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# Variación cromática del color azul en maderas de construcción europeas por la aplicación superficial con ácidos. Chromatic variation of blue colour on European construction timbers by surface application with acids.

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*Resumen*— **La variación cromática de la superficie de las maderas de construcción, mediante la aplicación controlada superficial de ácidos incoloros en estado líquido permite establecer un modelo predictivo entre las maderas ensayadas y las maderas no ensayadas en esta investigación. El modelo predictivo obtenido está basado en ábacos, ordenados por ácidos, maderas y el color azul (porque es el color con mayor porcentaje de variación cromática superficial comparado con los colores rojo ó verde), lo cual permite predecir el comportamiento del porcentaje de variación cromática superficial de maderas y ácidos no ensayados en esta investigación, comparándolos de acuerdo con su clasificación, densidad, especies, origen, color, fuerza y división con siete maderas de construcción europeas y quince ácidos que han sido ensayados. La metodología usada define los parámetros de elección de los materiales escogidos y el método de realización de la variación cromática de las maderas de construcción, presentando y ordenando los resultados obtenidos de variación del color azul en una tabla.**

*Palabras clave*— Modelo predictivo, Variación cromática superficial, Madera de construcción, Ácido.

***Abstract*— The chromatic variation of the surface of construction timber, by means of the controlled surface application of colorless acids in liquid state allows to establish a predictive model between timbers tested and not tested in this research. The predictive model obtained is based on an abacus, ordered by acids, timbers and blue color (because is the color with the greatest percentage of surface chromatic variation compared to red or green colors), which allows to predict the behavior of the percentage of surface chromatic variation of timbers and acids not tested in this research, comparing them according to their classification, density, species, origin, colour, strength and division with seven European construction timbers and fifteen acids that have been tested. The methodology used defines the parameters of choice of the materials chosen and the method of production of chromatic variation of construction timbers, presenting and ordering the results of variation of the blue color obtained in a table.**

*Index Terms*— Predictive model, Surface chromatic variation, Timber, Acid.

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## I. INTRODUCTION

The wood is a natural anisotropic and organic complex organic material, versatile, flexible, suitable for outdoor and indoor environment, without great variations in its properties under normal conditions and with a great chromatic variety due to the number of its species.

The characteristics of the traditional application of acids on construction timber are limited to improving the characteristics of the timber, understood as a functional improvement, for the purposes of dimensional stability or protection against atmospheric and biological agents, fire protection or cleaning (Mauro & Balarezo, 2014; Novoa et al., 2006; Özçifçi et al., 2009; Petric et al., 2013; Garay et al., 2017), normally not being applied externally and superficially and not being its objective to modify the colour or the texture of the timber.

No previous researches have been found on acids with the objective of investigating the surface chromatic variation produced by the surface application of acids on construction timber, to extend the range of surface colour of construction timber, an additional reason why this research is original.

Researches on colour change in timber generally study colour change due to its drying in an outdoor environment and prior to its final storage (Villegas, 2009; Sundqvist, 2002; Sandoval et al., 2012; Boonstra et al., 2006b), but colour change is not studied after the timber is stored and before being prepared to be marketed, therefore those researches do not focus on the final surface finish of the colour of the construction timber to be marketed.

The blue color is used because is the primary color with the greatest percentage of surface chromatic variation compared to red or green colors in this research.

Currently in the international market we can find several compounds that, depending on their nature, act as timber preservatives. They are commercialized as paints, varnishes, lacquers, glazes, oils, waxes, etc. All this variety of timber treatments alters their colour, texture and tone, even in the cases when those are colourless products (Rodriguez, 2012; Rodriguez et al., García, 2010). There are other authors who have studied the colour change in other materials (García & Conci, 2005; Coronado & García, 2010).

The chromatic modification of the surface of construction timber, by means of the surface application of colorless acids in liquid state, improves the expressiveness of the wood, through the change of color, differentiating it, customizing it, allowing his reuse and making possible his return to the market.

The research allows to obtain new tonalities in the wood, by means of an extension of the range of color, and by extension generating added value in the architecture, connecting with the parameters of reference that at present are in force of ecology, sustainability, saving and energetic efficiency.

The proposed predictive model is based on abacuses that establish a percentage value of the chromatic variation of the timber by the application of colourless acids in the liquid state according to their classification and strength and the origin, species and density of the timbers, allowing establishing a predictive percentage value.

## II. MATERIAL

The materials used in this research and the election and presentation parameters are detailed below.

