MODERN TIMBER CONNECTORS
Increase the Use of Wood
For Heavy Construction
by
Orval H. Rawie

A Thesis
Presented to the Faculty
of the
School of Forestry
Oregon State College

In Partial Fulfillment
of the Requirements for the Degree
Bachelor of Science
June 1940

Approved:

Professor of Forestry
Figure 1. Radio towers, 330 feet high, in the Muhlacker station, Stuttgart, Germany, built of southern yellow pine with Kubler wood dowels and brass bolts.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wood Research</td>
<td>1</td>
</tr>
<tr>
<td>General Properties of Wood</td>
<td>1</td>
</tr>
<tr>
<td>New Products of Research</td>
<td>3</td>
</tr>
<tr>
<td>Modern Timber Connectors</td>
<td>6</td>
</tr>
<tr>
<td>Their Importance</td>
<td>6</td>
</tr>
<tr>
<td>Origin and Development of Modern Timber Connectors</td>
<td>7</td>
</tr>
<tr>
<td>Theoretical Action of Bolts and Auxiliary Connectors</td>
<td>13</td>
</tr>
<tr>
<td>Significant Factors in Connector Design</td>
<td>18</td>
</tr>
<tr>
<td>Classification of Modern Connectors</td>
<td>19</td>
</tr>
<tr>
<td>Modern Connector Stressed in Bending</td>
<td>19</td>
</tr>
<tr>
<td>Meltzer Steel Tack</td>
<td>20</td>
</tr>
<tr>
<td>Hinged Joints</td>
<td>21</td>
</tr>
<tr>
<td>Auxiliary Bearings for Bolts in Joints</td>
<td>21</td>
</tr>
<tr>
<td>Connectors Stressed in Bearing</td>
<td>21</td>
</tr>
<tr>
<td>Bulldog Connectors</td>
<td>22</td>
</tr>
<tr>
<td>Spike Grid Connectors</td>
<td>24</td>
</tr>
<tr>
<td>Toothed Ring or Alligator Connectors</td>
<td>25</td>
</tr>
<tr>
<td>Split Ring Connectors</td>
<td>27</td>
</tr>
<tr>
<td>Claw Plate Connectors</td>
<td>29</td>
</tr>
<tr>
<td>Flush Type Shear Plate Connectors</td>
<td>31</td>
</tr>
<tr>
<td>Disk and Coned Dowels (Kubler Dowels)</td>
<td>32</td>
</tr>
<tr>
<td>Modern Connectors in Use</td>
<td>34</td>
</tr>
<tr>
<td>Advantage of Modern Connectors</td>
<td>36</td>
</tr>
<tr>
<td>The Future</td>
<td>40</td>
</tr>
<tr>
<td>Literature Cited</td>
<td>41</td>
</tr>
<tr>
<td>Appendix</td>
<td>42</td>
</tr>
</tbody>
</table>
The successful maintenance of our forest resources, in the condition of productivity that will supply the Nation's future needs for wood and wood products, is dependent largely upon creating a commercial incentive for tree growing.

Anything which helps to develop improved uses for wood, to broaden and increase the market for tree products, encourages the commercial incentive for tree growing.

Wood possesses a larger variety of inherently desirable qualities than any other material used in building; but, as in all raw products, these qualities require intelligent exploitation. "Produced by nature on her own terms, it is a nonhomogeneous and nonuniform substance whose strength and dimensions are sensitive to many influences."\(^2\)

Before the establishment, in 1910, of the Forest Products Laboratory at Madison, Wisconsin,\(^3\) little was attempted in this country in the way of refining this product and expanding its horizon of use. This may be attributed to the fact that wood is so versatile in a mediocre all around way in the raw state, and because centuries of tradition had defined the scope and manner of its use....and misuse.\(^2\)

**General Properties of Wood.**

Wood is easily workable, requiring only simple craftsmanship and tools; it is strong for its weight, of light weight in relation to volume, possesses high thermal and
sound insulation value. It has the advantage of being almost universally available, relatively inexpensive, resistant to fatigue, easy to finish, and is a renewable resource.

However, it has many undesirable qualities which, until recently, have greatly restricted its use. It is susceptible to extreme shrinkage, expansion, and warping. It is limited as to unit size; it absorbs water; its strength is not uniform in all directions; it cleaves easily, cannot be flexed and fixed, cannot be molded to desired shapes except within extremely close limits.

The preceding list of qualities, unfavorable to the use of wood, might seem to out-weigh its good qualities and definitely limit its use as a material for building. But, we all know that wood has for a long time, and still is being used for building. The disturbing thing, though, is the fact that competitive products are making great inroads upon its fields of use. Statistics show that the per capita consumption of lumber has decreased during the past thirty years by more than half, despite an actual net gain in building expansion during the same period.\(^4\) It is unfortunate that the exhaustable resources of this country, such as iron and other metals, should be used for construction purposes when those construction needs might well be fulfilled by wood, the material that grows.

The situation is, however, not hopeless. On the contrary, the future of wood is brighter than it has been for
some time. Through the medium of research the good qualities of wood are being further developed and the undesirable ones are being overcome quite satisfactorily.

The results of the efforts of the research laboratory staff on the improved uses of wood when distributed to the people, and when fully understood and appreciated by them should have a very favorable affect upon the regaining of lost, and the opening of new outlets for wood and wood products. Each of the most undesirable properties of the raw product can be eliminated to some extent by the special processing and manufacturing techniques.

