结构因取材方便而得到广泛使用，木结构技术发展十分迅速。现代木结构是集传统的建筑材料和现代先进的加工、建造技术为一体的结构形式。现代木结构材料不仅仅是天然木材，还有许多新型木产品，如结构胶合材、层板胶合木、木“工字形”梁和木桁架等。

在美国，木材是首选的住宅建筑材料，平均每年都有近 150 万幢新的住宅建成，其中约有 90%采用木结构。表 1-1 为美国 2000 年新建成的住宅的结构形式统计。

美国 2000 年新建住宅的结构形式统计 **表 1-1**

	单户住宅（幢）	多户住宅（幢）	总计（幢）	比例（%）
轻型木结构	1114000	275000	1389000	87
混凝土结构	124000	45000	169000	11
钢结构	6000	9000	150000	<1
原木结构	5000	—	5000	<1
梁柱体系木结构	3000	—	3000	<1
其他	12000	1000	13000	<1
总计	1264000	330000	1594000	100

注：数据摘自美国林业与纸业协会中文网站。

图 1-1 木结构独立住宅形式

在加拿大，木材工业是国家支柱产业之一，其木结构住宅的工业化、标准化和配套安装技术非常成熟。在日本，大量的住宅是利用木材、胶合木和刨花板建造的，即使人口稠密的东京地区也是如此。目前日本新建住宅房屋中，有半数以上采用木结构。在北欧的芬兰和瑞典，民宅的 90%为一层或二层的木结构建筑。图 1-1 为典型的北美形式的木结构独立住宅形式，即我们所称的木别墅。

木结构在公共建筑中也有许多应用。图 1-2 所示为美国华盛顿州塔科马市（TACOMA）的体育竞技馆，可用作足球、橄榄球、篮球及网球等多种竞赛的赛场。该体育馆穹顶采用木结构，穹顶的直径为 162m，矢高达 45.7m，1983 年建成时为当时世界最大的木穹顶结构。

(a)

(b)

图 1-2 塔科马体育馆

(a) 外观；(b) 木结构穹顶内部结构

该屋顶的主要受力结构为由三角形网格交织而成的半球形单层穹壳。穹壳构件采用截面为 200mm×762mm 的胶合梁。木檩条搁置在穹壳构件上，安装于檩条上的启口木板用作该结构的屋面板。每一根穹壳构件弯曲成弧形以适应穹顶曲面，使得穹顶形成一个三维的空间结构。穹顶结构能够承受相当大的荷载，如顶上安装着扬声器、场地照明灯具、永久性的计分牌以及冷却通风设备等，总重量达 160 多吨。

木结构除了被广泛用于住宅、商业场所、公共建筑外，在桥梁中也有不少应用，如图 1-3 所示的三铰拱桥有着大量的应用。

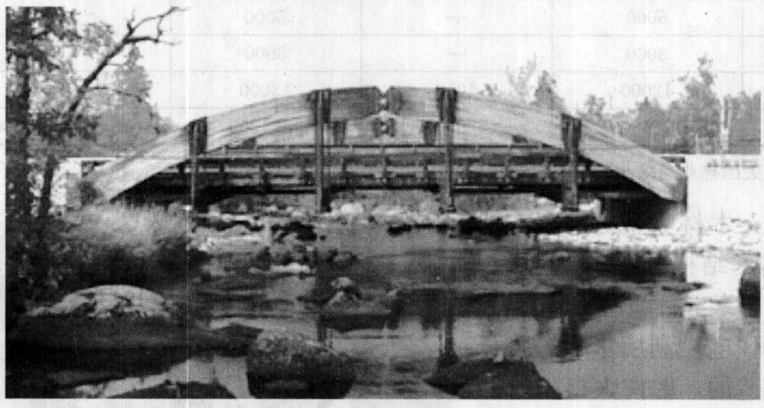
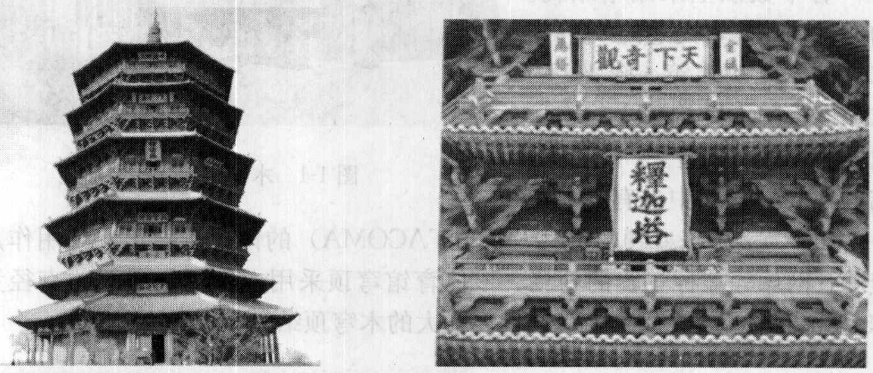