### A. *European construction timbers*

The election and presentation parameters of seven species on European construction timbers was chosen according to the following parameters: be wood whose normal use is for construction timbers; Classification according to species (leafy or conifers); Common use, accessibility and marketing; According to the colour of the construction timber; according to the density of the construction timber and according to the geographical location (continents).

Of all these properties, the density will be the starting variable to access the predictive model and obtain the percentage chromatic variation of the blue colour.

TABLE I

EUROPEAN CONSTRUCTION TIMBERS

| COD. | TIMBERS | DIVISION |
|---|---|---|
| M07 | Sweet Chesnut | Fro |
| M08 | White Poplar | Fro |
| M16 | European Beech | Fro |
| M26 | Radiata Pine | Cfa |
| M27 | Scots Pine | Cfa |
| M29 | European White Oak | Fro |
| M34 | European Lime | Fro |

Fro = Leafy ; Cfa = Conifer. Self elaboration.

The timbers selected in this research are present in the national and international market, and represent the continent of Europe, also using botanical divisions Division XVI - Gymnosperms, commonly identified as conifers and Angiosperms XVII division, commonly identified as leafy. Selected timbers also represent different colours and textures, as well as different physical properties such as density, dimensional stability, toughness, shrinkage and mechanical properties as compressive strength, resistance bending, machining such as sawing, cutting, brushing, gluing, nails and screws and other properties such as impregnability, applications or destination you are dedicated and timbers preparation. Selected divisions discussed above, are present in European continent, as shown in the following Table I.

### *B. Colourless acids in liquid state*

The election and presentation parameters of fifteen colourless acids in liquid state were chosen according to the following parameters: to be colourless acid in the liquid state; Belong to the field of organic or inorganic chemistry, according to the scope of the general classification of acids; According to the accessibility, commercialization and common use, according to the application of the acid in normal conditions; According to its acidic force; Be able to be located within an acid scale of the strongest to least strong as a function of the reference parameter Pka (Table V); Serve as reference standard given its characteristics; according to their group and characteristics applicable to colourless acids in liquid state. Table II.

TABLE II

SELECTED COLOURLESS ACIDS IN LIQUID STATE

| COD. | TIMBERS | DIVISION |
|---|---|---|
| A01 | Glacial Acetic | Organic |
| A02 | Acrylic | Organic |
| A03 | Hydrochloric | Inorganic |
| A04 | Hydrofluoric | Inorganic |
| A05 | Formic | Organic |
| A06 | Phosphoric | Inorganic |
| A07 | Lactic | Organic |
| A08 | Nitric | Inorganic |
| A09 | Octanoic | Organic |
| A10 | Oleic | Organic |
| A11 | Oxalic | Organic |
| A12 | Pyruvic | Organic |
| A13 | Propionic | Organic |
| A14 | Thioglycolic | Organic |
| A15 | 2-Ethylhexanoic | Organic |

Self elaboration

## III. METHODOLOGY

### *A. Essays and conditions of surface application with acids*

The essays have been developed in the laboratory of building materials ETSAM (UPM), where they are deposited and the samples are treated in indoor conditions at 25 °C and 36% relative humidity.

For mechanical processing of timbers, it has been used brush cutter machine, linear cutting machine, cross cutting, sanding etc. to produce timbers samples for further treatment.

Once the timbers have been selected (Table 1), boards of these timbers were obtained and mechanically processed to get samples of homogeneous dimensions of 36 cm2 of surface and 1,5 cm thick, that were then marked for identification, providing a perimeter plastic sheet to contain in its surface the acids in liquid state is obtained in order to study the timbers sample.

For surface application of acids in liquid state has been used a laboratory hood, plus common tools for making gloves trials nitrile, goggles, gown, mask, pipette calibrated in millilitres and mechanism propipette product extraction.

The methodology employed for the surface application of acids in liquid state is described as follows: 3 millilitres are poured by millilitre calibrated pipette and mechanism propipette product extraction at room temperature of 25°C under a laboratory hood, pouring it on the surface of the sample to be treated uniformly, being contained by a perimeter plastic sheet previously arranged and subsequently deposited in the space reserved in the laboratory for storage. A volume of 3 millilitres of acids is used, because it is the most suitable volume observed that allows a sheet of acids on the sample tested without getting to soak the timber, and so that it only affects the surface layer of the timber sample.

