Research on life-cycle working path of timber based on case study in United Kingdom

Xiaoxi Liu¹, Jing Ma¹, Liqian Lan², Hongjie Liu¹ and Kaiyu Peng³

¹Urban Construction Department, Beijing City University, Beijing, China
²North China Sea Marine Technical Support Center, State Oceanic Administration, Qingdao, Shandong, China
³China Construction Design International Co. Ltd, Beijing, China

*Corresponding author’s e-mail: liuxiaoxi@bcu.edu.cn

Abstract. This paper focuses on the general knowledge and basic use of timber based on the case study in United Kingdom. It is narrated from the whole life cycle of wood, from its cradle to death, including its growth, application, degradation, decay detection repairing methods and techniques, etc. The purpose of this paper is to provide guidance on the wider application of wood in architecture, especially on the conservation of historic buildings.

1. Introduction
Recently an increasing number of specialists, including architects, archaeologists, for their special historic and architectural interests, constructors and material engineers, pay much attention to timber framed buildings all over the world. The specific material applied most frequently in those buildings, timber, regarded as the most valuable element attracts much people. Because its material properties differ from other material, like iron, stone or lime, this gives possibilities for its special and wide use in manufacturing and architecture. Hence, a deep understanding of timber does contribute to a comprehensive study of timber framed buildings, which further promotes a successful achievement of conservation of timber framed buildings. Referring to a raw material, timber is one of the most sustainable construction material, renewable, low embodied energy, and locking up carbon dioxide, which provided that the rate of use is matched by regrowth (Forsyth, M., 2008). According to Brunskill (1985) compared with stone buildings in Britain, the number of surviving timber frame buildings is much comparatively smaller. That is another essential reason for study more about timber building. Naturally, it is not difficult to think about another relevant word, of frequent presence, simultaneously when mentioning timber, wood, which has a different definition and application boundary in comparison with timber. However, because of being derived from the same matrix-tree, both timber and wood, their properties are similar, including physical and mechanical properties. But in later constructional activities, the difference between buildings made in timber and ones in wood, for example, the diversity of their scales, appearances, as well as their functions, all point towards the inequality for those two material.

This report will focus on the general knowledge and basic use of timber without covering all tiny or detailing cases. It will study the material wood from its cradle to death, including its growth, application, degradation, decay detection repairing methods and techniques, etc. Due to the extremely wide range of the applications of wood, this report will choose one of them to extend, its application in construction. Besides, although there are various applications for timber, its repair skills and techniques can still generally be used in a similar way.
2. Definition
There are a number of technical words frequently appearing in the relative description of wood, such as wood, timber (commercial timber, structural timber), hardwoods, softwoods as well as other rarely appearing words. So it is necessary to distinguish these technical words clearly, which is useful to help understand their different application later.

2.1. Wood & Timber
Wood and timber are defined in Oxford Dictionaries separately as follows:
- Wood: “The hard fibrous material that forms the main substance of the trunk or branches of a tree or shrub, used for fuel or timber.”
- Timber: “Wood prepared for use in building and carpentry.”

Similarly, Waddell, J.J. (1985) stated that timber is one special kind of use of wood. It means that wood and timber are in a relationship of inclusion that wood has wider boundary than timber. Normally, wood employed in practical use is called commercial timber or structural timber or even just timber. However, Brunskill, R.W. (1985) defined timber and wood in terms of their subsequent applications that timber is regarded as structural members when used to build constructions such as roof, floor and post etc., while wood shows up in furniture making, tools or burnt materials as a replacement of coal. In other words, timber is used during the frame construction, while wood is used to finish the whole project. The emphasis or boundary of these two materials is different.

These two mainstream definitions of wood and timber to a certain extent, sometimes, make confusions to clearly define wood or timber in practice and even result in misunderstanding. So it is better to set a clear boundary for these two definitions just for this report, which is wood in this report is the commercial timber derived from the stem of tree.

2.2. Classification: Hardwoods & Softwood
Waddell, J.J.(1985) also stated in his construction materials manual that wood can be broadly classified into two types: the softwoods and the hardwoods. The boundary of this classification is based on the softness of wood. In another way, wood can also be sorted into structural timber and commercial timber (Levin, E., 1971).

