Radovan Despot

Mechanism of infection of fir wood joinery; Part 1: Exposure conditions, moisture content and permeability

Mehanizam infekcije jelove građevne stolarije; dio 1: Uvjeti izlaganja, sadržaj vode i permeabilnost

Original scientific paper - Izvorni znanstveni rad
Received - primljeno: 17. 07. 1998. • Accepted - prihvaćeno: 24. 09. 1998.
*UDK 634*812; 634*833.15; 634*829*

SUMMARY • *In Croatia the primary raw material for joinery production is fir wood (Abies alba Mill). The L-joints made of home-grown fir sapwood and prepared according to EN 330 were used to establish the colonisation and infection of micro-organisms in comparison with the performance of untreated and 1% TnBTO treated L-joints by ten-minute immersion. The L-joints surfaces were treated with two types of coat, and exposed on three different climate sites in Croatia: Zagreb, Zalesina and Rovinj. The first type of coat was alkyd paint and the second was a stain in three different colours: white, brown and black. The untreated L-joints were examined after 1, 2, 3, 4, 6, and 12 months and treated after 12 months of exposure. The influence of the climate, and the type of coat of paint was decisive on the moisture contents, permeability and colonisation. In Zalesina, a mountain site with the highest average air humidity and a great amount of precipitation colonisation was fastest and strongest due to the largest average moisture contents and permeability. The least moisture content and the least permeability occurred in the L-joints exposed in Rovinj, a site on the Adriatic coast, particularly on those coated with the darker stain. It was due to the well known vaporous diffusivity of the stains and the fact that Rovinj had the highest number of sunny days during the first two months of exposure when the dark stain surfaces absorbed many more of the sun's*

Autor je docent na Šumarskom fakultetu Sveučilišta u Zagrebu.
Author is an assistant professor at the Faculty of Forestry of the Zagreb University.

heat rays which caused accelerated seasoning, lower moisture contents and a lower increase in permeability. The influence of the coated colours later was not significant. Between the average moisture content and an average permeability of the untreated and treated L-joints coated with stain there were no signifficant differences. In comparison of untreated and treated L-joits coated with alkyd paint greater moisture contents and greater increase in permeability occurred on the untreated L-joints.

Key words: *Fir-wood , L-joints, exterior joinery, moisture content, permeability, preservation,*

SAŽETAK • *Osnovni je zadatak rada bio na temeljuu dugotrajnog izlaganja simuliranih elemenata vanjske građevne stolarije, tzv. L-spojeva (EN 330), izrađenih od domaće drvne sirovine i premazanih domaćim premazima za drvo, ustanoviti pojavu, slijed i mehanizam infekcije, odnosno proces truljenja drva. U radu su prikazana klimatske obilježja mjesta izlaganja i rezultati ispitivanja sadržaja vode i promjene permeabilnosti kao presudni čimbenici u naseljavanju mikroorganizama i infekciji drva.*

Za potrebe ispitivanja izrađene su dvije skupine L-spojeva. U prvoj su bili L-spojevi prethodno zaštićeni sredstvom za zaštitu drva od mikroorganizama, a u dugoj su bili kemijski nezaštićeni L-spojevi. Zaštićeni i nezaštićeni L-spojevi premazani su potom lazurnim, odnosno alkidnim premazom hrvatskog proizvođača i to u jednom od tri tona, bijelom, smeđem i crnom. Za kemijsku zaštitu L-spojeva prve skupine upotrebljena je 1%-tna otopina TnBTO-a , a zaštita je obavljena desetminutnim potapanjem. Za mjesta izlaganja odabrani su Zagreb, s naznakama tipične kontinentalne klime, Zalesine, s naznakama planinske vlažne klime i Rovinj, s naznakama mediteranske suhe klime. Nezaštićeni L-spojevi sukcesivno su ispitivani na sva tri mjesta izlaganja nakon 1, 2, 3, 4, 6 i 12 mjeseci izlaganja, a zaštićeni L-spojevi koji su bili izloženi samo u Zagrebu, ispitani su samo nakon 12 mjeseci izlaganja.

Klima i vrsta premaza bili su najvažniji čimbenici promjena sadržaja vode i permeabilnosti. U Zalesini, planinskome mjestu s velikom prosječnom vlažnošću zraka i velikim brojem kišnih dana u godini, prosječni sadržaji vode u L-spojevima i prosječne permeabilnosti drva bili su najveći, odnosno napad mikroorganizama i infekcija bili su najjači. Nasuprot tome, najmanji prosječni sadržaji vode i najmanje povećanje prosječnih permeabilnosti bile su zabilježene u L-spojevima izlaganim u Rovinju.