### *B. Methodology of imaging*

For the realization of the photos has been used a table photo shooting of samples, composed of board with reference grid, column graduated in millimetres and with four lighting energy saving lamps 23W (115W) and 6.400k colour temperature (daylight) and a photo camera Nikon Coolpix P-100 subject to the column of table photo shooting.

### *C. Space RGB. Histograms and chromatic variation*

For study the percentage chromatic variation of blue colour of fifteen acids, surface application on seven European construction timbers, RGB colour space is used.

There are various colour spaces to study the chromatic variation of colour in construction timbers, but from the point of view of architecture, interest in colour variations that are easy to differentiate and perceive by the human eye.

The choice of RGB colour space, compared to other colour spaces such as CIELAB (which would also be valid to use it) is based on the fact that the space of RGB being a more restrictive space in terms of colour range, allows differentiation better of the colours for the human eye, starting from primary colours, since for this investigation interest those differences of colour that are clearly perceptible for the human eye, whereas in CIELAB all the colours of a mathematical model are represented, being difficult to differentiate them between similar or very close colours (value ΔE, difference in colour perception for the human eye).

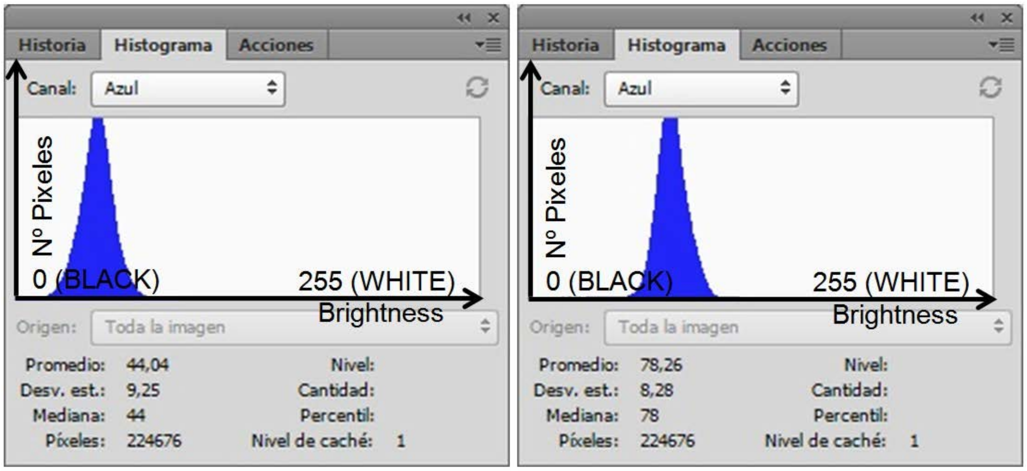


Fig. 1. Histogram. Blue colour. Brightness. Octanoic acid surface application on Sweet Chesnut.Treated timber (left). Untrated timber (right).

The RGB space allows to establish relative percentage values, that is to say, a percentage variation between the untreated sample and the treated sample, whereas the values in CIELAB are absolute values between the treated sample and the untreated sample, but the percentages of variation between both they are similar.

In addition, the CMYK space, which is used in the printing devices, is more suitable to the RGB space, and cannot cover a wide area of colours of the CIELAB space and also because RGB is the most universal system of interchange between the various spaces of colour, being its linear conversion with the other spaces of colour and independent of the devices in which it is used.

The RGB (red, green and blue) space uses histograms to represent the chromatic modification, which for this research is the chromatic modification obtained by the surface application of acids in liquid state on the construction timber (Fig. 1).

In the RGB colour system, where the histograms corresponding to the primary colours red, green and blue are used, which allow us to obtain data on the percentage differences of the colours. In order to observe the chromatic modification of the photographs obtained from the samples tested before being treated and after being treated, the software of photos has been used. In statistics a histogram describes graphically the number of pixels per colour intensity level, which normalized to the unit, can be understood as the probability that a value of a given colour intensity level will appear in the image and allows to offer a quick image of the tonality of the image (Aristizábal, 2006; Gómez, 2015).

The number of pixels or repetition frequency of a colour intensity level is represented on the vertical axis and the level of colour intensity is represented on the horizontal axis, where the histogram also takes into account the position coordinates of the pixel in an image.

The histogram of a digital image with L colour intensity levels and range [0, L-1] is a discrete function of the form:

$$h(r_k) = n_k/n$$

h (rk) = Distribution function of histogram.
rk = k-th colour intensity level.
nk = Number of pixels in the digital image for a certain rk.
n = Total number of pixels in the digital image.
k = 0, 1, 2….L-1

The procedure for obtaining images before and after being treated timbers sample and observing the chromatic variation of the samples with acids in liquid state described below.

