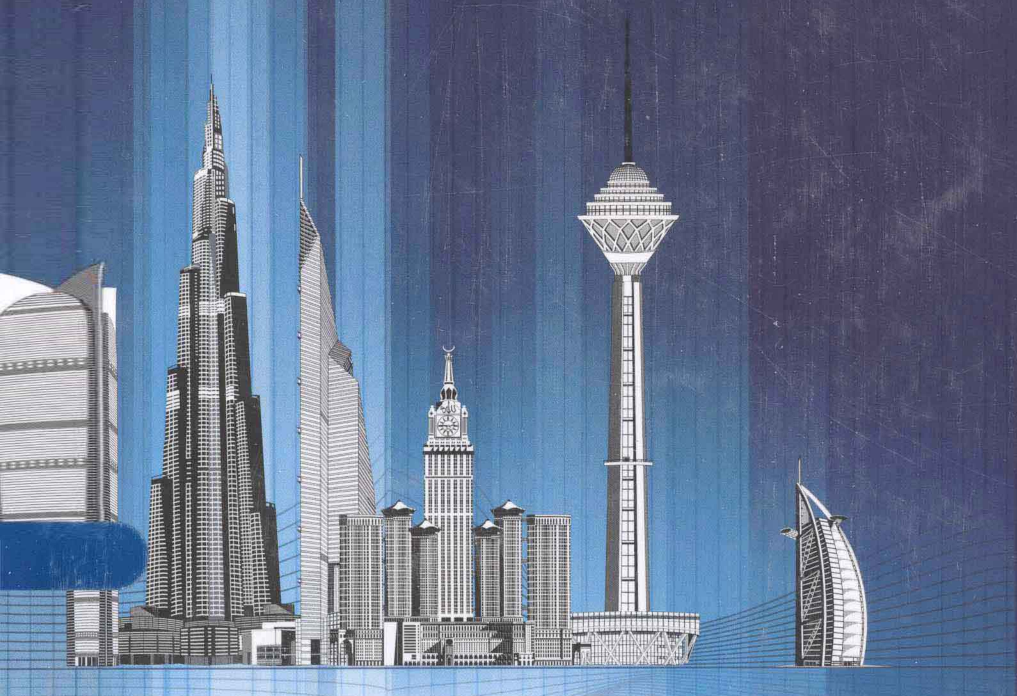
普通高等教育“十二五”规划教材

土木工程专业英语教程

Lectures of Specialized English for Civil Engineering

姜晨光　主编



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·北京·

本书以目前世界科技界对当代土木工程科学的主流认识为依据，从宏观的角度出发，全面地介绍了土木工程科学的概貌，对读者了解土木工程科学具有一定的启蒙作用，对大土木工程行业各专业学生了解当代土木工程题材英文文献著作的写作特点具有一定的积极作用。本书的英文部分全部出自英、美土木工程科学家之手（是原汁原味的英语），全书的内容涵盖了 Materials Engineering（材料工程学）、Geotechnical Engineering（岩土工程学）、Structural Engineering（结构工程学）、Surveying Engineering（测量工程学）、Construction（建筑施工学）、 Transportation Engineering（交通工程学）、Hydraulic Engineering（水利工程学）、Environmental Engineering（环境工程学）8 大土木工程类学科。本教材适合作为我国普通高等教育土木工程、工程管理、测绘工程、交通工程、水利水电工程、环境科学与工程、地理信息科学、地理科学、遥感科学与技术、房地产开发与管理、工程造价、城市管理、城市地下空间工程、道路桥梁与渡河工程、水务工程、导航工程、地理国情监测等专业的专业英语教材，也可作为相关专业的英文版《土木工程概论》双语教材使用，还可供我国大土木工程行业人员阅读、写作英文专业资料时作为参考。