Neovisno o mjestu i duljini izlaganja, pokazalo se da je zbog dobro poznate paropropusnosti lazurnih premaza infekcija mikroorganizmima bila slabija na L-spojevima premazanim lazurom. Tamnije lazurirane površine jače su apsorbirale toplinske zrake, što je pak rezultiralo bržim sušenjem, manjim sadržajima vode i slabijim naseljavanjem drva bakterijama i gljivama što je pak utjecalo na slabije povećanje permeabilnosti. Neovisno o vrsti premaza, utjecaj tonova premaza pokazao se važnim za sadržaj vode, osobito tijekom prva dva mjeseca izlaganja, kada je toplinsko djelovanje sunca bilo izrazitije, a zagrijavanje tamnijih premaza jače. Ovisno pak o vrsti premaza i mjestu izlaganja, najveći prosječni sadržaji vode i najveća mikrobiološka aktivnost zabilježeni su na kemijski nezaštićenim bijelim alkidnim L-spojevima izlaganim u Zalesinama, a najslabija na tamnim lazurama premazanim L-spojevima izlaganim u Zagrebu i Rovinju.

Usporedbom prosječnih sadržaja vode nezaštićenih i zaštićenih, 12 mjeseci izlaganih lazuriranih L-spojeva, nisu zabilježene signifikantne razlike. Istodobno su u nezaštićenih i zaštićenih L-spojeva premazanih alkidnim premazom signifikantno niži prosječni sadržaji

vode ustanovljeni u zaštićenim L-spojevima . Usporedbom prosječnih permeabilnosti svih nezaštićenih i zaštićenih, 12 mjeseci izlaganih L-spojeva, najveće povećanje permeabilnosti ustanovljeno je u nezaštićenih L-spojeva premazanih bijelim alkidnim premazom , a najmanje u zaštićenih L-spojeva premazanih lazurnim premazom.

Ključne riječi: *jelovina, vanjska stolarija, L-spojevi, kemijska zaštita, sadržaj vode , permeabilnost*

1.INTRODUCTION
1. Uvod

The lifetime of wooden products in out-door service depends on many factors. Those products, particularly external joinery, are exposed both to the abiotic and biotic factors and must be well protected particularly against micro-organisms which produce decay. However the application of experimental trials in the evaluation of preservative performance in outdoor situations out of ground contact is well established (Fougerousse 1976, Purslow and Williams 1978, Savory and Carey 1979, 1980, 1982, Carey and Bravery 1989). It is also suggested that destructive examination prior to obvious failure of the samples, could give early indications of the mechanism of infection and the relative efficacy of preservative treatments (Savory *et. al.* 1977).

The decaying of external joinery is a long process, so the major problem is the long-term nature of all the exposure trials (Carey 1982). The L-joints method which has been accepted as a European Norm since 1993 (EN 330) has enabled a number of investigations into the biodeterioration of exterior wooden joinery to be performed in service, both on untreated and preservative treated joinery.

The referent wood species for making the L-joints in those investigations was Scots Pine (*Pinus sylvestris* L.), particularly its sapwood. As Carey (1982) confirmed, micro-organisms invading the L-joints appear to have entered via the joint, since they were isolated first close to the joint, and then spread along the length of the members (Carey 1982, 1983). Colonisation occurs in the following sequence: bacteria, followed by moulds and blue stain fungi, soft rot fungi and basidiomycetes (Carey 1982, Mendes 1982, Le Poideven 1986, Despot 1996).

Each country, however, prefers the use of that home-grown wood species which constitutes significant resources and is traditionally used for joinery. The properties of that wood species, particularly its natural durability and permeability, sometimes are not acceptable.

Beside spruce, the main coniferous species in Croatia is silver fir (*Abies alba* Mill.) and therefore in the Croatian joinery industry fir-wood is a traditionally primary raw material. It is well known that fir-wood is not durable and a poorly permeable wood species (Petrić 1971, Petrić *et al.* 1990, Despot 1991 and 1996). During its out-door service, the fir-wood products, particularly external joinery, are simultaneously exposed to the abiotic and biotic degradation factors. As a wood with low durability, fir-wood must be well preserved against micro organisms particularly against the action of fungi. In this article, the aim was to establish the moisture conent and permeability of untreated and treated fir wood L-joints as main factors and indicators of microbial colonosation .