New Products of Research.

In the past twenty-five years belated research has been made in many directions which has resulted in better control of the inherent properties and development of greater uniformity in the raw product by silvacultural methods; formulation of more exact and more satisfactory data on standards of strength, deflection, etc.; reconstruction into new physical forms; improvements in methods of distribution; and bettering the wood in its original form by adding chemicals to it.

By forcing substances inhibitive to bacteria and fungi into its fibrous tubes, wood can be made to resist decay and fungus growths for apparently unlimited periods of time. By forcing substances inhibitive to bacteria and fungi into its fibrous tubes, wood can be made to resist decay and fungus growths for apparently unlimited periods of time.2

Fixed dimensions are assured by deep impregnation with chemicals which make the wood structure practically impene-trable to the movement of moisture vapor.2
Lumber can also be made to resist combustion by impregnation with chemical salts which fill the hollow cell structure, leaving no space for oxygen. This should make even more valid the statement that, "In fires of short duration but enormous heat, almost any variety of wood of more than a specified minimum size (4" by 4") resists fire better than exposed steel and commands a lower insurance rate. The fire hazard of a building is determined more by the contents than by the structure itself."\(^2\)

Within the last year a salt process has been developed to eliminate checking and warping of large timbers during seasoning. The treatment brings about a state of moisture equilibrium in which the wood dries from the center outward, reversing the usual direction, and in the final dry condition, the salt absorbed acts in a way to hold the wood against shrinkage and change of shape.\(^2\)

The many advancements which have taken place in the production of plywood may be attributed to the new types of binders used. Many types of glues have been used as binders--animal, vegetable, casein, albumen, and silicate--but the newest and seemingly most satisfactory type is phenolformaldehyde resin which has greater water resistance, is non-toxic and is not attacked by fungus growths or bacteria.\(^2\)

The production of plastics from lignin, a former waste product of chemical utilization of wood, is another of the results of research effort.
All of these products of research are very important contributors to the expanding uses of wood. However, one of the fields of wood uses, which has in the past consumed a very large volume of wood, has been losing much of its importance to substitutes because of a definite weakness in use methods. This field is the field of heavy timber construction and the weakness is the methods of construction which have been greatly directed by an inefficient jointing system. Research on this problem has been conducted and the results have and will perform wonders with the old methods of timber construction. This revolutionary product of research is called the "Modern Timber Connectors".
MODERN TIMBER CONNECTORS

Their Importance

Wood is an important material for the construction of large structures, but due to research activity on other types of structural material which improved and increased their uses, timber has slipped badly in the volume used for this purpose. Other materials have gained ground because wood was limited as to the strength which could be developed in wooden structures.

Now wood itself is a very strong material—weight for weight some wood is equally as strong as iron2—, but whenever it was necessary to join two pieces of wood together, engineers were obliged to discount from 40 to 60% of the strength of the wood itself. This, as can easily be seen, is a serious draw-back to the use of wood for structural purposes. The reason for such a condition is naturally the lack of a suitable means of joining timbers. The overcoming of this situation has been another of the problems which research attempted, and with successful results. From an investigation into the problems of joining timbers came a series of devices called modern timber connectors.

These timber connectors consist in general of metal rings or plates or wood disks that, imbedded partly in each member, transmit load from one structural wood member to another. Their purpose is, of course, to strengthen the joint between the members of a wood constructed unit. As before stated, this joint has long been known as the weakest
part of any structure built of wood, and the use of wood as a structural material has been greatly restricted because of this weakness.

Connections in timber framing are usually made by lapping the ends of the members to secure friction surface to aid in transmitting load from one member to another. It is necessary to use bolts or some such device to secure the members together and help transmit the load. With the use of only bolts in the joints it is possible to develop but from 40 to 60% of the allowable working strength of the members. The use of timber connectors, on the other hand, make it possible, in most cases, to count on the full allowable strength of the wood.

Origin and Development of Modern Timber Connectors.

The extensive development and use of keys and dowels, which are essentially what modern connectors are, started during the four catastrophic years of the First World War, chiefly among the Central Powers whose enormous war machines were demanding and consuming in increasing quantities vast amounts of munitions and war materials. At the end of the war, steel and iron for structural purposes and skilled labor, which was needed for their erection, had become very scarce and costly. In the Scandinavian countries the effects of the war had brought about conditions of great similarity. 1

During the period of reconstruction, which must inevitably follow destruction if a country is to continue to
function, there was a great demand for materials with which to build. Since steel and iron and the skilled labor with which to erect it were so scarce, it became necessary to use some material which was relatively cheap and easy to use. Because economical construction was necessary, engineering talent turned to the natural resources of the forest.

Although of traditional importance in Europe, wood construction had always been handicapped by the limitations of the timber grown in their own forests. It was predominately of species comparable to the softer pines, true firs and eastern spruce of this country. Their forests, being mostly second growth, produced lumber of small size and of considerably lower strength than our southern yellow pine and Douglas fir.

The necessity of using an economical material and the weakness of this material for construction compelled the engineers of Europe to seek means of improving the existing methods of framing. The timber joint, being the weakest link in every wood structure, was the most logical place to make improvements. The simple bolted joint had largely displaced the inefficient and elaborate cutting methods of framing wood, but this bolted joint was always troubled with unfavorable stress distribution. So attention was principally focused on improving the distribution of stresses within this joint. Closely allied to this was the need for improving the familiar hardwood keys, if their field of use-
fulness was to be maintained.

