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Water vapour transmission properties of natural paints

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Abstract. Natural building materials including paints have been used historically for a long period of time. Today natural paints are of interest in the environmental point of view as 'ecological' building materials and at restoration works it is important to know the properties of materials used. From physical and environmental (indoor climate) aspects of building one of the most important properties of natural plasters and timber covering is ability of hygroscopic sorption. As paint is cover for them, its water vapour transmission properties have to be known as the first step for evaluating properties of substrate and the co-action of paint and plaster.

A lot of data is available describing the water vapour transmission properties of building materials, but not much has been written about natural paints.

The study focused on the following natural paints: casein paint, linseed oil paint, and egg tempera. The results are compared with alkyd paints. Natural paints were mixed by using traditional recipes. As for interior works, one layer of paint is often used; therefore, specimens were covered with one paint layer only. Water-vapour transmission rate was determined by using standards EVS-EN ISO 7783-1:2001 Paints and varnishes – Determination of water-vapour transmission rate – Part 1: Dish method for free films and EVS-EN ISO 7783-2:2001. Paints and varnishes – Coating materials and coating systems for exterior masonry and concrete – Part 2: Determination and classification of water-vapour transmission.

Water vapour transmission rate of linseed oil (54.8…124.5g $(m^2d)^{-1}$) is equal to or up to 2.5 times higher than that of alkyd paint (50.3g $(m^2d)^{-1}$) as average. The high rate of water-vapour permeability of casein paint indicates that casein paint does not have influence on the sorption ability of substrate (mortar or plaster) or diffusion through the boarders. The values of egg tempera (3,030–4,980 * 10^{-12}kg $(m^2sPa)^{-1}$) and linseed oil (558–1,300 * 10^{-12}kg $(m^2sPa)^{-1}$) for one layer paint can be taken into account during the designing process of boarder and have influence on diffusion and sorption process as well. Depending on the construction solution of boarder or desired indoor climate conditions it could be useful to choose covering with high or lower water-vapour permeability.

Key words: Natural paints, water vapour transmission, linseed oil, egg tempera, casein paint.

INTRODUCTION

Historically paints and colours have had a great importance in architecture. Broken white colors ranging from off white to dark stone were considered most elegant in the second half of the 18th century. This influence may be seen in the Russian Empire in the first half of the 19th century, when in the architectural policy of Alexander I a significant step was taken by the decree of making standard façades in private buildings mandatory throughout Russia which was issued in 1809. In 1817 standard façade colors were established for painting the stone and wooden houses with lighter colors, such as white, canary yellow, and socket charcoal tones (PSZ, T.XXXIV, 1817).

Secondly, the late eighteenth-century palette displayed ‘archaeological’ colors, such as green bronzing or Pompeian red, but the early one saw a movement towards duller tones, so that by the end of the period observed in this study, clear tints can be seen on large areas of interiors. The advent of the full-blown Neo-Classical style ushered in a taste for more complex painted treatments and richer colors, including bright yellows, blues, greens, pinks, and most importantly, terracotta reds, inspired by ancient Roman wall paintings excavated at Herculaneum and Pompeii. The pigments which were used for reds and terra-cottas were derived from plants, such as madder (Bristow, 1996).

In 1807, the phrase ‘interior decoration and paining’ – distinct from architecture – was coined for the first time in Thomas Hope`s *Household Furniture and Interior Decoration*, and printed manuals and guides for professionals and enthusiasts began to appear. Rooms continued to be dominated by single color, with red being the most popular for walls: typical hues included crimson, ruby, and maroon in conjunction with yellow. Austrian and German Biedermeier styles had emphasis on clear bright wall colors and white ceilings (Thornton, 1984).

The stronger colors associated with Owen Jones`s *Grammar of ornament* (1856) and Gottfried Semper`s theories manifested themselves in dramatic patterned polychromatic paint effects on ceilings and walls in the second half of 19th century. Other innovation of the late 19th century was associated with the Arts and Crafts Movement. Many William Morris interiors used densely patterned wallpaper and woodwork stained or painted dull green (Cumming, 2006).