2. MATERIALS AND METHODS
2.. Materijali i metode

2.1. Material
2.1 Materijal

L-joints were prepared from an air dry stock of Croatian-grown silver fir sapwood (*Abies alba* Mill.) according to EN 330 (Figure 1).

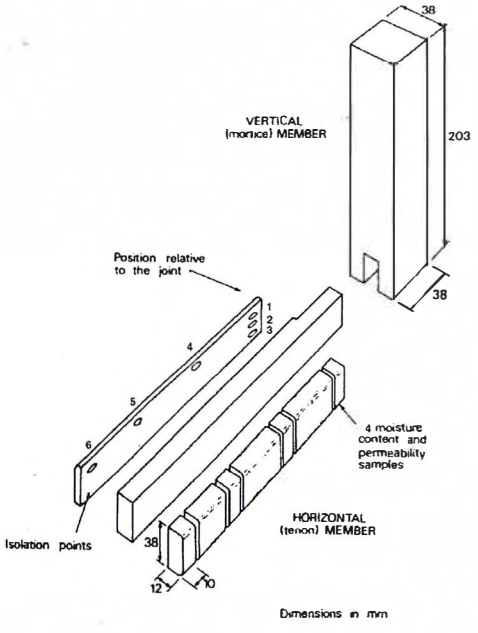

Figure 1.
Method of conversion of L-joint for visual assessment. • Postupak obrade i pripreme L-spoja za vizualna ispitivanja (Donji dio uzorka prikazan je u dijelovima-probama koje se od njega ispiljuju nakon izlaganja

