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STRUCTURAL TIMBER FOR BRIDGE CONSTRUCTION IN CENTRAL AMERICA

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Although a large part of Central America is covered with forests, the utilization of these woods for the production of bridge timbers and lumber has been extremely limited. In order to determine the suitability of the species in these forests for specific war uses the Coordinator of Inter-American Affairs in cooperation with the Department of Agriculture established the Latin American Resources Project. The personnel for this Project was drawn largely from members of the U. S. Forest Service, including the author, who was assigned to the project from the Forest Products Laboratory.

Of especial concern to the project was the fact that the Pan-American Highway needed timber for bridges, culverts, houses, and other structures to be built in Costa Rica. It was desirable to use, insofar as possible, the woods growing near that highway.

Timbers used in bridge construction must meet definite requirements as to strength and decay resistance. The specific requirements, however, may vary with the type of structure, the location of the timber in the structure, and the type of load the timber is require to carry. Thus, caps require compressived strength perpendicular to the grain; stringers, bending strength and stiffness; floors, stiffness and resistance to abrasion; and piling, decay resistance and adequate compressive strength parallel to the grain. When a wood is known to be deficient in a required property it may be practical to compensate for the deficiency by preservative treatment or by design. Preservative treatment can be applied to nondurable woods and design can provide increased size to compensate for low strength. Since compensating for low joint strength—an important requirement in trusses—is difficult, woods that meet the use requirements without modification are much desired.

The woods in the United States that best meet the requirements of bridge construction are such softwoods as Douglas-fir and Southern yellow pine. The strength properties of these woods have been determined by test at the Forest Products Laboratory, and service records are available for determining their decay resistance. Structural timbers cut from them, are available in standard sizes treated or untreated, and they, as well as other species, are available in stress grades; that is, grades that limit defects in accordance with their effect on strength. Douglas-fir and Southern yellow pine, therefore, furnish most of the bridge timbers used in the United States, although other species are also used, particularly for piling.

No similar information or standards are available for the woods of Central America. The characteristics and properties of a few of the more generally used woods, such as mahogany, or specialty woods, such as lignumvitae or cocobola, are well known from experience with them in numerous uses. The properties and characteristics of most of the other species, and their availability are unknown. They are not manufactured to any given standard of size or quality, and stress grades have not been developed for them. Furthermore, nearly all the woods are hardwoods with characteristics somewhat like

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those of the hardwoods in the United States whose uses on bridge construction has been limited. There are a great many species of wood in Central America, some of which never reach the commercial markets of the United States. They extend through a great range of strength, varying from balsa, which is soft, light, and weak, to woods, such as almendro, which are heavy, strong, and so hard that they are too difficult to work with ordinary tools. There are many species intermediate between these that can be worked, but their strength properties, decay resistance, shrinkage, ability to stay in place, and other properties are unknown. Until such information is available the general use of these species, especially in bridges, will be limited.

Much information for evaluating an unknown species for structural purposes may, however, be obtained from local practice. Natives are usually willing to provide information on species characteristics, particularly decay resistance. Such information can be checked by observing the type of use to which a species is put locally. If it is used extensively for posts, for example, its decay resistance is likely to be high. Indications in regard to strength characteristics of a wood can also be obtained from observing the character of its use locally. A wood used for stringers for small bridges or for rafters that carry heavy loads is likely to be strong and stiff; one used for striking handles is usually high in bending strength and tough; and one subjected to heavy wear or abrasion is usually hard. Such an evaluation, while helpful, is rough as regards strength, and the engineer wants and usually requires a more accurate evaluation.

The engineers of the Pan-American highway in Costa Rica usually design structures for a bending stress of 1,000 lb. per sq. in. By eliminating all the lighter woods, therefore, strength of the woods was considered sufficient to withstand safely all anticipated stresses.