Although the war furnished the wide spread economic demand for the development of modern timber connectors, this period was not the beginning of their use. Some research had been done on improving the timber joint before the World War.

Back in 1889, here in America a patent had been granted on a toothed plate for joining timber and, even before this, records show that cast-iron plate rings had been used in American bridge construction.¹

Over in Europe, "In 1911, a Swedish engineer, Prof. Carl Forssell, had stated in his book that wood might be made the most economical material for many structural uses, provided a suitable means of connecting timbers could be developed. He experimented for several years and in 1915 obtained a patent on a friction-plate connector, which was used by Swedish Military engineers in a bridge having a span of 360 feet."¹

In Europe, and especially in America, at the time of these patents economic conditions had not furnished the impetus necessary for a wide commercial application and the possibilities of these earlier connectors were ignored.

On the other hand, during the last days of the war and during the days of reconstruction, when many European engineers were devoting their attention to wood-construction possibilities they developed a wide variety of timber-joint connectors, which found immediate and extensive commercial application in wood structures designed on a strict engineering basis.¹

More than 60 different types and variations of con-
nectors have been patented in Europe. Of this number about 15 of the more important types have been tested by various technical laboratories in Europe. The practibility of the connectors was demonstrated by these tests, which enabled the manufacturers to establish working loads for design under conditions there.

When the many advantages of the connectors were illustrated in Europe, large contracting firms, alert to the possibilities, became specialists in timber framing and built many spectacular structures. Some of the outstanding ones are numerous radio towers, one of which is 460 feet high, bridges over 1000 feet long, and an auditorium with a seating capacity for 75,000 persons.

Application of Modern Connectors to Conditions in America.

Conditions in Europe where the advantages of the connectors were first demonstrated, are in many respects much less favorable for the adoption of modern wood-construction methods than they are in the United States. Here we have numerous soft pines, spruces, hemlock, and true firs fully equal to the European species used in construction, and in addition such outstanding structural woods as southern yellow pine and Douglas fir, to say nothing of larch, redwood, the cedars, cypress, and oak.

Because their superior strength properties are recognized, some American structural woods are imported by European countries, through special dispensation in some instances where the general economic policy has been to
favor native species by actual prohibition of foreign lumber. Certainly the conditions that lead to such importation are far less favorable than those in the United States.

Also, as a result of exhaustive research at the Forest Products Laboratory, accurate and complete data are available as to the strength properties of all commercial American species and grades. In Europe, engineers have been handicapped by lack of complete data on their native woods. Yet, despite this, modern connectors have gained in popularity abroad.

Another factor which should contribute much to the advancement of the use of connectors in the United States is that the ratio of cost of labor to cost of material on a construction job is greater than in Europe and in consequence, the possibilities of savings by increasing the efficiency of labor are correspondingly greater. Furthermore, local common labor may be employed in erection with modern connectors.

The modern construction systems, so widely used in Europe, have been developed almost wholly during the past 12 or 15 years, prior to 1933. It would be unprecedented if, in this comparatively brief period, the modern connectors had reached the pinnacle of perfection. Each year European engineers have introduced improvements and new designs. In the United States, where economic conditions and wood species are different from those in Europe, it seems safe to predict that our engineers and builders, once
they have become familiar with the basic principles of modern connectors, will contribute still further improvements and make these connectors even more effective.

In 1933 the Forest Products Laboratory published much of the results of their tests performed upon timber joints using native structural species of wood and the various types of timber connectors. These results lived up to the expectations and from that time on, the use of modern connectors here in the United States has become more extensive each year, with structures being built which are every bit as spectacular as those in Europe. Also, greater limits of safety are placed on structures built here.

The need of an organized and intelligent method of distributing the connectors and insuring their proper use made it advisable to give nearly exclusive control to one company. This company is the Timber Engineering Company of Washington, D. C., a subsidiary of the National Lumber Manufacturing Association. They secured the patents on some of the more promising connectors and now control their sales and manufacture. Representatives of the Timber Engineering Company, located in most of the principle cities throughout the country, handle the sales and promotion work. They distribute the connectors and information for their proper use. They furnish safe working load specifications and typical design illustrations. They also cooperate in any way possible to insure appropriate use of their product.

Their efforts are equally as beneficial, if not more
so, to the lumber producers because it increases the uses of wood for construction and also promotes its proper use. The business of timber treating with preservatives is also helped by the growing use of connectors in that structures can be prefabricated then treated and installed in many places where wood was not formerly used extensively.

The practical advantages of modern connectors are many and important, but before enumerating them, it might be well to discuss the principles of their operation and then describe a few. The basis upon which modern connectors work is one of efficient distribution of load stresses.

**Theoretical Action of Bolts and Auxiliary Connectors.**

Wood connectors are of two general types--those stressed in bending, such as bolts and long dowels, and those stressed chiefly in bearing, as most modern connectors. Shearing stress is, of course, a factor in all types.

In joints that are merely bolted, the load produces excessive stresses at the edges of the wood and in the small area under the bolt, as shown in figure 2. The excessive pressure against the comparatively small area in contact with the bolt causes the wood at that contact point to give way as increased load is applied. (Fig. 3)

It was to relieve these high edge stresses that engineers first inserted short simple metal or wood bushings around the bolt at the faces of the members to increase the bearing area. From these "half dowels", which later were increased to full dowels, coned each way from the middle,
LOAD STRESS DISTRIBUTION

When a bolt is used alone.