Today natural paints are of interest in the environmental point of view as ‘ecological’ building materials and at restoration works it is important to know the properties of materials used. From the the aspect of physical and environmental building (indoor climate) one of the most important properties of natural plasters and timber covering is the ability of hygroscopic sorption. Clay has good reputation as a regulator of indoor relative humidity because of its good and quick moisture absorptivity (Madisson et al., 2009).

As paint is cover for them, its water vapour transmission properties have to be known as the first step for evaluating properties of substrate and the co-action of paint and plaster. Minke (2006) has found that double latex and single linseed oil coating can reduce absorption rates to 38% and 50%, respectively, at loam plaster (clay 4%, silt 25%, sand 71%) of 1.5cm thickness after sudden rise of RH from 50% to 80%.

Measurement of water vapour transmission is often done by wet cup method, but for materials with high water vapour permeability it could be complicated (Hu, et al., 2000).

The study focuses on natural paints, such as casein paint, linseed oil paint, and egg tempera. The results are compared with alkyd paint.

Linseed oil paint is traditionally used for interior and exterior works as well. It can be used on timber, gypsum, and plastered surfaces on walls, ceilings, floors, doors, and windows. It is a good repairing cover for enamel and oil paints.

Casein paints are used in interior works on timber, brick masonry, paper, and carton. Color effects like lasuring, fulling, mordanting (pickling) are widely used.

Egg tempera is used in interior works for timber and plastered surfaces – walls, ceilings, furniture. Decorative techniques involve graining, marbling, and lasuring.

MATERIALS AND METHODS

Natural paints - casein paint, linseed oil paint and egg tempera – were mixed by using traditional recipes (Antell et al., 1997). As for interior works one layer of paint is often used, therefore specimens were covered with one paint layer only. For the substrate constructional carton was used. Following traditional recopies were used to produce paints. *Linseed oil paint*: 0.5 l varnish, 100g titanium dioxide (pigment), 200g kaolin, pigments. *Egg oil tempera*: 1 egg, 30–40ml varnish, 30–40ml water, 2ml siccative. *Casein paint*: part I, extenders: 400g chalk, 100g kaolin, 100g talc, 2g methyl cellulose, 30ml varnish. Part II, adhesive: I10g borax (promote casein hydrolysis), 250g cottage cheese (fat-free), 30ml hot boiled water.

Standards EVS-EN ISO 7783-1:2001 Paints and varnishes – Determination of water-vapour transmission rate – Part 1: Dish method for free films, EVS-EN ISO 7783-2:2001. Paints and varnishes – Coating materials and coating systems for exterior masonry and concrete – Part 2: Determination and classification of water-vapour transmission were followed on test planning. Supported film procedure was used. As the resistance of whole system consists from resistances of layers (1/conductivity), Formula 1 describes interdependency between the vapour transmission rates of porous coating with substrate V_{cs} g (m^{2}d)$^{-1}$, water transmission rate of coating system (paint) V g (m^{2}d)$^{-1}$, and water transmission rate of porous substrate V_s g (m^{2}d)$^{-1}$.

$$\frac{1}{V_{cs}} = \frac{1}{V_s} + \frac{1}{V} \tag{1}$$

Water vapour transmission rate for coating V can be found by Formula 2 (derived from Formula 1)

$$V = \frac{V_{cs} \cdot V_s}{V_s - V_{cs}} \tag{2}$$

Three specimens were prepared for each paint. Dishes with diameters 90 and 115mm were used. The climate chamber RUMED was used to keep the conditions of air temperature at 22°C and RH=50%. Potassium nitrate was used to ensure conditions of RH=93% in the dishes. Specimens were weighed regularly once a day and weight change over test period was estimated as first result.