2.2.1. Hardwoods. Hardwoods are produced from broad leaf trees. They are not used as much as softwoods. Brentnall, C.(2008) states that from medieval times of Britain, “the imported softwoods from the Baltic or Dominions became the norm in Georgian and Victoria times”. The common species of hardwoods include ash, beech, birch, cherry, mahogany, maple, oak and walnut. Most commercial hardwoods are harder than the majority of commercial softwoods.

2.2.2. Softwoods. Softwoods are from coniferous trees. The softwoods are generally available woods used in construction. Most commercial softwoods are softer than the majority of hardwoods.

2.3. Age counting: Annual ring
Annual rings are a series of concentric circles that can be observed on the end of logs. They are valuable evidence to identify the conditions of this wood, such as ages and growing region, because each growing season a tree produces a new layer of wood just below the bark when temperature is preferential. There are many secrets hiding under the annual ring, such as, if the distance between two rings is wide, it can be an evidence of adequate moisture; while close interval can be symbol of a drought season. Besides, the annual rings of spring trees and late summer trees are comparatively different.

2.4. Carpenter & Joiner
Due to the various definitions of timber and wood, people employed or engaged to manage this different materials are considered and named separately, normally, the timber constructor is named carpenter, and the wood maker is named joiner. Although with the emergency of special concern on
particular wood-making field, a number of specialists came out and worked more professionally and specifically. The carpenter is still invariably employed into structural timber making.

3. History of Timber Use in Britain

Timer as a raw material has been widely used in many countries, such as Britain, China as well as Japan. Due to the traditions of timber use in different regions differing from each other, the standards set to specify timber use are correspondingly different. This report will focus on the use of timber in Britain.

With reference to what Forsyth, M. (2008) claims in his publication, it concludes that the earliest extent carpentry can be dated back to the 11th century in Britain. Also, with the extension of the woodlands in Britain and development of constructional skills in medieval ages, the zenith or blooming period of English carpentry came in the 16th century. Then it seemed to be decadent until the 18th century for the introduction of truss forms and uniform timbers set on edge.

European oak, such as the quercus robur, petrace, chestnut and elm, the most valuable as well as the commonest timber tree which has a wide range of sizes, were the mainstream species employed in constructing in Britain, claimed by Forsyth, M. (2008). The uses of oak are variable, flexible because it can suitably fulfill the adequate requirements from carpenters. The prices of this material would be extremely different depending on their sizes. According to Rackham, O. (1976), for example, the price of the largest oak tree is approximate as 90 times as the smallest one.

Referring to the timber-framed buildings, most of the ambitious timber buildings were erected between 18th and 19th century before timber was replaced by iron in an overall scale. England is considered to nearly cover all types of examples of such buildings in Britain for two reasons:

- Wales has totally similar types for its close geographical location
- There is relatively smaller number of timer framed buildings surviving in Scotland, and these fewer existing timber buildings seem share similar construction basis.

4. Growth: Formation of Wood

This part will illustrate the formation of a tree from biological perspective. After being planted factitiously or naturally, the seed gradually grows to a mature tree after experiencing a series of biological growth steps, for example, one step is that cell diversion leads to growth of timber. It is a good way to know timber by analyzing its property from four perspectives as macro scope, microscope, ultrastructure and molecular. This comprehensive and deep analysis can contribute to understand the mechanical and physical properties of timber. Confined by the space of this paper, only the description from the perspective of macro scope is detailed. Besides, apart from its internal biological structure which determines the formation of a tree, the outside environment will also influence its growth.

4.1. Internal Structure Analysis in The Macro Scope Perspective

From the perspective of macro scope, tree is composed of four parts including root, trunk, branches and leaves. Two of them usually serve as raw material. Among those four elements trunk is the primarily commercial or practically used part. Growth of trunk expands in the longitudinal direction and it thickens as growing. Trunk consists of five layers; from outmost layer to core layer is bark, phloem, cambium, sapwood, heartwood. Bark is a dead layer to protect inner parts from being attacked by insects. The second layer is phloem whose function is transferring the sugar from leaves. The third layer, cambium is the main part for growth of the tree. And the following layer is responsible to transfer moisture from root to other parts of tree. Normally the color of this layer is light. The last layer is heartwood which accounts the most of the tree, whose color is darker than the sapwood. Apart from these main members of a tree, there are other a number of less important but still of significant impacts on performance of a tree, including knots and grain angle (Dinwoodie, J.M., 1981).