Bolt end view. Cross section.

Figure 2.

Deformation of a slender bolt in a timber joint.

Figure 3.

When Ring Dowel Modern Connectors are used.

Bolt end view. Cross section.

Figure 4.
came in time the modern rings, toothed plates, double tapered disks, and more elaborate shapes that have established themselves as effective connectors. These connectors, when inserted around the bolts, tend to transfer the stress from bending to bearing. The modern connectors which are stressed in bearing distribute the load stress over a much larger surface than do the bolts, consequently reducing the proportionate pressure per unit of area for the same load. (Fig. 4). For this reason, much larger loads are allowable with joints made with modern connectors than are allowable with simple bolted joints. However, it must be kept in mind that these so called modern connectors do not eliminate bolts. They only decrease their number and size. Bolts are still essential as a means of holding the members in contact so that the connectors may perform their function.

All modern types of connectors are governed by the same basic principles that apply to the simple retangular wood key which is often used to increase the efficiency of wood joints. By inserting a hardwood key either a tensile or a compressive force may be transferred from one member to another with one or more bolts holding the members together. Such a key will be subjected to (1) Compression at the ends, (2) to shear lengthwise, and (3) to an overturning moment, (Fig. 5b), absorbed eventually by a bolt either through or near the key. Also, of course, the length that each member extends beyond the key must be sufficient to resist the shear along its grain.
Load Stress Distribution Comparison

Action of simple wooden key

A key or other device in order to successfully transfer load from one member to another must have sufficient end area to avoid over-stressing the wood members where they bear against it, and to resist shear, the area of the longitudinal section must be adequate. In other words, the key or device must be strong enough to withstand the load.

The variable overturning tendency of the connectors used in a timber joint creates a potential spreading apart of the joint, thus necessitating the use of one or more
bolts to hold the members together.

(“The use of several keys with one bolt, as in a built-up member, however, does not increase the bolt tension. This tension does not become a multiple of the stress value for a single pair of keys, as might seem to be the fact at first glance, but remains unchanged, provided the load per key is the same.”)

There are also other forces than the action of the bolts which counteract the tendency to increase the stresses in the wood where it bears against the key, and check the overturning moment. First is the resistance of the wood in compression perpendicular to the grain, which may be considered as acting at the center of gravity of the load—distribution triangle at the side of the key. This resistance is exerted against metal ring connectors, for example, just as it is with the rectangular wooden key. Next is the friction between the key and the members, as well as between the members themselves. Designers customarily ignore friction, although it usually contributes an appreciable amount on the side of safety, because it varies from joint to joint and sometimes also varies during the life of the joint. With the metal connectors that have teeth, friction between the teeth and the wood is considerable. With a connector such as the flush type shear plate, a large resistance may be developed in the higher loading stages by the connector bearing against the bolts. Finally, the washers under the bolt-head and the nut transmit tension to the bolts and thus also offer resistance in bending against the overturning of the key and the resulting
opening up of the joint.

Summarizing the action of the modern timber connectors:
(1.) In transmitting the load from one member to another, they distribute the stress over a larger unit of area than do the bolts. (2) Especially true with some types is the fact that they increase the friction which resists slip between the members. (3) The application of a load to a joint fitted with modern connectors creates a tendency for the connector to overturn with a resultant opening of the joint. This must be overcome by a force which works against the overturning moment.

Significant Factors in Connector Design.

There are a number of different forces acting which determine the load carrying capacity of the various metal or wood connectors. It is obviously impossible to make any accurate computation of all of the different forces. Nevertheless, the designer or manufacturer, through studying the various forces, is able to obtain an idea of the shapes and forms of connectors that will afford the best possibilities.

There are several matters which should be noted when considering the design of any connector.

1. The connector material should possess adequate strength to transmit the expected loads.

2. The connector should have sufficient size and be of proper shape to develop adequate resisting moments.

3. The strength of the wood to be used and the connector material strength, should be considered for the two
load limits of proportional limit and maximum load.

4. The possible and allowable slip of the joint are also factors.

5. The cost of the connector and ease of installation are very important when considering general use.

6. The adaptability of the connector to the type of use intended should be considered.

7. Connectors should be designed to have a positive action with an adequate factor of safety, despite service conditions or changes in volume of wood.

"Joints that fail suddenly at a point not much above the proportional limit should be considered less desirable from a standpoint of safety than those that fail gradually, since slow progression to complete failure permits some warning."[1]

Classification of Modern Connectors.

Modern connectors for timber joints may be divided into two main divisions:

1. Connectors stressed in bending, including simple modifications of bolted joints.

2. Connectors stressed in bearing.
   a. Keys and simple shapes of plate metal.
   b. Cast or punched plate dowels with teeth, rings, or other projections to engage the wood.
   c. Ring dowels, both closed and split.
   d. Disk and coned dowels.

Modern Connectors stressed in bending.

There are but two types of connectors stressed in
bending which have acquired commercial importance, and even these are not especially important in this country. These connectors make no striking departures from bolted or pinned joints, but they offer certain improvements.

Meltzer Steel Tack.

