MASTER'S THESIS - 1947

Preliminary Study of the Shearing strength of Five Brazilian Species Glued with Cold-setting Resins.

L.Tatto

THE UNIVERSITY OF MICHIGAN

PRELIMINARY STUDY OF THE SHEARING STRENGTH OF FIVE BRAZILIAN SPECIES GLUED WITH COLD-SETTING RESINS

A DISSERTATION SUBMITTED IN
PARTIAL FULFILLMENT TO THE SCHOOL OF FORESTRY AND
CONSERVATION IN CANDIDACY FOR THE DEGREE OF
MASTER OF WOOD TECHNOLOGY

BY
LINO TATTO

ANN ARBOR, MICHIGAN
JANUARY, 1947

TABLE OF CONTENTS

FOREWORD

The results herewith presented were obtained at the Wood Utilization Laboratory of the School of Forestry and Conservation of the University of Michigan, where the work was carried out under the supervision of Mr. Louis A. Patronsky, Instructor of Wood Technology.

Due to its preliminary character, it aims to present only a moderate amount of fundamental data with regard to the shear strength of five Brazilian hardwood species when glued with cold-setting resins.

As the field of application of plywood is broadened, new adhesives and new gluing techniques will become more and more necessary as the ones already in use do not fulfill the requirements for most of the new uses to which plywood is put. In the case of the Brazilian plywood industry, casein glues, which are the most extensively used throughout the country, must be replaced by some other kind of an adhesive capable of yielding bonds of satisfactory quality for outdoors applications.

It will be desirable, however, that the new adhesives and gluing techniques are such as to permit the utilization of approximately the same equipment as called for the use of casein and still make bonds resistant chiefly to moisture and to biological deterioration.

The cold-setting resins were chosen for this work because (1) they could be mixed, spread and pressed using approximately the same equipment required for casein and following a similar technique, and because (2) they were considered as yielding bonds which are resistant to moisture and biological deterioration.

The author is indebted to Mr. Louis A. Patronsky for his constant interest throughout the laboratory work, for the helpful information given and for the constructive criticism of this paper.

Lino Tatto
January 14, 1947

INTRODUCTION

In spite of being one of the newest industries in Brazil, the plywood industry has experienced an extraordinary development that could hardly be matched by any other wood using industry.

It is concentrated in the four southernmost states of Brazil where the availability of the "pinho do Paraná" - Araucaria angustifolia - in almost pure stands insures an ample supply of high quality veneer logs.

According to the latest data available(1)[1] there were in the southern part of the country, 168 veneer mills and plywood plants, of which, 102 were already producing and 66 being installed. The distribution per state of the plants already engaged in production was as follows:

States	No. of plants
Paraná	44
Rio Grande do Sul	22
Santa Catarina	29
São Paulo	7
Total	102

Their export in the first half of the year 1944 was as follows:

---

[1] The numbers in parentheses refer to literature cited p.

What units

States	Veneers		
	Pinho	Other species	Total
Paraná	1,519,167	1,491,599	3,010,706
R. G. do Sul	130,200	173,300	303,500
S. Catarina	191,230	558,408	749,638
São Paulo		3,530	3,530
Total	1,840,597	2,226,837	4,067,434

States	Plywood		
	Pinho	Other species	Total
Paraná	11,843,893	1,257,725	13,101,618
R. G. do Sul	1,383,685	148,014	1,531,699
S. Catarina	2,160,658	1,414,817	3,575,475
São Paulo	288,763	78,000	363,763
Total	15,676,999	2,898,556	18,575,555

Because of the shortage of transportation which became critical during the war years the Federal Government has established limits of production. It is expected that with the improvement of the transportation, the industry will be able to reach a total output of 51,700,000 cubic meters, distributed as follows:

States	Production expected (m^3)
São Paulo	3,900
Paraná	21,800
Santa Catarina	18,200
Rio Grande do Sul	7,800

Although the development of the industry is controlled by the Federal Government with view to protecting the native forests from quick depletion and to overcome the transportation difficulties which existed prior to its interference, there have been constant requests for the installation of new plants. Thirty-five new concerns have been permitted to erect new plants and mills, so that the number of veneer mills and plywood plants will be raised to 203 in the near future.(1) The following chart gives a good picture of the situation of the industry in Southern Brazil at the present time and in the near future.

Number of veneer mills and plywood plants in Southern Brazil
Present and future number of plants and mills

States	Producing		Being Erected		Permission To Erect		Total No. Mills, Plants	
	No.	Mo. Capacity(m^3)	No.	Mo. Capacity(m^3)	No.	Mo. Capacity(m^3)	No.	Mo. Capacity(m^3)
São Paulo	7	3,689	--	------	--	------	7	3,869
Paraná	44	21,868	36	17,892	14	6,958	94	46,718
Santa Catarina	29	18,154	10	6,260	13	8,138	52	32,552
Rio Grande do Sul	22	7,810	20	7,100	8	2,840	50	17,750
Total	102	51,701	66	31,252	35	17,936	203	100,889

The great majority of the plywood plants in those states use casein glues as the bonding agent; however, the tendency is to change this situation so that a good part of the industry makes use of synthetic resins. How far this policy will succeed is dependent upon several factors of which, foreign markets requirements and the possibility of fabricating the resins at low cost in the region, seem to be the most important.

The development of new foreign markets will certainly be attempted by the plywood industry of Brazil, whose product made up already 99 percent of the plywood imports of Argentine in 1944. To accomplish that, it must face the competition from other countries which already possess a thoroughly organized plywood industry, and so, being in a better position to offer a high quality product at low price.

The encouragement of the use of synthetic resins by the Brazilian plywood industry, which has been the policy since December, 1944, is then a very appropriate step towards improving the serviceability of its product and of increasing its chances to be accepted in the foreign markets.

Although the plywood quality is very important it is not the only factor considered when the product is purchased. Cost, color, figure and density, machinability, and volume available, are very important considerations.

So far as is known, Brazilian hardwoods forests are potentially fit to produce woods suitable for most of human needs due to the large number of species that grow in them. However, technical data concerning the technological characteristics of a great number of the species are still lacking, so that the enormous supply of those hardwoods has not been introduced to the international markets.

In spite of the fact that very little technological information on most of Brazilian hardwoods is available several species are now being regularly exported. As can be seen from the following chart, 29 hardwood and 1 softwood species have been exported during the years 1939-1945.[2]

Brazilian exports of woods (1939-1945)

Quantity in tons

No.	Species	1939	1940	1941	1942	1943	1944	1945
1.	Acapú	418	88	--	--	--	--	--
2.	Aguano	8958	9047	5921	2677	2789	6983	7683
3.	Andiroba	1524	965	152	79	--	--	84
4.	Baguaçú	223	369	271	151	36	236	145
5.	Cabriuva	243	93	89	232	553	188	666
6.	Canéla	345	170	364	96	442	964	302
7.	Cedro	5341	4496	10496	14147	14878	18289	10083
8.	Cupiúba	--	--	--	--	--	--	76
9.	Freijó	5315	4276	80	--	--	--	153
10.	Gonçalo Alves	91	136	328	64	64	--	86
11.	Guajuvira	498	434	306	254	72	230	61
12.	Guaruba	21786	922	--	--	--	--	141
13.	Imbúia	1112	1278	1206	993	413	1282	7890
14.	Ipê	10301	3709	9870	4107	1475	1402	1065
15.	Itaúba	94	50	95	--	298	248	32
16.	Jacarandá	2043	1789	2475	553	686	493	3275
17.	Jequitibá	10666	11	185	925	1668	799	56
18.	Louro vermelho	4216	509	--	10	--	565	835
19.	Macacaúba	1573	746	50	141	14	143	803
20.	Massaranduba	132	179	7	--	105	290	801
21.	Pau amarélo	93	25	11	--	--	--	128
22.	Pau Brasil	7	15	5	3	5	--	6
23.	Pau d'arco	--	--	--	--	--	--	6
24.	Pau rosa	73	6	272	--	139	--	--
25.	Pau rôxo	46	28	--	--	--	--	--
26.	Peroba	39	460	1618	4736	3066	2667	405
27.	Pinho	307794	247042	293701	321074	272061	282556	238550
28.	Quebracho	2460	--	--	--	--	--	--
29.	Sucupira	107	774	15	30	4	32	624
30.	Violêta	2	--	--	1	--	--	--

The five species dealt with in this study are all represented in the chart above - Nos. 2, 19, 21, 25 and 29 -

meaning that they have attained some economic importance. The informations presented in this paper acquires, then, a broader significance in that they refer to species which are items of foreign consumption.

OBJECT

The object of the present study is to investigate about the shearing strength of five Brazilian species glued with two cold-setting resins. For that resorcinol-formaldehyde and cold-setting urea-formaldehyde were used.

In order to have means of comparing the results obtained with the cold-setting resins, casein glue and phenol-formaldehyde were used as controls. The former can be considered the standard glue of the Brazilian plywood industry, which uses it for a rather long time. The latter was chosen as the type of a resin that yields the highest quality bonds, chiefly in relation to its water resistance.

Since 1944 there is a noticeable tendency towards the use of synthetic resins in the manufacture of plywood in Southern Brazil. By the end of that year the President of the "Instituto Nacional do Pinho", which controls the lumber industry in Brazil, decided not to permit the erection of any more plywood plants in the States of São Paulo, Paraná, Santa Catarina and Rio Grande do Sul, that were not equipped to use synthetic resins as the bonding agent of the plywood they produced.(3)

If the use of synthetic resins proves to be economical, there will be many possibilities of that trend becoming universal for the country. Among the synthetic resins, the cold-setting ones are outstanding in that they require less expensive equipment and are meant to be used under less exacting gluing conditions than the hot press resins.

Materials

Woods.-- Woods of the following species(10) were used in this study:

Common name	Scientific name
Aguano	Swietenia macrophylla King
Macacauba	Platymiscium Ulei Harms
Pau amaielo	Euxylophora paraensis Huber
Pau roxo	Peltogyne densiflora Benth
Sucupira	Bowdichia brasiliensis (Tul.) Ducke

In view of the impossibility of getting veneers of the desired species from the importers in this country, all the wood used in this study was obtained from strength test specimens which existed in the collection of the School of Forestry and Conservation of the University of Michigan. Thus, all the wood available was 2-inch by 2-inch in cross-section and not more than 6 inches long.

To make the veneer, the 2-inch wide wood blocks were sawed to a thickness as close to 1/8" as possible and then planed down to either 1/8" or 1/16" according to what extent the small pieces could be handled safely. With few exceptions, at least one of the faces of the veneers was made smooth in order that proper gluing could be accomplished.