It is these elements full of possibilities that give timber unique character, variability. Even there are significant distinctions in a same tree, such as cells length, cell wall thickness, density as well as other variations in terms of growing routine. Due to inadequately technical knowledge of biology and
a number of jargons, the description of the structure of timber may be out of professional terms. Even so, they still invariably contribute to the sequent understanding of a series of performances of timber.

4.2. Environmental Influence
Tree as a product given by nature and time (Dinwoodie, J.M., 1981) will be invariably influenced by series of natural factors, mainly lie in climatic and biological terms. At first, in respect of climatic impacts, tree grows annually between April and October for the temperature is suitable for growing. The moisture content of the atmosphere has significant influence on growth speed of a tree, which will consequently affect the density of the timber, which results the diversity in tree’s physical and mechanical properties. Secondly, when considering the biological factors, fungal and insect attack should be considered as two primary aspects, which will be encountered during the whole life of timber, living or dead.

5. Timber Properties
The outstanding properties of timber give it access to occupy a hugely significant position among various materials over centuries. Especially, the physical and mechanical properties make it possible to be used in constructional activities since the ninth century in Egypt. One of the most notable properties is its durability.

   Durability, strength characteristics, weights, seasoning and shrinkage and other properties have been systematically standardized in reference publications by the Building Research Establishment (BRE), the Timber Research and Development Association (TRADA) and British Standards (Forsyth, M., 2008).

6. Timber Selection
After author giving a general presentation about the structure, property and factor which may affect the growth of timber, this part designed to tell how to select the right timber in real application among flood of timber material shows a case study in decision making. Of course, this kind of timber selection roots on the understanding about the properties of all kinds of timber.

   Oak: It is considered as an outstanding timber for its broad application, which means, almost every part of the oak has its own use. As described by Brunskill, R.W. in 1985 that: “straight oak trunks made posts and beams, thinner branches made rafters and joists, curved boughs made braces, sawn sections made floor boards, inferior stuff when split made laths and wattles...the twigs made a merry fire.”

   Elm: it is not commonly employed in building construction, but sometimes can be used as alteration or replacement of floorboards or beams. The comparably advantage of this timber is its stable property when kept in long-term wet or dry conditions. It can also be a choice for joiner to be applied in wheels or machinery making.

7. Timber Conversion
Once selecting one timber, then the problem about how to convert the raw material shows up. The 17th century had witnessed the change of time for timber tree felling. Before that time, the selected timber trees were felled in winter before the launching of the building construction in spring. But due to the equally importance role played by bark for in tanning industry, the chosen trees were felled in spring after the 17th century, which is because it is easier to peel the barks when the sap was raising that happens in spring. Structural timber was generally used unseasoned. Green timber is easily to work.

   From felling down to be employed into construction, the shape of timber is converted from the originally round to different sizes. Although a number of growing timbers can well match the intended uses, it is still limited for considerably various applications. So sometimes, conversion is necessarily needed. Such conversion primarily depends on the species of trees. For instance, “Softwood logs are normally converted directly to section sizes required in construction and for joinery, depending on its particular uses” (Borneo, J., 2003). The secondarily important basis of conversion is its use. For example, the piece used as beam is treated in different method compared with the piece served as post
or decorative purpose. So conversion, to boards or planks, all is the matter of its use, another practice of the principle that form follows function. Correspondingly, deformations of converted timbers during the process of seasoning will be presented at different levels as a result differing patterns. So the selection of conversion type is driven by the particular conditions. Generally, logs sawn through and through give wide boards but these tend to cup on seasoning. While conversion to gain quartersawn boards gives narrower appearance can ensure the stability of timber when seasoning and in service. With all these matters taken into account, conversion process will achieve a time-efficiency, material-saving as well as economical goal.