Of these types the Meltzer "steel tack", Fig. (6), which was developed in 1910, is the more important. The connector is a steel pin of small diameter, from one-fourth inch to eleven-sixteenths inch. The "steel tack" is installed by driving it into holes drilled to the exact pin diameter. Friction is relied upon to hold the members together, and the pins are without heads or nuts, although occasionally bolts are used to draw the members up tight. The Meltzer joint system is a practical application of the principle that under equal unit bearing stress, bolts of small diameter are less likely to split the wood than are bolts of larger diameter.¹

Fig. (6), Meltzer Steel Tack

A truss with a span of 19 feet 8 inches, built with Meltzer "steel tacks" in 1925, was tested a year later under
a load 2.6 times the design load. It showed a deflection of only one inch and, after the load was removed, a set of one-sixth inch, about one fourteen-hundredths of the span. On examination the joint revealed no bending in the pins.¹

Hinged Joints.

Although pins of hardwood and of piping have been in use for many years, a modification of old methods have been developed, called the Cabrol method,¹ which permits a true hinge action at the joint. Metal bearing plates are used between the pipe and the wood-filler blocks that transmit stresses to other pins.¹

Auxiliary Bearings for Bolts in Joints.

Another modification of the bolted joint is the use of hardwood or metal blocks, end bushings, angles, and T's inserted next to the bolt and usually flush with the surface of the connecting members. These bearing blocks and bushings, sometimes referred to as half dowels, act in no wise to transmit loads from one member to another but serve to distribute the load within the member, thus relieving some of the high edge stresses caused in wood by the bolts.¹

Connectors Stressed in Bearing.

The connectors stressed in bearing comprise all the modern connectors, including various plain, processed, and cast plates, simple and split rings, and disks. The more important connectors developed in the past 25 years may be classified broadly as:
1. Plates with teeth, spikes, or corrugations that are forced into the faces of the wood members to be joined.

2. Plain rings that fit into pre-cut grooves in the wood members or toothed rings that are forced in.

3. Disks, usually tapered each way from the middle, that fit into pre-cut holes, half in one member and half in the other.\(^1\)

More than 60 different types and variations of connectors have been patented in Europe and a number have been patented in the United States. Some of the more important American connectors are discussed here.

**Bulldog Connector.**

The Bulldog connector, or clamping plate, consists of a steel plate, circular, square, or oval in shape, with teeth spaced evenly along the edges at an angle of 100 degrees with the plate. (Fig. 7). Joints using Bulldog connectors are formed by placing the connector between two wood members, forcing them together, and then holding them in place with a bolt through the center of the connector. The manufacturers recommend that the bolt holes be one-eighth inch larger than the bolt diameter except for the
single Bulldogs. This allows the joint to adjust itself to the load so as to distribute it evenly. The teeth on both sides of the plate are forced into the wood as far as the plate, thus automatically insuring equal penetration of all teeth, regardless of the species of wood used.

The Bulldog connector as used in timber construction is made in six sizes, five of which have teeth on both faces. The smallest are circular, with diameters of 2, 3, and $3\frac{3}{4}$ inches, respectively. The largest are square, 4 by 4 and 5 by 5 inches, respectively, and these have teeth around the square inside opening as well as at the outer edges. The sixth style, which is circular, is called the "single" Bulldog because it has teeth on only one face, at the outer edge; acting as a half dowel at a bolt between a metal plate or strap and a wood member, it distributes the bolt-bearing stress in the wood. A seventh style used for fastening round timbers, which has teeth on one face or on both faces, as required, is oval, 3 by 5 inches; it is curved to fit the surface of the members.

Bulldog connectors are especially adaptable to use between bridge ties and guard rails or stringers, between trestle caps and the tops of piles, and at other points where lateral movement of one timber on another must be prevented. They have a safe load carrying capacity, varying with the connector size and conditions of use, of from 1600 to 3400 pounds per connector.
Spike-Grid Connectors.

Spike grids are malleable castings in the form of a grid or frame, with sharp spikes or points projecting from both faces. There are four common types of grid connectors.

Figure 3. Square Spike-Grids

(1) Single curve grid for use between pile and sawn brace;
(2) Double curve grid for use between two poles or piles;
(3) Plain grid for use between two sawn faces. The above three types are all of square shape, 4 1/8 by 4 1/8 inches with 16 teeth held in place by fillets. (Fig. 3). (4) Number four is a circular spike connector 4 5/16 inches in diameter with teeth 1 1/16 inches from tip to tip. (Fig. 9).

Figure 9. Circular Grid

Twelve arms extend radially from a central circular plate about 2 inches in diameter to an outer ring with a tooth at
each end of each arm and on each face. The central plate is cored for the bolt. A three-fourth inch connecting bolt is used with this type of connector.

Joints using spike grid connectors are assembled by first boring the bolt hole to the same diameter as the bolt. The connectors are then placed between the members and forced into the wood by means of pressure from a special type steel bolt.

Spike grids are especially adapted for use in railroad bridge construction, piers and wharfs, and other construction in which round members are used. Their safe loading capacity ranges from 1700 to 4500 pounds, depending upon the size of the bolt and the kind of wood used.  

Toothed Ring.