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前　言

人类的语言是一个区域或多个区域（一个族群或多个族群）的人相互表达思想、情感的一种比较固化的声文体系，是一种约定俗成的东西，为什么要那样进行声文表述是没有多少道理好讲的，这就是为什么从来没有上过学的人也能流利地运用本民族语言的原因之所在。学习外民族的语言不可以机械地学习（即按所谓的语法进行排列组合。任何一种语言都是先有语言后有语法的，而不是先有语法后有语言的）、不可以问为什么要这样说。回忆一下我们学习本民族语言的过程就可以明白外民族语言学习的基本途径，那就是先学说话、再学写字、再背写课文、再造句、再写作文、再学习语法，因此，背写课文就是语言学习的关键，学好外民族语言的关键也是背写课文，课文背写得多了想说的话也就脱口而出了，想写的话也就甩手而出了。

英语是当代地球上不同族群人类之间相互交流的通用语言，当代任何国际会议的通用语言都是英语，因此，学好英语非常重要，要了解当代世界风云（包括自然、社会、政治、经济、科技、教育、军事、文化、体育等）离开英语是万万不成的。作为大土木工程类大学生不但要掌握基础英语，更要掌握专业英语，只有这样才能了解当代土木工程的发展方向，才能为土木工程事业的发展作出更好的贡献。鉴于上述原因，编者精心挑选素材写成了这本《土木工程专业英语教程》。

本书以目前世界科技界对当代土木工程科学的主流认识为依据，从宏观的角度出发全面地介绍了土木工程科学的概貌，对读者了解土木工程科学具有一定的启蒙作用，对大土木工程行业各专业学生了解当代土木工程题材英文文献著作的写作特点具有一定的积极作用，书中的英文部分全部出自英、美土木工程科学家之手（是原汁原味的英语），本书英文部分的整编得到了美籍土木工程教授 M. A. Harris, J. E. Vance, M. T. Walker, R. L. Callahan, F. R. Carson, A. B. Riggs 等（排名不分先后）的无私帮助与关怀，谨此致谢！

全书由江南大学姜晨光主笔完成，江西理工大学刘小生，广西大学陈伟清，青岛农业大学贺勇，莱阳市住房和规划建设管理局王世周，福州大学方绪华、范千，长沙理工大学唐平英，深圳市勘察测绘院有限公司王双龙，深圳市国土资源与房产管理局吴笃兵，中勘冶金勘察设计研究院有限责任公司付宏达，深圳市长勘勘察设计有限公司尹建章，中山市岩土工程勘察有限公司刘洪奇，从化市建设和市政管理局宋跃平，江南大学张清峰、姜勇、徐伯清、赵国强、郝志刚、应志斌、曹秋萍、王风芹等同志（编者排名不分先后）参与了部分章节的整编工作。限于水平、学识和时间关系，书中内容难免粗陋，谬误与欠妥之处敬请读者提出批评与宝贵意见。

主编　姜晨光

2013 年 6 月于江南大学

目　　录

1 Materials Engineering
(材料工程学)

1.1 Introduction

Concrete has been the most common building material for many years. It is expected to remain so in the coming decades. Much of the developed world has infrastructures built with various forms of concrete. Mass concrete dams, reinforced concrete buildings, prestressed concrete bridges, and precast concrete components are some typical examples. It is anticipated that the rest of the developing world will use these forms of construction in their future development of infrastructures.

This brief introduction to wood as a material is written primarily to inform the practicing civil engineer about what wood is; its cellular makeup; and therefore how it may be expected to react under various loading conditions. Space limitations preclude much detail; instead, references are given to lead the reader to detailed cause-effect relationships. Emphasis is placed on those items and relationships that most often lead to wood misuse or problems of proper wood use in structural applications and that may provide useful, practical guidelines for successful wood use.