The most accurate method of estimating the strength of an unknown wood, apart from actual strength tests, is by means of its specific gravity. Extensive tests made at the Forest Products Laboratory have shown that strength properties of wood have a fairly definite relation to its specific gravity. The higher the specific gravity, the stronger is the wood. Thus mastic with a specific gravity of 1.03 has a maximum crushing strength parallel to the grain and in the green condition of 5,880 lb. per sq. in.; and balsa with a specific gravity of 0.11 has a maximum crushing strength of 644 lb. per sq. in. Specific gravity was therefore used in estimating the strength of Central American woods that were used on the Pan-American highway and in evaluating the strength of some of the individual timbers.

Specific gravity and modulus of rupture values for a number of Central American woods are shown in Table 1. The specimens on which the specific gravity values for species in Table 1 numbered 1, 4, 5, 9, 10, 11, 15, 16, and 19 are based were obtained from San Isidro del General, Costa Rica; those for species numbered 3, 8, 21 from El Volcan, Panama, and the specimens of species No. 25 were obtained 36 kilometers south of Cartago, Costa Rica. The values for the remaining species in Table 1 are based on specimens from various bridge sites and sawmills in Costa

TABLE 1
DETERMINATIONS OF SPECIFIC GRAVITY AND BENDING STRENGTH OF 25 SPECIES OF SOUTH AMERICAN WOODS

Specimen number	Species	Specific gravity, based on weight when oven-dry and volume when green	Modulus of rupture when green
			Lb. per sq. in.
1	Alasán (*Ormosia toledoana*)[a]	0.45	9,750
2	Amarillón (*Terminalia amazonia*)	0.59	
3	Bambito colorado (*Ocotea cuneata*)[a]	0.43	
4	Bolador (*Persea Austin-Smithii*)	0.50	11,300
5	Campana (*Laplacea semiserrata*)	0.48	10,350
6	Cedro Amargo	0.38	
7	Cedro macho (2)	0.50	
8	Cenizo (*Chaetoptelea mexicana*)	0.61	
9	Chancho blanco (*Goethalsia meiantha*)	0.57	11,300
10	Colorado (*Nectandra concinna*)	0.72	13,350
11	Comenegro (*Hieronyma oblonga*)	0.73	11,750
12	Cristobal	0.62	
13	Fruta Dorada (*Virola Koschnyi*)	0.39	
14	Guayacán (*Sweetia panamensis*)	0.80	
15	Ira chiricana (*Vantanea Barbourii*)	0.62	13,800
16	Ira rosa (*Lauraceae*)	0.34	6,840
17	Laurel (*Cordia alliodora*)	0.34	
18	Magnolia (*Vochysia* sp.)	0.35	
19	Mariá (*Calophyllum brasiliense*)	0.45	9,780
20	Pilón or Zapatero (*Hieronyma alchorneoides*)	0.59	
21	Pizarrá (*Persea pallida*)[a]	0.43	
22	Pochote (*Bombacopsis Fendleri*)	0.34	
23	Quina	0.58	
24	Quizarra	0.44	
25	Roble (oak) (*Quercus copeyensis*)	0.74	

[a] Probable species. Information was insufficient for accurate identification.

Rica. The modulus of rupture values were obtained from specimens 1 by 1 by 15 in. tested over a 12-in. span on a homemade machine. The values have relative significance only and are not comparable with the results of standard tests made elsewhere.

The specific gravity determinations were made on representative samples 1 by 1 by 6 in. in size. The volume of these samples was determined by measurement or by submersion of the samples in a graduate containing water, following which they were dried in an oven and weighed. The specific gravities shown in Table 1 were then computed by dividing the oven-dry weight by the volume when green. A comparison of these specific gravities was then made with those of known woods. To illustrate, the average specific gravity (based on weight when oven-dry and volume when green) for Douglas-fir (Coast type) is 0.45, for shortleaf pine 0.46, for white oak 0.59, and redwood 0.38. The specific gravity for Chancho blanco, from Table 1, is 0.57, indicating that its strength is at least comparable to that of Douglas-fir and shortleaf pine, but probably not so high as white oak. This method of estimating the strength of wood from specific gravity determinations is not intended to be exact. It furnishes a starting point, however, for estimating the strength of a species in the absence of strength tests. It can be especially valuable in Central America where a large number of species are encountered on which little information is available.