Toothed ring, or Alligator connectors, consist of a circular band of low-carbon, sixteen-gage sheet steel, cold-rolled, stamped and bent to shape. (Fig. 10). The metal is cut so as to form triangular teeth having a convex outer surface to increase their holding power. The rings are light and cause only a slight decrease in the cross section of the
wood, even though some of the teeth are perpendicular to the grain. Also, when used to join woods of unequal hardness, the Alligator rings will have a tendency to penetrate into the softer wood farther than into the harder piece, thus developing a more nearly equal load-bearing capacity in each member. Moreover, a toothed dowel such as this will tend also to restrict any incipient splitting or checking of the wood, as much as do the irons frequently driven into the ends of railroad ties.1

Four sizes of Alligator connectors are commercially available in the United States, i.e., 2 inch, 2 5/8 inch, 3 5/8 inch, and 4 inch, especially adapted to use in 3, 4, 5, and 6-inch nominal widths of timber.

When using Alligator rings in a joint, the manufacturer recommends that the bolt hole be bored about one-sixteenth inch larger than the bolt diameter. In assembly the rings are fastened in place with small nails, the bolt and washers are set in position, and the joint is then closed up. To sink the rings into the wood some means of applying pressure is used. Clamps and frames with jacks are used, but the most common and possibly the most advantageous method is the use of a special high strength bolt, (Fig. 11), which is replaced with an ordinary bolt.

The high strength rod assembly as shown in (Fig. 11), is used for seating all of the connectors which require pressure to facilitate joint construction. A complete assembly consists of a heat treated high tensile steel rod
threaded on both ends and equipped with double depth nuts, a pair of plate washers, and a ball bearing washer. Special

![Diagram of Special Strength Bolt Assembly](image)

Figure 11. Special Strength Bolt Assembly

reversible ratchet wrenches are commonly used to turn the nuts and force the connectors into the wood.

Toothed rings are used exclusively for wood-to-wood connections and have relatively less load carrying capacity. The safe load capacity per connector varies from 1000 to 3800 pounds, with factors of connector size, bolt size and species of wood used, affecting the carrying capacity.  

Split Ring Connectors.

The split ring connector is one of the most important modern timber connectors. Split rings are made of round edge, hot rolled, low carbon steel, with a tongued and
grooved break in the perimeter. (Fig. 12). There are four sizes of split rings commercially available, i.e., 2\(\frac{1}{2}\) inches, 4 inches, 6 inches, and 8 inches.

Figure 12. Split Ring Connectors and Grooving Tools.

When using split rings, the joints are made by first boring the bolt hole about one-sixteenth inch larger than the bolt diameter. With the bolt hole as an axis, a special grooving tool is used to cut grooves in each of the members in which the rings are placed. There is a separate grooving tool for each size of ring, (Fig. 12), and the grooves are made a little larger than the diameter of the ring. After the rings are placed in the grooves and the members put in place, a bolt is inserted in the bolt hole and the joint drawn tightly together.

The split in the split ring connector plays a very important part in the efficiency of the connector. When a split ring connector is loaded, it opens, if the inner cores in the two connecting timbers come into action first, to bear against the ring, and tends to close if the outer walls of the grooves do so. With normal conditions, in which the ring fits fairly tight in the grooves, both the cores and
the outer walls bear against the ring whether load is applied or not. With every width of groove, both the outside wood and the inner cores will eventually bear against the ring, until something fails.¹ This adjustability of the ring to the conditions of load is valuable when the wood changes as it does when it shrinks and swells.

The split ring connector has wide application for medium loads and timber sizes, and for conditions where imbedment of the toothed or spike grid types is not readily feasible. The maximum load allowable with safety per connector is 10,500 pounds for a six inch connector, using a three-quarter inch bolt in dense structural wood.²

Claw Plate Connector.

A claw plate connector, (Fig. 13), is a malleable casting consisting of a circular plate with teeth arranged about the perimeter of one face, and a cylindrical hub on the opposite face concentric to a hole for the bolt which holds the assembly together. They also come without the hub.

Figure 13. Claw Plate Connector With Grooving Tool

In making wood-to-wood joints two connectors are used, one with a hub and the other without; the hub in one, fit-
ting into the central hole of the other. To make a joint requiring that the load be transferred from wood to metal or from metal to wood, the connector with the hub is used, in which case the hub fits into a hole in the metal strap or plate.

Claw plate connectors come in diameters of 2 5/8 inches, 3 1/8 inches, and 4 inches. A special grooving tool is used to facilitate embedding the connector into the wood flush with the surface. The connectors are set in the pre-cut grooves or daps and then the teeth points are further embedded in the wood by the use of high tension bolts.

With the hub arrangement, little or no stress, except the tension to hold the joint together, occurs in the bolt. Any small shrinkage in the wood members does not loosen the wood from the teeth, but instead merely causes the metal parts to separate slightly without seriously detracting from the bearing capacity of the joint.6

Claw-plates are convenient for footing connections when a tension load must be transferred to anchor bolts, and in general for all situations where steel-to-wood connections are desired.

The allowable load in pounds per connector unit and bolt varies from 5980 pounds for the largest connector in Douglas Fir and Southern Pine, to 1410 pounds for the smallest connector in Cypress and Redwood.8
Flush Type Shear-Plate.

Plain flanged, flush type shear plates of malleable iron in 4 inch diameter and pressed steel in 2 5/8 inch diameter are without teeth, (Fig. 14), and are set in grooves cut to receive the entire connector. The grooves are cut by special grooving tools which cut away the wood so that the connector will fit with its back flush with the surface of the member.

Flush type shear plates are used as "units" in pairs for timber-to-timber joints with two plates placed back to back, or singly in timber-to-metal joints with the plate placed with its back toward the metal.