图 1-3 三铰拱桥



(a)　　(b)

图 1-4 应县木塔

（a）外立面；（b）局部放大

1.2.2 木结构在我国的兴衰

我国木结构建筑历史悠久，远溯到 3500 年前，我国就基本上形成了用榫卯连接梁柱的框架结构体系，到唐代趋于成熟。正是由于掌握了木结构的特点，能流传下来历经数百年甚至上千年的古代木结构。如建于公元 1056 年的中国应县木塔（图 1-4），为八角形楼阁式木塔，全部由木材以榫卯连接而成。外观五层，夹有暗层四层，实为九层。总高 67.13m，底层直径 30m。塔建在 4m 高的两层石砌台基上，内外两层立柱，构成筒中筒结构。暗层中用了大量斜撑，加强木塔结构的整体性。应县木塔是当今世界上最古老、规模较大的木结构建筑之一，被誉为世界建筑史上的奇迹。建成千年来，经历了 5 级以上的

地震十几次、抗日战争被日本炮弹击中 20 余发、加之洪水冲击，至今依然巍然屹立，充分展示了中国古代木结构的建造技术水平。

宋代《营造法式》从建筑、结构到施工全面系统地反映了中国古代木结构建筑的体系。正由于木结构建筑既能满足使用功能要求，又具有艺术魅力，木结构在我国大量用于房屋、宫殿及寺院等的建设。

到了 18 世纪末，西方科学技术传入以后，用材较费的梁柱体系逐渐被砖墙支承木桁架体系所取代。我国解放后的头两个"五年计划"期间，由于建设速度较快，木材能够就地取材又易于加工，砖木结构在所有建筑中占有相当比重，特别是"大跃进"时期竟达 46%。到 20 世纪 80 年代，我国结构用材采伐殆尽，当时国家又无足够的外汇储备从国际市场进口木材，以致停止使用木结构，木结构学科无形中在中国停止发展竟长达 20 多年。

1.2.3 木结构在中国的前景

目前我国的建筑结构仍以砖混结构、钢筋混凝土结构以及钢结构等为主，而木结构除了在一些低层住宅中有所应用外，在其他类型建筑中的应用几乎是一片空白。

长期以来，国内一直使用的实心黏土砖，因为浪费大量的土地资源、污染环境，我国在大城市已经禁止使用。木结构因为用料省、可回收利用而显示出较强的竞争力和良好的市场前景。

木结构建筑在中国沉寂了二十几年后，现在正处于复苏阶段。1998 年，我国实施天然林保护工程后，计划内木材产量逐年递减，而木材消费不断上升。2001 年中国成为世贸组织成员国后，木材进口关税进一步下降，因此进口木材连年不断增加。美国、加拿大两国有关木材贸易和建材机构也大力向我国建筑市场推荐新型木结构房屋，并逐渐得到建设部门以及建筑师和房地产开发商等的支持和认可，迄今已陆续建起数千幢轻型木结构住宅。国家队游泳训练馆木结构屋面于 2003 年落成，各地也陆续建起了一些木结构或木屋面结构的中小型场馆、桥梁等。国家标准《木结构设计规范》(GB 50005—2003)、《木结构设计手册》等的修编为木结构建设提供了一定的技术保障。