The term *structural steel* is generally taken to include a wide variety of elements or components used in the construction of buildings and many other structures. These include beams, girders, columns, trusses, floor plates, purlins and girts. Many of these elements are made from standard hot rolled structural shapes, cold formed shapes or made up from plates using welding. They are joined at connections made using plate, structural shapes, welding and fasteners. Fasteners include bolts, nuts, washers and stud shear connectors. For a more complete listing of *structural steel* elements see the American Institute of Steel Construction (AISC) Code of Standard Practice for Steel Buildings and Bridges, Section 2.1.

The term *bituminous materials* is generally used to denote substances in which bitumen is present or from which it can be derived (Goetz and Wood, 1960). *Bitumen* is defined as an amorphous, black or darkcolored, (solid, semi-solid, or viscous) cementitious substance, composed principally of high molecular weight hydrocarbons, and soluble in carbon disulfide. For civil engineering applications, bituminous materials include primarily *asphalts* and *tars*. Asphalts may occur in nature (natural asphalts) or may be obtained from petroleum processing (petroleum asphalts). Tars do not occur in nature and are obtained as condensates in the processing of coal, petroleum, oil-shale, wood or other organic materials. *Pitch* is formed when a tar is partially distilled so that the volatile constituents have evaporated off from it. *Bituminous mixtures* are generally used to denote the combinations of bituminous materials (as binders), aggregates and additives.

1.2 Wood as a Construction Material

Next to stone, wood is perhaps the building material used earliest by humans. Despite its complex chemical nature, wood has excellent properties which lend themselves to human use. It is readily and economically available; easily machinable; amenable to fabrication into an infinite variety of sizes and shapes using simple on-site building techniques; exceptionally strong relative to its weight; a good heat and electrical insulator; and—of increasing importance—it is a renewable and biodegradable resource. However, it also has some drawbacks of which the user must be aware. It is a "natural" material and, as such, it comes with an array of defects (**knots**, irregular grain, etc.); it is subject to decay if not kept dry; it is flammable; and it is anisotropic.

Chemically, wood of all species is composed of five basic components: **cellulose**, in the form of longchain molecules in large groups that make up threadlike structures called **microfibrils**; **hemicelluloses**; **lignin**; *extractives*; and *ash*. Cellulose gives the wood its strength, particularly along the microfibrillar direction, and constitutes 40% to 50% of the wood by volume, depending upon species. Hemicellulose is about 20% to 35% of the wood of a tree by volume and is a more readily soluble form of cellulose; it is a polysaccharide often referred to as "fungi food". Lignin is the natural adhesive that glues the cellulose molecules and wood cells together to give the wood its rigidity and its viscoelastic and thermoplastic properties. Extractives typically constitute about 1% to 5% of the wood, and while they have little or no effect on wood strength, they impart resistance to decay and insects to those species that are termed durable. Extractives may also impart color to the heartwood. It is important to note that while all species probably contain some amount of extractives in the heartwood portion of a tree, they do not necessarily create a coloration different from that of the sapwood, nor do they necessarily impart any degree of durability or toxicity to insects and fungi to the heartwood. Ash is normally about 1% of the volume of wood.

The major problems that arise in wood use may be attributed either to the effects of grain distortions (cell orientation or alignment), to the effects of excess moisture, or to defects that occur as a result of the drying process. The specific defects taken into account in the grading of lumber products include

Knots: The result of cutting across a branch in lumber manufacture.

Slope of grain: A deviation of cell orientation from the longitudinal axis of the member.

Wane: Lack of wood.

Shake: A lengthwise separation of the wood, which usually occurs between or through the annual growth rings.

Splits and cracks: Separations of the wood cells along the grain, most often the result of drying stresses as the wood shrinks.

As a general rule, specific gravity (SG) and the major strength properties of wood are directly related. SG for the major native structural species ranges from roughly 0.30 to 0.90. The southern pines and Douglas fir are widely used structural species that are known to exhibit wide variation in SG; this is taken into account in the lumber grading process by assigning higher allowable design values to those pieces having narrower growth rings (more rings per inch) or more dense latewood per growth ring and, hence, higher SG.