The shear in joints made with these connectors is transferred from one timber to another through a bolt. The bolt does not bear directly on wood—a feature which eliminates enlargement of the bolt hole with characteristic play and looseness of the structure. Instead the shear plate acts as a distributing member between the bolt and the timber.

The flush type shear plate was developed to meet a demand for a timber connector especially adapted for field
connections of timber structures and for a connector which will make timber structures demountable with 100% salvage of the timbers therein. The allowable load capacity in pounds per connector unit and bolt for these connectors is 6370 pounds for the largest connector and 7/8 inch bolt used in Douglas Fir and Southern Pine, and 1600 pounds for the smallest connector and 3/4 inch bolt used in Cypress and Redwood. 8

Disk and Coned Dowels.

The disk and coned dowels, which are solid except for the bolt hole, fit into bored holes instead of grooves. Such dowels are made of hardwood or metal.

Figure 15. Kubler Dowels

The Kubler dowel, (Fig. 15), undoubtedly the best known of the disk and coned type, is used usually in two sizes, one approximately 2 3 inches in diameter, and the other approximately 4 inches in diameter. Until 1923 these dowels were made of cast iron. The large quantities needed, however, led to an investigation of the possibility of using a somewhat cheaper material. It was found that oak could be used with just as much efficiency and with much
greater economy. Now a large percentage of Kubler dowels in use are made of oak.

In shop fabrication the members of a joint that will use Kubler dowels are cut to size and the truss or other structural unit is assembled and fastened with a minimum of nailing. Bolt holes are then bored for each joint, after which the joints are taken apart and the seats for the dowels are counterbored, the bolt hole serving as a guide. The parts, clearly marked, are then shipped to the building site and assembled. The dowels are readily tapped into place in the tapered holes and the joints are finally secured with \( \frac{3}{8} \) inch bolts.

The Kubler dowels are not used widely in the United States, but they have been used extensively in Europe and in some very impressive structures. (Fig. 1). The recommended working load for two Kubler wood dowels symmetrically loaded is, for the \( 2\frac{3}{8} \) inch dowel, 1,650 pounds (load parallel to the grain) and 990 pounds (load perpendicular). The parallel load capacity, for the 4 inch dowel, is 3,750 pounds and the perpendicular load is 1,425 pounds. These loads are for oak dowels used in seasoned southern yellow pine or coast region Douglas fir.\(^6\)

The above mentioned modern connectors are not, by far, a complete listing of the connectors used in modern timber construction, but included there are the most common and fundamental types, from which most of the others take their origin.
Modern Connectors in Use

The several types of connectors take different shapes and are installed in different ways in different kinds of joints but the basic function of them all is to perform the same task; that of increasing the efficiency of the joint in modern timber construction. They do this by a larger and better distribution of the load stresses encountered in the past methods of timber construction.

No one type of modern connector is universally the best, although of necessity some are always superior to others. Among the best, some are of course more suitable for one class of construction and others for another class. Structures of almost every type, however, have been built with modern connectors. A list of representative ones shows both the diversity of the types and the magnitude of the structures entrusted to one kind or another of these connectors.

Users of timber connector construction include city, county and state governments, railroads, power companies, oil producers, manufacturing plants, contractors and private builders.

Several million connectors have been installed in the last three years in a total of over 9,000 buildings, bridges, towers, trestles, piers, barrel racks, ships, cofferdams, retaining walls and many other types of structures. Their use in most of these cases has followed careful investigation, by experienced engineers and architects, of the
soundness and practicability of timber connectors for their purposes. Many concerns have made connectors a part of their standard building practice.

Timber connectors are used for a great variety of purposes, and the number of uses is increasing steadily. The following list of uses may serve to suggest the scope of the field of timber construction in which they play an important part.

Practical examples of use.

Pile driver frame stiffened with toothed rings.
Laminated oak ribs of Coast Guard ice breakers strengthened with split rings.
Framework of the world's largest cooling tower stiffened and strengthened with brass split rings.
Roof truss connections made with toothed or split rings in spans ranging from 20 feet, for C.C.C. camp buildings, to 120 feet, for hockey rinks and airplane hangars.
Roof trusses and wall framing of California school buildings stiffened and strengthened against earthquake shocks with connectors.
Joint connections in all-wood radio towers, ranging from 160 to 326 feet, made with split rings and Kubler wood dowels.
Ornamental trusses for churches and auditoriums framed with shear plates and split rings.
Highway suspension bridges, up to 343 foot span, arched bridges up to 130 feet, and through truss bridges up to 210
foot spans; railway truss bridges up to 90 foot span, and bridge trestles 750 feet long and up to 90 feet high, framed with all types of timber connectors.

Pile bracing around permanent piers, and false work for San Francisco-Oakland and Golden Gate Bridges, built with toothed rings and shear plates.

Forest lookout towers, up to 100 feet in height, built with split rings and shear plates.

Oil derricks, casing racks and pipe trestles built with connectors.

Many buildings on Treasure Island, Golden Gate International Exposition, San Francisco, California, are built using modern timber connectors in arches having a clear span of 200 feet.

A ski jump, at Soldiers Field, Chicago, was built using modern timber connectors. It is the tallest free standing ski jump in the United States. This 180 foot all-wood structure is erected each winter; demounted and stored during the summer.

