Thesis:

Timber

in Its Relations to

Civil Engineering

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C. E. Class '74.

I. I. U.

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Preface.

The following authorities have been liberally consulted: Van Nostrand's Engineering Magazine, Vols. I. II. III. IV. London Builder, for 1844. The Articles in American Cyclopedia on Preservation of Timber. Journals of Franklin Inst. for 1873-74. Bruce's Civil Engineering and Civil Engineer's Journal for 1865-66-67. The tables given here with were copied direct from Rankine's Rules and Tables.
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Timber:

Part First.

Strength.

Introduction.—The importance of this subject to the Engineer can be best understood if we take into account the fact that there are about 70,000 miles of railroad now in operation in the United States. There will necessarily require large amounts of timber for the construction of bridges, culverts, snow-sheds, and no small amount for the two other items of telegraph poles and railroad ties. Allowing that in each mile of road there are only 2,000 sleepers, each 10 inches wide, 6 thick and 8 feet long, we have 666,666 feet in the ties of each mile.
of road. Multiplying this by the number of miles constructed and we have a grand total of 1,660,000,000 feet used for this purpose only. As the average life of the American slinker is only about seven years, the amount required to keep the roads in use alone is alarmingly great. Any process which could easily and cheaply be applied to prolong their usefulness would literally save millions to the country in post cost besides the improductive labor of replacing the worn out ones with new.

Nods should not forget to take into account the employment of timber in river and harbor improvements and canal embankments and locks, street pavements, wagon and railroad bridges. Straw is coming into more general use for the coo-
struction of bridges, yet the amount of
woods in use in these structures
at the present time and which will
from the nature of the case be used
for a long time to come is enormous.
The timber in some of the latter
named constructions is in a more
exposed condition than the rail
road tie just mentioned, and also
would be much more difficult to re-
place with new ones. In the finan-
cial view of this subject then we have
strong argument for the Preservation
of timber. But there are higher
and stronger grounds for opposing
this extravagant waste of this to
the engineer most important of Nat-
ural gifts. The Engineer and Archi-
itect will always require large
amounts of timber in their construc-
tions and our present injudicious
rates of consumption are far in ex-
cess of the growth of our forests.
We have no right to uselessly and knowingly waste that which belongs to the generations which shall come after us, for thereby we leave them in a helpless condition. A broad and liberal but truly economic view of the subject would endeavor to devise some way of keeping our consumption and production of timber carefully balanced. This can be best accomplished if those who use timber would carefully determine the office he expects the timber used to fill and then decide what species will best satisfy these ends. Having determined what his wants are and what will satisfy them, he should use his better judgement and see that they are satisfied only with the best of material. The material having been secured, thought to take particular care that it is treated in such a manner as to present
its decay and thus secure the full benefit arising from its use. The object of this discussion is the statement of facts, the proper observance of which will successfully satisfy the above conditions.

Descriptions of Timber.

We now proceed to treat of the various timbers individually, taking them approximately in the order of their importance to the Engineer.

Oak.—To the oak has been justly awarded the preeminent title of "King of the Forest," and when we consider its high qualities as well as the length of its existence, we must approve of the distinction and give it in our notice of the timbers. That first place to which it is so honorably entitled. About forty species of this tree are enumerated by the Botanist as found in our forests and those of Mexico. The most of them afford a good timber for
engineering purpose. However it is not very well suited for beams or small timbers owing to its liability to warp and split. But for use where large timbers are required to bear heavy transverse strains, the oak has no equal. Of the several varieties the White Oak is the most valuable. It is so named from the color of its bark. It is stiff, straight, tough, and close grained and generally long sticks can be had free from knots. These qualities make it very desirable for long beams that are required to sustain great strains.

Post Oak.—This tree seldom attains a greater diameter than fifteen inches and on this account it is mostly used for posts from which it takes its name. It is not so straight grained nor so free of knots as White Oak. But these properties rather add than detract from its value for compressive timbers in any construction. When sawn up, it makes
excellent building material for the lighter kinds of framework.