It was impossible in some cases to get away from old shear failures resulting from the previous testing to which the woods used now were submitted. How far this factor affected the final results of the present study is difficult to say. Its influence was readily noticeable whenever the plywood shear test specimens broke at an old shear failure, but some specimens might have broken at some initial failures(6) and the fact passed unnoticed.

Glues.-- Four different types of glues were used, namely: ready mixed casein, cold-setting urea formaldehyde, resorcinol formaldehyde, and hot-setting phenol formaldehyde. The commercial makes of each type listed below were those available at the moment at the Wood Utilization Laboratory of the School of Forestry and Conservation.

Casein: Perkins Metal-veneer glue powder, made by Perkins Glue Company, Landsdale, Pa.

Cold-setting urea formaldehyde: Perkins Plastic Resin No. D.C. 246. Cold press type.

Resorcinol formaldehyde: Durez 12688 and catalyst Durez 12689 made by Durez Plastics & Chemicals Inc., North Tonawanda, New York.

Hot press phenol formaldehyde: Tego film made by Resinous Products & Chemical Company, Washington Square, Philadelphia, Pa.

Water:-- The water used was tap water furnished for public consumption.

Equipment:-- Beakers, erlenmeyers, weighing scale, wax paper, cold and hot presses, and plywood shear test machine.

Procedure

<u>Gluing</u>.-- This operation was carried out at a room temperature between 75° and 80° F. The adhesives mixtures were prepared according to the recommendations given out by the manufacturers.

The proportions used were as follows:

Casein glue: 1 part of Perkins Metal-veneer by weight.
2 parts of cold, clean water by weight.

Resorcinol-formaldehyde: 100 parts of Durez 12688 by weight.
20 parts of Durez 12689 by weight.

Urea formaldehyde: 100 parts of Perkins DC - 246 by weight.
65 parts of clean, cold water by weight.

Phenol-formaldehyde: No mixing is necessary.

The following spreads were adopted:

Casein glues: single spread of 30 grams per square foot.

Resorcinol-formaldehyde: double spread of 12.5 grams per square foot.

Urea formaldehyde: double spread of 12.5 grams per square foot.

Phenol-formaldehyde: two sheets of the film for each panel glued.

The use of double spread was adhered to because after gluing the first panels with casein, it was found out that the manufacturers of Durez 12689 strongly recommended the use of double spread in connection with that resin. Although that practice is not universally followed in commercial production, it is recommended to be used in connection with phenolic resins in order to secure a uniform penetration in the surface of both plies.(11) Two sheets of Tego were used to take care of any unevenness in the gluing surfaces.

As regards single and double spread in connection with casein glues, the results of tests carried out on plywood glued by both methods showed that only a slight increase in strength was obtained by double spreading.(12)

A 30-minute closed assembly was used for all glues. After glued, the panels were stacked and placed under pressure at room temperature. In order to avoid gluing one panel to another sheets of wax paper were interleaved between the panels.

A Universal testing machine was used to apply a pressure of 150 pounds per square inch in all cases of cold-setting glues. As the machine was not constructed to apply constant pressure throughout the gluing period, the pressure was kept constant during the first three hours. The use of two rubber pads, each approximately one-half inch thick proved very helpful in maintaining constant pressure for at least one hour. The panels were left under pressure overnight.

The hot press bonding used in connection with Tego was carried out in an electrically heated press of 5500 pounds of capacity. 150 pounds per square inch - bonding pressure - and 310°F - bonding temperature - were used.

As shown below the bonding time used varied with the species being glued in order that the glue line could be submitted during one minute to a temperature of 310°F.

Species	Bonding time (min.)
Águano	4
Macacauba	2 1/3
Pau amarélo	3
Pau rôxo	3 1/2
Sucupira	2 2/3

In order to restore the moisture removed by hot pressing and to obtain a flat panel, the bonded panels were dipped in water immediately after being taken from the press and placed under pressure afterwards.

All the glued panels and test specimens were kept at a room temperature varying between 79-82° F and at a relative humidity of 30 percent for at least six days before testing. The moisture content of the specimens varied from 5 to 6.5 at the time of tests.

Two-ply test specimens, with the grain of both plies laid parallel were used throughout the experiment. The two-ply laminated construction was given preference because it measures true shear, whereas, in the standard three-ply specimens a combination of shear and rupture is measured.(7) The relation of two-ply to three-ply construction was found by Truax(7) to be of 640 to 375 pounds per square inch for dry tests and 300 to 220 for wet tests, using 1/16 inch veneers.

All the test specimens were made so that the area under stress was ½ square inch. That practice was followed in order to simplify the work of sawing the specimens, as a part of them, those made up of two plies 1/16 inch thick, had to have a working area of ½ inch to be in accordance with the specifications in force in this country.[4] A part of the test specimens was made 3/4 inch wide in order to overcome the scarcity of wood material.

The test specimens were divided into three groups and tested in three different conditions, namely, dry, after 24-hour soaking[10] and after going through the Douglas Fir Test for exterior type.[5]

Testing.-- Thirty test specimens of each species were tested for each glue. Ten of them were tested dry, ten after a 24-hour soaking period, and ten after the cyclic test recommended in the Commercial Standard CS 45-45 published by the U. S. Department of Commerce in 1945.

All the testing was carried out in a Riehle plywood testing machine specially designed for plywood tension shear tests, the load being applied at a rate of 600 to 1000 pounds per minute. The percentages of wood failure were estimated by visual inspection.

Results

The results obtained from the testing are shown in Tables 1-20. The breaking loads obtained from the tests were recorded in the first column. The column under the heading "Total stress (p.s.i.) was obtained by just doubling the figures in column 1 for the specimens made up of 1/8" thick plies or by doubling the results in column 1 and reducing the total by 10 percent. The remaining columns are self-explaining. The abbreviation D.F.E.T. means that the specimens were tested in shear after being submitted to the Douglas Fir Test for exterior type.

Table 21 gives the average figures for total stress and for wood failure for the different types of glues and species. In Table 22 the average soaked and D.F.E.T. strengths were transformed into percents of the dry strength. Figures 1-5 are based on the averages given in Table 21.

The results showed in Tables 1-20 were somewhat influenced by the two major causes discussed below which were difficult or impossible to control or to get rid of.

The various thicknesses of the veneer used may have affected the results of the tests and, therefore, may have upset a little their comparative values. Truax[12] found that the test values vary with the thickness of both the face and core plies. Although his results were based on tests for the standard cross-ply construction, the general rule may hold true for the two-ply laminated wood construction.

Due to the fact that the wood for this study was supplied by old strength test specimens, some of the results obtained may be somewhat lower than if wood entirely free from defects were used.

Another factor that did not affect the numerical values of the test, but which will be significant if any of the results are to be used to any practical extent, is the fact that the woods used in this experiment were taken from very few trees,[10] and so, are not truly representative of the whole range in density and gluing characteristics of the species.

Discussion of the Results

With few exceptions the results for dry strength for each species varied little, regardless of the adhesives used. However, the values for 24-hour soaked and alternate wet-and-dry* strengths and percents of wood failure for the material glued with casein showed much more noticeable departure from the dry strength than the resins (Table 22).

It seems to be safe to state that, within the scope of this work, the cold-setting resins proved to be superior to casein glue and identical to hot-pressed phenol in strength when used to glue the species under consideration in this paper.

There seems to have been no relationship between specific gravity and dry shear strength in connection with some of the glues and species used. Sucupira and pau rôxo which are, respectively, the heaviest and third heaviest of all,[10] showed strength values close to those for águano which is the lightest species used, when glued with casein. The same applies to pau amarelo and pau roxo with regard to resorcinol-formaldehyde and to sucupira glued with phenol-formaldehyde.

---

*Refers to both strength and wood failure after the test specimens have gone through the Douglas Fir Association exterior type test.

The results obtained with casein glue confirm that it has a low water-resistance. The decrease in strength from the dry condition to the soaked varied between 78 percent for *pau rôxo* to 56 percent for *águano*. The Douglas Fir Association cyclic test[5] showed for all of the species glued with casein less effect in lowering the joint strength than plain soaking. This unexpected result was also noted in connection with *águano*, *macacaúba* and *pau amarélo* glued with resorcinol-formaldehyde and *sucupira* glued with phenol-formaldehyde resins (Table 22).

The cold-setting resins showed good soaked and alternate wet-and-dry joint strengths in all cases but alternate wet-and-dry strength for *sucupira* and *pau rôxo* glued with urea-formaldehyde.

Resorcinol showed results somewhat higher for alternate wet-and-dry strength in connection with *pau roxo* and *sucupira* than urea-formaldehyde and, although dry and soaked strengths were higher for both species glued with the urea resin, the percent of strength maintained after soaking and after the Douglas Fir Association cyclic test was higher for resorcinol.

Urea resin did not appear to yield good bonds with *pau roxo* and *sucupira* although the results of the tests have been consistent (Tables 14 and 15). The results obtained with *pau amarelo* bonded with the resorcinol resin were inconsistent (Table 10). Apparently the resin had not cured enough when the test specimens were tested dry. The low average percent of wood failure can be taken as an indication of the poor bond obtained. Additional data on the gluing of those species with the above named glues are necessary in order that a final conclusion can be drawn.

The results obtained with phenol-formaldehyde were satisfactory for the majority of the species glued. The low percents of wood failure obtained in connection with sucupira seem to indicate the need of further work for a definite conclusion.

Gluing Characteristics Observed

Throughout this experiment certain gluing characteristics of the species used were noted. As the observations apply to a study based on only a small number of test specimens their value must be properly considered if any of them is to be used in practice.

The casein glue used stained pau rôxo although it did not show through the plies. Sucupira and pau amarélo were stained to less extent.

The wood failure in tangential surfaces of sucupira, except in cases where some sort of grain deviation occurred, was along the vessel lines. This fact can be related to the amount of paratracheal parenchyma in the wood and probably accounts for the low wood failures for the species.

Pau rôxo and sucupira cupped noticeably when glued with casein and pau amarélo showed delamination when glued with urea and resorcinol resins.

Águano and *macacaúba* glued well with all the adhesives tried. The fibers of both species were somewhat compressed when bonding with Tego at 310° Farenheit.

Possibilities of the Use of Cold-setting Resins in Brazil

The preliminary character of this work does not allow broad and final conclusions that could be used to advantage in industrial applications. It confirms, however, for the species used, that cold-setting resins yield bonds superior in water resistance to those accomplished with casein glues.

The commercial use of cold-setting resins in Brazil must be brought about by economic needs. Although they are superior to casein in some respects, the plywood industry in the country has been built up based on the use of casein, which has given and is still giving satisfactory economic and physical results.

