**FEDERAL EDUCATION AGENCY**
Public Educational Institution of Higher Professional Education
**Saint-Petersburg State FORESTRY ENGINEERING ACADEMY**
**named after S.M. Kirov**
**Chair of Technology of Wood Composite Materials**

194021, Saint-Petersburg,
Institutski per., 5

tel.: 550-02-53,
550-08-52 (add. 343)
fax: 550-08-15
E-mail: wood-plast@mail.ru

# REPORT

## on efficiency of ERGOWAX 60 Paraffin Wax Emulsion for Woodchips Boards Hydrophobization

Scientific Adviser, Head of the Chair,
Professor A.A. Leonovich

Executor, Principal Engineer A.S. Butuzov

15.06.2007

Saint-Petersburg
2007

## Introduction

Wood chipboards hydrophobization means effect, providing decrease of their affinity with water. Affinity is conditioned by interaction of polar groups of wood complex with polar hydroxyl groups of water.

Measures, providing mentioned decrease come to wood complex polar groups block due to chemical reactions, or to wettability change.

Hydrophobization methods, which realization costs commensurable to the reached effect have practical significance. Such wood materials as woodchip boards (WCB), wooden fiber boards of medium density (MDF) need minimum costs for hydrophoby provision with minimum consumption of reagents and substances, changing wettability. In the latter case they are called *waterproofing agents*.

In the general case wood boards interaction with water may be accompanied by water absorption from liquid phase, or from gas phase. Mechanisms of these variants are principally different, as achieved equilibrium positions differ.

### *Ways of Water Absorption from Liquid Phase*

Wood always contains some moisture. Two indexes characterizing moisture content are distinguished: wood humidity (relative humidity) and humidity content (absolute humidity).

*Humidity* – is moisture content, relatively to mass of damp (moist) wood and expressed in percents. *Humidity content* (absolute humidity) – is moist content in percents relative to mass of absolutely dry wood. *Absolutely dry* wood is conditionally taken as wood, dried to constant mass at $105^0$C (such wood always contains small quantity of residual moisture).

In practice the following notions, characterizing wood humidity content are differentiated:

1. Humidity content of green wood (from 35 to 60%, some times up to 100% and more of mass of absolutely dry wood). It depends mainly on time of harvesting, and on wood species, vegetation conditions etc.
2. Humidity content of air-dry wood (usually 15 – 20 %). It depends on relative air humidity.
3. Humidity content of damp wood. It may be very high. Damp wood is got after wood long time being in water. Such wood may contain moisture up to 150% of mass of absolutely dry wood.

Damping capacity of wood and WCB is evaluated by such characteristic as *water resistance*. Water resistance may be temporary and constant. Temporary water resistance is conditioned by physicochemical effects, worsening damping, constant water resistance – by decrease of polar groups in wood. Main groups – are hydroxyl. But effective methods of their decrease by chemical reactions (such as acetylation etc.) are expensive. That's why methods of temporary water resistance get practical significance.

To make WCB temporary water resistant apolar hydrocarbons are used – paraffin wax, slack wax, petrolatum etc. Emulsions (suspensions) on the basis of paraffin wax are the most perspective as in respect of efficiency, so manufacturability.

Direct definition of water absorption is in the basis of hydrophobization results evaluation, which is expressed in percents to air-dry mass, or as water content in absolutely dry wood. Scientific index of surface hydrophoby is cos θ (angle of damping), formed on substrate by hydrophilic substance drop, it refers to water absorption in liquid phase.

Water absorption is possible from steam and gas phase (from air) or form liquid phase at direct material immersion into water. In the first case water molecules are absorbed by wood substance as realization of *Specific Free Surface Energy* (SFSE), with relative air humidity increase steam condenses in wood porous structure. In the second case water penetrates capillary porous structure of wood and interstices between wood particles in WCB.

Water absorption is a standard method of evaluation and is registered in 2 and 24 hours on 100 x 100 mm size samples being in water (GOST 10634-88). It depends on boards density and binding content, decreasing with their increase.

Technical literature contains information on WCB quality decrease concerning strength at paraffin wax quantity increase. Results relate to paraffin wax content of 2% and more. According to other information, in case of 10% solutions of waterproofing emulsions use there is no strength decrease. Emulsion preparation method and used emulsifiers effect. Indexes variations turn to be important.

Thus, it was necessary for set aim realization to make a series of experiments with the use of paraffin wax emulsion ERGOWAX 60, produced at the enterprise «Ergotek» (Perm, Russia). This high concentrated emulsion with paraffin wax content 60 ± 2%, has acidity of pH 8,5-9,5 and particles size 0,6…1,0 μm.

It was necessary to find out the effect of alkalescent condition on urea-formaldehyde binding hardening process, for which in WCB production subacid condition pH 4,5 is necessary. pH values variance may be the negative factor, paraffin wax particles fine dispersion must also be taken into account, which must provide high hydrophobization efficiency due to large wood particles surfaces covering.

The aim – is to determine effective consumption of paraffin wax emulsion ERGOWAX 60 to decrease water absorption. There are three levels accepted: 0,2%; 0,6% and 1,0%. These levels were designated to use for determination of three levels of consumption: <u>insufficient</u> consumption, <u>optimal</u> and <u>excessive</u> referring to standard index (2 and 24 hours), and also to long time water absorption and evaluation of dimensions reducing capacity with presence of paraffin wax emulsion.

## Experiment Method:

**a) WCB Samples Manufacturing**

Urea-formaldehyde resin of KF-MT-15 (TU 6-06-12-88) mark was used, solid residual content is 70%. Industrially manufactured emulsion of ERGOWAX 60 mark was used as paraffin wax emulsion.

Woodchip boards of 400 x 400 x 15 mm size were manufactured of birch wood with the method of plane pressing. Chips were got at the plant of «Nevski Laminate Plant» Ltd. Chips were treated by three levels of paraffin wax emulsion consumption 0,2; 0,6 and 1,0 %.

Paraffin wax emulsion was introduced with the help of pneumatic pulverizer and mixed with chips in drum mixer. Chips stood for 2 days, and then were resinified by urea-formaldehyde binding for outer layer with concentration of 55%, for internal layer - 60%, packet was formed and pressed at hydraulic press of «AKE» mark of type HPA 500 x 500 x 1 x 160 TON (Sweden) at temperature of $190^0$C and specific pressure of 2,5 MPa in calculation of 0,30 min per mm of board thickness. Boards were conditioned for two days.

**b) WCB Samples Test**

Ready made boards tests were made with determination of:

1. Density (GOST 10634-88)
2. Breaking point at static bend (GOST 10635-88)
3. Breaking point at stretching perpendicular to the board plane (GOST 10636-90)
4. Swelling – $\Delta S$, %; water absorption – W, % (GOST 10634-88).

Actual water absorption and swelling full cycle 12 days were determined additionally. Then samples were dried to constant mass (7 days) and water consumption changes were fixed regarding to initial before water absorption test.