The Chestnut White Oak, Rock Chestnut Oak, and live oaks are important and useful timbers, however, they are mostly used in shipbuilding.

Pine.—This genus is considered inferior only to oak, from the excellent timber afforded by nearly all of its species. It is regarded as a most valuable building material, owing to its strength and durability, the straightness of the grain, and the ease with which it is wrought and its applicability to all purposes of construction.

White Pine, which takes its name from the color of the wood, is the species most commonly used. It constitutes the principal part of the great pine forests of Michigan, Wisconsin, and Minnesota. The wood is light, soft, straight-grained, and easily worked. The resinous matter
which fills the pores makes the timber very durable, especially in this true of the heart-wood. Wherever it can be had without too much cost for transportation it supersedes all other for general building and engineering purposes. When lightness and length are demanded in their highest degree, Norway pine is used. It is very superior in this place on account of tenacity and inflexibility. It is found in considerable quantities in the pineries of the Great Lakes.

Elm.—This is a very valuable timber for use in situations constantly moist. However it loses much of its value if subjected to changes of temperature and moisture. The sapwood is almost equally valuable with the heart.

Its great length and uniform size
render it very useful in engineering constructions for longitudinal ties and piles which require great length combined with great strength. As proof of the durability of elve, when constantly wet, mention may be made that it was used chiefly for the piles on which the Old London Bridge was founded. After having been driven upwards of 800 years they were found sufficiently sound to build upon again. The elve piles under the old Savoy Palace in London were also found sound 650 years after they were driven. These piles had been constantly wet with fresh water. As long as allowed to remain in this position, these piles were plenty strong enough to sustain the weight put upon them, but when exposed to the air decayed rapidly.
Cedar.—Though comparatively scarce, it is among the most valuable building timbers. It is almost indestructible and no insect will attack it.

Beech.—To secure the best result from this timber, it is best to place it where it will remain damp; then it is a long enduring tree.

Chesnut.—If this wood is kept dry, it is equally durable with oak. It grows with frequent twist and contortion which detract from its value for the engineer's use. These very defects are points which recommend it to the shipbuilder by whom it is highly prized. The trees in the Westminster Abbey roof are chestnut. They were examined a year or so ago and found to be perfectly sound. They had been in use 460 years! Of those not yet named
the principal ones are Ash, Birch, Fir, Sarch, Maple, Poplar and Walnut. These all are more or less used by the engineer. In selecting the timber for any structure care should be taken to secure maximum strength and durability with minimum weight and cost.

<table>
<thead>
<tr>
<th>Name of Timber</th>
<th>W E R C T</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ash</td>
<td>43.1</td>
</tr>
<tr>
<td>Beech</td>
<td>53.3</td>
</tr>
<tr>
<td>Birch (kn)</td>
<td>40.5</td>
</tr>
<tr>
<td>Cedar</td>
<td>56.5</td>
</tr>
<tr>
<td>Chestnut</td>
<td>36.3</td>
</tr>
<tr>
<td></td>
<td>W</td>
</tr>
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<td>-------</td>
<td>-------</td>
</tr>
<tr>
<td>Elm</td>
<td>367</td>
</tr>
<tr>
<td>Fir</td>
<td>545</td>
</tr>
<tr>
<td>Sarch (green)</td>
<td>3262</td>
</tr>
<tr>
<td>Sarch (dry)</td>
<td>85</td>
</tr>
<tr>
<td>Maple</td>
<td>49.5</td>
</tr>
<tr>
<td>Oak</td>
<td>573</td>
</tr>
<tr>
<td>English Beech</td>
<td>258</td>
</tr>
<tr>
<td>Pine Am. Yellow</td>
<td>412</td>
</tr>
<tr>
<td>Pitch White</td>
<td>28.9</td>
</tr>
<tr>
<td>Poplar</td>
<td>41.9</td>
</tr>
<tr>
<td>Walnut</td>
<td></td>
</tr>
</tbody>
</table>

The figures just given are at best only approximate for there are so many causes which influence the strength of timber. The soil on which a tree grows greatly affects the strength and durability of the timber. Generally the timber grown in low, damp places will be weaker and less durable than that grown in dry, rich loam. Also the age of a tree greatly influences the timber it produces. Trees should not be felled for timber until they have at
tained their mature growth not after they exhibit signs of decline, otherwise the timber will be less strong and much less durable. Most forest trees arrive at maturity between fifty and one hundred years. The age of the tree can in most cases be ascertained either by its external appearance or by cutting into the center of the trunk and counting the annual rings of both sap and heart. When a tree commences to decline the extremities of the branches, and particularly the top, begin to show signs of decay.