8. Application Of Wood

Wood is one of the most basic and renewable materials in the world and can be used in many ways. As it is a raw material, it can be shaped in many forms and applied in many wood products, including building construction, fuel for fire as well as other assisted uses. Wood that derives from a tree can be applied for different purposes according to the positions it comes from. Brunskill, R.W. (1985) states that: Each individual tree could itself be made to produce bark for tanning, branches for burning as well as timber for building” (p.27).

Strength and natural durability give wood access to diverse uses. The major application of timber is building. Rackham, O. (1976) stated that written records suggest that over half of the timber produced by wood was used in building. So the methods of how to form or organize these timbers into a building are worth of studying. Generally they include selection of timbers in terms of their shape and size, seasoning, and constructional skills or techniques.

Two principal timber applications in construction are carpentry use and joinery use. Carpentry use is structure emphasized, while the joinery is decoration focused. Due to the continuously changed taste of aesthetic value, the joinery principles are difficult to illustrate systematically. Whereas the principles, especially timber frame techniques, employed in the procedure of carpentry courses are shaped by the cunning carpenters over centuries, including timber roof, floor as well as other joints.

Carrick construction is one of the most typical applications of timber in construction. This kind of architecture is considered as the oldest type of timber buildings, so compared with later complex construction techniques, it is simple or sometimes crude. The principal achievement of this simple construction is to tackle the problem of roofing and walling simultaneously. It has been erected using the original trunk without further processing, which made such buildings unique in appearances. But because it is not an efficient way of using material and the nature of a tree is a time consumption activity, this tradition has gradually died out over centuries.

9. Durability and Degradation

Performance of timber will invariably face with degradation during a long-term service. Threat may come the nature, as mentioned before, insect and fungal attack and fire; an important factor is the timber’s deformations or settlement due to the loads being put on it. Dinwoodie, J.M. (1981) defined durability as “The resistance of timber to attack from a whole series of agencies whether physical, chemical or biological in origin “. Among these factors which will influence the durability of timber, the biological agencies including the fungi and the insects play a dominantly primary role leading to degradation of the timber, so as fire which is also of significant impact on the durability of timber. Apart from there three factors, the chemical, thermal and mechanical actions are comparatively less important factors. So this part will put emphasis on the former three aspects.

9.1. Durability of timber

At first, this part explains why timber has good durability though so many unfavorable conditions exist. There are three main reasons for timber’s good resistance to biological attack. The most significant one is the presence of the extractives of heartwood. Another reason is its low nitrogen content about 0.03-0.1% which cannot fulfill the requirement for fungi growth; At last, the last important element is related to timber’s natural structure which provides a protecting coat for itself from being attacked by fungi, for example, the crystalline cellulose is protected by its surroundings, lignin which make it in better degree of resistance to fungal attack in comparison with non-lignified plants. Besides, fungal
attack also has requirements for moisture content, rate of diffusion, density and deposition of gums and resins. Compared with heartwood, sapwood of all timbers is vulnerable to attack for its porosity. However, no matter heartwood or sapwood, their natural durability can be improved by application of chemical agencies, such as preservative treatment which technique will be illustrated in following part.

9.2. Timber Degradation
Totally, there are so many reasons which can explain the degradation of timber. Shrinkage may cause the deformation. The timber may completely fail if much load is added on it. Others, the fungi attack is also countable in the whole factors resulting in timber degradation. Last but not the least, in real life, all kinds of accident may finally break the timber material.

9.2.1. Shrinkage. Reduction in dimensions of timber, is one type of dimensional changes which also include timber movement. It is an inevitable result during the process of seasoning because of the change of moisture content. Because timber is hygroscopic which means that it will absorb moisture from the atmosphere if it is dry or correspondingly yield moisture to the atmosphere when wet. But there still is a saturation point which plays a determinative role to decide whether the timber will face with shrinkage or swelling. Both of these two behaviours will lead to warping, checking, splitting, or performance problems that will weaken the properties of timber. While due to the particular complex structure, the degree of shrinkage is different on the three principal axes, which is technically considered as anisotropic in terms of shrinkage. Generally, “It shrinks most in the direction of the annual growth rings (tangentially), about one-half as much as across the rings (radically), and only slightly along the grain (longitudinally).” Another related operation based on the shrinkage types is the sawing which should give comprehensive consideration on the specific shrinkage of the material. That would be demonstrated in the part: conversion of timber.