Damping angle was determined.

**c) Plywood Samples Coating with Paraffin Wax Emulsion**

ERGOWAX 60 paraffin wax emulsion was used, samples of three-layer plywood size 130 x 20 mm, glass, laboratory balance, spray gun, compressor.

Emulsion Applying

Arbitrary quantity of concentrated paraffin wax emulsion is pored into glass. Plywood samples are smoothed out by fine sand paper, weighted on laboratory balance.

Paraffin wax emulsion mass necessary for surface coating, based on paraffin wax specific consumption in diapason of 0,2…1,0% of sample plane area was calculated.

At chip flakers with cutter shaft DC-6 processing measured pieces of different species chips of the following fraction content were obtained.

| Fraction number | –/10 | 10/7 | 7/5 | 5/3 | 3/2 | 2/1 | 1/0 |
|---|---|---|---|---|---|---|---|
| Chips content, % | 9 | 20 | 20 | 22 | 15 | 8 | 8 |

We chose 5/3 fraction for our research, as it had the most chips content of the total mass. According to UkrNIIMOD, specific surface of wood particles of 5/3 fraction is equal to 25,1 $sm^2/g$. Then for 1% level of paraffin wax emulsion treatment we get consumption of 0,01 g of 1 g of absolutely dry chips, i.e. 0,01 g of paraffin wax emulsion for chips surface equal to 25,1 $cm^2$.

Analogous applying paraffin wax emulsion mass is calculated at specific consumption of 0,2 and 0,6 %. Loss coefficient at coating is equal to 1,05.

Paraffin wax emulsion is applied with the help of pneumatic sprayer connected to compressor. It allows to apply even drops on all sample area. Spray time depends on paraffin wax emulsion consumption. Applied paraffin wax emulsion mass is determined by sample weighing, actual specific emulsion consumption is calculated. In 2 minutes after paraffin wax emulsion application to the sample binding solution is applied for determination of damping contact angle.

**d) Determination of Damping Contact Angle of Binding on Wood Substrate**

Apparatus and materials:

1) stereoscopic microscope МБС – 2;
2) cathetometer RFUESS;
3) glasses with capacity 25…50 $cm^3$;
4) scales with error up to 0,1 g;
5) pipette with capacity of 5 $cm^3$, scale factor equal to 0,1 $cm^3$;
6) micropipette for a drop with capacity of 0,03 $cm^3$;
7) urea-formaldehyde resin;
8) veneer sheet.

Test:

10 g of 70% resin is weighed in glass. Calculated quantity of water is added to resin to make its concentration equal to 55%.

Resin drop of 0,03 $cm^3$ volume is applied with micropipette to plywood sample. In 2 minutes after drop application drop diameter along and across the grain with the help of microscope and the height of the drop with the help of cathetometer are measured.

Damping contact angle tangent is calculated by formula:

$$tg\ \theta = 4dh / d^2 - 4h^2,$$

where $\theta$ – damping contact angle, degree;
d – drop diameter, mm;
h – drop height, mm.

Area of drop in the form of ellipse is found, mm:

$$S_k = \pi \cdot r_1 \cdot r_2,$$

where $r_1$ – small ellipse radius, mm
$r_2$ – big ellipse radius, mm

Test results are presented in the form of diagrams of $S_k$, d, h and θ changes along and across the sample grain at three resin concentrations.

## Test Results

Samples at three levels of paraffin emulsion treatment and control (without paraffin wax emulsion) are given on Figure 1 for two variants of urea-formaldehyde binding content.

Figure 2 – gives information on swelling.

To make it more clear experiment area most interesting for consideration is given on Figure 3 and Figure 4.

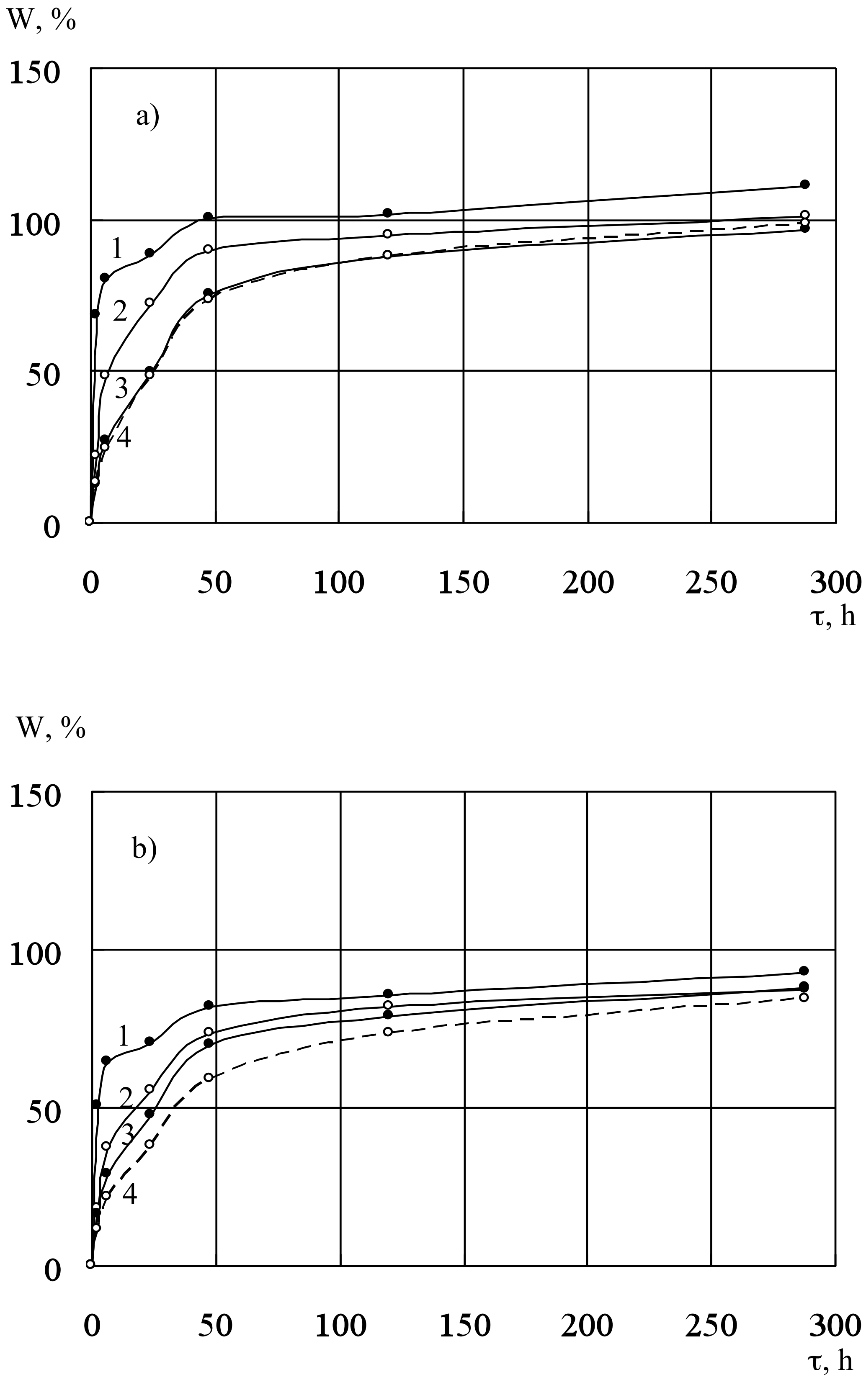



Figure 1. Dependence of WCB water absorption on paraffin wax emulsion consumption at binding consumption a) – 10%; b) – 14% of absolute dry chips: 1 – control (without paraffin wax emulsion); 2 – 0,2%; 3 – 0,6%; 4 – 1,0%