Again timber taken from differenties in strength as great as that between different trees. Until the tree reaches maturity the best timber is found farthest from the bark. After the tree has commenced to decline, the
Best timber is midway between the bark and center. The bark if allowed to remain on after the tree is felled, only serves to hasten decay. The sapwood has but little value as timber.

Many experiments have been made to devise means whereby it may be improved both in strength and durability. These experiments have been mostly directed towards the manner of preparing the tree before felling and the determination of the best time of the year to fell. One method consists of girdling, or making an incision with an ax around the trunk, completely through the sapwood, and then allowing the tree to stand until it dies. Another method is to strip the bark from the trunk in the spring and allowing the tree to stand until the new leaves have fal-
low off and then cut the tree. This method does not injure the sap and by cutting it but to the contrary improves it materially. The latter method is much more highly recommended than the former.

This now brings us to the

**Part Second.**

**Durability.**—The protection of timber from decay is a subject which for some time past has been attracting much attention both in Europe and this country. In this discussion we shall consider it chiefly in reference to the construction of rail roads and their accompanying bridges and to river and harbor improvements.

**Kinds of Decay.**

**Dry Rot.**—A very destructive form of decay is that known as dry rot. It commences within the body of the timber and however well it may be protected
by paint or varnish, it comes with-out any indications of its existence upon the outside, and goes on converting the fiber of the wood into dry dust and spreading from the interior outward. This form is the more destructive from the fact that it is communicated without direct contact of the sound and unsound timber. The heart wood, being of a closer texture and without cells or sap, is less liable to dry rot than the sap wood, if it goes on more rapidly where there is no circulation of air. Only timber in a damp situation is subject to this species of decay. If the timber is kept perfectly dry, it will last for centuries as is the case before mentioned of the roof of Westminster Abbey. The timbers of the roof of St. Paul in Rome were sound and good after 1000 years of use. So many cases
could be rehearsed as to give authority to the statement that under this condition artificial preservatives are unnecessary. There is considerable discussion as to the exact nature of this species of decay. Some contend that it is caused by parasites, others believe that parasites only appear after decomposition has set in. This question we will not discuss, but take as a fact that timber is subject to decay if not allowed a free change of air. There is a probability that dry rot is a result of filling timber while it is in full sap, that is between the beginning of spring and autumn. Impregnating the timber with a solution of rock salt is a preventive of dry rot and a preventative from various insects as well. Timber treated in this way is caro
paratively incombustible at least it will not burst into flames. Another mode of prevention consists in soaking the timber for a short time in lime water. A potted tank of a size suitable to the amount of timber to be treated is necessary. The lime is added to the water in the proportion of 88 grains to one gal. Timber treated in this way stands the weather remarkably well. It has the recommendation of cheapness in a high degree.

**Wet Rot.**—When exposed to the action of the atmosphere timber is progressively acted upon by damp. This is especially noticeable in timber fixed in the ground. The action commences at the parts immediately above the ground where the fibrous portions are softened by moisture, mould and decay being pro...
dried. These are indications of a sort of slow combustion which is set up by the alternations of wet and dry. Timber is subject to this kind of decay in either of four conditions:

1. Constantly damp
2. Constantly wet in fresh water
3. Alternately wet and dry
4. Alternately wet and dry in sea water

The two first conditions are not very difficult cases, as far as the decay of timber is concerned. Timber under these conditions is subject to attacks of marine destroyers which will be noticed hereafter.