There are many more examples of the favorable results which modern connectors have had upon the increased use of wood for heavy construction purposes. New examples are being erected every day which further expand "The growing use of the building material that grows".9

Advantages of Modern Connectors

Obviously the experimental stage of modern connector
use has long since been passed. Through the application of these devices, wood has assumed a new structural importance. Some of the factors that have made this possible are given here.

Timber connectors increase the efficiency of timber joints from only 40 to 60 percent of the capacity of the wood itself, up to 80 or 100 percent of the wood strength. This increased efficiency is obtained by a better distribution of the load stresses from one of a small area to a large area in that section of the wood where it is most important.

The increased efficiency of the joint permits either a decrease in the gross sectional area of the members, the use of low grades of the same species, or the use of weaker species, with consequent decrease in cost of material.

"These improved connections enable a pound of good structural timber to do in general the same work that can be expected from a pound of steel."10

As compared with the earlier types of notched or hand-fitted joints, timber connectors greatly reduce labor costs. As compared with joint details in which timbers are bolted to steel gussets, the connectors are lighter and cheaper, not only in the weight of metal used, but also in the amount of timber required for a given load and in the assembly labor required.

Design features are also greatly simplified because with connectors, the strength of joints can be quickly and
accurately computed. This encouraged engineers to design many new and different types of structures which have here-to-fore not been built.

As compared to steel structures, within a class, structures made with timber and connectors originally save money, and this type of construction keeps that money in the builder’s community and affords maximum local employment, because the material is often produced locally and can be fabricated on the job. Modern timber-connector structures, because of their simplicity, require no unusual skill. The methods of fabrication and erection follow the every-day practices of any good carpenter-contractor.

All modern connectors are well adapted to shop fabrication of structural units. In addition, many types are equally well adapted to field fabrication. Both prefabrication and facile field fabrication reduce the cost of labor.

When desired, structural units, such as those in oil derricks, may be taken down, moved to a new site, and re-erected, without harming the wood members. This is done by merely removing a few bolts and easily pulling the members apart, allowing the same pieces to be used again and again.

Connectors lend themselves ideally to the use of boards and planks and built-up members to replace heavy solid timbers. This factor may be much more important in years to come when the virgin forest, from which large solid timbers
are now cut, are gone and builders must rely upon second growth material of smaller size.

A final factor, which has done much to increase the use of wood for structural purposes, is the constructive efforts of the producers of the connectors. Through their published advertisement, their recommended safe working loads of the various woods and structures, and their cooperation with builders and contractors have aided greatly in increasing the momentum of building structures with wood.
THE FUTURE

Modern connectors, which are now relatively scarcely known in the United States, have been in popular use in Europe for little more than a decade. Naturally, perfection in design and in methods of application has not yet been reached. On the other hand, the incentive to reduce costs, especially labor costs, is greater in the United States than in Europe, and for that cause alone, American engineers have ample reason to build upon the foundation now ready, waiting fully set, and to develop modern connectors to an even higher degree of excellence and to make them still more suitable for the best American structural woods. Economic conditions have thrown down a challenge, and the weapons to meet it in wood construction are at hand.

Highway and railway bridges are only one field in which modern connectors, perfected for American practice, should cut costs markedly. Many more roof trusses and framed arches, grand stands and stadiums, and nonmagnetic radio and transmission towers are waiting for modern connectors, made even more efficient by American designers and builders, to make it possible for them to be erected at costs that should often eliminate competition.

Wood is a natural resource, constantly renewable. To use wood industrially and thereby widen its markets, is obviously to promote reforestation; and multiplying uses of wood—there are thousands of them—contributes to the demand for it and thus to the extension of the forests.
Literature Cited


APPENDIX

Pictorial Examples of

Modern Timber Construction
Figure 16. The 460 ft. Timber Arch Used as a Center for the New Concrete Railway Bridge at Berne, Switzerland.

Figure 17. North Umpqua River Bridge--Span 135'--United States Forest Service, Region 6.
TIMBER SKI JUMP at Soldiers Field, Chicago is partly inside and partly outside the Stadium. The top platform is 180 ft. high. Members are all prefabricated and all joints are made with split-ring connectors. Ground ice serves as snow.
Figure 19. Composite trestle-type bridges, Port Angeles, Wash. Two bridges, each 755' long, Maximum Height 100'.

Figure 20. Dolan Creek Bridge, Monterey Coast Highway, Calif. A 130' timber arch, used in crossing V-canyon with grade line 130' above stream bed. Constructed of California Redwood.
Figure 21. Timber arches of 200 ft. span for a structure to be enclosed by means of prefabricated roof and wall panels.

Figure 22. Red River Lumber Company, Westwood, California. This loading shed is 100' x 250' with a total of 25,000 square feet of working area.

Figure 23. City auditorium, Sarasota, Florida. Span 100', height above floor 33' 2" to lower chord.
Figure 24. Ice arena, Spokane, Washington. Prefabricated Arch-Rib 120' trusses, ready for erection.

Figure 25. Types of heavy and costly joint hardware which the use of modern connectors eliminates.
Figure 26. America's tallest all-wood structure. 326' triangular radio tower WRVA radio station, Richmond, Virginia.

Figure 27. Lookout Tower. 100' high, exclusive of cab. Cass Lake, Minnesota.

Figure 28. Skating Club, Superior, Wisconsin. 125' clear span lattice trusses.
Figure 29. Oil derrick. Prefabricated demountable all-wood 130' derrick.