Both untreated and treated original samples were photographed with acids on the table photo shooting provided with 4 lateral energy saving lamps setting the same conditions jacks photos, both untreated samples as once treated photographed, then placed the camera on the table photo shooting, in which, at its base the specimen timbers at a fixed distance from the upper face thereof to the camera lens is placed, and the sample timbers is placed in the table top face being in front of the camera and this is always fired under the same conditions, obtaining a complete picture of the sample.

Once available image proceeds to view by computer program, cropping the image around the perimeter of the sample, eliminating the areas outside the sample, then a grid on the sample is projected, which are obtained the histogram data belonging to the RGB color space. In the grid obtained a central area of the same size in all samples is selected by said histogram projected on to a representation of cartesian coordinates by a bar graph representing the number of pixels of the image for each value of brightness, placing on the axis of abscissa (horizontal) different luminosities divided into 256 columns, placing the "black" value (0) on the left and the "target" value (255) on the right and on the vertical axis (vertical) where the height of each of the columns determines the number of pixels from each of the brightness values, and obtaining both the average (mean value of brightness of all pixels), as the brightness values, red , green and blue separately, to then compare the values obtained proportionally and observe the chromatic variation of samples, by analysing the results (Fig. 1).

The blue colour is used because is the primary colour with the greatest percentage of surface chromatic variation compared to red or green colours in this research.

The condition or characteristic of the anisotropy of the wood, since it is an organic material, is determinant to understand the chromatic variation produced by the surface application of colourless acids in the liquid state on the timbers.

The anisotropy of the wood implies that any wood has a different chromatic behaviour still coming from the same tree, zone and plank, because in the wood there are singular points like veins, knots, cracks, etc. and changes of colour due to which it is an organic material and therefore the surface of a cut wood varies of form, configuration and aspect, which by extension that unify and to understand the chromatic variations of the wood in each point means that the values obtained will always be different, so its study in this research is carried out from a point of view proportional that allows to buy such chromatic variations.

## IV. RESULTS AND DISCUSSION

The Table III shows the percentage values of chromatic variation of the blue colour by the surface application of fifteen colourless acids in the liquid state on the seven species on European construction timber.

The values are obtained from the difference between the values of the untreated timber and the timber treated with acid, obtaining its percentage colour value for the blue colour. It is understood that the values range from 0 (black) to 255 (white) of the blue colour histogram.

If the result of the test results in a percentage value of the colour blue that has a value of "0" (black) with respect to the original untreated sample, the difference will have a positive value, that is to say the sample undergoes a "darkening", if the result is to the value 255 (white), the difference will have a negative value, is the sample will have experienced a "clearing".

In Table III, the position of the acid applied as a function of the value of the percentage chromatic variation obtained for the blue colour and represented by a greyscale is ordered in each wood, allowing a ranking of the values obtained in each of the species presented in the upper area of the table, the negative values representing the "clearance" of the sample and in the lower area of the table those positive values representing a "darkening” of the sample by the surface application of colourless acids in the liquid state.

The acids used are normally marketed products and can serve as a standard of comparison, to observe the chromatic variation of the construction timbers, by their surface application and by extension to have formulas accepted for their realization, allow

TABLE III

VALUES OF PERCENTAGE CHROMATIC VARIATION OF BLUE COLOUR OF 15 ACIDS SURFACE APPLICATION ON 7 EUROPEAN CONSTRUCTION TIMBERS