As stated before, wood strength depends on several factors unique to wood as a material; these factors include species (and associated inherent property variability), wood (properties parallel or perpendicular to the grain), MC at time of use, **duration of load**, and lumber grade (reflective of type and degree of defects present). It is important to note that these values are for wood that is straight-grained, defect-free, and at a green MC (i.e., above FSP). The data are best used for property comparisons between species.

Wood in bending is amazingly strong for its weight; however, in many applications beam size is limited more by deflection criteria than by strength. Young's modulus (*E*) values for native species will range from about 3450 MPa (0.5 million psi) to about 17,250 MPa (2.5 million psi). Wood in tension parallel to the grain is exceedingly strong; however, it is readily affected by wood defects, particularly by knots and slope of grain. For this reason tensile allowable design properties are taken as 0.55MPa. bending values. Also, tension perpendicular to the grain properties are very weak and fracture in this mode is abrupt; design for this mode of possible failure is not acceptable (a singular exception to this rule is made for laminated arches, haunched frames, and similar members where shear stress is unavoidable); allowable design values in these cases are in the range of only 0.10 to 0.20MPa (15 to 30 psi).

Beginning with small trees and limbs, then lumber and plywood, structural uses of wood have evolved slowly into "artificial" products, such as wood composite beams and laminated veneer lumber, which have greatly expanded the architectural design capabilities of wood structures as well as conserving a valuable natural resource through more complete utilization. Thin-kerf saws, improved veneer production techniques, better adhesives, and extensive research and development on modern timber products have led not only to new products but also to the efficient utilization of more of the tree and of a much wider range of species.

The simplest form of wood for use is the *pole* or *piling*. This is merely a delimbed and debarked tree. Common species used for this purpose are the southern pines and Douglas fir, both of which must be preservative-treated prior to use. Western red cedar is also used extensively but does not need to be treated. Poles are often **incised** (surface perforated to permit deeper, more uniform preservative penetration) before treatment. Poles have wide usage in farm structures, in the utility field, and to obtain a rustic appearance in restaurants and residential construction. Piling is, of course, used in marine structures or as foundation supports when driven into the ground. Piling has been known to have been used for several decades, removed, inspected and reused; the exclusion of oxygen underground essentially eliminates the danger of decay except at ground level. For this reason poles and piling should be inspected regularly for signs of deterioration at any point where wood, moisture and oxygen meet for any significant period of time and where the ambient temperature lies between 15 and 35℃. In dealing with poles and piling (long columns) it is essential that lateral stability and adequate bracing against buckling be carefully considered.

For all practical purposes only a few native species are truly immune to fungal deterioration, and then, as stated earlier, only the heartwood portion of the wood is decay-resistant. Availability and economy usually dictate that where decay resistance is required, preservative treatment is a must. Any structural component that is in contact with the ground, subject to periodic wetting (leakage or rain), or in a high relative humidity atmosphere for extended time periods, may be expected to decay.

There are several preservatives available; degree of exposure and the use of the member will indicate which specific preservative to use. In all cases a pressure treatment is required; dip treating, soaking, or painting the surface with a preservative solution are only temporary deterrents at best and are not recommended where structural integrity is required. Creosote, one of the oldest and most effective treatments, is used primarily for treating utility poles and marine piling. It is an oil borne preservative of high toxicity and is not recommended where human contact is anticipated. A number of arsenic containing treatments are commonly used. CCA (chromated copper arsenate) is used with dimension lumber, particularly with southern pine, and ACA (ammoniacal copper arsenate) is also commonly used. Both CCA and ACA are waterborne preservatives that are pressure-impregnated into dry (below FSP) lumber; the chemicals become permanently bonded to the wood as the wood becomes redried after treatment. It is very important to know that until the wood has become dry again after treatment, it is dangerous to handle. Resawn wood that is wet on the inside of the piece, even if it appears dry on the outside, can produce arsenic poisoning. It is also important to know that even under high impregnation pressures, the depth of penetration of the preservative into the wood may be incomplete. Resawing may expose untreated wood to decay; treatment after cutting or boring members to final size is recommended. CCA and ACA treatments are commonly used for foundations, decks and greenhouses. Dry CCA- and ACA-treated lumber is approved for human contact use. Under no circumstances are wood scraps of CCA- or ACA-treated wood to be burned in the open air; this will ultimately release poisonous arsenic and chromium compounds into the air.