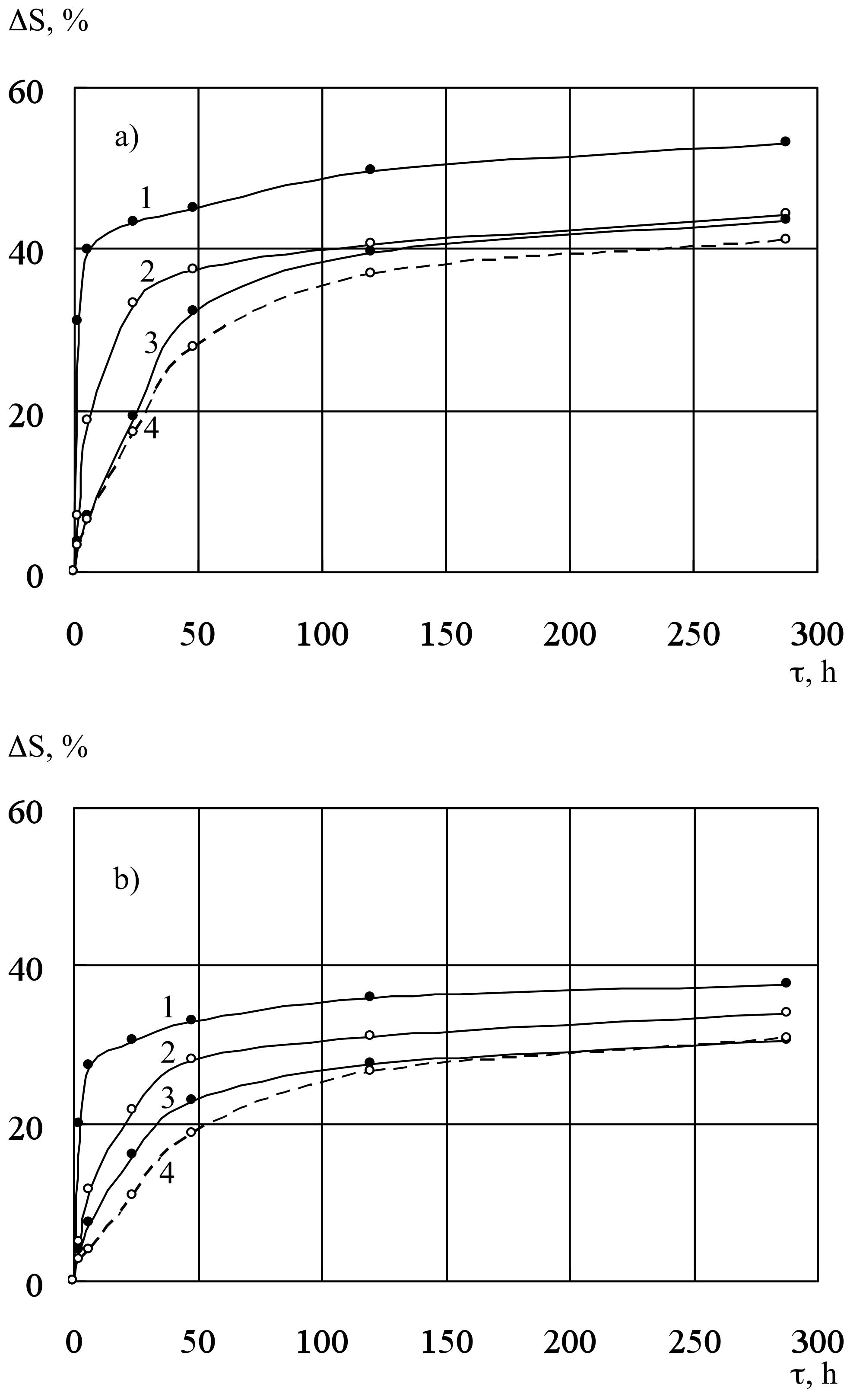
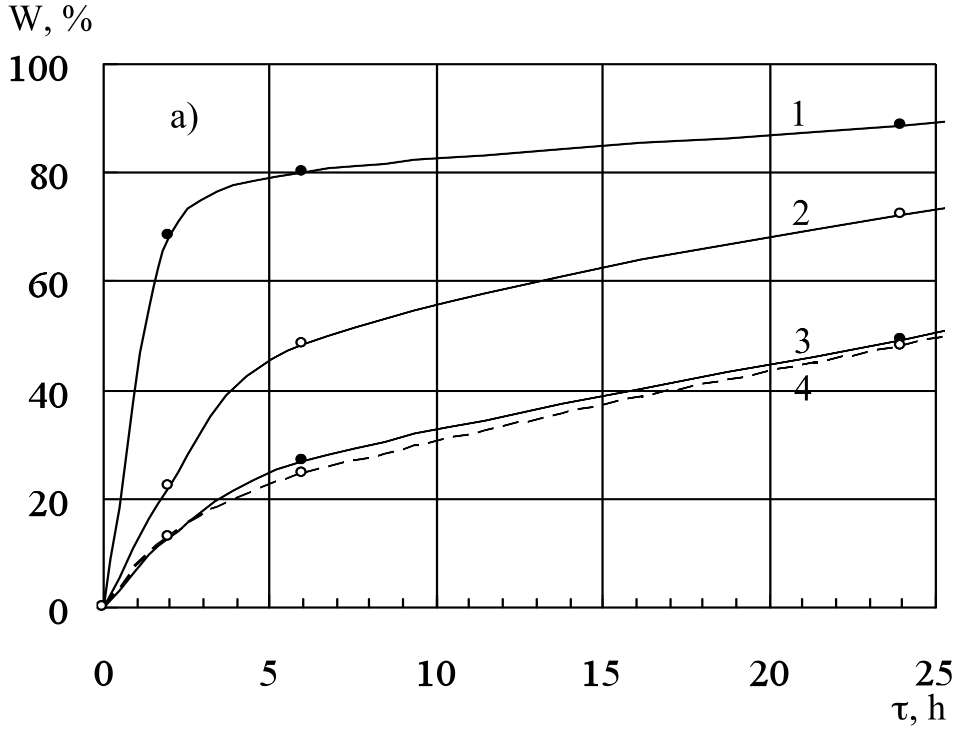