Due to the adverse impacts of timber shrinkage on the performances of this material and appropriate methods should be approached. It is essential to be dried down to an expected moisture content which is in equilibrium with the relative humidity of the atmosphere, separately 12% for regular intermittent heating and 10% in buildings with central heating.

9.2.2. Failure in timber. From the above description, commonly, failures in timber are resulted from following reasons. Rot due to various reasons: (1) to the action of insects, primarily the larvae of the death watch and beetles, (2) the growth of various fungi (dry out), and (3) to the shrinkage which caused by constant dimensional changes based on moisture content. Constructional factors: (1) originally poor design, (2) too slight timbers, (3) to mutilation done after the work is complete, and more rarely, (4) to loose of nature in the timber itself, such as durability.

9.2.3. Fungal decay. Fungal decay can generally be classified into three groups: (1) a group of fungi, like the mounds, just exists on the surface resulting in timber staining but without any effect on strength properties; (2) the sustain fungi will lead to both colour distinction and strength loose of parts of timber, and the conditions of strength loss will be based on the regions where timber trees grow; (3) the most important group of fungi, wood-rotting fungi, will result in decay by chemical decomposition completed by the digesting action of enzymes hided by the fungi hyphae. This part will demonstrate the third group of fungi in detailing. Wood-rotting fungi can be classified into two patterns: Brown rots and White rots. Generally, the brown rots mainly contribute to constructional timbers, while white rots normally lead to decay of external joinery.

9.2.4. Performance of timber in fire. As for durability and defects, the bark and paler sapwood of tress are non-durable and susceptible to insect and fungal attack, because the sapwood is porous to be the primary part to transfer moisture from root to other parts of the tree. But even these, if kept out of moisture can last centuries. So the courses referring to protecting timber from dampness should be paid a great deal of attention.
9.2.5. Temperature and termites. Air, moisture and normal temperatures are three factors that will invariably result in wood decay. But the capabilities of different species to resist decay are various. In a constantly damp environment, decay can become significant within a year’s exposure. A number of circumstances can be considered as damp environment, such as wet soil, marine structure, water spray or vapor or poorly drained structures. Wood is dry or only occasionally wet for a short period of time will not decay. Wood that is completely inundated in water without exposure to air will not decay. And timber used externally but without contact with the ground will generally have a much longer life, though quantification of this is impossible. So, the necessary factors for wood decay are moisture and air.

Besides, if parts of wood are in contact with the soil, they would be damaged by termites in a short time. In such a case, a preservative is needed to protect the wood from being attacked. The termites can enter any small openings, in plus of the porosity of the wood, which give more possibilities to be attacked. So application of poisoning agents such as chlordane or aldrin is necessary to protect the wood.

9.2.6. Accidental decay. Royal Institution of Chartered Surveyors (RICS) (1993) figured out a number of check points that should be taken into account during the process of assessment towards current conditions of existing buildings in the publication, A checklist for the structural survey of period timber framed buildings, which can be concluded in two aspects:

- Different employment positions will lead to different degrees of decay. The south elevation of a building suffers longer sunshine, which may result in loss of the moisture, so it is easier to fine joint shrinkage in the south elevation in comparison with other elevations.

- Apart from the environmental influences, the activity of loads will also lead to decay. So the characteristics of timber especially the mechanical properties of timber should be assessed and employed in an appropriate way. For example, frame distortion may happen at different positions if the load is distributed differently.

In total, although timber has to suffer this degradation, it can still be a durable material that can be continuously used over centuries. But as found in references, the majority of timber framed buildings are of less important architectural purposes. On a plus side, the presence of fires and particular weather in Britain whose climatic condition provides positive atmosphere for fungal decay, the number of survival timer-framed buildings is not considerable. But most of these survival buildings are recognized age-valued and of historic and architectural interest. So, more awareness towards the importance of timber-framed buildings should be achieved and an increasing deal of effort should be put on their conservation.