Lumber stress-grading procedures for structural purposes are under the jurisdiction of the American Lumber Standards Committee and follow guidelines given in several ASTM documents. Although several rules-writing agencies publish grading rules with grade descriptions, they all conform to ALSC guidelines and restrictions, and therefore the common grades are identical for American and Canadian producers. There are currently two grading methodologies: visual grading and machine stress rating (MSR). Visual grading is accomplished by skilled graders who visually assess the size and location of various defects and other characteristics on all four faces of a board. The main defects assessed include slope of grain, knots (size, number and location relative to the edges of the piece), wane, checks and splits, decay (not permitted except for "white speck" in some grades) and low density for the species. Strength reductions for various defects are termed **strength ratio** (SR) values and are applied to strength values representing a statistical 95% lower confidence limit on mean strength for the property and species. Strength ratio factors delimit the grades as Select Structural (SR = 0.65), No. 1 (SR = 0.55), No. 2 (SR = 0.45), No. 3 (SR = 0.26). Because *E* and compression perpendicular to the grain are not considered to be life-threatening properties, their use is treated differently. The SR value for all grades of lumber for compression perpendicular to the grain is 1.00. *E* values do not use an SR term; instead "quality factors" are used. Quality factors, dictated by ASTM standard (ASTM, 1992), are less severe than SR factors. Special dense grades (Dense Select Structural, etc.) are assigned to slow-growing, dense pieces of southern pine and Douglas fir. Structural lumber is produced in three MC categories: S-GRN (surfaced in the green MC condition, above 19% MC); S-DRY (surfaced in the dry condition, maximum MC of any piece is 19%); and MC-15 (surfaced at a maximum MC of 15%). Southern pine grade rules have additional designations of KD for kiln-dried material and AD for air-dried material; drying lumber in a kiln is accomplished at temperatures high enough to effectively kill insects and to dry areas of accumulated pitch. Southern pine may be labeled MC-15AD, MC-15KD, MC-19AD, etc. Pieces over nominal 4 in. in thickness are normally sold S-GRN. The various strength characteristics, as outlined in ASTM documents, including an appropriate safety factor, are applied to each board by the grader to arrive at a relatively conservative assessment of a grade. Every stress-graded piece is required to have a grade stamp on it; the grade stamp contains five pieces of information: producing mill number; grading association under which the grade rules have been issued; species or species group; moisture content at time of grading (e.g., S-DRY); and lumber grade.

Fasteners come in a wide variety of sizes, shapes, and types. Nails are the most common fastener used in construction. Design loads for nails depend upon type of nail (common wire, threaded hardened steel, spike, coated, etc.), wood species or density, thickness of the members being fastened together, nail diameter and length, depth of penetration of the point into the main member, and failure mode. Various failure mode criteria have been incorporated into fastener design in the 1991 edition of NDS. Fastener design for bolts, lag screws and shear connectors have similar design considerations. Most wood fasteners used in construction tend to have rather large safety factors incorporated into their design and tend to form tenacious joints; however, small deformations of fasteners at a joint also tend to result in serious deformations and structural deficiency over time. Inadequate or inappropriate joint design is a common cause of building problems that are often mistakenly attributed to "wood failure". For all fastener designs the following aspects must be kept in mind: DOL (shorter term loads allow higher design values per fastener); MC factors for dry, partially seasoned, or wet conditions at time of fabrication or in subsequent service; service temperature; group action (a reduction of design load for a series of fasteners in a row); the effect of having a metal side plate in lieu of a wood side plate; and whether the fastener is loaded in lateral or withdrawal mode. In general, placing fasteners into the end grain of wood is to be avoided, certainly so in a withdrawal mode.