RESULTS AND DISCUSSION

Thickness of paint layer was estimated as the first result. As in interior works sometimes only one layer of paint is used, the 1-layer paint was chosen for experiment. Thickness of 1-layer varies up to five times 4.4–21.6μm (Table 1) depending on the paint. The thickness of porous casein paint is the biggest one. Thickness of 1-layer linseed oil varies more than others (6.2–13.3μm) probably because of its good absorption into the substrate.

Water vapour transmission rate of substrate (Table 1) as average of 628g $(m^2d)^{-1}$ is more than 240g $(m^2d)^{-1}$, which meets the minimum requirements of standard EVS-EN ISO 7783-2:2001.

Values recorded for water vapour transmission through substrate and coating V_{cs} (Table 1, Fig. 1) vary from 32.5 (alcyd paint) to 666.4g $(m^2d)^{-1}$ (carton). Casein paint does not influence the water vapour transmission significantly. Values recorded are comparable with pure carton.

Table 1. Water vapour transmission rate, permeation coefficient, and resistance of paints.

Item	Paint				
	Casein paint	Linseed oil paint	Egg tempera	Alcyd paint	Construction cartong
d, μm	17.9–21.6	6.2–13.2	4.6–6.3	4.4–5.4	28.3–28.8
V_{cs}, g $(m^2d)^{-1}$	410.0–602.3	50.4–103.9	201.8–274.7	46.4	627.6
V, g $(m^2d)^{-1}$	1,183–14,960	54.8–124.5	297.4–488.5	50.3	–
δ, 10^{-12}*kg $(msPa)^{-1}$	–	0.0058–0.0104	0.014–0.031	0.0025	0.18
Δ_1, 10^{-12}*kg $(m^2sPa)^{-1}$	–	558–1300	3,030–4,980	514	6,380
r, 10^9 $m^2sPa\ kg^{-1}$	–	0.79–1.79	0.20–0.33	2.12	0.16
Δ_2, 10^{-12}*kg $(m^2sPa)^{-1}$	–	404	1,900	260	–

By using Formula 2, water transmission rates for coating were calculated. The value for casein paint varies from 1,183–14,960g $(m^2d)^{-1}$ and is excluded from further calculations. Because of the nature of formula 2 (V_{cs} and V_s are almost equal), the results are unreliable. Free film method has to be used probably for paints with high water vapour permeation.

According to standard EVS-EN ISO 7783-2:2001 paints classification by water-vapour transmission rates is established by the following categories (Fig. 2).

1) High > 150g $(m^2d)^{-1}$,
2) Medium 15 to 150g $(m^2d)^{-1}$,
3) Low < 150g $(m^2d)^{-1}$.

By that classification 1-layer casein paint (>1,000g $(m^2d)^{-1}$) and egg tempera have high and 1-layer linseed oil has medium water vapour permission rate. It has to be notified that standard referee method focuses on final thickness of paint suggested by manufacturer (2-3 layers for alcyd paint, up to 12 layers for linseed oil) and for exterior works totally paint layers have more of thickness and must be analysed separately.

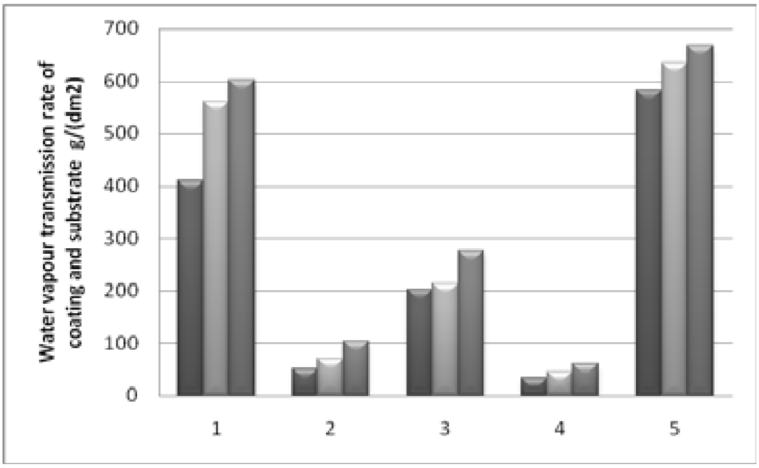

Figure 1. Water vapour transmission rate of coating and substrate V_{cs}, : 1 – casein paint, 2 – linseed oil paint, 3 – egg tempera, 4 – alcyd paint, 5 – carton.