10. Tools and Techniques Used in Dealing With Timber
Tools and techniques applied in the whole life of timber from felling to sawing then to constructing as well as conservation differ in terms of both the types and times. Complex and skilled medieval carpentry techniques exploited the natural properties of the material, and thus avoided the labor, waste and loss of strength involved in converting crooked cylindrical logs to the precise rectangularity that modern convention demands (Rackham, O., 1976). Because the various purposes will lead to different requirements for types and with the development of the people’s understanding and intelligence the techniques has hugely improved. Considering the complexity and diversity of the techniques employed in the timber course, this part will demonstrate the wide range of techniques in sequencing order.

10.1. Durability of timber

10.1.1. Axe. Axes are the earliest tool used in felling timber trees. Then when being used to convert the felling trees, the first tool applied in converting historic timber is also axe. Then if the dimension of a tree is as close to the expected timber’s dimension as possible, a process of hewing is enough. But if necessary, sawing will follow to shape the hewn timbers. During this procedure, one interesting thing should be mentioned that different marks will be left on the timber referring to various sawing
techniques (Forsyth, M., 2008). Also there are a number of cunning principles serving during this process, for instance, it is an easier way to use timber immediately after felling, which can simultaneously reduce the problems of organization.

10.1.2. Sawing. The employment of saws in conversion of timbers have been a symbiotic relations with Romans and it finally returned in the 12th century (Forsyth, M., 2008). But the requirements of different shapes of timber demand more corresponding tools to be introduced. Apart from the felling axe, more various saws are needed, mentioned by Brunskill (1985), the pit-saw and its mechanical successors and the cross-cut saw for cutting timber to length (p.30). Besides, the tendon saw has been associated with the joints. There are also other a number of tools used in shaping timbers, setting out work and assembling the differing timber members, which has been studied deeply in the book-Timber Building in Britain and will be shown in Appendix.

10.1.3. Extra Hardware. Referring to timber construction, extra hardware includes a number of items used for fastening and supporting the timber components. These items include nails, spikes, bolts, screws, staples, and several kinds of timber connectors in order to ensure the convenience and efficiency of timber construction, the tools and hardware applied are required to be standard (Waddell, J.J., 1985). However, these items used for timber constructions are available in various types and sizes. Due to the amount information that they will include, they will be out of the scope of this report. But a number of reference materials will be provided for users to refer. (Chapter wood, pp.253-264).

10.2. Techniques

10.2.1. Marking. From the past to present, the marking of timber has played different, but equally important roles. During the past, marking timbers was used by carpenters to identify the process of timber construction, including joints testing and subsequently reassembling. Consequently such marks can be considered as significant evidences for dating timber-framed works, which is one of the most commonly used for cost-efficiency methods for conservation surveyors. In this case, the positions of marking in timbers and the tools applied for marking are two essential elements that should be clearly identified chronologically. With these done, the subsequent dating would be more accurate.

10.2.2. Timber survey. It is the earliest procedure of repair. The date of timber and the current conditions should be given. When referring to the techniques, non-destructive testing of suspect timbers can be carried out using a micro-drill that measures the density of a beam, highlighting voids or rotten material. The word, non-destructive, also simultaneously shows the regard to the original condition. One of the dating methods is with the assistance from documentary references (Brunskill, R.W., 1985). It means that all the existing records related to survival building, including the original serviceable contract, relevant alteration or extension or family records or anything else reflecting this building can be regarded as evidences to date the structure. But there are inevitable uncertainties in terms of this method, for instance, whether there is a contract worked with or the precision of the existing records, especially in case of some humble buildings. So this method is not completely accurate. Another dating method mainly lies on the dating of timber itself. A number of carves which can illustrate the date of construction on timber can be served as evidences for specific dating. Besides, according to Brunskill, R.W. (1985), an increasingly useful technique for timber constructions dating is provided by dendrochronology or scientific examination by Carbon 14.