To impose the use of the synthetic resins upon the industry, as seems to be the trend in Brazil, may not prove successful because there will always be ground for argument as to the advantages and limitations of the new adhesives as compared with casein. The main drawbacks of the use of casein are its lack of a good resistance to moisture and to biological deterioration. The former can be partly overcome by the use of hydrated lime, and it seems to be possible to get around the latter by the incorporation of certain organic preservatives in the glue powder. It appears as if the durability of the joints glued with a high lime content casein glue can be materially increased if some protection against biological deterioration is given to them.[8] If that can be accomplished without sensibly raising the cost of the glue line, casein glues will be able to stand the competition from cold-setting resins, in most of its present applications.

The use of the cold-setting resins will bring about few changes in equipment and plant lay up what facilitates their accepting by the Brazilian plywood industry. Their use, however, will be conditioned by technical and economic factors of which the supply of the resins and their cost will be of fundamental importance if they are ever to attain any commercial significance. Their fabrication at low prices in the country, therefore, seems to be a necessary step.

Of both types of cold-setting resins considered in this paper, the urea resins can be produced in Brazil more easily than resoreinol. While it is a product based upon a reaction between ammonia and carbon dioxide, resoreinol is a coal-tar derivative and, therefore, based on coal, whose mining is not well developped in the country.

Although the cost of adhesives is only a small fraction of the price of the final products, a question arises as to the price at which the resins could be sold in Brazil. Assuming, for the purpose of this discussion, that they will cost as much as they cost in this country, resoreinol would be used in straight mixtures only in exceptional conditions, as a pound of it costs about sixty cents at the present time. That price would bring the cost of glue line to approximately twenty dollars per thousand square feet, or as much as 4 and 3 times more expensive than the dearest casein and urea glue lines respectively,[11] if a spread of 40 pounds per thousand square feet is used for resorcinol.

The cost per thousand square feet of straight cold-setting urea glue line varies from five dollars and forty-two cents to six dollars and sixty-two cents, whereas for casein it goes from a little over three dollars up to five dollars.[11] In other words, the most expensive casein glue line is still below the least expensive straight cold-setting urea glue line.

If the cold-setting resins produce bonds of good durability, the difference in prices mentioned above would be offset by the better quality of the joints. However, data from other[12] sources, obtained in various tests to which cold-setting urea were put through showed that they exhibit low resistance to exposure to high humidities and ordinary temperature and low durability to combinations of high humidities and high temperatures. Being more acid than other glues of the urea-resin type they appeared to lose strength noticeably when aged at 80°F and sixty-five percent relative humidity during one year period.[12] Comparing cold-setting urea resins with preservative-treated casein Wangaard[12] states that the performance of cold-setting urea resins at ninety-seven percent relative humidity and 80°F temperature, for nine months, was "considerably less satisfactory". Casein glues also showed superiority over cold-setting urea resins in resistance to cyclic exposures involving high temperatures. Therefore, although cold-setting urea resins showed higher water resistance than casein they seem to be inferior to it in certain other respects.

Cold-setting urea resins could be used extended in which case the glue line cost would be brought down to the level of the cost of straight casein glue line. However, the addition of extenders to the mixture seems to decrease the water resistance of the bond to such a degree that its weathering qualities are practically lost.[9]

According to the statements above, the possibilities for cold-setting ureas to replace casein in the Brazilian plywood industry are not entirely favorable because they would have to be used for approximately the same purposes as casein glue is being used now.

Whenever a high water resistance and low glue line price are deemed important the hot-press phenolic resins must be used.

Very little can be said about resorcinol resins as they represent a development of the last three years. They seem to be much superior to the cold-setting urea resins, although much more expensive. If they can be sold in Brazil at a price as low as the phenolic resins are sold at present in this country, they will be likely to acquire great importance in the plywood field.

Summary

The cold-setting resins showed better results than casein as judged from the joint strength and wood failure figures (Tables 20 and 22).

Specific gravity was not the only factor governing the dry strength of <u>sucupira</u> and <u>pau rôxo</u> glued with casein, <u>pau amarélo</u> and <u>pau rôxo</u> glued with resorcinol-formaldehyde and <u>sucupira</u> glued with phenol-formaldehyde resins.

<u>Pau roxo</u> and <u>sucupira</u> did not seem to glue well with urea formaldehyde resin and <u>pau amarélo</u> showed low strength and low wood failure for its specific gravity when glued with resorcinol-formaldehyde. Additional data will be necessary to permit any final conclusions with regard to the shearing strength of those woods glued with the two cold-setting resins above mentioned.

Table 21 - Averages of total stress in pounds per square inch and of wood failures in percent

Averages For Casein Glue

Species	Ave. Total Stress (p.s.i.)			Ave. Wood Failure (%)		
	Dry	Soaked	D.F.E.T.	Dry	Soaked	D.F.E.T.
Águano	577.	292	368	35.5	1.0	1.0
Macacaúba	932	382	540	63.5	0.2	1.5
Pau amarélo	1030	278	456	69.5	0.0	3.0
Pau rôxo	778	169	316	49.7	0.0	0.0
Sucupira	709	281	293	22.5	0.0	0.2

Averages for Resoreinol-formaldehyde Resin

Species	Dry	Soaked	D.F.E.T.	Dry	Soaked	D.F.E.T.
Águano	654	696	699	83.3	87.6	79.0
Macacaúba	907	910	1106	65.1	79.3	64.5
Pau amarélo	781	707*	910*	11.5	16.0*	14.4*
Pau rôxo	811	696	607	65.5	68.0	73.0
Sucupira	1061	918	824	76.5	26.5	36.5

Averages for Urea-formaldehyde Resin

Species	Dry	Soaked	D.F.E.T.	Dry	Soaked	D.F.E.T.
Águano	681	867	819	89.0	83.5	63.5
Macacaúba	751	1088	897	99.5	70.0	64.5
Pau amarélo	1150	1176	707	79.5	70.5	36.5
Pau rôxo	1051	856	390	53.5	49.5	15.0
Sucupira	1248	965	554	30.5	45.0	13.0

Averages for Phenol-formaldehyde Resin

Species	Dry	Soaked	D.F.E.T.	Dry	Soaked	D.F.E.T.
Águano	843	530	600*	80.5	66.0	62.0*
Macacaúba	945	1034	945	74.0	60.5	56.0
Pau amarélo	1114	1187	777	51.0	41.0	32.5
Pau rôxo	1335	1297	1099•	81.0	45.5	61.0
Sucupira	1107	920	1037•	11.5	14.5	20.0•

*Average of 9 test specimens.

•Average of 7 test specimens.

Table 22 - Soaked and D.F.E.T. strength in percent of dry strength

Species	Casein Glue		
	Dry	Soaked	D.F.E.T.
Águano	100	43	54
Macacaúba	100	41	58
Pau amarélo	100	27	44
Pau rôxo	100	22	41
Sucupira	100	40	41

Species	Resorcinol-formaldehyde		
	Dry	Soaked	D.F.E.T.
Águano	100	106	107
Macacaúba	100	100	122
Pau amarélo	100	90	117
Pau rôxo	100	87	75
Sucupira	100	86	79

Species	Urea-formaldehyde		
	Dry	Soaked	D.F.E.T.
Águano	100	128	120
Macacaúba	100	144	119
Pau amarélo	100	101	61
Pau rôxo	100	81	37
Sucupira	100	77	44

Table 22 - continued.

Species	Phenol-formaldehyde		
	Dry	Soaked	D.F.E.T.
Águano	100	75	71
Macacaúba	100	109	100
Pau amarélo	100	106	70
Pau rôxo	100	97	82
Sucupira	100	78	89

LITERATURE CITED

1. Anonymous. A nova e florescente industria de modeira compensada - Brasil Madeireiro, Ano I, No. 1, Março, 1945. Pp. 10-11.

2. Woods - Brazilian Exports from 1939-1945- Brazil Trade Journal. Vol. II, No. 2. April, June, 1946. P. 8.

3. Resolução No. 28 de 6 de Dezembro de 1944 - Brasil Madeireiro - Ano I, No. 1. Marco, 1945. P. 34.

4. Testing and mixing of aircraft glues. U. S. Dept. Agr. For. Prod. Lab. Report No. 1338. Nov., 1941.

5. Douglas Fir Plywood Commercial Standards CS 45-45. Pp. 5-6. U. S. Dept. Comm. 1945.

6. Garratt, G. A. <u>Mechanical Properties of Wood.</u> John Wiley and Sons, Inc., New York. 1931. P. 276.

7. Grinsfelder, H. and Collins, M. R. Plywood Bonding. Ind. Eng. Chem. Vol. 36. P. 153. 1944.

8. Kaufert. "Increasing the durability of casein glue joints with preservatives" U. S. Dept. Agr. For. Prod. Lab. Report No. 1332. Oct., 1943.

9. Kynoch, W. and Norton, N. A. "Mechanical properties of certain tropical woods chiefly from South America." University of Michigan, School of Forestry and Conservation, Bull. 7. Ann Arbor. 1938.

10. Patronsky, L. A. Mimeographed Laboratory Exercises. Unpublished. 1946.

11. Perry, Thomas D. Modern Wood Adhesives. Pitman Publishing Co. New York. 1944. Pp. 15-16, 68, 100-102. Illust. p. 208.

12. Truax, T. R. Gluing wood in aircraft manufacture. U. S. Dept. Agr. Tech. Bull. 205.

13. Wangaard, F. F. Summary of information on the durability of aircraft glues. U. S. Dept. Agr. For. Prod. Lab. Report No. 1530. 1944.

TABLE 1.

Stress in pounds per square inch, percent of

Wood Failure and Type of Failure.

Species: AGUANO

Glue used: CASEIN

Area under Stress: 1/2".

Plies Thicknesses: 1/8".

Total Load (lbs.)	Total Stress (p.s.i.)	Wood Failure	Type of Failure	Condition Tested	Date Tested	Remarks
350	700	50	Shear	Dry	12/1/46	
310	620	10	"	"	"	
390	780	40	"	"	"	
365	+ 730	10	"	"	"	
375	750	95	"	"	"	Radial section
300	600	90	"	"	"	" "
375	750	100	Tension	"	"	
380	760	10	Shear	"	"	
390	780	5	"	"	"	
150	300	10	"	"	"	Dry joint
120	240	0	"	Soaked	"	
100	200	0	"	"	"	
130	260	0	"	"	"	
140	280	0	"	"	"	
225	450	0	"	"	"	Dry patches of glue
120	240	0	"	"	"	
125	250	0	"	"	"	
300	600	10	"	"	"	Dry patches of glue
100	200	0	"	"	"	
100	200	0	"	"	"	
120	240	0	"	D.F.B.T.	12/5/46	Radial section
190	380	0	"		"	75% of working area dry

TABLE 1.
(cont'd)

Total Load (lbs.)	Total Stress (p.s.i.)	Wood Failure	Type of Failure	Condition Tested	Date Tested	Remarks
285	570	0	Dry		12/5/46	30% of working area dry slots improperly cut
200	400	0	"		"	20% " " "
105	210	0	"		"	30% " " "
130	260	0	"		"	
175	350	0	"		"	
356	710	10	"		"	70% of working area dry
185	370	0	"		"	
95	190	0	"		"	

TABLE 2.