| M07 | SWEET CHESNUT | M08 | WHITE POPLAR | M16 | EUROPEAN BEECH | M26 | RADIATA PINE | M27 | SCOTS PINE | M29 | EUROPEAN WHITE OAK | M34 | EUROPEAN LIME |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A02 | -20,11 | A11 | -17,61 | A14 | -47,03 | A14 | -34,25 | A14 | -37,61 | A14 | -19,65 | A14 | -35,32 |
| A14 | -11,90 | A14 | -15,85 | A11 | -12,30 | A01 | -21,59 | A11 | -8,40 | A01 | -6,96 | A02 | -20,93 |
| A04 | 3,86 | A02 | -9,29 | A13 | -7,34 | A11 | -15,79 | A01 | -4,80 | A02 | -6,42 | A11 | -17,98 |
| A13 | 8,20 | A04 | 3,28 | A01 | -2,79 | A13 | -0,33 | A13 | -4,79 | A07 | 2,01 | A13 | -0,29 |
| A07 | 8,97 | A13 | 4,88 | A02 | 6,72 | A02 | 7,91 | A02 | 5,79 | A15 | 9,48 | A01 | 1,57 |
| A05 | 16,48 | A05 | 9,60 | A07 | 8,52 | A07 | 11,71 | A05 | 12,84 | A12 | 10,81 | A05 | 5,14 |
| A01 | 18,87 | A12 | 24,35 | A03 | 11,37 | A05 | 16,46 | A07 | 13,11 | A13 | 12,02 | A12 | 11,73 |
| A12 | 24,02 | A01 | 26,44 | A04 | 13,82 | A04 | 26,80 | A09 | 20,54 | A04 | 13,24 | A07 | 22,76 |
| A03 | 32,28 | A07 | 27,10 | A05 | 15,40 | A15 | 40,42 | A15 | 27,97 | A05 | 17,13 | A04 | 25,02 |
| A11 | 40,78 | A09 | 33,43 | A09 | 18,93 | A12 | 40,82 | A04 | 31,38 | A11 | 17,18 | A09 | 30,90 |
| A15 | 42,28 | A03 | 36,26 | A12 | 20,22 | A03 | 43,54 | A03 | 37,47 | A09 | 26,53 | A15 | 34,41 |
| A09 | 43,73 | A15 | 40,91 | A15 | 34,40 | A09 | 53,40 | A12 | 42,03 | A03 | 27,82 | A03 | 34,71 |
| A06 | 59,74 | A10 | 45,79 | A10 | 54,10 | A10 | 66,31 | A10 | 45,28 | A06 | 69,41 | A10 | 51,16 |
| A10 | 71,25 | A06 | 69,44 | A06 | 77,41 | A06 | 66,94 | A06 | 70,78 | A10 | 69,42 | A08 | 68,45 |
| A08 | 99,14 | A08 | 83,02 | A08 | 96,83 | A08 | 94,54 | A08 | 97,88 | A08 | 95,74 | A06 | 70,14 |

to serve as starting point or pattern of standardized reference, which serve as a comparison with these or other tests, future lines of research or future industrialized processes of surface treatment of wood, having by extension a standardized comparison pattern, having technical data sheets, which serve as a comparison with these or other tests, future lines of research or future industrialized processes of surface treatment of wood, having by extension a standardized comparison pattern, having technical data sheets, which provide data on their configuration.

It is understood that these commercial products respond to the best form of presentation, with the best properties of conservation, transfer, compliance with technical regulations and also allow ease of application for purposes of later industrial applications.

### *A. Abacuses of percentage chromatic variation*

Two abacuses are presented as a unified representation of the data obtained, and the areas or ranges of percentage chromatic variation can be defined by means of a grey scale and used as an element of determination or predictive model of the chromatic variation of the blue colour, using them as pattern of comparison between the woods and acids tested and the woods or acids to be compared.

Depending on the volume of data, a denser mapping of results can be obtained and thus obtain more adjusted percentage blue colour values.

This research does not intend to obtain a mathematical formula that predicts the absolute value of colour when treating a wood with an acid, due to the anisotropic condition of the wood, but to observe a common tendency, which helps perceptually through an approximation of percentage relative values to predict how their behaviour may be, using reference abacuses.

### *B. Abacus Type 1*

It establishes the codes of the construction timbers tested that defines its species, its origin and its density and in the grayscale, it is detailed the code of the acids and its corresponding graduation in the grayscale.

In abacus Type 1, three ranges are established, with a percentage of the chromatic variation of the blue colour, where negative values are represented by 0 to -50%, is the wood has undergone a clearance (white tendency), detailing the acid corresponding with the dark grey represents the variation obtained between 50 and 100% positive, is the wood has experienced a darkening (tendency to black) and detailing the corresponding acid, with light grey represents the value between 0% and 50 % positive is the wood has undergone a darkening (tendency to black) although of smaller variation (Table IV).

In the left side of the table, an arrow indicating the change in colour variation of the white or sample lightening to the black or darkening of the sample is represented, representing predict the behaviour of the percentage of superficial chromatic variation of timbers and acids not tested in this research, comparing them according to their properties with fifteen tested acids and seven tested European construction timbers.

In the same way as before, in the left area of the table an arrow indicating the change in colour variation of the white or sample lightening to the black or darkening of the sample is shown (Table V).