Figure 2. Dependence of WCB swelling on paraffin wax emulsion consumption at binding consumption a) – 10%; b) – 14% of absolute dry chips: 1 – control (without paraffin wax emulsion); 2 – 0,2%; 3 – 0,6%; 4 – 1,0%



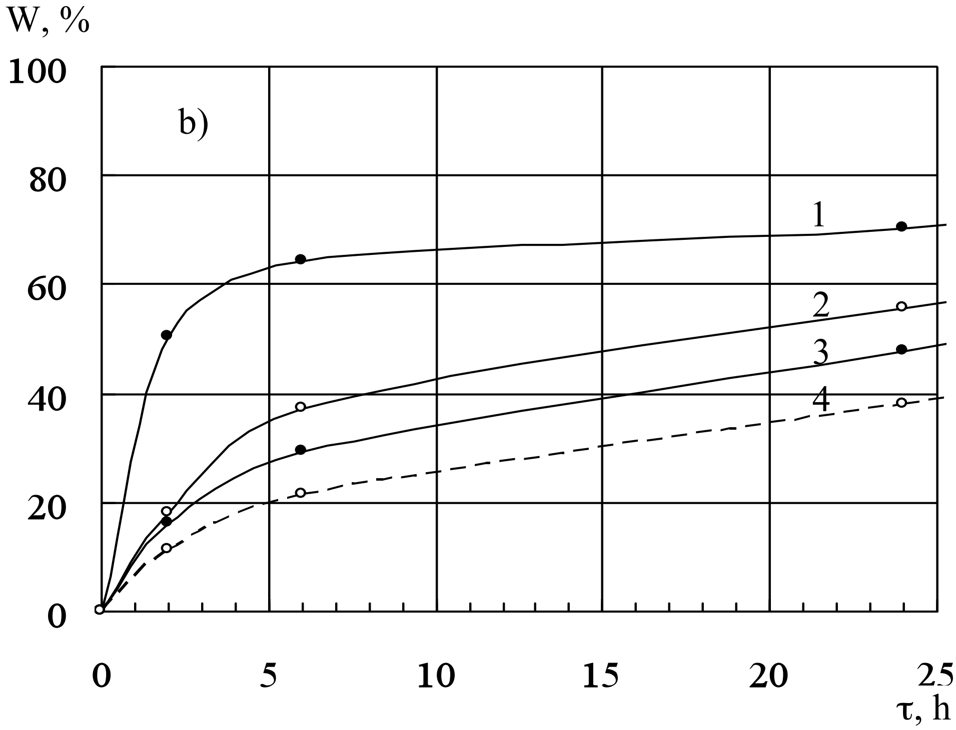




Figure 3. Dependence of WCB water absorption on paraffin wax emulsion consumption at binding consumption a) – 10%; b) – 14% of absolute dry chips: 1 – control (without paraffin wax emulsion); 2 – 0,2%; 3 – 0,6%; 4 – 1,0%

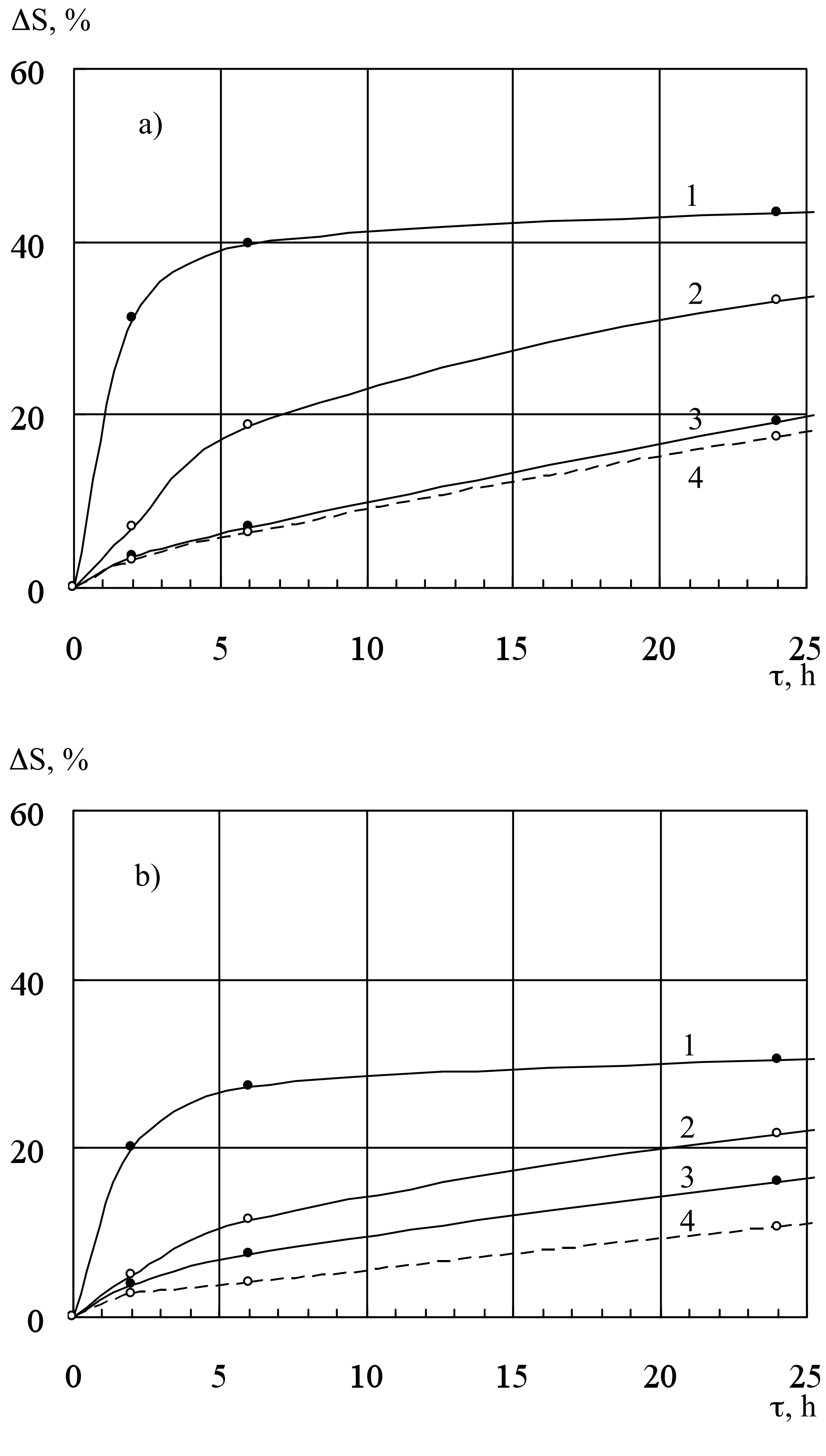



Figure 4. Dependence of WCB swelling on paraffin wax emulsion consumption at binding consumption a) – 10%; b) – 14% of absolute dry chips: 1 – control (without paraffin wax emulsion); 2 – 0,2%; 3 – 0,6%; 4 – 1,0%

From given information it follows, that paraffin wax emulsion considerably slows down water absorption and related swelling. Maximum specific effect is at first portions of paraffin wax emulsion, and then dieing out closing to consumption of 1,0%. For internal layer (urea-formaldehyde binding consumption 10%) paraffin wax emulsion has practically no effect on water absorption decrease at paraffin wax emulsion consumption increase from 0,6 to 1,0%.