Stress in pounds per square inch, percent of

Wood Failure and Type of Failure.

Species: MACAUBA

Glue used: CASEIN

Area under Stress: 1/2"

Plies Thicknesses: 1/8"

Total Load (lbs.)	Total Stress (p.s.i.)	Wood Failure	Type of Failure	Condition Tested	Date Tested	Remarks
350	700	25%	Shear	Dry	11/30/46	
680	1360	85%	"	"	"	
505	1010	85%	"	"	"	
475	950	50%	"	"	"	
625	1250	20%	"	"	"	
495	990	15%	"	"	"	
325	650	90%	"	"	"	
325	650	95%	"	"	"	
410	820	85%	"	"	"	
470	940	85%	"	"	"	
130	260	0	"	Soaked	12/7/46	
130	260	0	"	"	"	
00	00	0	"	"	"	Specimen failed while setting it in machine.
245	490	0	"	"	"	Dry patches of glue
320	640	0	"	"	"	30% of working area dry.
240	480	0	"	"	"	
145	290	0	"	"	"	
185	370	0	"	"	"	20% of working area dry.
300	600	2	"	"	"	30% " " " "
215	430	0	"	"	"	
300	600	0	"	D.F.E.T.	12/5/46	80% " " " "
200	400	0	"	"	"	50 " " " "

TABLE 2.
(cont'd).

Total Load (lbs.)	Total Stress (p.s.i.)	Wood Failure	Type of Failure	Condition Tested	Date Tested	Remarks
385	770	10	Shear	D.F.E.T.	12/5/46	80% of working area dry
315	630	5	"	"	"	80% " " " "
150	300	0	"	"	"	
380	760	0	"	"	"	3% of working area dry
245	490	0	"	"	"	
240	480	0	"	"	"	30% of working area dry
210	420	0	"	"	"	
275	550	0	"	"	"	30% of working area dry.

TABLE 3.

Stress in pounds per square inch, percent of

Wood Failure and Type of Failure.

Species: PAN AMARILO

Glue used: CASEIN

Area under Stress: 1/2"

Plies Thicknesses: 1/8"

Total Load (lbs.)	Total Stress (p.s.i.)	Wood Failure	Type of Failure	Condition Tested	Date Tested	Remarks
475	950	5	Shear	Dry	12/14/46	
440	880	60		"	"	
390	780	40		"	"	Diagonal grain.Radial surface
550	1100	100		"	"	Cross grain
440	880	100		"	"	" "
440	880	100		"	"	Radial surface
550	1100	80		"	"	
865	1730	10		"	"	
630	1260	100		"	"	
370	740	100		"	"	Diagonal grain.Radial Surface
260	520	0	Shear	Soaked	12/1/46	30% of the working area dry
0	0	0	"	"	"	Specimen failed before testing
165	330	0	"	"	"	
00	00	0	"	"	"	Specimen failed before testing
00	00	0	"	"	"	" " " "
75	150	0	"	"	"	
65	130	0	"	"	"	
100	200	0	"	"	"	
170	340	0	"	"	"	
00	00	0	"	"	"	Specimen failed before testing
00	.00	0	"	D.F.E.T.	12/21/46	Specimen failed during 2nd soaking
50	100	0	"	"	"	

TABLE 3.
(cont'd)

Total Load (lbs.)	Total Stress (p.s.i.)	Wood Failure	Type of Failure	Condition Tested	Date Tested	Remarks
50	100	0	Shear	D.F.E.T.	12/21/46	
00	00	0	"	"	"	Specimen failed while setting it into machine
575	1150	0	"	"	"	Slots not cut deep enough
355	710	30	"	"	"	" " " " "
75	150	0	"		"	
255	510	0	"		"	
320	640	0	"		"	30% of the working area dry.
145	290	0	"		"	

TABLE 4.

Stress in pounds per square inch, percent of Wood Failure and Type of Failure.

Species: PAU ROXO

Glue used: CASEIN

Area under Stress: 1/2"

Plies Thicknesses: 1/8"

Total Load (lbs.)	Total Stress (p.s.i.)	Wood Failure	Type of Failure	Condition Tested	Date Tested	Remarks
260	468	2	Shear	Dry	11/30/46	
520	936	25	"	"	"	
560	1008	70	"	"	"	
425	765	20	"	"	"	
475	855	70	"	"	"	
270+	486	80	"	"	"	
495	891	90	"	"	"	
335	603	50	"	"	"	
395	711	15%	"	"	"	
585	1053	75	"	"	"	
000200	360	0	"	Soaked	12/1/46	80% of working area dry. Slots not cut deep enough.
00050	90	0	"	"	"	30% of working area dry
000.75	135	0	"	"	"	50% of working area dry. Slots not cut deep enough.
000.170	306	0	"	"	"	50% " " " "
000.155	279	0	"	"	"	70% " " " "
000140	252	0	"	"	"	30% " " " "
000.50	90	0	"	"	"	60% " " " "
000100	180	0	"	"	"	Specimen failed while setting it into machine.
000000	00	0	"	"	"	
000000	00	0	"	"	"	
140	252	0	Shear	D.F.E.T.	12/5/46	30% of working area dry.

TABLE 4.
(cont'd)

Total Load (lbs.)	Total Stress (p.s.i.)	Wood Failure	Type of Failure	Condition Tested	Date Tested	Remarks
175	315	0	Shear	D.F.E.T.	12/5/46	
225	405	0	"	"	"	50% of working area dry.
300	540	0	"	"	"	30% " " " "
135	243	0	"	"	"	
115	207	0	"	"	"	
135	243	0	"	"	"	
200	360	0	"	"	"	30% of working area dry.
195	351	0	"	"	"	40% of working area dry.
135	243	0	"	"	"	30% of working area dry.

TABLE 5.

Stress in pounds per square inch, percent of

Wood Failure and Type of Failure.

Species: SUCUPIRA

Glue used: CASEIN

Area under Stress: 1/2"

Plies Thicknesses: 1/8"

Total Load (lbs.)	Total Stress (p.s.i.)	Wood Failure	Type of Failure	Condition Tested	Date Tested	Remarks
370	666	70	Shear	Dry	12/14/46	
365	657	5	"	"	"	
480	864	10	"	"	"	
350	639	70	"	"	"	Cross grained
365	657	0	"	"	"	
390	702	0	"	"	"	
450	810	0	"	"	"	
300	540	0	"	"	"	2% dry joint
455	819	70	"	"	"	
410	738	0	"	"	"	
000		0	Shear	Soaked	12/1/46	
225	105	0	"	"	"	
175	315	0	"	"	"	
00	00	0	"	"	"	Specimen failed while setting it in the machine
375	675	0	"	"	"	
00	00	0	"	"	"	Specimen failed while setting it in the machine
185	333	0	"	"	"	
125	225	0	"	"	"	
230	504	0	"	"	"	
195	351	0	"	"	"	
170	306	0	"	D.F.E.T.	12/5/46	
00	0	0	"	"	"	Specimen failed while setting it in the machine

TABLE 5.
(cont'd).

Total Load (lbs.)	Total Stress (p.s.i.)	Wood Failure	Type of Failure	Condition Tested	Date Tested	Remarks
170	306	0	Shear	D.F.E.T.	12/5/46	
00	00	0	"	"	"	Specimen failed while setting it in the machine.
120	216	0	"	"	"	
135	243	0	"	"	"	
335	603	0	Tension	"	"	Tension due to improper setting of slates
75	135	0	Shear	"	"	
325	585	0	"	"	"	50% of working area dry
300	540	2	"	"	"	40% of working area dry

TABLE 6.

Stress in pounds per square inch, percent of

Wood Failure and Type of Failure.

Species: AQUANO

Glue used: RESORCINOL

Area under Stress: 1/2"

Plies Thicknesses: 1/8"

Total Load (lbs.)	Total Stress (P.s.i.)	Wood Failure	Type of Failure	Condition Tested	Date Tested	Remarks
435	870	98	Shear	Dry	12/1/46	
255	510	90	"	"	"	Radial section
530	1060	35	"	"	"	
190	380	100	"	"	"	Radial section
250	500	100	"	"	"	
370	740	80	"	"	"	
230	460	50	"	"	"	Radial section
245	490	95	"	"	"	" "
395	790	85	"	"	"	
370	740	100	"	"	"	
430	860	85	"	Soaked	12/2/46	
325	650	98	"	"	"	
405	810	90	"	"	"	
375	750	50	"	"	"	
275	550	98	"	"	"	Radial section
115	230	100	"	"	"	Specimen broke at an old shear failure
360	720	95	"	"	"	
325	650	100	"	"	"	
435	870	60	"	"	"	
435	870	100	"	"	"	
450	900	70	"	D.F.E.T.	12/17/46	
410	820	90	"		"	

TABLE 6.
(cont'd.)

Total Load (lbs.)	Total Stress (p.s.i.)	Wood Failure	Type of Failure	Condition Tested	Date Tested	Remarks
390	780	70	Shear		12/17/46	
360	720	100	"		"	
455	910	95	"		"	
445	890	95	"		"	Cross grain
310	620	85	"		"	
305	610	95	"		"	Specimen broke at an old shear failure
370	740	90	"		"	Radial section

TABLE 7.

Stress in pounds per square inch, percent of

Wood Failure and Type of Failure.

Species: MACACAUBA

Glue used: RESORCINOL

Area under Stress: 1/2"

Plies Thicknesses: 1/8"

Total Load (lbs.)	Total Stress (p.s.i.)	Wood Failure	Type of Failure	Condition Tested	Date Tested	Remarks
410	820	98	Shear	Dry	12/6/46	
370	740	70	"	"	"	
450	900	50	"	"	"	
605	1210	50	"	"	"	
650	1300	98	"	"	"	
500	1000	60	"	"	"	
345	690	85	"	"	"	
450	900	40	"	"	"	
440	880	98	"	"	"	
315	630	10	"	"	"	
375	750	85	Shear	Soaked	12/2/46	
460	920	98	"	"	"	
545	1090	70	"	"	"	
615	1230	85	"	"	"	Cross grain
315+	630	90	"	"	"	" "
560	1120	85	"	"	"	
485	970	100	"	"	"	
435	870	5	"	"	"	
435	870	100	"	"	"	
325	650	75	"	"	"	
820	1640	15	"	D.F.E.T.	1/2/47	
580	1160	95	"	"	"	

TABLE 7.
(cont'd.)