TABLE IV

Abacus Type 1. Values of chromatic variation percentage of the blue color by European construction timbers.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| ( - ) | A11 | A14 | A14 | A14 | A14 | A02 | A14 |
| ↓ | A14 | A11 | A02 | A11 | A01 | A14 | A01 |
| ↓ | A02 | A01 | A11 | A13 | A02 | A04 | A11 |
| ↓ | A04 | A13 | A13 | A01 | A07 | A13 | A13 |
| ↓ | A13 | A02 | A01 | A02 | A15 | A07 | A02 |
| ↓ | A05 | A05 | A05 | A07 | A12 | A05 | A07 |
| ↓ | A12 | A07 | A12 | A03 | A13 | A01 | A05 |
| ↓ | A01 | A09 | A07 | A04 | A04 | A12 | A04 |
| ↓ | A07 | A15 | A04 | A05 | A05 | A03 | A15 |
| ↓ | A09 | A04 | A09 | A09 | A11 | A11 | A12 |
| ↓ | A03 | A03 | A15 | A12 | A09 | A15 | A03 |
| ↓ | A15 | A12 | A03 | A15 | A03 | A09 | A09 |
| ↓ | A10 | A10 | A10 | A10 | A06 | A06 | A10 |
| ↓ | A06 | A06 | A08 | A06 | A10 | A10 | A06 |
| ( + ) | A08 | A08 | A06 | A08 | A08 | A08 | A08 |
| | M08 | M27 | M34 | M16 | M29 | M07 | M26 |

| | |
|---|---|
| A11 | Nº Acid + Variation -50% a 0% negative (white tendency) |
| A07 | Nº Acid + Variation 0% a 50% positive (black tendency) |
| A08 | Nº Acid + Variation 50% a 100% positive (black tendency) |
| | Timber. Density = 0 a 540 Kg/m$^3$ |
| | Timber. Density = 540 a 700 Kg/m$^3$ |
| | Timber. Density = 700 a 1,100 Kg/m$^3$ |

Self elaboration

### *C. Explanation of the use of abacuses*

The abacuses obtained lead to a predictive model of the percentage chromatic variation of the blue colour of European construction timbers through the surface application of colourless acids in liquid state.

The predictive model obtained is based on an abacus, ordered by acids, timbers and blue colour, which allows to this abacus takes into account the strength, classification, division and origin of the acids and the density, specie, color and origin of the woods.

TABLE V

Abacus Type 2. Values of percentage chromatic variation of the blue color by colorless acids in liquid state.

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ( - ) | M34 | M07 | M27 | M29 | M16 | M29 | M26 | M29 | M34 | M16 | M34 | M16 | M08 | M34 | M16 |
| | M08 | M26 | M08 | M27 | M27 | M34 | M29 | M16 | M08 | M27 | M07 | M29 | M07 | M08 | M27 |
| | M26 | M29 | M34 | M16 | M29 | M16 | M27 | M07 | M27 | M26 | M08 | M07 | M29 | M26 | M34 |
| | M29 | M08 | M16 | M34 | M34 | M07 | M16 | M26 | M16 | M34 | M29 | M34 | M16 | M16 | M26 |
| | M16 | M34 | M26 | M26 | M08 | M08 | M34 | M27 | M26 | M08 | M27 | M08 | M34 | M27 | M29 |
| | M27 | M27 | M29 | M08 | M07 | M26 | M07 | M34 | M07 | M07 | M16 | M27 | M26 | M29 | M08 |
| ( + ) | M07 | M16 | M07 | M07 | M26 | M27 | M08 | M08 | M29 | M29 | M26 | M26 | M27 | M07 | M07 |
| | A08 | A06 | A10 | A15 | A09 | A12 | A01 | A07 | A05 | A13 | A02 | A03 | A04 | A11 | A14 |

| | |
|---|---|
| M34 | Nº Timber + Variation -50% a 0% negative (white tendency) |
| M26 | Nº Timber+ Variation 0% a 50% positive (black tendency) |
| M07 | Nº Timber + Variation 50% a 100% positive (black tendency) |
| A03 | Nº Acid + Strength = Strong acid ; Pka interval -6,22 / +3,60 |
| A07 | Nº Acid + Strength = Middle acid ; Pka interval +3,60 / +4,35 |
| A01 | Nº Acid + Strength = Weak acid ; Pka interval +4,35 / +5,02 |

Self elaboration

The construction timbers are an anisotropic material and by extension conceptually the results of the essays should be understood from the point of view of relative values (percentages) and not absolute (numbers), although the latter are used as reference to obtain the abacuses and by extension the predictive model.