Metal plate connectors are also commonly used; they are almost universally used in truss fabrication for residential and light frame construction. Although accurate plate placement is critical, their performance has proven their utility for decades, and numerous computer software packages are available to design structural frames or components that integrate metal plate fasteners into the design. Various types of joist hangers and heavier metal fixtures are also readily available and tend to speed construction of larger structures, particularly where modular components can be fabricated on site. Various fastener manufacturers provide engineering specifications for use of their specific products.

Wood and wood products are relatively simple engineering materials, but the conception, design, and construction process is fraught with problems and places to err. In using wood in its many forms and with its unique inherent characteristics, there are problem areas which seem to present easily overlooked pitfalls. As gentle reminders for caution, some of these areas are discussed below.

Wood and water do not mix well — Wood is hygroscopic and unless preservative-treated, rots when its MC rises above 20%. It must be protected in some way. Minor roof leakage often leads to pockets of decay, which may not be noticed until severe decay or actual failure has occurred. Stained areas on wood siding or at joints may indicate metal fastener rust associated with a wet spot or decay in adjoining, supporting members. In many cases what appears to be a minor problem ends up as major and sometimes extensive repair is required. Improper installation or lack of an adequate vapor barrier can result in serious decay in studs within a wall as well as paint peel on exterior surfaces. Ground contact of wood members can lead to decay as well as providing ready access to wood-deteriorating termites. Placement of preservative-treated members between the ground and the rest of the structure (as a bottom sill in a residence) is usually a code requirement. Timber arches for churches, office buildings and restaurants are usually affixed to a foundation by steel supports; if the supports are not properly installed, they may merely form a receptacle for rain or condensation to collect, enter the wood through capillary action and initiate decay. Once decay is discovered, major repair is indicated; preservative treatment to a decayed area may prevent further decay, but it will not restore the strength of the material. Elimination of the causal agent (moisture) is paramount. Visible decay usually means that significant fungal deterioration has progressed for 1 to 2 feet along the grain of a member beyond where it is readily identifiable.

Trees are nature's only renewable resource for building materials. Trees use energy from the sun and carbon dioxide to create cellulose while cleansing the atmosphere and giving off oxygen. Wood is a significant "storehouse" for carbon, and it does all this with little or no input from people. Converting trees into useful products requires much less energy than is needed for other construction materials. Considering any other structural material in terms of production costs to the environment and use through recycling and ultimate disposal, wood is certainly the most environmentally benign material in use today. It is renewable, available, easily converted into products, recyclable and biodegradable with no toxic residues.

Although controversy regarding just how we are to allocate the nation's timber resource to provide for endangered species, increased demand for "wild" areas, and increasing numbers of products made from wood will certainly continue, it is possible to retain many of the "natural" aspects of forests and still obtain products from this remarkable resource on a sustainable basis if attention is paid to proper management and skillful utilization. Current (1990s) controversy over environmental policies will lead to acceptable compromise in time. However, the nature of trees and all the wood products derived from them will assure wood a prominent place as a highly preferred, environmentally desirable, and economically competitive building material.

1.3 Structural Steel

A variety of steel types are used to produce these structural shapes, plates and other components depending on the intended use and other factors such as the importance of cost, the weight of the structure and corrosion resistance. The properties of steel products result from a combination of the chemical composition, the manufacturing processes and the heat treatment. The properties most commonly used as a basis for specification and design are the specified minimum yield stress (yield point or yield strength) and the specified minimum tensile strength (or ultimate strength), both obtained from tensile tests on small representative specimens of the steel (see below). Other properties also required are ductility, weldability, and fracture toughness (or notch ductility) although these requirements are often not explicitly stated. The steels most commonly used are:

- carbon steels.
- high-strength low-alloy steels.
- corrosion resistant, high-strength low-alloy steels.
- quenched and tempered alloy steels.