Total Load (lbs.)	Total Stress (p.s.i.)	Wood Failure	Type of Failure	Condition Tested	Date Tested	Remarks
500	1000	20	Shear	D.F.E.T.	1/2/47	
590	1180	90	"	"	"	
555	1110	40	"	"	"	
590	1180	95	"	"	"	
455	910	100	"	"	"	
185	370	5	"	"	"	
255	510	5	"	"	"	
1000+	2000+	95	"	"	"	

TABLE 8.

Stress in pounds per square inch, percent of

Wood Failure and Type of Failure.

Species: PANAMARELO

Glue used: RESORCINOL

Area under Stress: 1/2"

Total Load (lbs.)	Total Stress (p.s.i.)	Wood Failure	Type of Failure	Condition Tested	Date Tested	Remarks
400	800	15	Shear	Dry	1/4/47	
400	800	0	"	"	"	
565	1130	0	"	"	"	
730	1460	5	"	"	"	
555	1110	60	"	"	"	
395	790	20	"	"	"	
0	0	0	"	"	"	Specimen failed before any load could be read
300	600	0	"	"	"	
0	0	0	"	"	"	Specimen failed before any load could be read
560	1120	15	"	"	"	
240	480	0	"	Soaked	1/5/47	
490	980	50	"	"	"	
195	390	20	"	"	"	
415	830	5	"	"	"	
270	540	10	"	"	"	
420	840	0	"	"	"	
545	1090	60	"	"	"	
325	650	0	"	"	"	
285	570	15	"	"	"	
			-	"	"	
755	1510	60	"	D.F.E.T.	1/9/47	
675	1350	5	"	"	"	
490	980	0	"	"	"	

TABLE 8.
(cont'd.)

Total Load (lbs.)	Total Stress (p.s.i.)	Wood Failure	Type of Failure	Condition Tested	Date Tested	Remarks
520	1040	10	Shear	D.F.E.T.	1/9/47	
520	1040	10	"	"	"	
580	1160	30	"	"	"	
00	0	0	"	"	"	Specimen collapsed while setting it in the machine
435	970	15	"	"	"	
125	250	0	"	"	"	

TABLE 9.

Stress in pounds per square inch, percent of

Wood Failure and Type of Failure.

Species: PAUROXO

Glue used: RESORCINOL

Area under Stress: 1/2"

Plies Thicknesses: 1/8"

Total Load (lbs.)	Total Stress (p.s.i.)	Wood Failure	Type of Failure	Condition Tested	Date Tested	Remarks
600	1080	15	Shear	Dry	12/6/46	
690	1242	70	"	"	"	
310	558	70		"	"	Cross grain
375	675	70		"	"	" "
370	666	90		"	"	Specimen broke at an old Shear failure
305	549	10		"	"	" " "
450	810	80		"	"	
395	711	95		"	"	
370	666	80		"	"	
640	1152	75		"	"	
320	576	30	Shear	Soaked	12/2/46	
425	765	60	"	"	"	Diagonal grain.Radial section
375	675	70	"	"	"	
320	576	80	"	"	"	
390	702	90	"	"	"	
435	783	40	"	"	"	
395	711	15	"	"	"	
275	495	100	"	"	"	
555	999	95	"	"	"	
375+	675	100	"	"	"	Cross grain
350	630	80	"	D.F.E.T.	12/7/46	Specimen broke at an old shear failure.
340	612	60	"	"	"	

TABLE 9.
(cont'd.)

Total Load (lbs.)	Total Stress (p.s.i.)	Wood Failure	Type of Failure	Condition Tested	Date Tested	Remarks
425	765	90	Shear	D.F.E.T.	12/7/46	
250	450	100	"	"	"	Specimen broke at an old shear failure.
350	630	100	"	"	"	" " " "
255	459	10	"	"	"	
300	540	60	"	"	"	
580	1044	70	"	"	"	
225	405	100	"	"	"	Specimen broke at an old shear failure.
300	540	60	"	"	"	

TABLE 10.

Stress in pounds per square inch, percent of

Wood Failure and Type of Failure.

Species: SUCUPIRA

Glue used: RESORCINOL

Area under Stress: 1/2"

Plies Thicknesses: 1/16"

Total Load (lbs.)	Total Stress (p.s.i.)	Wood Failure	Type of Failure	Condition Tested	Date Tested	Remarks
425	765	100%	Shear	Dry	12/6/46	
765	1377	70%	"	"	"	Cross grain
680	1224	80%	"	"	"	
690	1242	95%	"	"	"	
450	810	100%	Tension	Dry	"	Specimen warped
600	1080	100	"	"	"	
625	1125	100	Shear	"	"	
475	855	20%	"	"	"	
750	1350	100%	"	"	"	Specimen broke at an old shear failure.
435	783	70%	"	"	"	Radial section.
715	1287	10	"	Soaked	12/2/46	
335	603	10	"	"	"	Cross grain
555	999	60	"	"	"	
385	693	50	"	"	"	Radial section.
575	1035	10	"	"	"	
455	819	35	"	"	"	
625	1125	10	"	"	"	
505	909	15	"	"	"	
385	693	40	"	"	"	
565	1017	25	"	"	"	Specimen broke at an old shear failure.
410	738	20	"	"	"	

TABLE 10.
(cont'd.)

Total Load (lbs.)	Total Stress (p.s.i.)	Wood Failure	Type of Failure	Condition Tested	Date Tested	Remarks
530	954	5	Shear	D.F.E.T.	12/17/46	
220	396	5	"	"	"	
425	765	30	"	"	"	
490	882	40	"	"	"	
505	909	25	"	"	"	
500	900	80	"	"	"	
450	810	60	"	"	"	
515	927	60	"	"	"	
535	963	40	"	"	"	

TABLE 11.

Stress in pounds per square inch, percent of

Wood Failure and Type of Failure.

Species: AGUANO

Glue used: UREA

Area under Stress: 1/2"

Plies Thicknesses: 1/8"

Total Load (lbs.)	Total Stress (p.s.i.)	Wood Failure	Type of Failure	Condition Tested	Date Tested	Remarks
460	920	100	Shear	Dry	12/22/46	
410	820	100	"	"	"	
330	660	95	"	"	"	
385	770	100	"	"	"	Radial section
290	580	100	"	"	"	" "
350	700	100	"	"	"	" "
435	870	100	"	"	"	Specimen broke at an old shear failure.
420	840	100	"	"	"	Radial Section
330	660	100	"	"	"	" "
195	390	95	"	"	"	Specimen broke at an old shear failure.
370	740	100	Shear	Soaked	12/20/46	Radial Section
360	720	95	"	"	"	
375	750	100	"	"	"	Radial Section
420	840	95	"	"	"	" "
560	1120	100	"	"	"	" "
450	900	30	"	"	"	
360	720	70	"	"	"	Specimen broke at an old shear failure.
455	910	70	"	"	"	
475	950	95	"	"	"	Radial Section
510	1020	80	"	"	"	" "
505	1010	40	"	D.F.E.T.	12/24/46	" "

TABLE 11.
(cont'd.)

Total Load (lbs.)	Total Stress (p.s.i.)	Wood Failure	Type of Failure	Condition Tested	Date Tested	Remarks
385	770	100	Shear	D.F.E.T.	12/24/46	Radial Section
405	810	100	"	"	"	" "
370	740	15	"	"	"	
615	1230	100	"	"	"	
365	730	30	"	"	"	Specimen broke at an old shear failure
290	580	10	"	"	"	
385	770	100	"	"	"	Radial section
505	1010	60	"	"	"	
270	540	70	"	"	"	Radial section.

TABLE 12.

Stress in pounds per square inch, percent of Wood Failure and Type of Failure.

Species: MACACAUBA

Glue used: UREA

Area under Stress: 1/2"

Plies Thicknesses: 1/8"

Total Load (lbs.)	Total Stress (p.s.i.)	Wood Failure	Type of Failure	Condition Tested	Date Tested	Remarks
485	970	100	Shear	Dry	12/21/46	
325	650	100	"	"	"	
435	870	95	"	"	"	
300	600	100	Tension	"	"	Cross grain
140	280	100	"	"	"	" "
350	700	100	Shear	"	"	
245	490	100	Tension	"	"	Cross grain
515	1030	100	Shear	"	"	" "
350	700	100	"	"	"	
610	1220	100	"	"	"	
530	1060	35	"	Soaked	12/20/46	
680	1360	80	"	"	"	Radial Section
580	1160	95	"	"	"	
550	1100	95	"	"	"	Radial Section
460	920	30	"	"	"	75% of working area dry
425	850	30	"	"	"	40% of working area dry
410	820	95	"	"	"	
550	1100	90	"	"	"	30% of working area dry
570	1140	50	"	"	"	30% " " "
635	1370	100	"	"	"	Cross grain
590	1180	30	"	D."F.E.T.	12/24/46	
690	1380	100	"	"	"	

TABLE 12.
(cont'd.)

Total Load (lbs.)	Total Stress (p.s.i.)	Wood Failure	Type of Failure	Condition Tested	Date Tested	Remarks
280	560	25	Shear	D.F.E.T.	12/24/46	Dry joint
375	750	100	"	"	"	Cross grain
485	970	100	"	"	"	Radial section
410	820	40	"	"	"	
275	550	30	"	"	"	Dry joint
425	850	100	"	"	"	Radial section
485	970	100	"	"	"	
470	940	15	"	"	"	

TABLE 13.

Stress in pounds per square inch, percent of

Wood Failure and Type of Failure.

Species: PAN AMARELO

Glue used: UREA

Area under Stress: 1/2"

Plies Thicknesses: 1/8"

Total Load (lbs.)	Total Stress (p.s.i.)	Wood Failure	Type of Failure	Condition Tested	Date Tested	Remarks
625	1250	100	Shear	Dry	12/20/46	
700	1400	100	"	"	"	
455	910	40	"	"	"	
550	1100	95	"	"	"	
445	890	100	"	"	"	
640	1280	30	"	"	"	
340	680	100	"	"	"	
800	1600	40	"	"	"	
590	1180	100	"	"	"	
655	1310	90	"	Soaked	"	
535	1070	100	"	"	"	Radial section
540	1080	5	"	"	"	
555	1110	95	"	"	"	
530	1060	100	"	"	"	
635	1270	95	"	"	"	
485	970	10	"	"	"	
775	1550	90	"	"	"	Specimen broke at an old shear failure
565	1130	100	"	"	"	Radial section
675	1350	40	"	"	"	
585	1170	70	"	"	"	
345	690	40	"	D."F.E.T.	12/24/46	Radial section

TABLE 13.
(cont'd.)

Total Load (lbs.)	Total Stress (p.s.i.)	Wood Failure	Type of Failure	Condition Tested	Date Tested	Remarks
465	930	15	Shear	D.F.E.T.	12/24/46	
525	1050	95	"	"	"	
125	250	35	"	"	"	
200	400	0	"	"	"	
415	830	40	"	"	"	
555	1110	85	"	"	"	
310	620	10	"	"	"	
370	740	40	"	"	"	
175	350	5	"	"	"	

TABLE 14.