The predictive model through abacuses allow to predict the behavior of a timber not tested according to its density, origin, specie and color and an acid according to its strength, division and origin.

The process of using the abacuses would be to choose a European timber and a colourless acid in liquid state, that they were not tested.

Depending on the volume of data, a denser mapping of results can be obtained and thus obtain more adjusted percentage blue colour values.

In the case of the chosen sample on European timber has not tested, its density, specie and colour are observed, and a timber of the tests carried out that resembles these characteristics is chosen.

In the same way, the chosen colourless acid in the liquid state has not tested, and its chemical division, characteristics and strength are observed, and an acid of the tests carried out which resembles these characteristics is chosen.

Once the commented parallelism is established, one enters the abacus Type 1 and it is observed where the wood is compared and the vertical position that the acid occupies compared, observed that grey graduation corresponds to him and of the same form proceeds in the same one Abacus Type 2, observing the position of the wood in the grayscale.

Once we have the obtained ranges of chromatic variation of the blue colour derived from the abacuses and taking into account the difference between the wood and tested acids and the chosen ones can arrive at a predictive determination of the range of colour variation that can be produce between the chosen wood and acid. An example of predictive model of timber is presented below.

The density of timber not tested, it will be the starting variable to access the predictive model and obtain the percentage chromatic variation of the blue colour.

The Silver Birch (Betula pendula Roth) has not been tested in this research and it is a European leafy construction timber of light orange colour with density 650 kg/m$^3$.

This timber is compared with similar European timbers of species (leafy), colour with closer densities that have been tested in this research as the timber Sweet Chesnutt (M07) with density 590 kg/m$^3$ and the timber European Beech (M16) with density 730 kg/m$^3$(Fig. 2).

The density of the Silver Birch is closer to the Sweet Chesnutt (M07), it is observed that in the table by acids force, the (M07) for a strong acid like the Nitric acid (A08) and for a weak acid like the Oleic acid (A10), the timber Sweet Chesnutt (M07) is placed nearer to 100%, which is closest to the Silver Birch, and the timber European Beech (M16) is closer to 50%, so it is estimated that the timber of Silver Birch not tested, it would approach with the acids Nitric acid (A08) and Oleic acid (A10) to a percentage chromatic variation of the blue colour around 85%.

In the same way for a middle acid like the Phosphoric acid (A06), the timber Sweet Chesnutt (M07) approaches to 50% and the timber (M16) at 100%, so it is estimated that the timber

Silver Birch not tested, it would approach with the Phosphoric acid (A06) to a percentage chromatic variation of the blue colour around 75%, thus predicting its behaviour with these acids. (Fig. 3).

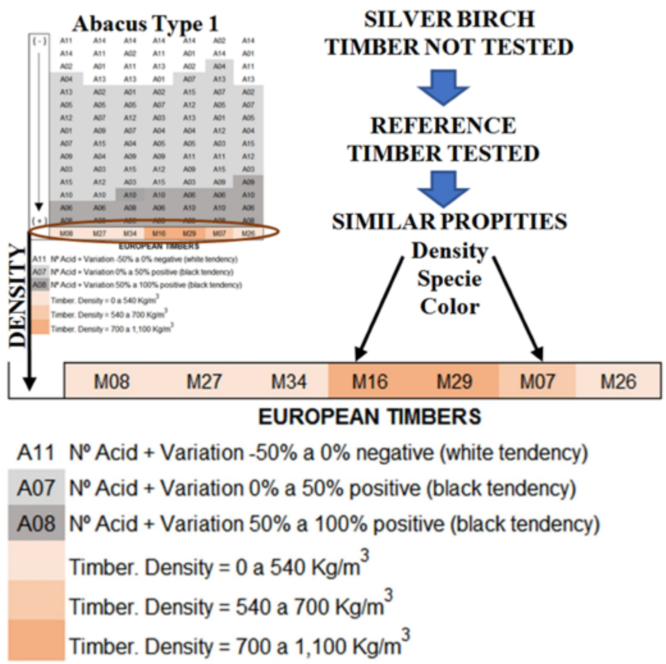


Fig. 2. Explanation on the Abacus Type 1. Comparison of Density, Specie and Colour, between a timber not tested and two timbers tested with closer densities.