Therefore, for internal layer maximum effective paraffin wax emulsion content is 0,6% of absolutely dry chips mass.

In case of urea-formaldehyde binding consumption 14% use paraffin wax emulsion continues to show its hydrophobic action. Therefore, for external layer maximum efficient paraffin wax emulsion content may be 1,0%.

So, it is expedient to recommend different paraffin wax emulsion consumption for multi-layer woodchip boards.

Long time water absorption leads to reduction of hydrophobic effect. If standard water absorption value for 2 hours is less than control, then in 288 hours the difference decreases to the level, when there is practically no effect. At the same time, swelling nevertheless decreases a little. This illustrates *Temporary Water Resistance*.

Drying leads to almost the same water losses. Some samples mass decrease for the variant of paraffin wax emulsion application 1% is conditioned by pores plugging, which leads to less water absorption.

The degree of irreversible swelling points out to paraffin wax emulsion ability to stabilize woodchips board structure in a definite way.

Studying of wood surface damping with water showed (table 1), that paraffin wax emulsion presence on the surface in quantity, corresponding its content in WCB, decreases its damping with hydrophilic agent. In our experiment it is KF-MT-15 resin with concentration of 55%. It could be seen by resin surface tension along and across the grain and by adhesion action.

Table 2 gives source information of damping contact angle in recalculation from given to actual consumption.

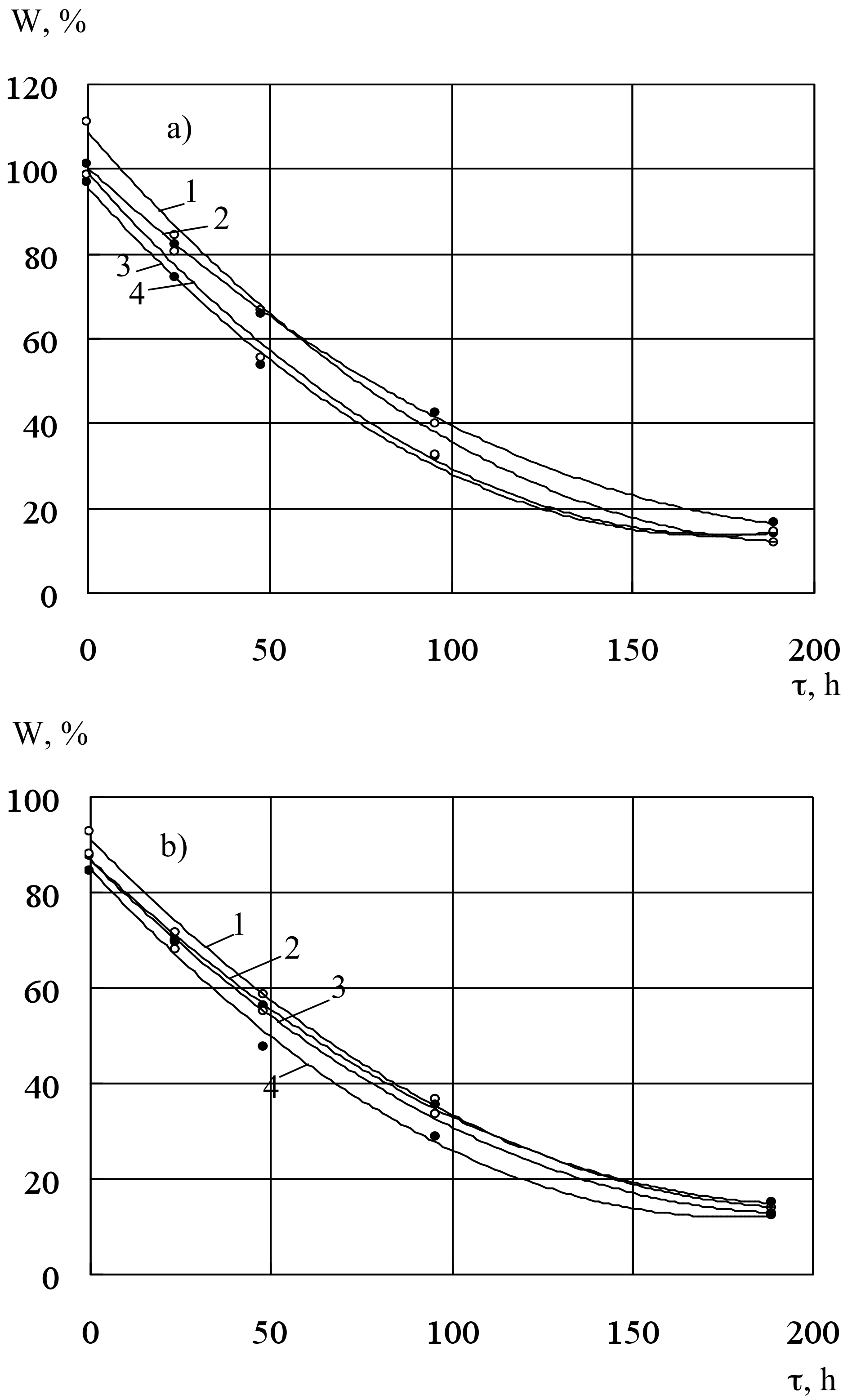



Figure 5. Dependence of WCB water absorption at air dry on paraffin wax emulsion consumption at binding consumption a) – 10%; b) – 14% of absolute dry chips: 1 – control (without paraffin wax emulsion); 2 – 0,2%; 3 – 0,6%; 4 – 1,0%