我国木结构建筑复苏的意义深远。首先为人们提供了温馨、自然、安宁、舒适的场所，木材为古老而又年轻的绿色环保材料，木材纹理美观、色泽丰富、吸声、隔声性能良好；其次将极大地促进我国木材工业的发展和技术水平的提高。中国目前是全球第五大产木国，但没有充分意识到森林的经济价值，总的原木产量的 2/3 作为燃料被烧掉。实践表明结构木产品是木材最有价值的产品之一。据统计 2001 年我国社会木材消耗总量为 25000 万 m^3 左右，其中建筑及房屋装修用材为 5400 万 m^3，仅占总量的 21.6%，而发达国家一般均在 30%～50%。如果我国建筑中的木材消耗水平逐渐达到该水平，则木材工业的加工量将大大扩大，同时也将有利于速生林的加速发展。加快国家速生丰产用材的发展，这既利于建材企业原材料的供应，又有益于生态建设的发展，并有助于实现资源培育与加工利用相结合、产业与生态两双赢。

1.3 木结构主要结构形式

木结构的主要结构形式为"梁柱结构体系"(Post and beam construction) 和"轻型木结构体系"(Light wood frame construction) 两种，当然也有一些其他木结构体系或

“杂交体系”。

（1）梁柱结构体系

梁柱结构体系是一种传统的建筑形式，它是由跨距较大的梁、柱结构形成主要的传力体系，无论竖向荷载还是水平荷载，都由梁柱结构体系承受，并最后传递到基础上。我国《木结构设计规范》中普通木结构和胶合木结构均属于梁柱结构体系的建筑。

（2）轻型木结构体系

轻型木结构是北美住宅建筑大量采用的、由构件断面较小的规格材均匀密布连接组成的一种结构形式，它由主要结构构件（结构骨架）和次要结构构件（墙面板、楼面板和屋面板）等共同作用、承受各种荷载，最后将荷载传递到基础上，具有经济、安全、结构布置灵活的特点。当这种结构通过合理设计，部分结构体系（如楼面均匀密布的梁采用轻型木桁架）能够承受和传递跨距较大的荷载时，它也能用于其他大型的工业和民用建筑。这种结构称之为“轻型木结构体系”，并不是说它只能承受较小的荷载，而是以它单个构件的断面较小、结构整体上自重较轻而得名。

（3）其他木结构体系

除了上述最常见的梁柱木结构和轻型木结构体系外，还有重型木桁架、门式框架、拱结构、穹顶结构等常见的木结构体系。重型木桁架相对于均匀密布的轻型木桁架来说，桁架间距往往较大，桁架构件采用截面较大的原木或方木制成，重型木桁架构件之间一般采用受力可靠的螺栓等连接；木结构门式框架与钢框架类似，采用两铰或三铰形式，往往用于单层工业建筑；拱结构大都用于桥梁或大型屋面结构，曲拱两端的推力较大，由两者之间的拉杆来平衡是最为经济的，当然设置拉杆会在使用功能方面有所限制；穹顶结构将屋面荷载传递到下方的周边构件上，如果下方的这些构件有足够承载力和刚度，则穹顶结构跨度可做得很大，且穹顶杆件的截面高度较小。

Reading Material 1
Wood as a Construction Material

Wood is one of the oldest natural building materials in the world. It would not take too much effort to come up with a long list of wood product applications through history. Examples could include the caveman's wooden club, tool handles, furniture, sailing vessels, airplanes, railway ties, sport equipment, bridges, piles, temples, palaces, sports arenas, swimming halls, low rise commercial buildings and residential housing. The list is indeed long, as wood was the primary structural material until the beginning of the 20th century. Although more modern materials, including steel, concrete, and fiber composites, have extended some structures and buildings to long span and high-rise applications, a strong demand still exists for wood in single and multi-family housing and low-rise commercial markets. In particular, over 90% of residential housing in North America and Japan is wood frame or post-and-beam systems. In these countries, over two million housing units are built annually. Wood is more suitable than steel and concrete in these markets for many reasons: ease of workmanship, customer preference for natural materials and thermal insulation properties of wood etc. A brief overview of wood as a construction material from the points of view of the forest resources, the structural properties of wood are provided.