The predictive values of the percentage chromatic variation of the blue colour of the Silver birch not tested, for the acids (A08) and (A10) around 85% and for the acid (A06) around 75%, are calculated by making the average of the values for each position of the timber tested (M07) and (M16) that are obtained by observing the number of steps or intermediate positions, between the values of 50% and 100% for this case of predictive example.

It is observed that timber (M07), has the same variation for a strong acid (A08; 100%) that for a weak one (A10; 100%) and very reduced for a medium acid (A06; 50%), and in the same way the timber (M16) has similar variations for a strong acid (A08; 78%) than for a weak acid (A10; 70%) and greater for a medium acid (A06; 100%), from which it can be deduced that in the timbers (M07) and (M16) does not influence the strength of the acids in the percentage chromatic variation of the blue colour.

Fig. 3 explains the procedure for obtaining the percentage chromatic variation values of the blue colour of the predictive example.

## V. CONCLUSIONS

The abacuses obtained lead to a predictive model of the percentage chromatic variation of the blue colour of European construction timbers through the surface application of colourless acids in liquid state.

The Abacus Type 1 rule with the European construction timbers codes tested by density and the Abacus Type 2 rule with the colourless acids codes by strength are elements of determination or predictive model of the chromatic variation of the blue colour, using them as pattern of comparison between the woods and acids tested and the woods or acids not tested.

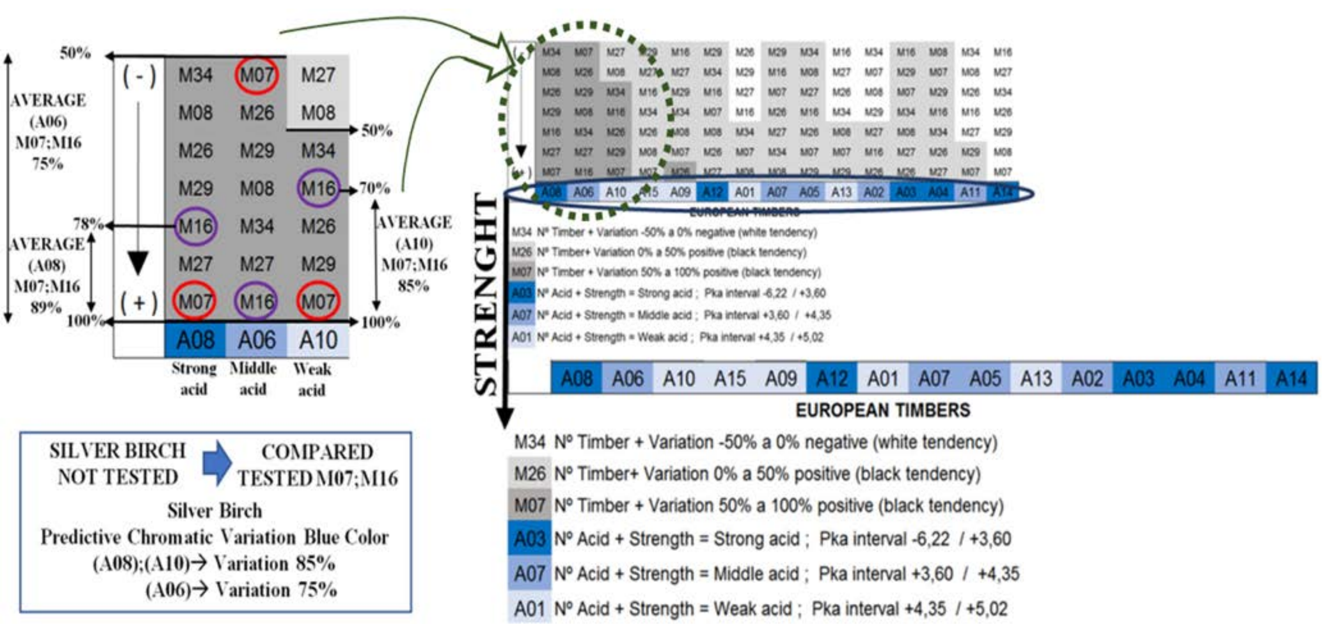


Fig. 3. Correlación entre el módulo de elasticidad y la tensión de rotura.

The presented methodology allows to establish a predictive model of the percentage chromatic variation of the colour blue in the RGB space for European construction timbers through the surface application of colourless acids in liquid state and obtain a value of the percentage chromatic variation of the blue colour for a European construction timber that has not been tested.

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