As a consequence of its high cost either on-site or in laboratory examination it is also not commonly or frequently used in timber dating, though it has been considered as a most useful method in dating course. Whereas, the most frequently employed method for dating is records based or experience based recognition. Therefore, a wise or cunning carper or an experienced consultant is necessarily required in timber dating as well as timber survey, which will provide a series of contributory results for subsequent conservation.
11. Timber Building Protections

It can be divided into two aspects to illustrate: precaution treatment and repair. In respect of precaution, preservative should be adopted to preserve any timber to be used under such a condition that is vulnerable to decay. It would be an efficient method to reduce the risks of decay in later service. If other decays occur in subsequent serviceable period, treatments should be given, to a certain degree, depending on the reasons resulting in decay.

Although good buildings can successfully avoid dry rot infection, it is still at the risk of being attack by some species of beetles which can be active under a fungal infection. There are two available or possible accesses for many beetles to get into wood, which are separately small gap between roof-covering unites and the space between wood and the wall. All these easily get into entrance for egg-laying beetles should be treated specifically, by well painting, varnishing, polishing or being poisoned with insecticide. Timber floor surfaces should be wax polished, treated with floor-seal, painted or liberally coated with an insecticide.

Timber at different damaged levels are advisable to be treated in different methods: injection of flight holes every 3 to 4 inches (76 to 102 mm ) in this way is only necessary to give added penetration in hardwood. While timber that has been heavily attacked may have to be cut out and burnt, and replaced with new timber suitable treated. As important as treatment, following observation towards timber behaviour is also required. In order to achieve this goal, a new found hole should be filled with putty, beeswax or a wood-filler of non-organic material on the basis of surface finish. Both regularly check and treatments are contributory elements of timber conservation.

- Timber-to-timber repairs
- Metal reinforcement

Metal that can be used in timber repair for strengthening purpose chiefly includes iron and steel. Although, sometimes, they are more useful and efficient than any other methods, it is still advisable to be avoided in the repair of historic timber framed buildings. Because such intervention would not be timber-to-timber repairs which are considered as the most acceptable method for repair. In this case, a new oak can serve the purpose. On a plus side, the connection between metal and timber will result in further decay problems, such as fungal attack. Therefore, just under the following situations, a metal repair is suggested or acceptable: (1) have slightly visual impacts on the original ancient timber work; (2) cost constraint, sometimes it is not allowed to repair using oak material. (Powys, A.R., 1929)

12. Conclusion

China plays a significant role at the international level for the large number of timber framed historic buildings. Apart from the respect of chemical matters decay, there are other inevitable reasons for this particular region. One of the most important reasons is dynamic effects mainly from natural disasters, including earthquakes, typhoons and other similar phenomenon. These put more structural problems on the timber framed historic buildings, which should be paid more attention to study and produce an efficient method to preserve. In case of these particularly regional reasons, a further study towards each special field should be produce.

Interestingly, from the timber framed building examples given by Brunskill, R.W. (1985) in part three, chronological survey of timber building, of his publication “Timber Building in Britain” that from the early ninth century until the nineteenth century, the commonest types of timber building in Britain are farm buildings (barns), dwellings and small scale churches. Almost all these humble buildings similarly are less significant buildings as the grand cathedrals or other buildings of significantly architectural intent. As one of the most possible consequences the number of survival timber framed buildings has declined through past centuries. However, these seldom survival timber buildings are of special historic and architectural interest, which makes it an essential issue to conserve them. Hence, a deep understanding and survey upon these survival buildings should be achieved and recorded.

References

[1] Borneo, J., 2003. A report on the material timber towards the degree of Master of Science in the conservation of historic buildings. Bath: the University of Bath
[2] Brunskill, R.W., 1985. Timber building in Britain. London: Victor Gollancz Ltd in association with Peter Grawley
[3] Waddell, J.J., 1985. Construction materials ready-reference manual. USA: McGraw-Hill, Inc.
[4] Levin, E., 1971. Wood in building. London: Architectural Press
[5] Forsyth, M., 2008. Materials & skills for historic building conservation. Oxford: Blackwell
[6] Dinwoodie, J.M., 1981. Timber: its nature and behaviour, 2nd edition. London: E & FN Spon.
[7] Scott, G.A., 1968. Deterioration and preservation of timber in building. London: Longmans, Green and Co Ltd.
[8] Powys, A.R., 1929. Repair of ancient buildings. London & Toronto: J.M. Dent & Sons Ltd.