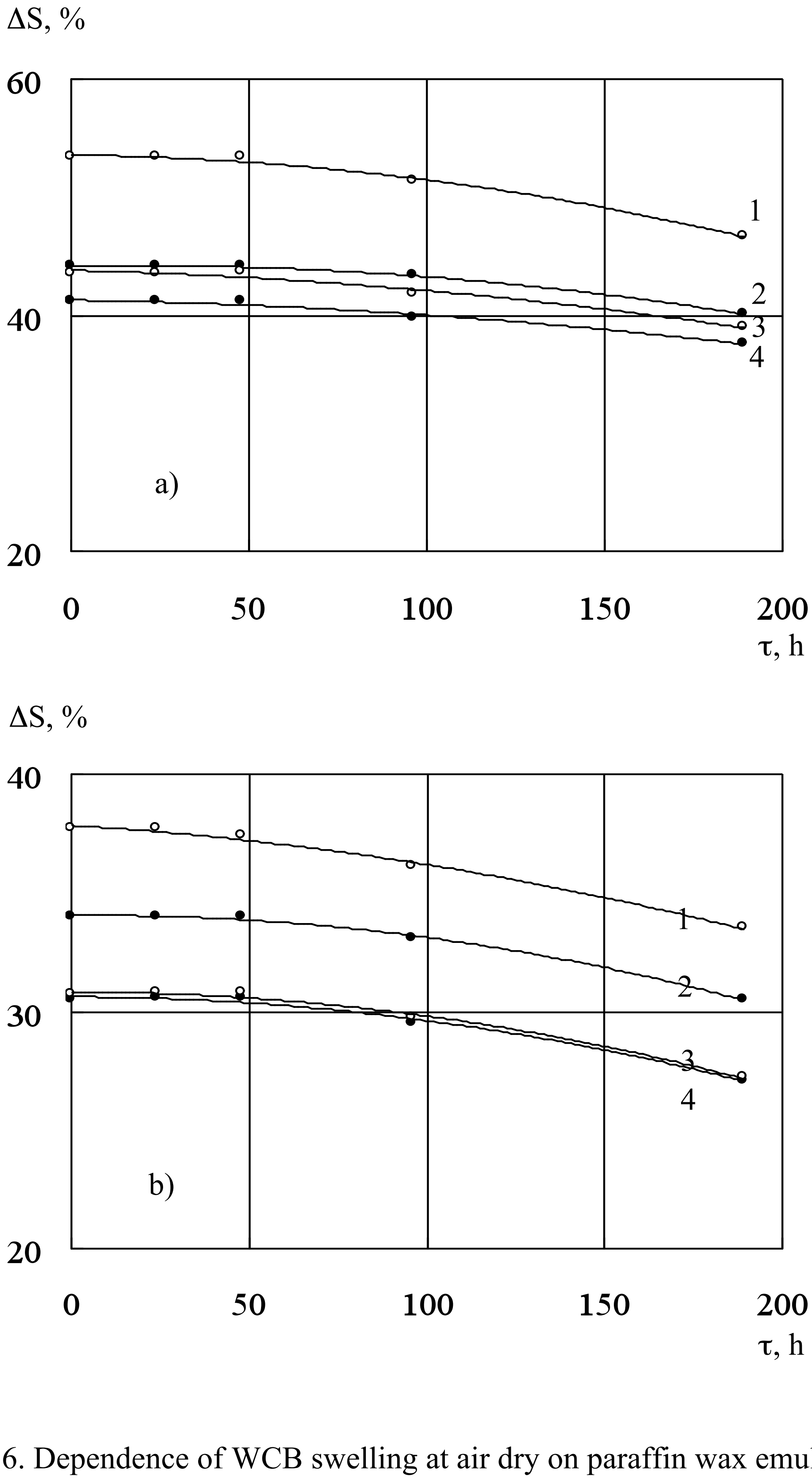



Figure 6. Dependence of WCB swelling at air dry on paraffin wax emulsion consumption at binding consumption a) – 10%; b) – 14% of absolute dry chips: 1 – control (without paraffin wax emulsion); 2 – 0,2%; 3 – 0,6%; 4 – 1,0%

Table 1

Binding Surface Tension and Adhesion Action
in Paraffin Wax Emulsion Presence

| Paraffin Wax Emulsion consumption, % | Drop area, $mm^2$ | Surface tension along the grain, mN/m | Surface tension across the grain, mN/m | Adhesion action along the grain, $J/m^2$ | Adhesion action across the grain, $J/m^2$ |
|---|---|---|---|---|---|
| Control | 40,84 | 30,09 | 18,09 | 56,42 | 28,72 |
| 0,2 | 30,72 | 23,16 | 17,68 | 35,50 | 18,06 |
| 0,6 | 25,54 | 19,35 | 17,57 | 16,76 | 8,85 |
| 1,0 | 25,77 | 20,80 | 16,69 | 17,28 | 7,51 |

Table 2

Source Information of Damping Contact Angle

| Paraffin Wax Emulsion consumption, % | Theoretical Paraffin Wax Emulsion consumption, % | Actual Paraffin Wax Emulsion consumption, % | θ along the grain, ° | θ across the grain,° |
|---|---|---|---|---|
| Control | 0 | 0 | 26,77 | 43,07 |
| 0,2 | 0,2 | 0,30 | 43,53 | 56,35 |
| 0,2 | 0,2 | 0,35 | 46,67 | 57,99 |
| 0,6 | 0,6 | 0,83 | 59,82 | 65,55 |
| 0,6 | 0,6 | 0,84 | 59,53 | 63,77 |
| 1,0 | 1,0 | 1,10 | 59,69 | 70,72 |
| 1,0 | 1,0 | 1,17 | 58,31 | 70,35 |

From table information it follows, that paraffin wax emulsion worsens binding spreading on wood surface and adhesion. This fact negatively affects glue joint strength and may worsen woodchip board strength as a whole.

At the same time, it is known, that wood particles are covered by binding, forming mosaic distribution. Then, at small paraffin wax emulsion consumption significant particles surface is left, directly contacting with binding. These contacts are enough to reach standard board strength. Direct determination of board strength at bend, when external layers strength is evaluated, and at stretching perpendicular to plate, when middle layer strength is evaluated, proves our hypothesis.

Results are given in Table 3, and variation of specific indexes is given in Appendixes 1 and 2.

Table 3

Paraffin Wax Emulsion Effect to the Strength of Woodchip Boards of Given Density of 750 kg/m$^3$

| Paraffin Wax Emulsion content, % | Binding consumption, % | |
|---|---|---|
| | 10 | 14 |
| Strength at static bend, MPa | | |
| control | 16,1 | 21,1 |
| 0,2 | 19,9 | 22,7 |
| 0,6 | 20,7 | 20,8 |
| 1,0 | 21,0 | 22,8 |
| Strength at stretching perpendicular to plane, MPa | | |
| control | 0,30 | 0,39 |
| 0,2 | 0,31 | 0,38 |
| 0,6 | 0,31 | 0,37 |
| 1,0 | 0,32 | 0,39 |

To determine emulsion operation concentration consumption, depending on parameters of jets mounted on mixers, we based on requirements to operation viscosity ($\eta_т$), which according to «Directory on Woodchip Boards Manufacturing» page 49 is not more than 25 c by B3-246 with nozzle diameter of 4 mm. For greater viscosity value, which is advisable to decrease water introduced with emulsion, more strong nozzles are necessary.

Initial relative viscosity of paraffin wax emulsion is 29,2 c. Emulsion dilution with water with the use of electrical mixer from concentration of 60% to concentration of 55 and 50% showed viscosity η change according to diagram (Figure 7).

