

**THE RESEARCH OF BORAX PENTAHYDRATE EFFECTS
WITH WATER-BASED DOUBLE COMPONENTS IN
VARNISH APPLICATIONS OF WOODEN MATERIALS**

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ABSTRACT

In this study, a different amount of borax pentahydrate is added into water-based varnish, which is used for upper surface treatments of wooden materials. The pre-prepared water-based varnish is implemented on upper surfaces of Scotch pine (*Pinus sylvestris* L.) and Chesnut (*Castanea sativa* M.) woods for wood materials. After that toughness, brightness and surface sticking resistance experiments are conducted over these water-based varnish stratum. The effect of the pentahydrate added into the water-based varnish is determined. Consequently, it is determined that the pentahydrate added into the water-based varnish increased the toughness and sticking resistance on both wood types substantially; however, it also decreased the brightness value of the varnish greatly.

KEYWORDS: Water-based varnish, resistance of stick, hardness, brilliance.

INTRODUCTION

The surface coatings of the wood materials with preservative treatments as a natural raw material are based up to B.C. 200's. Throughout the history, early surface preservative treatments were prepared with wood shell liquids and after that this process has gained new dimensions after natural resins and dried oil began to be used as components (Sonmez 1989).

Numerous types of varnishes and paints are used in Turkey as preservative treatments. Dependent on the difference of the elements used in production of these varnishes, their resistance to different external effects is expected to be different also. Besides the difference in the preservative materials there may also be some differences in the wood materials used to make furniture. There

are some structural differences among different tree types in the frame of their anatomical structure. This difference may also exist among the same kind of woods and even between two different parts of the very same ingot or between the two pieces cropped differently. Considering these, it is estimated that the same kind of preservative material will not provide the same endurance against exterior effects on different kinds of wood; this is also the case for different stratum on the very same massive (Sonmez and Budakci 2002).

Except for the studies conducted by varnish producing companies to develop their products in Turkey so far on resistance of the varnish stratum against exterior effects, this study dwells on the effects of borax pentahydrate on varnish stratum. With the testing methods implemented on samples used, the study determined the changes in hardness, brilliance and the surfaces sticking values of varnish surfaces implemented on Austrian pine and beech wood surfaces after adding different rates of pentahydrate into double component cellulose brilliant varnish in each time. The study also informs that the sticking resistance of water-based varnishes prepared for furniture surfaces is lower than the resistance of solvent resolving polyurethane and acrylic varnishes (Budakci 2003).

It is also determined in the study that in polymeric composition varnishes the more that stratum thickness increases, the more its sticking resistance increases (Budakci 1997).

It is also determined that in light-proof paint applications the type of wood does not affect the sticking resistance but the kind of the paint is influential and it is also reported that synthetic paint gave the best result in this frame (Kaygin 1997).

The main reason behind the rapid increase in production and consumption rates of water-dissolvent paint/varnishes and the diversity of their usages stem from the developments and variation in the characteristics and qualities of the stratum creating varnishes. The polyurethane resins constrain an important place in the frame of their usage with the qualities they provide to the product (flexibility, resistance to chemicals and mechanic effects etc.) (Désor and Stephan 1997).

A different amount of borax pentahydrate is added into cellulose bright varnish, which is used for upper surface treatments of wood materials. Toughness, brightness and surface sticking resistance experiments are conducted over these varnish stratum. Consequently, it is determined that the pentahydrate added into the varnish increased the toughness and sticking resistance on both wood types (Beech wood and Austrian pine) substantially; however, it also decreased the brightness value of the varnish greatly (Ozalp 2008).

It has been observed that borax pentahydrate addition to urea formaldehyde did not significantly reduce the strength properties of plywood bonded using this resin and that there was a moderate reduction in free formaldehyde content as a result of borax addition (Sensogut et al. 2009).

MATERIAL AND METHODS

Wood materials

Scotch pine (*Pinus sylvestris* L.) and Chesnut (*Castanea sativa* M.) woods were used while preparing the experimental subject. The subjects were selected randomly from first quality wooden materials, which did not have knots, splits, with no color and smell, chopped vertically according to the annual rings and from strong wood parts in the frame of TS 2470 (1976) regulations.