Many cases are recorded of the great durability of timber constantly wet in fresh water. The piles of the London Bridge were found 100 years after they were driven. Piles under the Savoy Palace, London, were found to be in a perfect state of preservation after they had been there 650 years. These are not iso-
lated cases, but others could be cited to prove that when under such conditions as to exclude the air, it is doubtful if artificial preparations would prolong the life of timber.

As a mere matter of curiosity we might state that in the S.W. part of New Jersey there is what we might call a timber mine. The facts in this strange phenomenon were obtained through the kindness of Prof. Webb. The surface is covered with quite an extensive forest of cedar trees of some size. At the distance of about 100 feet below are found logs of cedar perfectly sound. These logs are brought up and worked into shingles which are of excellent quality. It would be unsafe to hazard any statement as to how long they have been buried.
The only reasons that can be assigned for this anomaly are that the temperature was constant and that the air was excluded. We then conclude that where timber is to be constantly covered with water, no mode of preserving it is necessary except as protection against the ravages of marine insects.

We pass to the consideration of the next two conditions viz.: constantly damp and alternately wet and dry. These two are the conditions most destructive to timber.

It is to guard timber under these conditions that all preservatives are designed. But no matter what mode of preservation is used a free circulation of air about timber in damp places tends greatly to prolong its life.
Unseasoned timber which is surrounded by dead air decays very rapidly. The timber of many modern constructions is transferred from the forests and enclosed in a finished building in a few weeks; unless it is subject to a free circulation of air, it inevitably decays rapidly.

**Causes of Decay.**

The chief causes of decay of timber lie in the fermentation or decomposition of albuminous matter in the cells of the wood. This matter may be coagulated and destroyed by heat, which hardens the wood, or the albumen may be expelled or nullified by thoroughly steaming or it may be neutralized by some chemical agency, as by creosoting, burnt sizing.
Modes of Preservation.

Seasoning.—The indifference of a distinction by builders between seasoned and unseasoned timber is manifest in many modern constructions. The instance of the before mentioned footbridge over the I. C. R. R. is an example of this. The use of unseasoned timber in bridges is the cause of frequent accidents. The timber is subject to rapid decay. The authorities force themselves that the bridge is new, hence strong. By this means bridges are allowed to become weak and as a result we hear of some frightful accident. Thus there is frequent loss of life and large waste of money. In the use of unseasoned timber, for seasoned can always be secured at a trifling cost extra.
By seasoning, we do not mean simply expelling the water of the sap but a removal or a change of the albuminous substances. There are numerous methods for promoting the process of seasoning. Some have in view simply drying. Seasoning timber by exposure to the open air is very good provided the timber is not to be exposed to dampness. In the seasoning process the natural juices of the wood are hardened and thus rendered harmless, so long as they continue in that condition. The moisture penetrating the pores redissolves these juices and the fungus soon makes its appearance. Some dry with hot air, others with steam.
Salt. case if the steam is superheated the process is very rapid but seems to damage the timber. It is recorded that wood which has lasted perfectly well for 600 years, by an unfavorable exposure to moisture has been attacked in a few weeks by rot. Other methods have in view the expulsion of the albuminous substance. This process is very good for any timber but resinous, as pine and cedar, it injures the latter named timbers.

There are many patented processes for securing neutralizing and changing the albuminous substance by an injection of some chemical, thereby promoting its strength and durability. The following are the principal ones.
Hydrating.—In this process the timber is immersed in a corrosive sublimate until it is saturated. If it is desired to hasten the process, it is done by placing the timber in a strong tank and after exhausting the air from the solution under a high pressure. This is a perfectly satisfactory process when it is faithfully conducted. The only objection against this is tediousness of the process without the closed tanks and the extra cost with them. For these reasons it has been almost entirely abandoned.

Bourcheric process.—This is a method in common use in France for the preparation of railroad sleepers and telegraph poles.
The material used is sulphate of copper dissolved in a hundred parts of water. By suitable apparatus, this mixture is forced into the timber lengthwise of the grain. This method has the element of comparative cheapness to recommend it. Several other salts have been used in much the same way.