Water vapour transmission rate of linseed oil (54.8…124.5g $(m^2d)^{-1}$) is equal or up to 2.5 times higher than of that alkyd paint (50.3g $(m^2d)^{-1}$) as average (Fig. 2). It is commonly known that alcyd paint has good water vapour resistance, but linseed oil is vapour tight as well. Historically it has been used in exterior works as well, but often in log construction, where the layer of timber guarantees a good water vapour resistance. Water vapour regime of construction must be analysed carefully before using it at new light constructions.

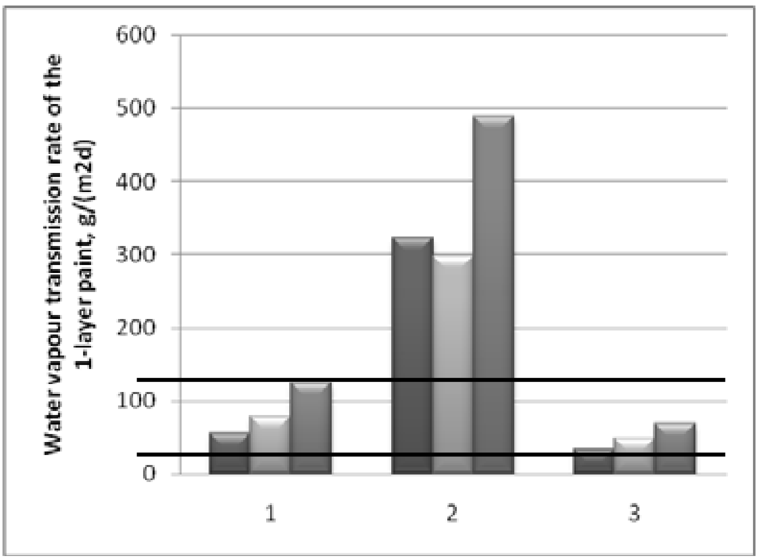

Figure 2. Water vapour transmission rate of paints V: 1 – linseed oil paint, 2 – egg tempera, 3 – alcyd paint.

Formula 3 (EVS-EN ISO 7783-2:2001) enables to calculate the water-vapour permeation coefficient δ, g $(\text{mdPa})^{-1}$, where d – thickness of coating, m, Δp – the difference in water-vapour pressure, Pa. In Table 1 δ is presented by unit kg $(\text{msPa})^{-1}$, as that unit is more commonly used in literature (Handbook of Building Construction, 2010).

$$\delta = \frac{V * d}{\Delta p} \tag{3}$$

According to the standard the test must be carried out at temperature 23±2°C and RH of 50±5 and 93% at different sides of specimen, the water vapour pressure difference between the two sides of specimen as $\Delta p = 1137$ Pa was calculated.

The possible interaction between thickness of paint layer and water vapour permeation coefficient was analysed (Fig. 3). It can be noticed that water vapour permeability properties are better when thickness of layers is higher.