The examples, being exposed to open air humidity, were chopped in 110 x 110 x 10 mm sizes and were kept in the climatic refrigerator under 20 ± 2 °C temperature and 50 ± 5 % humidity climate conditions until they reached their dead weight. The average humidity of the randomly selected 10 samples was determined as $9 \pm 0,5$ %. The samples were reshaped to have the dimensions of

100 x 100 x 8 mm and were sandpapered with number 80 and than number 100 abrasives. The dust on the sample surfaces was velured and vacuumed after that. Totally 40 samples, 5 for each wood type and solution concentration, were used during the research.

Borax pentahydrate

The rate of pentahydrate to be added into the water-based varnish and padding was determined as 0 %, 10 %, 20 % and 30 % of the solid materials rate in the varnishes considering the rate of these materials in water-based varnishes.

The name borax etymologically comes from the “Buraq/baurach” in Arabic and “Burah” in Persian. Borax element, which is at the very top of the 3A group in the Periodical Table and its atomic number is 5. This element has two isotopes with mass numbers of 10 and 11. Its symbol is B and it is the only element in the 111A group which is not metal (Cetin 2002). Borax element is like a white stone at first look and resistance to high temperatures with its strong and hard structure. It does not exist in nature as an independent mater but it is found as salt ingredient in nature. Borax’s color while it is in the amorphous dust shape is Brown. However its color is yellowish Brown when it has monoclinic crystal shape. In this shape it is the toughest element after crystal (Bozkir 1995).

Being the 51st most common element on earth Borax can be found in soil, rocks and water generally. The weight range of borax in sea water is 0.5-9.6 ppm; in soil 10-20 ppm and in fresh waters in 0.001-1.5. The high concentrated and economical borax beds exist mostly as borax’s compounds tied with oxygen in Turkey and America’s dry volcanic areas where hydrothermal activities exist. Borax is an element which has many similarities with silicon and carbon; and it’s affinity to oxygen is quite high. Being an element, which can be solved in water, which is colorless and spar less, borax first loses heat with when it is exposed to heat and than begins to melt (Altinok at all 2009).

Borax can be found in two different types as crystal, with 2.33 g.cm^{-3} and as amorph with a density of 2.3 g.cm^{-3} (Kocabas 2002). Borax minerals are classified according to Ca, Na and Mg elements they constitute. The ones with Na root are called borax, Ca rooted ones named as colemanit and Na-Ca rooted type is named as ulexite (Ediz and Ozday 2001). Even if Borax element can be found in 150 different types in nature with borax oxide economically valuable borax minerals are found with Cad, Nah and MGK elements as hydrate compounds (DPT 1995).

Borax minerals can be subcategorized within themselves by dividing them sub compounds as follows:

1. Borates including crystal water,
2. Compound borates (Hydroxyl and/or other salts),
3. Boric acid,
4. Waterless borates,
5. Borosilicate Minerals

Most important types of borates which are important in term of commerce and include crystal water and their chemical compositions were shown in Tab. 1.

The importance and usage of borax compounds, which already have a wide usage area in industry, constantly increases day by day. It is used as an indispensable material for more than 400 end products produced today. It is possible to observe borax including materials in any area of modern life. Borax is used in glasses, engine oils and steel rims, vehicle paints in order to increase brightness and decrease scratches. The steel wires in wheels are strengthened with borax also and the fiber optic wires used in computers and walkmans cannot be strong enough without borax

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element. Borax is also used in fertilizers used in agriculture and in templates and cookie cutters.

Tab. 1: Important borax compounds in Turkey and the places they are found

Mineral	Formula	B ₂ O ₃ (%)	Place found
Borax	Na ₂ B ₄ O ₇ 10H ₂ O	36.6	Kirka, Emet, Bigadic, USA
Ulexite	NaCaB ₅ O ₉ 8H ₂ O	43.0	Bigadiç, Kirka, Emet, Argentina
Colemanit	CA ₂ B ₆ O ₁₁ 5H ₂ O	50.8	Emet, Bigadic, Kucukler, USA
Boric acid	Mg ₃ B ₇ O ₁₃ Cl	62.2	Germany
Hydroboracid	CaMgBO ₁₁ 6H ₂ O	50.5	Emet

The percentages of borax usage according to different areas are as follows: Isolation, fiberglass, and textile industry 41 %; ceramics and its components 13 %; detergent and cleaning industry 12 %, metallurgy industry 8 %, and agriculture industry 7 %, and other areas 19 % (Ediz and Ozday 2001).