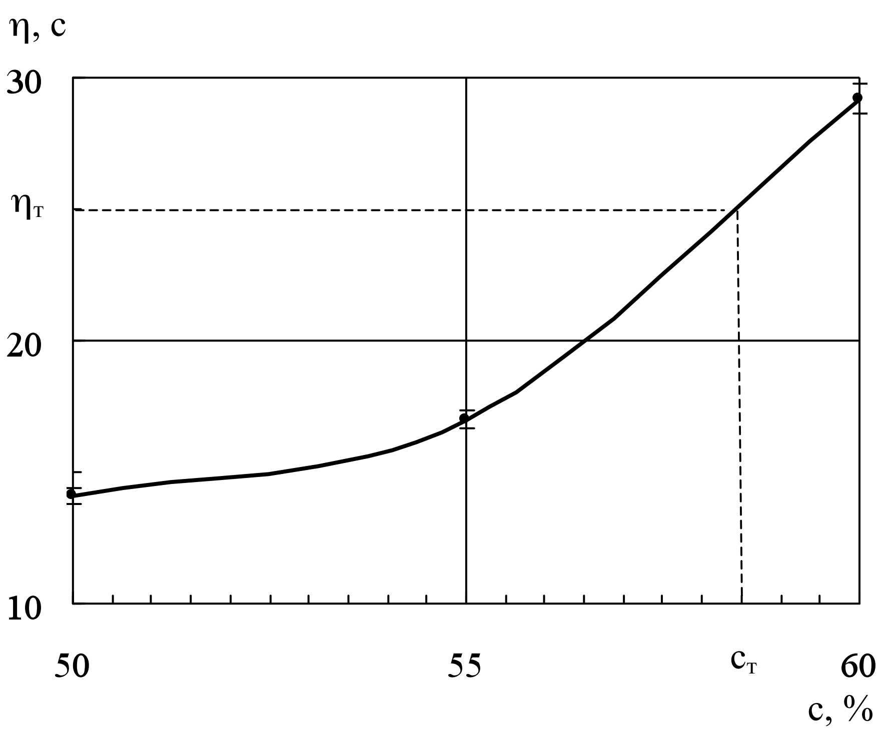



Figure 7. Dependence of paraffin emulsion viscosity η changes on concentration

On the basis of this diagram it is possible to select final paraffin wax emulsion concentration ($c_т$ = 58,5%) for operating enterprises, or specially determine the possibility of dispersion equipment for operation with concentration of 60%.

**Resume:**

1. For internal layer (urea-formaldehyde binding consumption 10%) there is practically no paraffin wax emulsion effect on water absorption decrease at paraffin wax emulsion consumption increase from 0,6 to 1,0%. For internal layer maximum effective paraffin wax emulsion content is 0,6% of absolute dry chips mass. In case of urea-formaldehyde binding consumption 14% paraffin wax emulsion continues to show its hydrophobic action. For external layer maximum effective paraffin wax emulsion content may be 1,0%.

2. Using ERGOWAX 60 paraffin wax emulsion it is expedient to recommend different emulsion consumption for multi-layer woodchip boards.

3. Mosaic distribution of ERGOWAX 60 paraffin wax emulsion has no negative effect to strength within emulsion consumption up to 1,0% of absolute dry chips mass.

4. For operating spraying systems, used at domestic enterprises, it is expedient to supply paraffin wax emulsion with concentration of 58,5%, or specially make it possible to equip dispersion for operation with concentration of 60%.

Appendix 1

WCB Strength at Static Bend

| № | m, g | l, mm | b, mm | h, mm | Failure load, kgc | Density, kg/m$^3$ | σ, MPa | Relative density, kg/m$^3$ | $σ_{av}$, MPa |
|---|---|---|---|---|---|---|---|---|---|
| 1 1 | 93,6 | 193 | 48,0 | 14,9 | 64,5 | 678 | 13,6 | 750 | |
| 1 2 | 104,0 | 199 | 48,0 | 15,1 | 65,0 | 721 | 13,4 | | |
| 1 3 | 101,5 | 199 | 47,0 | 14,8 | 65,4 | 733 | 14,3 | | |
| 1 4 | 104,8 | 200 | 47,0 | 15,0 | 76,2 | 743 | 16,2 | | |
| 1 5 | 110,9 | 190 | 50,0 | 14,7 | 92,8 | 794 | 19,3 | | 16,1 |
| 2 1 | 98,4 | 192 | 48,0 | 14,9 | 99,1 | 717 | 20,9 | 750 | |
| 2 2 | 97,4 | 189 | 49,0 | 15,0 | 88,5 | 701 | 18,1 | | |
| 2 3 | 101,4 | 197 | 46,0 | 14,5 | 84,0 | 772 | 19,5 | | |
| 2 4 | 99,6 | 197 | 47,0 | 14,5 | 108,0 | 742 | 24,6 | | |
| 2 5 | 101,8 | 197 | 47,0 | 14,4 | 81,0 | 764 | 18,7 | | 21,1 |
| 3 1 | 101,4 | 195 | 48,0 | 15,0 | 90,0 | 722 | 18,8 | 750 | |
| 3 2 | 94,7 | 188 | 47,0 | 14,9 | 86,0 | 719 | 18,5 | | |
| 3 3 | 103,1 | 197 | 48,0 | 14,6 | 82,0 | 747 | 18,0 | | |
| 3 4 | 103,9 | 198 | 47,0 | 14,6 | 81,0 | 765 | 18,2 | | |
| 3 5 | 99,7 | 198 | 47,0 | 14,4 | 99,0 | 744 | 22,9 | | 19,9 |
| 4 1 | 97,7 | 190 | 47,0 | 14,7 | 111,5 | 744 | 24,7 | 750 | |
| 4 2 | 98,7 | 194 | 47,0 | 14,8 | 95,0 | 731 | 20,8 | | |
| 4 3 | 108,7 | 201 | 47,0 | 14,4 | 114,5 | 799 | 26,4 | | |
| 4 4 | 101,9 | 201 | 47,0 | 14,2 | 120,5 | 760 | 28,6 | | |
| 4 5 | 97,8 | 200 | 47,0 | 14,5 | 81,0 | 718 | 18,4 | | 22,7 |
| 5 1 | 97,4 | 183 | 47,0 | 14,7 | 100,0 | 770 | 22,2 | 750 | |
| 5 2 | 95,4 | 188 | 50,0 | 14,7 | 75,0 | 690 | 15,6 | | |
| 5 3 | 101,2 | 194 | 47,0 | 15,1 | 85,5 | 735 | 18,0 | | |
| 5 4 | 99,3 | 198 | 48,0 | 14,9 | 98,5 | 701 | 20,8 | | |
| 5 5 | 108,0 | 198 | 48,0 | 14,8 | 95,5 | 768 | 20,4 | | 20,7 |
| 6 1 | 98,4 | 187 | 49,0 | 14,6 | 105,5 | 736 | 22,7 | 750 | |
| 6 2 | 103,3 | 190 | 48,0 | 14,6 | 100,0 | 776 | 22,0 | | |
| 6 3 | 97,3 | 199 | 47,0 | 14,9 | 79,0 | 698 | 17,0 | | |
| 6 4 | 96,8 | 198 | 47,0 | 14,9 | 75,5 | 698 | 16,3 | | |
| 6 5 | 102,2 | 198 | 48,0 | 14,7 | 87,5 | 732 | 19,0 | | 20,8 |
| 7 1 | 105,7 | 198 | 48,0 | 14,9 | 102,0 | 746 | 21,5 | 750 | |
| 7 2 | 98,2 | 199 | 48,0 | 15,2 | 80,0 | 676 | 16,2 | | |
| 7 3 | 101,2 | 198 | 48,0 | 14,8 | 90,5 | 719 | 19,4 | | |
| 7 4 | 103,5 | 195 | 47,0 | 14,7 | 105,5 | 768 | 23,4 | | |
| 7 5 | 105,2 | 192 | 47,0 | 14,7 | 98,0 | 793 | 21,7 | | 21,0 |
| 8 1 | 95,7 | 182 | 50,0 | 14,6 | 98,0 | 720 | 20,7 | 750 | |
| 8 2 | 108,0 | 200 | 50,0 | 14,5 | 95,0 | 745 | 20,3 | | |
| 8 3 | 102,1 | 197 | 49,0 | 15,0 | 95,0 | 705 | 19,4 | | |
| 8 4 | 96,7 | 187 | 50,0 | 14,8 | 98,0 | 699 | 20,1 | | |
| 8 5 | 105,0 | 186 | 52,0 | 14,8 | 118,0 | 734 | 23,3 | | 22,8 |