There are other factors, apart from specific gravity and strength, that may determine the suitability of a wood for a given use. A species may be heavy and strong, but may decay readily or may be too difficult to work with ordinary tools. Its shrinkage characteristics or its tendency to warp or split and check may be such that it would not be suitable for some uses. These factors, however, are not too difficult to determine from nontechnical information that can be obtained by questions and by observation of timber in service.

The greatest obstacles, aside from the total absence of data on species properties, to the use of Central American woods in construction are the mixed character of the forest stands and the difficulties and costs of transportation. There are generally no pure stands; many species grow together in the same forest. It is not practical to select a species suitable for structural purposes and use that species exclusively, for the logging of a single species from a mixed stand is difficult and, in spite of the low labor costs, expensive. It is common practice, therefore, to cut many or all of the species found in a stand at the same time. The use of such a mixture of woods for structural purposes requires on-the-spot knowledge of their properties and characteristics in order to assign each wood to its most advantageous use. This often presents a difficult problem, for example, one bridge examined in Costa Rica showed that the 52 stringers included 19 species.

The only species found in Costa Rica in a pure stand was white oak (*Quercus copeyensis*). This oak is located along the Pan-American right-of-way south of Cartago. Until the road made this section of country accessible, little was known about the extent of the stand or the size of the trees. The largest tree found in this stand by a U. S. Forest Service party was 8 ft. in diameter and 125 ft. high. Determinations made on this wood at the Forest Products Laboratory show that it has a density higher than that of the white oak found in the United States and therefore, presumably, will take stresses equal to or higher than those now assigned to white oak grown in the United States. Its shrinkage is about 75 per cent greater than that of white oak grown in North America. Much of the timber of this species now cut along the right-of-way is utilized in camp buildings and other construction needs. The major portion, however, is cut to size for use in tunnel construction. The highway in this locality passes through some exceedingly rugged country, necessitating several tunnels 300 ft. long.

Transportation of logs in Central America is usually difficult and expensive. Most of it is done by oxen, hauling one log at a time. Much of the timber is not easily accessible, and building access roads into the timber is frequently difficult because of rugged terrain or excessive rainfall.

The Pan-American highway in Costa Rica used native woods principally for bridges (Figs. 1, 2, 3, and 4) and culverts (Figs. 5 and 6). Among the species used are nispero, mora, guayacan, zapatero, laurel, maria, and Ira chiricana. The distribution of most of these species is local. Ira chiricana, for example,

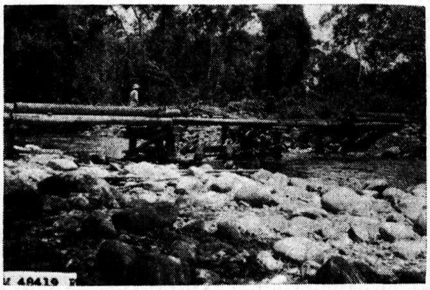

Figure 1. Long, low, temporary bridge under construction across Ria Cerbo near Buenos Aires, Costa Rica. All timber used in the bridge was obtained from adjoining woods, was hand hewn, and was lifted into place by hand labor.

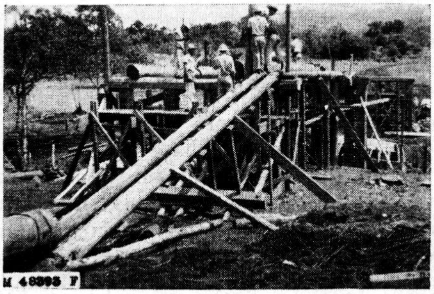

Figure 2. Bridge under construction at San Isidro, Costa Rica. All large timbers were hand hewn. Stringers were raised to floor level by block and tackle and skids. Lack of equipment, such as cranes, necessitates a large amount of heavy hand labor.