Used Varnish

A double component water-based varnish, which was produced by a particular trademark, was used during the experiments. While giving the examples the ASTM D-3023 (1981) regulations were followed, while preparing the varnishes for the application conditions the blend rates of water-based varnishes were adjusted in such rates that will not affect the varnish's performance and the producer's suggestions were followed.

The water-based varnish was penetrated into the woods with the help of a spray gun under room temperature (20 °C). The air pressure of the spray gun was 1-2 bars and aperture of its tip was 1.3 mm. The spray water-based varnish was sprayed to the surface 20 cm away from it in a vertical angle and it was moved in parallel directions to help the traces follow each other. The amount of solid material was determiner of the water-based varnish rate to be applied to the samples TS 6035 EN ISO 3251 (1997). Some of the features of the varnishes used are given in Tab. 2.

Tab. 2: Features of the water-based varnishes applied to the samples

Type of varnish	Solid material rate (%)	Ph Degree	Amount of Varnish to be Applied (g.m ⁻²)
Filling varnish	38	9.12	75
Brightening varnish	37	9.13	83

After applying the filling water-based varnish onto the samples they were left to dry for 24 hours on a dust free platform under room temperature. After drying the samples were sand papered with number 220 and 320 sand papers equally. The sand paper dust is velured and vacuumed after that it was ascertained once more and last water-based varnish application was made twice.

Method

The samples were kept in the laboratory conditions under 20 ± 2°C heat and 65 ± 3 % relative humidity for three weeks in order to let the water-based varnish stratums applied to the experimental samples. The samples were climated for 16 hours under 23 ± 2°C heat and 50 ± 5 % relative humidity

according to ASTM-D3924 (1991) regulations.

The toughness of the stratum were measured with the help of a pendulum measuring device with Köning measuring technique and in the frame of ASTM D-4366 (1984) regulations. The measuring device was tuned to make 100 undulations in 40 seconds with the help of a caliber glass prior to the measurement process and among the measurement sessions. The measurement process was conducted by counting the undulations of two spindles with 63 ± 3.3 HRC hardness and dimension of 5 ± 0.0005 from 6° to 3° . Principally there is less undulation on mild surfaces and more undulation on tougher surfaces.

Brightness measurements were conducted in the frame of principles defined in TS 4318 EN ISO 2813 (2002). According to this the gloss-meter, which measured the brightness with 60° angle, was moved horizontally and vertically to the fibers of the samples. Arithmetical mean of two measurements were considered in the evaluation step. The gloss meter was tuned prior to each measuring session and within the processes with a black glass having 1.567 index of refraction and 100 Lambert for all colors.

During the application multiple rippers with 6 cutting heads with 2 mm intervals and 15° - 30° wedge angles were used as they are suggested for samples with 50-125 μm width according to TS 6884 (1989). In this method, after the stratum was transected according to the determined intervals from one end to the other end until the surface of the sample a film was stuck to the water-based varnish in order to get it out. The equation given below was used while calculating the resistance of the sticking.

$$X = \frac{4F}{\pi.d^2}$$

where:

X : sticking resistance (MPa),

F : splitting force (N),

d : sample cylinder's radius (mm).

RESULTS AND DISCUSSION

The results of varnishes' surface sticking resistances

Five samples stratum's surfaces were used for each water-based varnish composition and wood type used in the experiments. The water-based varnish sticking measurements were conducted with adhesion measuring device and the results are given in Tab. 3.

It was observed that surface sticking resistance values of two different types of woods were close to each other after borax free varnish application. After the borax added water-based varnish application, though, sticking resistance values of two different wood types were different depending on the rate of pentahydrate in the varnish. According to these results, it was observed that the type of the wood and pentahydrate had great effects on water-based varnish stratum's adhesion value after applying normal and additive containing water-based varnish onto the surface.

Varnishes' toughness measurement results

The measurement of water-based varnish stratum used in the experiment was made with pendulum measuring device and the results are given in Tab. 4.