Stress in pounds per square inch, percent of

Wood Failure and Type of Failure.

Species: PAUROXO

Glue used: UREA

Area under Stress: 1/2"

Plies Thicknesses: 1/8"

Total Load (lbs.)	Total Stress (p.s.i.)	Wood Failure	Type of Failure	Condition Tested	Date Tested	Remarks
470	940	15	Shear	Dry	12/21/46	Radial section
670	1340	30	"	"	"	" "
475	1950	70	"	"	"	
385	770	15	"	"	"	
435	870	75	"	"	"	
425	850	30	"	"	"	
525	1050	90	"	"	"	Radial section
565	1130	70	"	"	"	
535	1070	90	"	"	"	
770	1540	50	"	"	"	
165	330	10	"	Soaked	12/20/46	
440	880	70	"	"	"	50% of working area dry
680	1360	10	"	"	"	30% of working area dry
290	580	0	"	"	"	
345	690	50	"	"	"	
575	1150	40	"	"	"	
500	1000	80	"	"	"	
495	990	100	"	"	"	
270	540	50	"	"	"	
520	1040	85	"	D.F.E.T.	12/24/46	Specimen showed delamination 1/2" deep in one edge
185	370	5	"	"	"	

TABLE 14.
(cont'd.)

Total Load (lbs.)	Total Stress (p.s.i.)	Wood Failure	Type of Failure	Condition Tested	Date Tested	Remarks
325	650	50	Shear	D.F.E.T.	12/24/46	
275	550	30	"	"	"	
00	00	0	"	"	"	Specimen failed while being set in the machine
535	1070	30	"	"	"	Slots not cut deep enough
00	00	00	"	"	"	Specimen failed while being set in the machine
100	200	5	"	"	"	Specimen showed delamination 1/4" deep in one edge
190	380	20	"	"	"	
50	100	8	"	"	"	
290	580	10	"	"	"	

TABLE 15.

Stress in pounds per square inch, percent of

Wood Failure and Type of Failure.

Species: SUCUPIRA

Glue used: UREA

Area under Stress: 1/2"

Plies Thicknesses: 1/8"

Total Load (lbs.)	Total Stress (p.s.i.)	Wood Failure	Type of Failure	Condition Tested	Date Tested	Remarks
875	1750	85	Shear	Dry	12/21/46	
550	1100	20	"	"	"	
435	870	10	"	"	"	
530	1060	40	"	"	"	
445	890	10	"	"	"	
735	1470	20	"	"	"	
670	1340	30	"	"	"	
550	1110	40	"	"	"	
720	1440	40	"	"	"	
725	1450	10	"	"	"	
545	1090	100	Shear	Soaked	12/20/46	Radial section
385	770	5	"	"	"	
500	1000	80	"	"	"	
425	850	35	"	"	"	Radial section
360	720	100	"	"	"	" "
345	690	40	"	"	"	
615	1230	10	"	"	"	
550	1110	60	"	"	"	
580	1160	10	"	"	"	
515	1030	10	"	"	"	
650	1300	15	"	D.F.E.T.	12/24/46	Radial section
165	330	5	"	"	"	

TABLE 15.
(cont'd.)

Total Load (lbs.)	Total Stress (p.s.i.)	Wood Failure	Type of Failure	Condition Tested	Date Tested	Remarks
0	00	0	Shear	D.F.E.T.	12/24/46	Specimen failed while being set in the machine.
385	770	50	"	"	"	Radial section
415	830	10	"	"	"	
220	440	20	"	"	"	Radial section
70	140	0	"	"	"	
290	580	10	"	"	"	
175	350	10	"	"	"	
400	800	10	"	"	"	

TABLE 16.

Stress in pounds per square inch, percent of

Wood Failure and Type of Failure.

Species: AGUANO

Glue used: PHENOL-FORMALDEHYDE - TEGO

Area under Stress: 1/2"

Plies Thicknesses: 1/8"

Total Load (lbs.)	Total Stress (p.s.i.)	Wood Failure	Type of Failure	Condition Tested	Date Tested	Remarks
415	830	100	Shear	Dry	12/29/46	Radial section
440	880	70	"	"	"	
415	830	85	"	"	"	
365	730	95	"	"	"	Radial section
275	550	100	"	"	"	" " cross grain
470	940	100	Tension	"	"	
560	1120	15	Shear	"	"	
490	980	100	"	"	"	
325	650	100	"	"	"	
460	920	40	"	"	"	
500	1000	70	"	Soaked	12/30/46	
330	660	95	"	"	"	Radial section
345	690	35	"	"	"	
295	590	100	Tension	"	"	Specimen broke at an old shear failure
315	630	95	Shear	"	"	
335	670	80	"	"	"	
280	560	80	"	"	"	
330	660	90	"	"	"	
225	450	0	"	"	"	
195	390	15	"	"	"	
145	290	0	"	D.F.E.T.	1/3/47	
365	730	95	"	"	"	

TABLE 16.
(cont'd.)

Total Load (lbs.)	Total Stress (p.s.i.)	Wood Failure	Type of Failure	Condition Tested	Date Tested	Remarks
315	630	50	Shear	D.F.E.T.	1/3/47	
375	750	70	"	"	"	
360	720	100	"	"	"	
225	450	100	Tension	"	"	Specimen broke at an old shear failure
240	480	30	Shear	"	"	
480	960	80	"	"	"	Radial section
195	390	100	"	"	"	" "

TABLE 17.

Stress in pounds per square inch, percent of

Wood Failure and Type of Failure.

Species: MACACAUBA

Glue used: PHENOL FORMALDEHYDE TEGO

Area under Stress: 1/2"

Plies Thicknesses: 1/8"

Total Load (lbs.)	Total Stress (p.s.i.)	Wood Failure	Type of Failure	Condition Tested	Date Tested	Remarks
510	1020	95	Shear	Dry	12/29/46	
525	1050	60	"	"	"	
415	830	100	"	"	"	
340	680	5	"	"	"	
425	840	50	"	"	"	
400	800	100	"	"	"	Cross grain
460	920	50	"	"	"	
515	1030	90	"	"	"	
650	1300	85	"	"	"	
490	980	95	"	"	"	
320	640	10	"	Soaked	12/30/46	
525	1050	60	"	"	"	
600	1200	90	"	"	"	
615	1230	30	"	"	"	
520	1040	30	"	"	"	
540	1080	50	"	"	"	
475	950	100	"	"	"	
560	1120	95	"	"	"	
605	1210	50	"	"	"	
410	820	90	"	"	"	
550	1110	95	"	D.F.E.T.	1/3/47	
120	240	5	"	"	"	

TABLE 17.
(cont'd.)

Total Load (lbs.)	Total Stress (P.s.i.)	Wood Failure	Type of Failure	Condition Tested	Date Tested	Remarks
305	610	20	Shear	D.F.E.T.	1/3/47	Cross grain
415	830	20	"	"	"	
380	760	100	"	"	"	
550	1110	100	"	"	"	
520	1040	40	"	"	"	
655	1310	50	"	"	"	
610	1220	50	"	"	"	
610	1220	80	"	"	"	

TABLE 18.

Stress in pounds per square inch, percent of

Wood Failure and Type of Failure.

Species: PAN AMARELO

Glue used: PHENOL FORMALDEHYDE TEGO

Area under Stress: 1/2"

Plies thicknesses: 1/8"

Total Load (lbs.)	Total Stress (p.s.i.)	Wood Failure	Type of Failure	Condition Tested	Date Tested	Remarks
450	900	100	Tension	Dry	12/29/46	
500	1000	95	Shear	"	"	
355	710	100	"	"	"	
525	1050	5	"	"	"	
585	1170	40	"	"	"	
435	870	100	"	"	"	
665	1330	10	"	"	"	
690	1380	5	"	"	"	
690	1380	5	"	"	"	
675	1350	50	"	"	"	
535	1070	95	"	Soaked	12/30/46	Radial section
765	1530	5	"	"	"	
645	1290	0	"	"	"	
610	1220	60	"	"	"	
605	1210	100	"	"	"	
605	1210	40	"	"	"	
415	830	0	"	"	"	
620	1240	70	"	"	"	
505	1010	0	"	"	"	
630	1260	40	"	"	"	
530	1060	5	"	D.F.E.T.	1/3/47	
470	940	30	"	"	"	

TABLE 18.
(cont'd.)

Total Load (lbs.)	Total Stress (p.s.i.)	Wood Failure	Type of Failure	Condition Tested	Date Tested	Remarks
595	1190	100	Shear	D.F.E.T.	1/3/47	
450	900	25	"	"	"	
220	440	0	"	"	"	
550	1100	30	"	"	"	
460	920	0	"	"	"	
550	1100	50	Tension	"	"	Specimen broke at an old shear failure
510	1020	15	Shear	"	"	
550	1100	70	"	"	"	

TABLE 19.

Stress in pounds per square inch, percent of

Wood Failure and Type of Failure.

Species: PAUROXO

Glue used: PHENOL FORMALDEHYDE TEGO

Area under Stress: 1/2"

Plies Thicknesses: 1/8"

Total Load (lbs.)	Total Stress (p.s.i.)	Wood Failure	Type of Failure	Condition Tested	Date Tested	Remarks
760	1520	75	Shear	Dry	12/29/46	
785	1570	85	"	"	"	
545	1090	30	"	"	"	
650	1300	80	"	"	"	
675	1350	90	"	"	"	
600	1200	100	"	"	"	
740	1480	90	"	"	"	
745	1490	60	"	"	"	
635	1270	100	"	"	"	
540	1080	100	"	"	"	
730	1460	10	"	Soaked	12/30/46	
515	1030	95	"	"	"	
390	780	10	"	"	"	
630	1260	90	"	"	"	
655	1310	100	"	"	"	
750	1500	60	"	"	"	
785	1570	90	"	"	"	
610	1220	40	"	"	"	
580	1160	10	"	"	"	
840	1680	50	"	"	"	
470	940	70	"	D.F.E.T.	1/3/47	

TABLE 19.
(cont'd.)

Total Load (lbs.)	Total Stress (p.s.i.)	Wood Failure	Type of Failure	Condition Tested	Date Tested	Remarks
620	1240	80	Shear	D.F.E.T.	1/3/47	
565	1130	90	"	"	"	
535	1070	80	"	"	"	
460	920	20	"	"	"	
665	1330	90	"	"	"	
600	1200	45	"	"	"	
745	1490	90	"	"	"	
310	620	15	"	"	"	
525	1050	30	"	"	"	

TABLE 20.