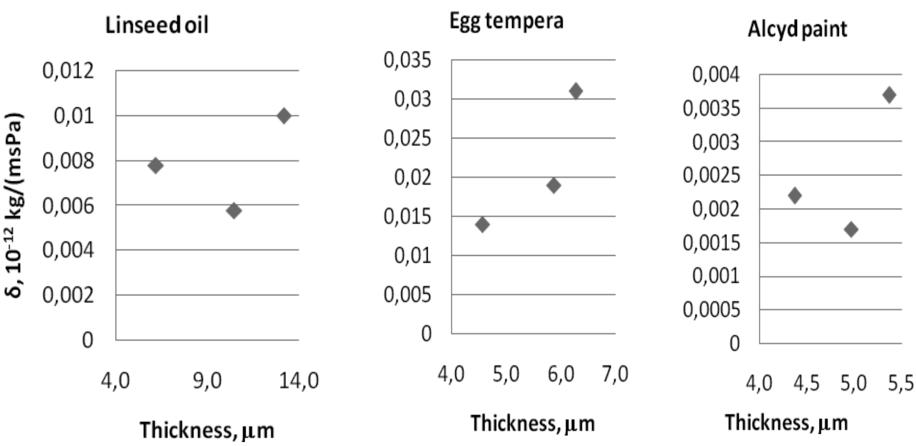

Figure 3. Water vapour permeation coefficient depending on the thickness of layers.

Water vapour permeability for 1-layer paint Δ_1 and 2-layer paint Δ_2 $(10^{-12}\text{*kg} (\text{m}^2\text{sPa})^{-1})$ was also calculated. Water vapour resistance of 1–layer paint or carton r 10^9 $\text{m}^2\text{sPa kg}^{-1}$ was also derived. These values can be used for diffusion calculations.

CONCLUSIONS

Knowledge about permeability of water vapour of paints (covers) enables us to design our living environment. The high rate of water-vapour permeability of casein paint indicates that casein paint does not have influence on the sorption ability of substrate (mortar or plaster) or diffusion through the boarders. The values of egg tempera and linseed oil can be taken into account during the designing process of boarders and have influence on diffusion and sorption process as well. Depending on the construction solution of boarder or desired indoor climate conditions it could be useful to choose covering with high or lower water-vapour permeability.

Different pigments were used, but results are not sufficient for making any conclusions. Possible influence of pigment on water vapour transmission rate needs further investigation.

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REFERENCES

Antell, O., Brydolf, E., Hjorth, S-O. 1997. Painting of Houses With Traditional Paints. Swedish National Heritage Board, 1997, translated by Anu Saluäär (in Estonian).

Bristow, I. C. 1996. Architectural colour in British Interiors 1615–1840. New Haven and London: The Paul Mellon Centre for Studies in British Art by Yale University Press. 214–216.

Cumming, E. 2006. Hand, Heart and Soul. The Arts and Crafts Movement in Scotland. Edinburgh: Birlinn. p. 19.

Handbook of Building Construction. 2010. Editor Tiit Masso. Tallinn, Ehitame Kirjastus, 576 pp. (in Estonian).

EVS-EN ISO 7783-1:2001 Paints and varnishes - Determination of water-vapour transmission rate – Part 1: Dish method for free films. Eesti Standardikeskus, 11 pp.

EVS-EN ISO 7783-2:2001. Paints and varnishes – Coating materials and coating systems for exterior masonry and concrete – Part 2: Determination and classification of water-vapour transmission. Eesti Standardikeskus, 8 pp.

Hu, Y., Topolkaraev, V., Hiltner, A., Baer, E. 2000. Measurement of Water Vapour Transmission Rate in Highly Permeable Films. Journal of Applied Polymer Science **81,** 1624–1633.

Maddison, M., Mauring, T., Kirsimäe, K., Mander, Ü. 2009. The humidity buffer capacity of clay–sand plaster filled with phytomass from treatment wetlands. Building and Environment 44, 1864–1868.

Minke, G. 2006. Building with Earth, Birkhauser, Publishers for Architecture, Basel. 199 pp.

PSZ, Polnoe Sobranie Zakonov Rossiijskoi Imperii, (PSZ), T.XXXIV. 1817, No. 27180.

Thornton, P. 1984. Authentic Décor; The Domestic Interior, 1620–1920, London and New York: Weidenfeld & Nicolson and Viking, 221–225.