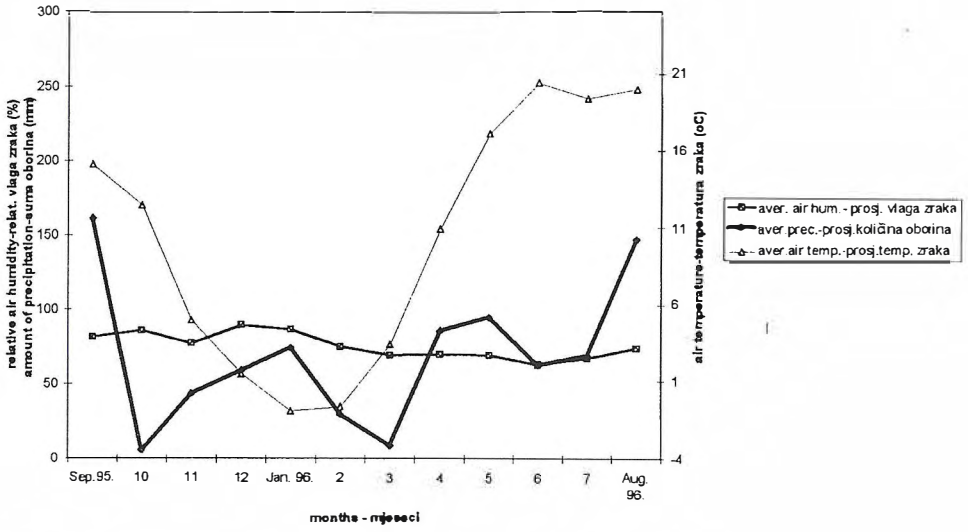

Figure 2. a) *Climatic characteristics of Zagreb • Klimatska obilježja Zagreba*

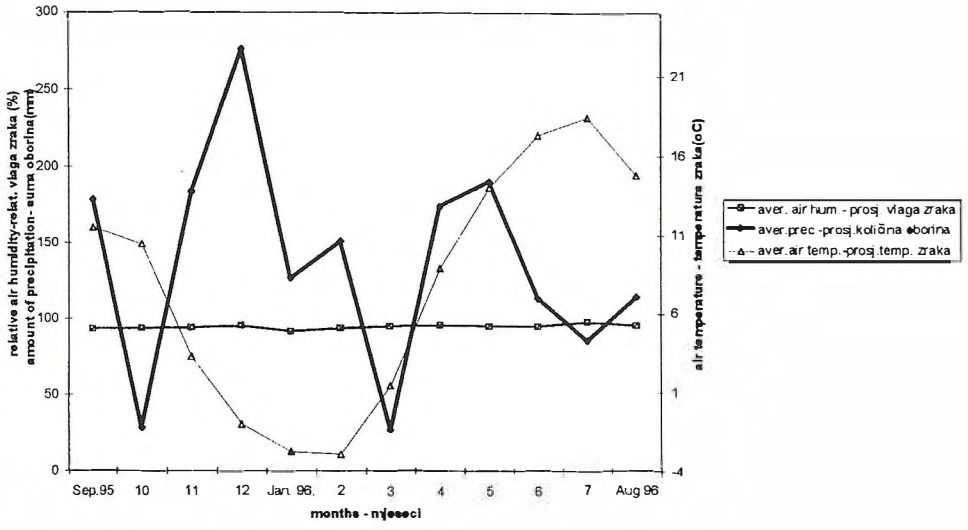

Figure 2. b) *Climatic characteristics of Zalesine • Klimatska obilježja Zalesina*

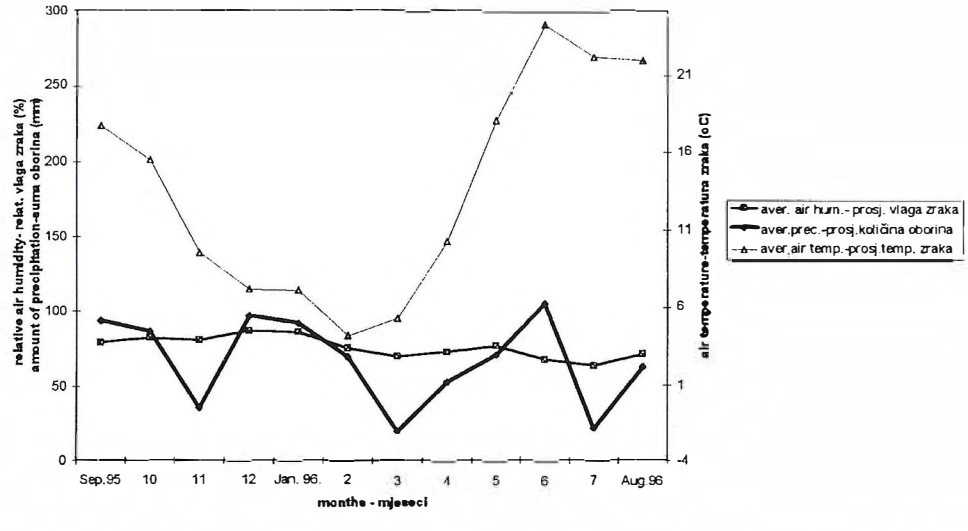

Figure 2. c) *Climatic characteristics of Rovinj • Klimatska obilježja Rovinja*

On each exposure site the number of untreated L-joints was equal. The preservative treated L-joints were prepared only for the examination after one year's exposure, and were exposed only in Zagreb. The untreated specimens were divided into groups for 1, 2, 3, 4, 6 and also 12 months exposure. The L-joints that were to be preservative treated were separated and each mortice and tenon was treated by immersion in the preservative solution, being weighed before and after the treatment to determine the uptake. A 1% by weight solution of the tri n-butyl tin oxide (TnBTO) in organic solvent "Shellsol E" was used for the preservation.

According to the type of coats there

were two main groups of L-joints. In the first group there were L-joints coated with a stain in three different colours: white, brown (teak) and black (ebony) and in the other one with alkyd paint, also in three different colours; white, brown-red and black. Both the coats of paint and stain were made in Croatia. The alkyd paint system applied consisted of: a.) first coat - wood primer, white, b.) second and third coat-alkyd paint, white, brown-red or black. The stain paint system employed consisted also of 3 coats. The end grain, opposite to the joint, was sealed with an epoxid resin with the flexibility and water resistance of modified coal tar pitch. As Miller and coworkers suggested (1987, 1995) this routine presents an appropriate protection. The vertical member of each L-joint was labelled with an aluminium numbered tag.

2.2. Methods
2.2. Metode rada

2.2.1 Preparation and exposure of samples
2.2.1 Izrada i izlaganje uzoraka

According to the EN 330, from the L-joints to be preservative treated, replicas were immersed ten minutes in the preservative solution. After drying for one week, standing on the ends remote from the joints, they were reassembled and then painted together with the untreated L-joints. Each coat was worked well into the splits and joints; at least 24 h was allowed between each paint application. After labelling, two coats of sealant were applied at 24 h intervals to the exposed end grain and lapped 4-5 mm over the paint system, to ensure a good seal. The paint film at each joint was broken by separating the two members and then reassembling the joint without pins or glue. Each treatment was exposed on a separate rack. There were three exposure sites with different climates: Zagreb with a typical continental climate (Figure 2.a), Zalesine with a mountain humid climate (Figure 2.b), and Rovinj with a typical Mediterranean climate (Figure 2.c).