Tab. 3: Varnishes'surface sticking resistance values (MPa)

Surface sticking resistance (MPa)								
Wood type	Chesnut				Scotch Pine			
Samples	Pentahydrate rate (%)				Pentahydrate rate (%)			
	0	10	20	30	0	10	20	30
1	0.414	0.562	0.567	0.647	0.394	0.423	0.459	0.533
2	0.420	0.587	0.601	0.636	0.392	0.420	0.464	0.514
3	0.445	0.573	0.609	0.623	0.389	0.405	0.453	0.530
4	0.433	0.585	0.575	0.662	0.375	0.412	0.448	0.528
5	0.439	0.550	0.592	0.668	0.382	0.425	0.466	0.541
Average	0.430	0.571	0.588	0.647	0.386	0.417	0.458	0.529

Tab. 4: Pendulum measure toughness values

Toughness measurement values (Pendulum)								
Wood type	Chesnut				Scotch Pine			
Samples	Pentahydrate rate (%)				Pentahydrate rate (%)			
	0	10	20	30	0	10	20	30
1	59	62	70	90	44	42	55	61
2	58	61	68	87	39	43	53	59
3	54	57	66	86	45	44	55	60
4	52	55	64	84	40	43	54	59
5	53	56	63	83	44	46	56	62
Average	55.2	58.2	66.2	86	42.4	43.6	54.6	60.2

As the toughness values resulted differently it was observed that the type of the wood and the rate of pentahydrate in water-based varnish are influential in the rate of toughness. According to these results the type of water-based varnish, type of wood and rate of pentahydrate are greatly influential in the rate of toughness, which is measured after the wood surface was water-based varnished with pentahydrate varnish. Consequently, using what kind of varnish on what type of wood and the rate of pentahydrate to be added into water-based varnish are considered to be important factors.

Varnishes' brightness measurement results

Five samples were used for each water-based varnish composition and wood type used in the experiments. Two measurements were conducted for each sample surface horizontally and vertically to the fibers of the wood. Arithmetic means of the measurements were calculated and average

surface brightness values were determined and the findings are given in Tab. 5.

Tab. 5: *Brightness measurement values*

Brightness measurement values (60°)								
Wood type	Chesnut				Scotch Pine			
Samples	Pentahydrate rate (%)				Pentahydrate rate (%)			
	0	10	20	30	0	10	20	30
1	73.4	52.08	45.30	23.16	74.8	68.06	59.17	31.52
2	73.1	51.50	44.80	22.78	74.9	68.20	59.37	30.87
3	72.3	51.29	44.62	22.69	74.5	67.74	58.93	29.64
4	72.5	51.37	44.59	22.80	74.2	67.56	58.83	30.79
5	72.3	51.91	45.16	23.03	74.3	67.58	58.73	30.53
Average	72.72	51.63	44.89	22.89	74.54	67.82	59	30.67

There may be some different results in brightness measurements depending on the direction of the measurement according to the position of the fibers. This diversification of the wood surface may increase or decrease depending on the vertical or horizontal brightness measurement of fibers. According to the highest brightness results in the water-based varnish compounds was observed in the experimental samples which did not have any pentahydrate included. As the level of pentahydrate added to the varnish increased the surface brightness decreased on the other side. As a result the pentahydrate added to the water-based varnish mats the surface of the varnish and decreases brightness quality of it.

As a result, if hardness and sticking resistance are important in water-based varnish applications, pentahydrate added into the varnish. If brightness criterion is important in the processes, pentahydrate should not be added into the varnish.

CONCLUSIONS

As a result of the research conducted, it is determined the rate of pentahydrate, which is a kind of borax element, is more influential in the frame of surface sticking resistance, brightness and toughness measurements besides the type of the wood used in samples. The explanations of these effects are given below.

As a result of the researches conducted, it is observed that as the rate of the pentahydrate added into the water-based varnish increased from 0 % to 30 %, the varnish', Sticking rate increased 50.46 % in Chesnut wood and 37.04 % in Scotch pine. Toughness rate increased 55.79 % in Chesnut wood and 41.98 % in Scotch pine, Brightness rate decreased 68.52 % in Chesnut wood and 58.88 % in Scotch pine.

Consequently, the pentahydrate added into the water-based varnish increased toughness and sticking resistance; however, it decreased the brightness rate of varnish on the other side. If high sticking resistance and toughness is demanded while using the varnish pentahydrate should definitely be added. However, it should be considered that this will reduce the rate of brightness

as a drawback. In some cases the water-based varnish should be mat while making furniture; for this reason the decrease in brightness turns into an advantage in these cases. Adding pentahydrate into water-based automobile paints in the frame of increasing the sticking and toughness could be subject to another research in the future also.

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