The elastic modulus is virtually the same for each of these types of steel, but their yield stress and ultimate strength vary widely.

Welding is perhaps the most important process used in the fabrication and erection of structural steelwork. It is used very extensively to join components to make up members and to join members into assemblies and structures. Welding used and done well helps in the production of very safe and efficient structures because welding consists of essentially joining steel component to steel component with steel that is intimately united to both. It can lead to very efficient paths for actions and stresses to be transferred from one member or component to another. Conversely, welding used or done badly or inappropriately can lead to potentially unsafe or ineffective structures-welds containing defects or inappropriate types or forms of joints can cause failure or collapse of members or structures with little or no warning. Thus care is required in the design of welds, in the design or specification of welding processes, in the actual process of welding components one to another, and in the inspection of welding to assure that it is as specified and fit for purpose.

Structural steel members or elements may become liable to brittle fracture under some conditions, although this rarely occurs in practice.

Brittle fracture normally only occurs when a critical combination of the following exist:

- a severe stress concentration due to a notch or severe structural discontinuity.
- a significant tensile force occurs across the plane of the notch (or equivalent) .
- low fracture toughness of the steel at the service temperature.
- dynamic loading.

The potential for brittle fracture is generally addressed by eliminating or minimizing the effect of each of these factors. Thus, using structural steels that have suitable notch ductility at the expected service temperatures, reduction in stress, particularly residual stresses due to welding or forming, and the use of details that do not give rise to severe notches or structural discontinuities are the preferred methods of reducing the risk of brittle fracture.

Fatigue of steel structures is damage caused by repeated fluctuations of stress leading to gradual cracking of a structural element. Most steel structures are not subjected to sufficiently great or sufficiently many fluctuations in load (and thus stress) that fatigue is a consideration in design. However, road and rail bridges, cranes and crane supporting structures, other mechanical equipment and machinery supporting structures are examples of steel structures that may be subject to fatigue.

In design for fatigue it is normal to design the structure for all of the other requirements (static strength, serviceability) first and then to assess the structure for fatigue. Fatigue design is normally undertaken with the actual (or estimated) loads that will apply to the structure rather than factored loads that are used in strength aspects of design. It is important in design for fatigue to ensure that all parts of the structure are considered and that structural details and connections are carefully detailed and specified as it is these details that will greatly influence the likelihood of fatigue damage occurring during the life of the structure.

The loads used in design should be the best estimates that can be made of those that will occur in practice and should take into account dynamic effects (for example, impact loads) and loads induced by oscillations of the structure or, for example, suspended loads. Moving or rolling loads may result in more than one cycle of load during their passage over a structure or part of the structure. Care should be taken to ensure that all of the load cycles on each element of the structure are considered in assessing the structure for fatigue.

The occurrence of fire in buildings and industrial installations is frightening and sometimes costly in lives, injuries, property damage and other consequences. Often the structures involved are not threatened with most human losses occurring because of exposure of occupants to smoke and sometimes heat, or both. However, the structure is often incorporated in the fire safety system in the building as a means to separate the occupants from the effects of a fire so that they may leave the building safely and as a means to prevent fire spread and thus minimize property loss resulting from a fire.

Creep is generally defined as time-dependent deformation that results from sustained loading and results in permanent deformation.

Steel at room temperature is not subject to creep or relaxation at normal ambient temperatures (say <50℃) unless subject to very high stresses. As pointed out above when subjected to high temperatures (say >400℃) steel can creep quite rapidly. At these temperatures and above steel creeps at a rate that is dependent on the applied stress. Creep is not required to be considered for most steel structures as they are not usually exposed to high temperatures.

In structures or structural elements that are subjected to high temperatures for long periods, it may be required to consider creep. This is normally covered in specialist codes and specifications appropriate to the usage.