Stress in pounds per square inch, percent of

Wood Failure and Type of Failure.

Species: SUCUPIRA

Glue used: PHENOL FORMALDEHYDE TEGO

Area under Stress: 1/2"

Plies Thicknesses: 1/8"

Total Load (lbs.)	Total Stress (p.s.i.)	Wood Failure	Type of Failure	Condition Tested	Date Tested	Remarks
255	510	0	Shear	Dry	12/29/46	
630	1260	60	"	"	"	
405	810	0	"	"	"	
510	1220	0	"	"	"	
705	1410	20	"	"	"	
460	920	0	"	"	"	
645	1290	0	"	"	"	
855	1710	15	"	"	"	
555	1110	20	"	"	"	
710	1430	0	"	"	"	
690	1380	30	"	Soaked	12/30/46	
735	1470	15	"	"	"	
190	380	0	"	"	"	
655	1310	30	"	"	"	Cross grain
380	760	40	"	"	"	
440	880	5	"	"	"	
420	840	20	"	"	"	
505	1010	0	"	"	"	
410	820	5	"	"	"	
175	350	0	"	"	"	Resin was not cured
550	1100	5	"	D.F.E.T.	1/3/47	

TABLE 20.
(cont'd.)

Total Load (lbs.)	Total Stress (p.s.i.)	Wood Failure	Type of Failure	Condition Tested	Date Tested	Remarks
590	1180	20	Shear	D.F.E.T.	1/3/47	
0	0	0	-	"	"	Specimen broke while setting it into machine
0	0	0	-	"	"	Experimental error.
525	1050	15	Shear	"	"	
530	1060	10	"	"	"	
455	910	30	"	"	"	
540	1080	40	"	"	"	
440	880	20	"	"	"	
0	0	0	-	"	"	Specimen broke while setting it into machine.

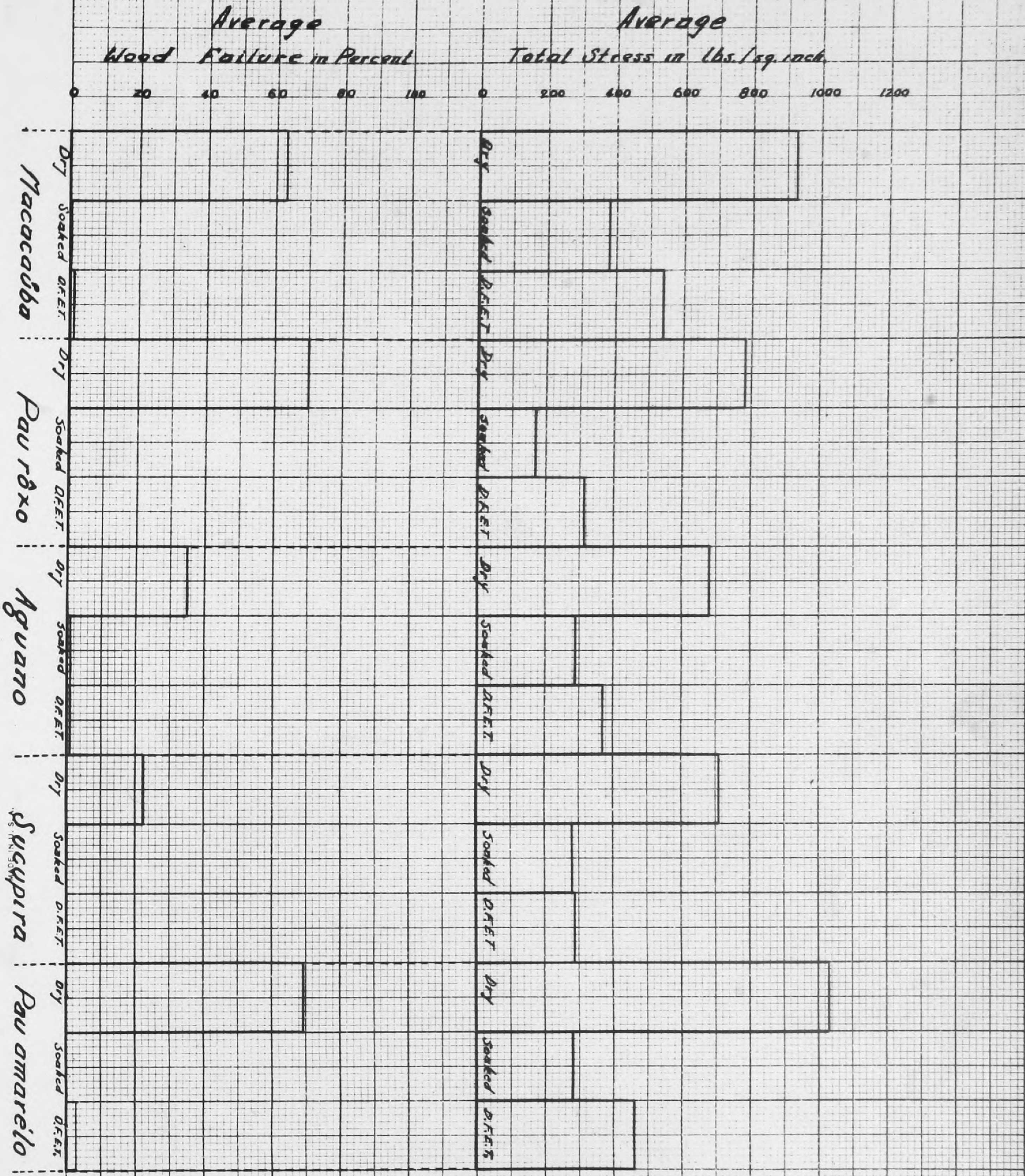


Fig. 1. Casein glue:- Average glue joint strength and Average wood failure

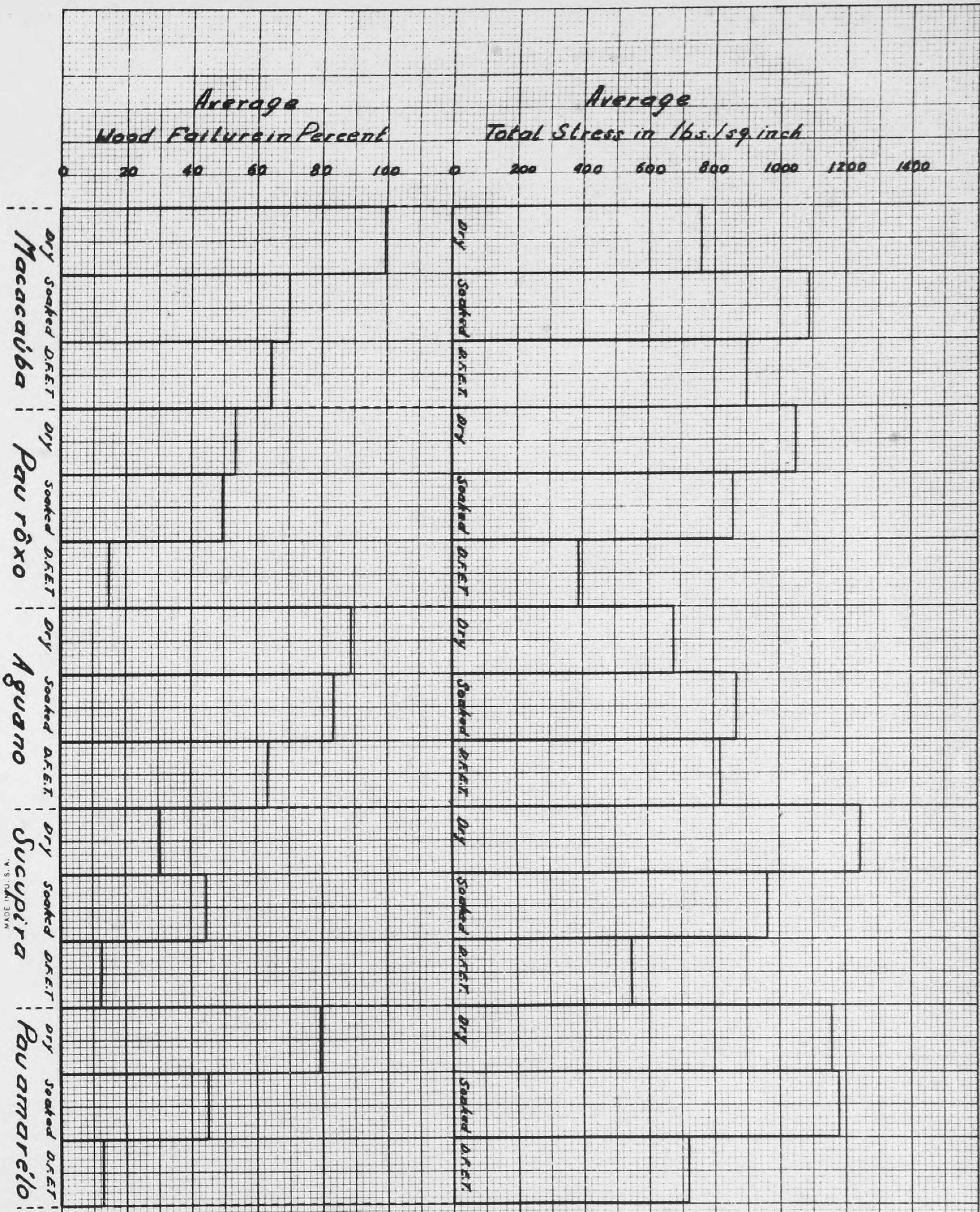


Fig. 2. Cold-setting Urea Formaldehyde: Average wood failure
Average joint strength