The L-joints were exposed at each site facing south on plywood racks, 900 mm above the ground, sloping at 10 degrees to provide a water trap in the joint area. In Zagreb, the racks were placed on the flat and wide terrace of the Faculty of Forestry, Zagreb (Figure 3).

The racks on all the exposure sites were monitored from 1st September, 1995 till 1st September, 1996.

2.2.2. Sampling
2.2.2. Uzrokovanje

Each L-joint group consisted of three replicas. After each exposure period, the L-joint groups were observed for visible signs of deterioration. The end seal overlapping the paint film was removed, to facilitate accurate sawing, and the horizontal member was sawn into samples for measurements of moisture content, permeability and the isolation of the micro-organisms (Figure 1.).

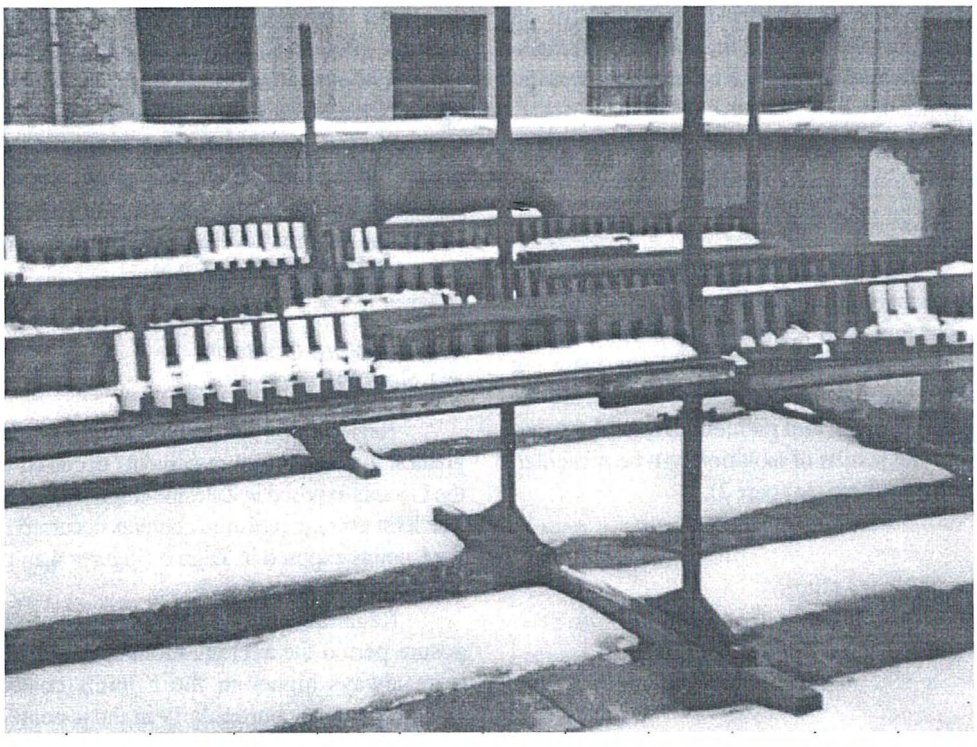

Figure 3.
The L-joints exposed in Zagreb • L-spojevi izloženi u Zagrebu

2.2.2.1. Permeability and moisture content determination
2.2.2.1. Određivanje sadržaja vode i permeabilnosti

One block from the end of each unpainted and untreated L-joint tenon was weighed, air dried, then oven dried for 18 hours to a constant weight at 50°C. After immersion for 10 seconds in dekalin (decahydronaphthalene), it was weighed again and the initial uptake of dekalin was established. After that, the dekalin was allowed to evaporate, than after 3 days each block was vacuum impregnated with water, soaked for 2 hours, air dried and subsequently oven dried at 50°C and retested with dekalin again to provide the measurement of the initial permeability of each L-joint (Carey 1982, 1995).

In order to establish and correctly calculate the final permeability of the exposed L-joints, the permeability and moisture content of the coated unexposed L-joints were also determined.