Cross-dying.—The wood to be treated is put into a close tank from which the air is exhausted, the operations of the air pumps being continued several hours. Then an oily mixture obtained from the distillation of the tarry liquor of gas works is admitted under a pressure of about 150 lbs. per sq. in. This is kept up for about 48 hours longer. This process is adopt
tled by several of the leading railroads in Europe, for the preservation of sleepers and is highly approved notwithstanding its somewhat expensive character.

Timber thus treated has a very disagreeable odor and is and even inflammable than before. Insects will not attack it. As long as the timber remains saturated it is perfectly protected against the ravages of the shipworm. The trouble is that the water washes the solution out. This process greatly increases the weight of timber its strength is also somewhat increased.

Prof. Searley of New York has lately invented a process somewhat similar to this. By his method the wood is subjected
to a temperature of about 230° while in a bath of creosote oil, for a sufficient time to expel all the moisture and coagulate the albumen of the wood. After the water has been driven from the pores and steam only remains, the temperature is reduced to 60° or 70° by means of which change the steam in the pores is condensed and a vacuum produced. The oil is then forced into the pores by the pressure of the atmosphere. This process has been credited with all the advantages of the English process and is much more simple in its application. Among the advantages claimed is that green wood can be treated as well as dry. This process is in successful operation at Chicago for the treat-
ment of R.R. ties and dock timbers. The Chicago, Burlington and Quincy R.R. are preserving all their timbers by this process. At Aurora shops they have a tank of boiler iron 10 feet square and 7 ft. deep. The sleepers are allowed to remain in the tank about 30 hours.

**Burnettizing.** This method is in more common use in the U.S. than any other. It has been used extensively at Lowell for the preparation of the timbers in and around the canals and locks. Works have been erected especially suited to preparing timber by this process. A cylinder two feet long 5 ft. in diameter made of boiler iron one inch thick is used. In the bottom of the cylinder is a small track on which runs trucks which
ferry the lumber. About 7000 can be treated at one time. After the truck is in and the cylinder is closed, the air is exhausted and a vacuum is maintained of 28 inches of mercury. The cylinder is then filled from a large tank, with a solution of 100 parts of water and 12 parts dry chloride of zinc, and the pressure raised to 125 lbs. per sq. in. about the atmospheric pressure. The process is expeditious and cheap. The charges are about $5 or $6 per M. board measure.

Painting: A good heavy coat of paint, pitch or other impervious substance applied to seasoned timber in damp places increases its durability greatly. But to the contrary if this coating be applied to un
seasoned timber it is very detrimental, for it encloses all the elements of decay and compels them to do their destroying work. Owing to this blunder alone, it is no unusual thing to find the painted woodwork of all buildings completely rotted away while the contiguous, naked parts are perfectly sound. It is best to paint in the winter if the surface is dry, for then the pores of the wood are shut.

Carboning. It is a common thing to char posts that are to be set in the ground. This increases the durability of dry, but promotes the decay of unseasoned timber, for the same reason that painting would. Unless a discrimination is made between green and seasoned timber, these operations will prove
A person applies his ear to one end of the stick while another strikes the other end and a smart blow with a hammer. If the wood is sound the sound will be heard distinctly, no matter what the length of the piece. If the timber is disaggregated by decay the sound will for the most part be destroyed. Care must be taken not to lay wood upon moist stone, which is sure to cause its decay. Take the precaution of interposing plates of lead or iron between stone and bearing timbers. Carefully exclude timber from stone work.

Torpedo Navalis.—This is one of the worst enemies of timber constantly wet in salt water. There has been no means de-
viscid for completely protecting timber against its ravages. Organizing affords protection for a time, but the constant motion of the sea water dilutes and washes away the poison with which the wood has been injected. The only way now possible seems to cover the timber tightly with a casing of metal.

Conclusion.
Our purpose will have been accomplished if we have succeeded in awakening attention to the absolute importance of the intelligent study of timber and its properties as a branch of the great profession of which the engineer, architect, shipwright are alike essential members.