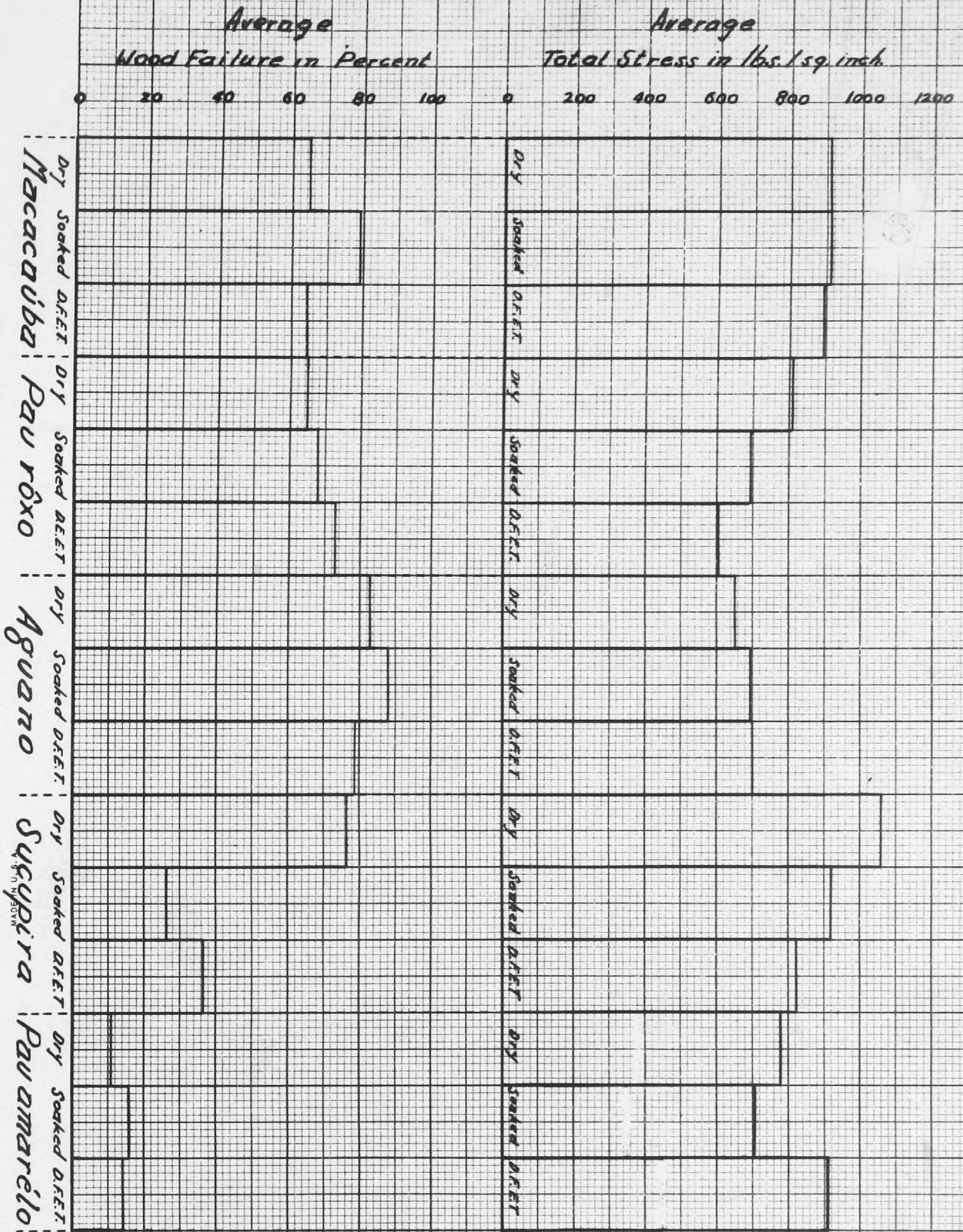


Fig. 3: Resorcinol Formaldehyde: Average wood failure
Average joint strength

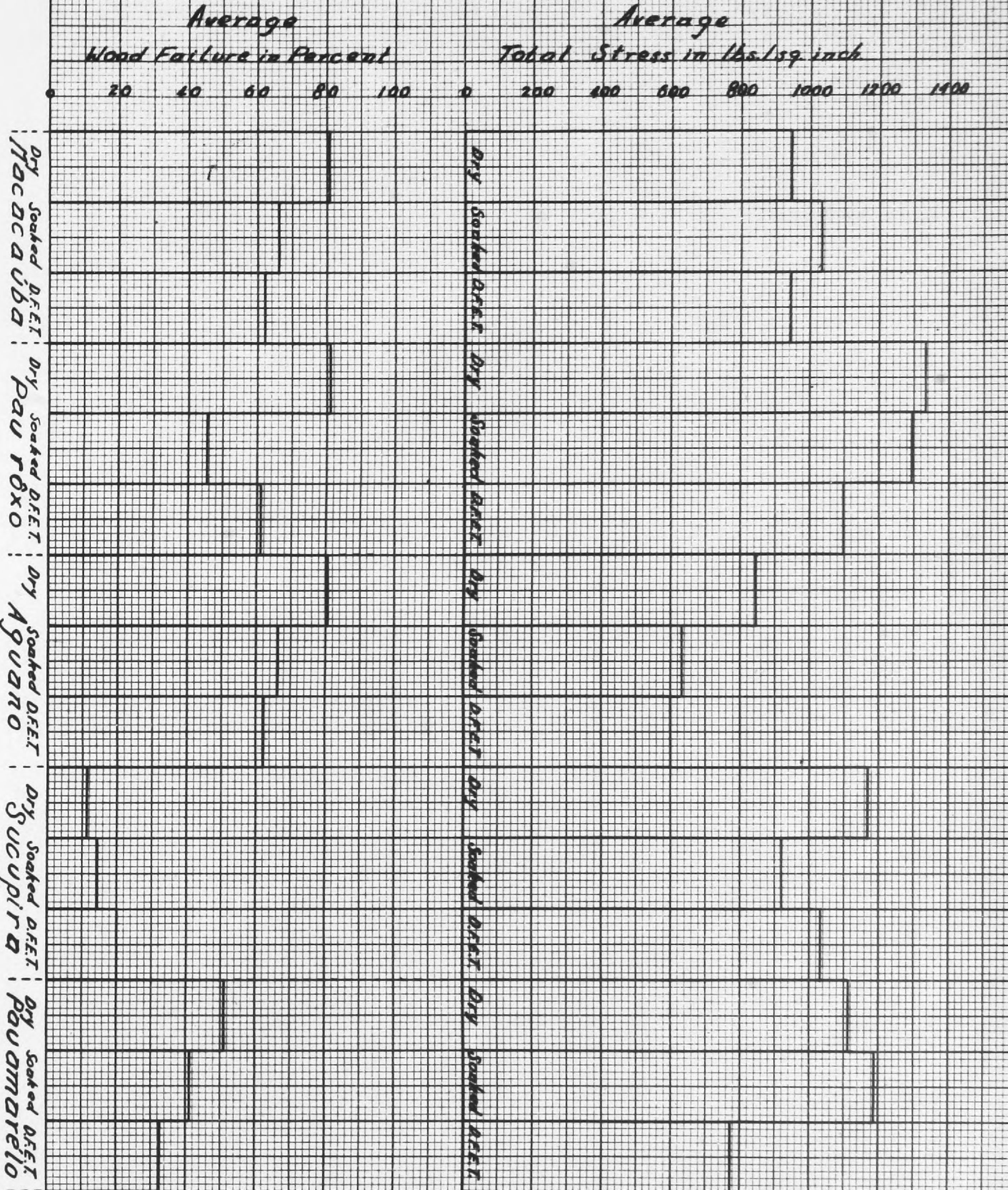
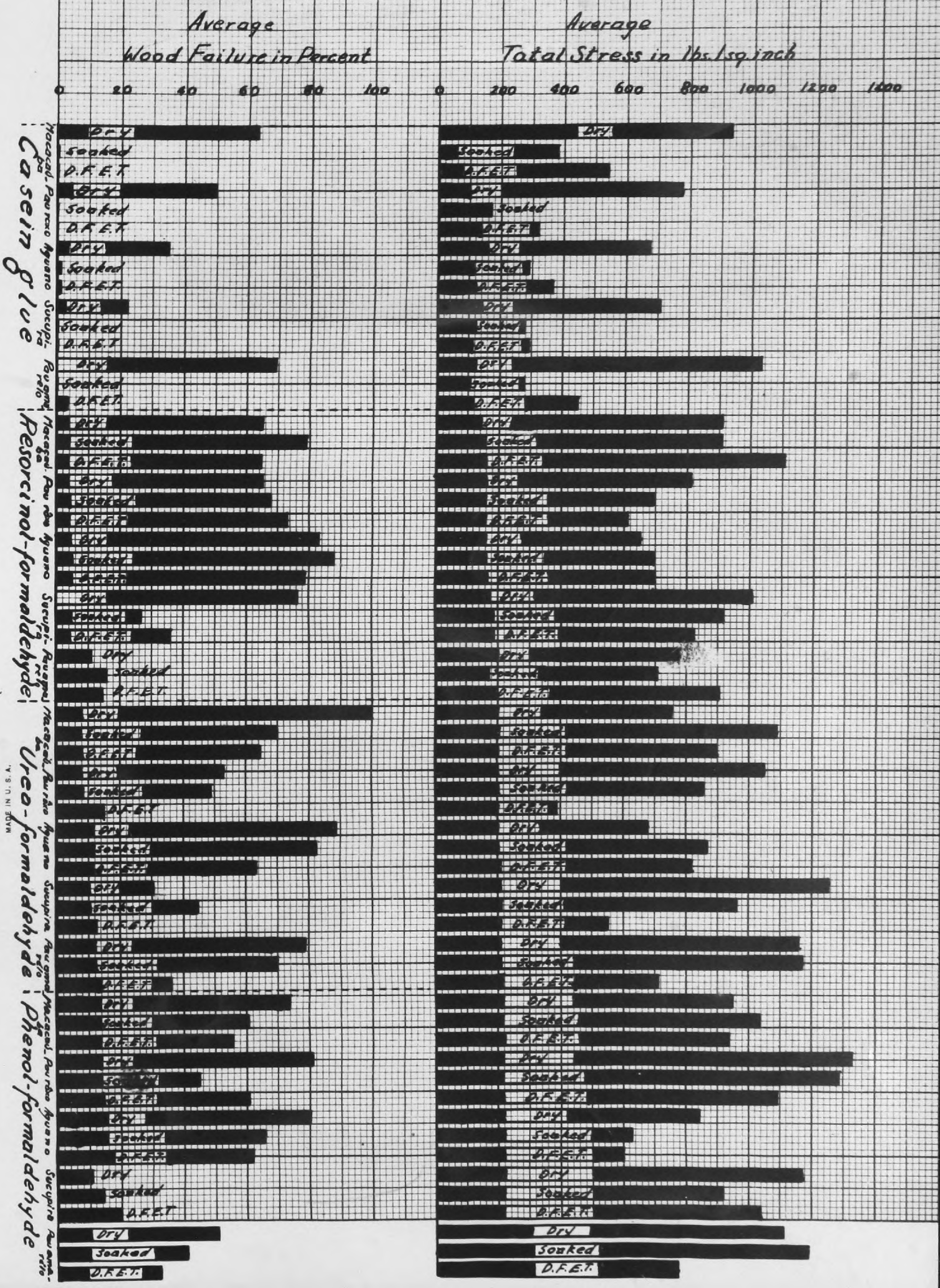


Fig. 4.- Phenol-formaldehyde: Average wood failure
Average joint strength

Fig. 5: Averages of Wood Failure (Perc.) and of Total Stress for the four glues used.



ACCOPRESS BINDER

BUS 2507 EMB.

MADE BY
ACCO PRODUCTS, INC.
LONG ISLAND CITY, N.Y., U.S.A.