Forest Resources in Canada and Worldwide

Trees are classified broadly into two categories: hardwoods and softwoods. These names are a little misleading as some softwood (e. g. , longleaf pine and Douglas-fir) is actually harder than some hardwood (e. g. basswood and aspen). Hardwoods are typically broad leaf plants that lose their leaves during autumn and winter. Softwoods are evergreen plants (except for larch) with needles or scale-like leaves. The seeds of hardwoods are kept in the ovary of the flowers (Angiosperms) whereas the seeds of softwoods are exposed in forms of cones (Gymnosperms). Hardwoods typically have vessel elements (tube-like wood cells with open ends) leading to a porous structure that serves as a conduit for the transport of water and sap (water and minerals) in the tree. Softwoods on the other hand, are non-porous and do not have vessels. Hardwoods tend to have many slender elongated cells and grain irregularities. In comparison with softwood, it is more difficult to work with hardwood in terms of cutting, nailing, or machining. The ease of workmanship is one of the reasons why softwood is commonly used as beams, columns, headers, posts, chords and braces in low-rise buildings in North America, Europe and Japan.

As one of the most common building materials in the world, when comparing wood to the other basic building materials, such as concrete and steel, only wood is renewable. If you cut down a tree to make wood products and replant it with new seedlings, in 50 to 100 years another tree will be available for consumption. The key is the management of the forest so that its use is sustainable through proper forestry practices.

Canada has 31.4 million people and a landmass of 922 million ha. Information on forest resources statistics from the Food and Agriculture Organization of the United Nations website (http://www.fao.org/forestry/fo/country/) shows that Canada has the third largest forest coverage in the world behind Russia and Brazil (Table 1). Canadian forests contain 14% of the world softwood resources behind Russia. With approximately 45% of the landmass under forest and other wooded land cover, the ratio of forest coverage to the number of inhabitants in Canada is one of the highest in the world. The forest is, therefore, very important to Canada as a natural resource. Besides the commercial value of this resource in forms of forest products, there are strong needs to balance other demands on the forest. The recognition of the forests as ecosystems and their impact on the environmental quality of the world is particularly important. The forest is part of an ecosystem that protects the watershed, allows nutrients to be recycled from the tree to the soil, provides storage for carbon, regenerates oxygen, influences global climate and provides shelter and food for animals. The forest also serves as a park and recreational area and provides spiritual inspiration for many people. The competing demands of the forest, as a source of commercial fiber, recreation, and a healthy environment, have led to debates. In some parts of North America, these concerns over environmental and sustainability issues have led to restricted availability of old growth fiber supply.

Forest coverage in some of the major forest product producing countries **Table 1**

	Land area	Forest Cover 2000	Forest Cover Change 1990—2000		Distribution of land cover/use % (1994)		
	10^3 ha	10^3 ha	10^3 ha/year	%/year	Forest	Other Wooded Land	Other land
Russia	1,688,850	851,392	135	0.02	50.4	0.0	49.6
Brazil	845,651	543,905	−2,309	−0.41	64.3	0.0	33.1
Canada	922,097	244,571	0	0.00	26.5	18.8	54.7
USA	915,896	225,993	388	0.17	24.7	8.5	67.0
China	932,742	163,480	1,806	1.18	17.5	3.7	79.6
Sweden	41,620	27,134	1	0.0	65.9	7.2	26.8
Finland	30,459	21,934	8	0.04	72.0	2.9	25.2
World	13,139,618	3,869,453	−9,319	−0.24	29.4	11.2	58.6

Source: Food and Agriculture Organization of the United Nations.

In 2000, the amount of sawn wood produced in USA, Canada, Russia, Brazil, Sweden, Finland, and China was 112.2, 69.6, 20.0, 18.1, 15.8, 12.8, and 6.3 million m^3, respectively. In terms of global softwood harvesting, Canada ranks third behind Russia and USA. China is the fifth largest wood producing country globally, although 2/3 of its roundwood production (190.9 million m^3) is burned as fuel. Similarly, Brazil and Russia commonly use wood as fuel (133.4 & 44.3 million m^3). In Canada, although substantial harvesting occurred during 1999-2000, forest coverage was unchanged (Table 1). This stability can be attributed, in part, to the natural regeneration of the forests and the requirement of reforestation after commercial harvest. In Canada, land designated as commercial forest is required to be maintained as forestland.