Many types of steel, including most common grades of structural steel will corrode if exposed to moisture and oxygen. If either or both of these are prevented from contacting the steel it will not corrode under normal circumstances.

Corrosion of steel takes place by a complex electro-chemical reaction between the steel and oxygen that is facilitated by the presence of moisture. In certain circumstances, corrosion can be exacerbated by pollutants or other contaminants in the water. Such materials can include common salt (sodium chloride) and many industrial chemicals. Where such materials are present special precautions should be taken to adequately protect exposed steelwork.

In the absence of such materials structural steel that is contained within the envelope of a building or structure and which is thus not subjected to periodic wetting by rain or other sources of moisture requires no corrosion protection.

Structural steelwork that is not protected in this way requires additional protection and the usual methods are paint systems and galvanizing. In considering a protection system it is necessary to consider the type of building or structure under consideration, its use, its expected life and the relative merits of initial cost against maintenance costs.

Steel structures, particularly those that are at risk of fatigue damage or brittle fracture, may be required to be inspected using non-destructive testing methods such as dye-penetrant, magnetic particle, ultrasonic and radiographic examination.

The most common form of examination is visual inspection and for many steel structures this is sufficient to ensure a satisfactory level of workmanship in fabrication and erection. This form of inspection can only be used to detect defects in the fit-up of components, in the shape or form of welds and lack of fusion or cracks that are visible on the finished surface.

Methods that can be used to detect smaller surface or near surface defects include dye-penetrant and magnetic particle inspection.

Detection of subsurface defects is usually done using ultrasonic or radiographic techniques. The choice of appropriate methods of examination is important as the cost of inspection varies widely depending on the method used. This requires consideration of the importance of the weld as well as consideration of the type and location of defects to be detected as the methods mentioned above have differing capabilities in relation to the size, orientation, depth and shape of defects that they can be used to detect.

Welding inspection is normally carried out to the requirements of AWS D1.1.

1.4 Constituents and Properties of Concrete

In pre-historic times, some form of concrete using lime-based binder may have been used (Stanley, 1980), but modern concrete using Portland cement, which sets under water, dates back to mid-eighteenth century and more importantly, with the patent by Joseph Aspdin in 1824.

Traditionally, concrete is a composite consisting of the dispersed phase of aggregates (ranging from its maximum size coarse aggregates down to the fine sand particles) embedded in the matrix of cement paste. This is a Portland cement concrete with the four constituents of Portland cement, water, stone and sand. These basic components remain in current concrete but other constituents are now often added to modify its fresh and hardened properties. This has broadened the scope in the design and construction of concrete structures. It has also introduced factors that designers should recognize in order to realize the desired performance in terms of structural adequacy, constructability and required service life. These are translated into strength, workability and durability in relation to properties of concrete. In addition, there is the need to satisfy these provisions at the most cost-effective price in practice.

The quality of concrete in a structure is determined not only by the proper selection of its constituents and their proportions, but also by appropriate techniques in the production, transportation, placing, compacting, finishing and curing of the concrete of the actual structure, often at a job site. Although these processes have an impact on the actual quality of concrete achieved, they are not included under this chapter. Sources for such information include publications of concrete institutes in various countries, e.g., American Concrete Institute in the U.S. and the Concrete Society in the U.K. .

The subject of concrete covers a very broad scope and a wealth of in-depth knowledge. This chapter is intended to provide a brief guide on the more important aspects for civil engineers rather than for concrete specialist in research or production of concrete. There are many textbooks and references besides those cited in this chapter from which more detailed information may be obtained. Some of these are listed under Further Information.

This chapter covers topics on the constituents and the properties of concrete. The engineer is concerned with both the properties of concrete in its fresh as well as its hardened state. The way fresh concrete is handled and the treatment of the hardened concrete at its early age have major influences on its as-built quality. These impact the resultant performance of the concrete structure as designed by the engineer. Since the information provided in this chapter targets readers in English-speaking countries, it has selected information from two major practices, the American and