Figure 3. Under side of Rio San Isidro bridge. Lack of information on the strength properties of the wood required the use of massive stringers for assurance of safety.

which field tests indicated had a high strength for its weight, was found only in the El General Valley of Costa Rica; and while its use in other locations might have been desirable,

Figure 4. Bridge over Rio Jelguere, Costa Rica. The 52 stringers in the deck were comprised of 19 species.

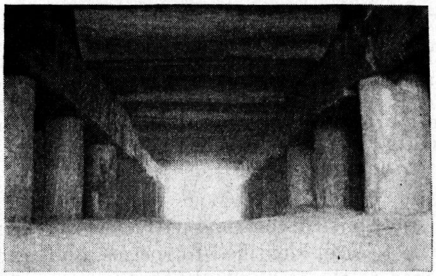

Figure 5. Interior of timber box culvert. Durable species are required when no treatment is used to assure a relatively long life.

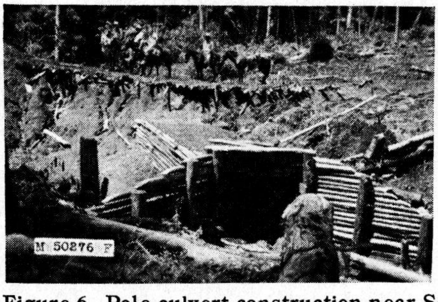

Figure 6. Pole culvert construction near San Isidro del General, Costa Rica. The life of such a culvert is entirely dependent upon the selection of durable material. Note corduroy road below horses to prevent floundering in the mud.

the cost and difficulty of transportation under present conditions made this impracticable.

In spite of the abundant stand of timber, considerably more lumber is imported into Costa Rica from the United States than is exported. The lumber imported is surfaced and fabricated to standard dimensions and conforms to a standard of quality that is known and recognized by engineers (Fig. 7). The Northern Railway Company of Costa Rica, for example, during normal times imports many creosoted pine ties from the United States and has also used untreated redwood

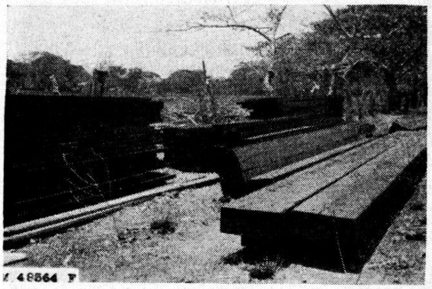

Figure 7. Creosoted Douglas-fir timbers imported from United States for use in bridges on the Pan-American highway. These timbers were prefabricated and of standard size and quality.

ties. Many native woods would be suitable for ties, but by the time native ties are hand hewn to size, identified to species, and transported to the railroad, the cost is as great or greater than the cost of importing from North America ties that have a proved and known standard of performance.

The situation as regards the use of Central American woods for bridge or other construction may be summarized as follows: Large mixed stands of timber, mostly hardwoods, exist in Central America. A number of the woods undoubtedly have a favorable combination of the properties required for structural timber, and the required sizes could be obtained from the trees. Detailed data on the strength and other properties of the wood, however, are lacking, and in the absence of such data no direct comparison can be made between Central American woods and those used in the United States for structural purposes, nor can the Central American wood be used to best advantage. The mixed stands and the transportation of lumber or logs from the forest present difficult problems. Until these problems are solved and until more adequate data are available on the properties of the various woods, the use of Central American woods for structural purposes will be confined largely to localities near the forests, to the more readily available stands, and to the woods whose properties are best known. There is little chance that they will be used in the United States in any quantity in the near future because better known North American woods are available in standard sizes and stress grades, at prices lower than timbers from Central American forests can be delivered in this country.