The forest coverage in China actually increased by 1.18%, due primarily to forest plantation practices. In Brazil and globally, the forest coverage reduced by 0.4% to 0.24% respectively. The global reduction in forest coverage occurred mainly in tropical forests where the land use would change from forest to agriculture after the forest was commercially harvested. The global deforestation caused by such practices can potentially be reduced if the local community recognizes the economical value of the forest (structural wood product is one of the most valuable) and practices sustainable forestry with reforestation and/or allows the forest to naturally regenerate as a longer-term investment.

Life Cycle Analysis-Is wood an environmentally friendly building material?

The increase in world population and the improvement in general living standards have led to an associated increase in demand for wood products. For example, in 1998, the consumed wood and fiber products in the United States reached an all-time high level requiring approximately 0.505 billion m^3 of round-wood production. The current worldwide demand for wood (approximately 3.5 billion m^3) has doubled in the last 30 years. By 2050, the projected future consumption of wood will increase to 5.2 billion m^3.

These projections have led to questions of sustainability and the environmental friendliness of using wood products instead of alternatives such as steel or concrete. As issues such as global warming, greenhouse gas emission, air and water pollution, ozone depletion and sustainable use of natural resources become front and center in our daily lives, consumers, builders, designers (architects and engineers) are increasingly more interested in using environmentally friendly material and methods. The Canadian Wood Council commissioned ATHENA™ Sustainable Materials Institute to conduct a study based on life cycle analysis. The study compared the environmental impact of constructing a 240 m^2 single family house using common building materials and techniques with the impact of using three different building materials: wood framing, sheet metal framing and concrete. The life-cycle analysis (LCA) assessed environmental effects at all stages of the product's life including resource procurement, manufacturing, on-site construction, building service life and de-commissioning at the end of the useful life of the building.

The major findings of the LCA study, as shown in the Canadian Wood Council website (www.cwc.ca), indicate that the wood-frame house is significantly more environmentally friendly in the following five out of six key measures.

(1) The embodied energy for the wood house is 53% less than sheet metal and 120% less than concrete. This is a measure of the total direct and indirect energy used during the

extraction, processing, manufacturing, transportation and installation of the materials from raw material to the final product in the house.

(2) In terms of global warming potential, wood is 23% lower than sheet metal and 50% lower than concrete. The global warming potential is referenced by greenhouse gas emissions measured in the form of CO_2 or equivalent amount of CO_2 for other greenhouse gases. This measurement includes the emission of CO_2 during the production process, such as steel making or cement production.

(3) The air toxicity index for the wood house is 74% less than sheet metal and 115% less than concrete. Similarly, the water toxicity index for the wood house is 247% less than sheet metal and 114% less than concrete. The toxicity indices are represented by an estimation of the volume of air or water needed to dilute the contaminated air or water emitted during the various life cycle of the material to within the acceptable level defined by the most stringent standard (such as meeting the drinking level standards).

(4) The weighted resource use for wood is 14% less than sheet metal and 93% less than concrete. The weighted resource use is a subjective measure based on survey of resource extraction and environmental specialists to develop subjective scores of the relative effects or ecological carrying capacity of different resource extraction activities.

(5) Solid waste generation, in kilograms of construction waste, is lowest for sheet metal. The solid waste generated in wood and concrete houses is 21% and 58% higher than steel, respectively.

The results of the ATHENA™ study confirm the findings of another LCA study conducted independently by the Building Research Establishment of the United Kingdom (www. bre. co. uk) where timber scored highly in the 13 environmental impacts studied-from climate change, pollution to air and water, waste disposal, and transport pollution and congestion. The study also concluded that timber is the only building material to have a positive impact on the environment due to the absorbed carbon dioxide and oxygen creation from a growing tree.

Summary

Wood is the only renewable construction material in the world. Currently there is still a healthy supply of forest resource in the world; however, sustainable forestry practice (e. g. tree replanting after logging practice) is needed to prevent over harvest. Wood is widely recognized as a"Green"building material and is commonly used as in construction in many parts of the world. Life cycle analysis is an objective measurement that shows wood to be superior to other building materials such as concrete and steel in terms of their environmental impact. Developing a good understanding of the physical properties of wood and how they influence the strength properties of wood is important to allow wood to be efficiently utilized as a construction material. Some of the key factors include: the strength properties of wood are influenced by moisture and the direction of loading.