# Appendix 2

WCB Strength at Stretching Perpendicular to Plane

| № | m, g | l, mm | b, mm | h, mm | Failure load, kgc | Density, kg/m$^3$ | $\sigma_{\perp}$, MPa | Relative density, кг/м$^3$ | $\sigma_{\perp cp}$, MPa |
|---|---|---|---|---|---|---|---|---|---|
| 1 1 | 24,2 | 50 | 48 | 14,7 | 65,0 | 686 | 0,27 | | |
| 1 2 | 25,5 | 49 | 49 | 15,0 | 67,0 | 708 | 0,28 | | |
| 1 3 | 24,9 | 48 | 47 | 14,8 | 52,0 | 746 | 0,23 | 750 | |
| 1 4 | 25,1 | 49 | 47 | 15,1 | 67,0 | 722 | 0,29 | | |
| 1 5 | 28,8 | 49 | 50 | 14,5 | 91,0 | 811 | 0,37 | | 0,30 |
| 2 1 | 24,5 | 49 | 48 | 14,9 | 80,0 | 699 | 0,34 | | |
| 2 2 | 25,3 | 49 | 50 | 14,9 | 61,0 | 693 | 0,25 | | |
| 2 3 | 24,9 | 49 | 47 | 14,6 | 102,5 | 741 | 0,45 | 750 | |
| 2 4 | 25,6 | 49 | 47 | 14,5 | 97,0 | 767 | 0,42 | | |
| 2 5 | 26,9 | 49 | 47 | 14,4 | 107,0 | 811 | 0,46 | | 0,39 |
| 3 1 | 25,8 | 50 | 48 | 15,0 | 71,5 | 717 | 0,30 | | |
| 3 2 | 23,7 | 49 | 46 | 14,8 | 71,0 | 710 | 0,31 | | |
| 3 3 | 25,7 | 49 | 47 | 14,7 | 67,0 | 759 | 0,29 | 750 | |
| 3 4 | 25,6 | 49 | 47 | 14,6 | 66,0 | 761 | 0,29 | | |
| 3 5 | 24,2 | 48 | 47 | 14,5 | 69,0 | 740 | 0,31 | | 0,31 |
| 4 1 | 24,3 | 49 | 46 | 14,6 | 71,0 | 738 | 0,31 | | |
| 4 2 | 26,1 | 49 | 48 | 14,9 | 98,0 | 745 | 0,42 | | |
| 4 3 | 26,9 | 49 | 48 | 14,5 | 66,0 | 789 | 0,28 | 750 | |
| 4 4 | 25,5 | 49 | 47 | 14,4 | 100,0 | 769 | 0,43 | | |
| 4 5 | 24,9 | 49 | 47 | 14,7 | 98,0 | 736 | 0,43 | | 0,38 |
| 5 1 | 26,3 | 49 | 47 | 14,6 | 85,0 | 782 | 0,37 | | |
| 5 2 | 26,1 | 49 | 49 | 14,6 | 75,0 | 745 | 0,31 | | |
| 5 3 | 25,3 | 49 | 47 | 15,0 | 67,0 | 732 | 0,29 | 750 | |
| 5 4 | 25,2 | 50 | 49 | 15,0 | 61,0 | 686 | 0,25 | | |
| 5 5 | 27,0 | 49 | 48 | 14,8 | 72,5 | 776 | 0,31 | | 0,31 |
| 6 1 | 26,6 | 49 | 48 | 14,4 | 96,0 | 785 | 0,41 | | |
| 6 2 | 25,6 | 49 | 48 | 14,8 | 74,0 | 735 | 0,31 | | |
| 6 3 | 24,5 | 49 | 46 | 14,8 | 55,0 | 734 | 0,24 | 750 | |
| 6 4 | 24,7 | 48 | 47 | 14,9 | 83,0 | 735 | 0,37 | | |
| 6 5 | 26,4 | 49 | 48 | 14,6 | 76,0 | 769 | 0,32 | | 0,37 |
| 7 1 | 27,2 | 48 | 48 | 14,8 | 81,0 | 798 | 0,35 | | |
| 7 2 | 26,1 | 50 | 48 | 15,0 | 80,0 | 725 | 0,33 | | |
| 7 3 | 26,8 | 49 | 48 | 14,7 | 76,0 | 775 | 0,32 | 750 | |
| 7 4 | 26,7 | 49 | 47 | 14,5 | 82,0 | 800 | 0,36 | | |
| 7 5 | 27,2 | 50 | 48 | 14,9 | 70,0 | 761 | 0,29 | | 0,32 |
| 8 1 | 25,5 | 49 | 49 | 14,4 | 91,0 | 738 | 0,38 | | |
| 8 2 | 27,0 | 50 | 50 | 14,8 | 123,0 | 730 | 0,49 | | |
| 8 3 | 26,1 | 48 | 49 | 14,9 | 104,0 | 745 | 0,44 | 750 | |
| 8 4 | 25,4 | 49 | 50 | 14,5 | 84,0 | 715 | 0,34 | | |
| 8 5 | 27,7 | 49 | 52 | 14,5 | 123,0 | 750 | 0,48 | | 0,39 |