Four blocks from one side of each exposed L-joint, numbered consecutively from the joint end, were weighed, air dried, then oven dried to a constant weight at 50°C. After immersion for 10 s in dekalin, they were left to remove the excess solvent and then re-weighed. The uptake of dekalin was calculated to provide the measure of permeability. Then the "coefficient of Microbial Activity" ("cMA value") for each replica was calculated:

(final permeability /initial permeability) x 100 = cMA (%)

When the solvent had evaporated, the blocks were oven dried at 103°C for 18 hours, re-weighed and their individual moisture contents at the time of sampling was determined.

2.2.2.2. Isolation studies
2.2.2.2. Izolacija

A 6 mm thick strip from the other side of each replica was sampled on its freshly sawn face at 6 set positions. Four samples, each approximately 15 mm long, were cut from each position using 6 mm wide U-shaped gouge, and planted on one of the media. The results of isolation will be presented in the next article (part 2).

3. RESULTS
3. Rezultati

3.1. Moisture contents
3.1. Sadržaji vode

The moisture content and permeability data have been averaged for the three replicas per treatment these being sampled after each exposure period on each exposure site. The moisture contents of the untreated L-joints coated with stain are shown in Figure 4.a - i , and the moisture contents of the untreated L-joints coated with alkyd coats are shown in Figure 5.a - i. The moisture contents of all preservative treated L-joints are mentioned in the discussion.

3.2. Permeability
3.2. Permeabilnost

The change in permeability of all the exposed L-joints on all the sites is presented in Tables 1 and 2. In all cases and for each group of L-joints those changes are described with the average "coefficient of Microbial Activity value" ("cMA value") which was calculated according to the initial and final permeability of each L-joint.

4. DISCUSSION
4. Rasprava

From the comparison of all the exposed L-joints on all the three sites, it is clear that the site climatic characteristics, and the types of coat were decisive on the moisture content and permeability.

As was established, in comparison with the other sites, Zalesine has the greatest amount of precipitation and the highest average relative air humidity (Figure 2.b). This was recorded after nearly each period of exposure. At the same time, the highest average air temperatures, the least amount of precipitation and the least average air humidity occurred in Rovinj (Figure 2.c).

4.1. Moisture Contents
4.1 Sadržaji vode

Regardless of the type of coat of paint the greatest average moisture contents occurred in the L-joints exposed in Zalesine (Figures 5.g - i). The least average moisture contents occurred in the L-joints exposed in Zagreb (Figures 4.a - c) and Rovinj (Figures 4.g - h).

Regardless of the exposure site and exposure period the average moisture contents were always higher in the L-joints coated with alkyd coats, particularly in those coated

with white alkyd paint and exposed in Zagreb and Zalesina (Figures 5.a and 5.d). Because of the well known stain vapour diffusivity the least average moisture contents occurred in the L-joints coated with stain, particularly on those coated with the brown (Figures 4.b and 4.h) and black (Figure 4.c) stain and exposed in Zagreb and Rovinj. The surfaces of those L-joints absorbed much more heat, particularly during the first two months of exposure. Such quick heating caused accelerated seasoning, lower moisture contents and fi-

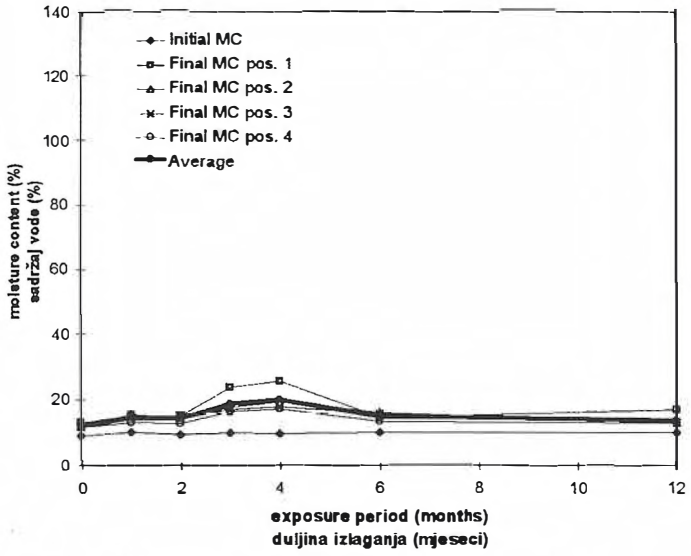

Figure 4. a)
The Moisture contents of L-joints coated with WHITE STAIN and exposed in Zagreb • Sadržaj vode u L-spojevima premazanim BIJELOM LAZUROM i izlaganim u Zagrebu

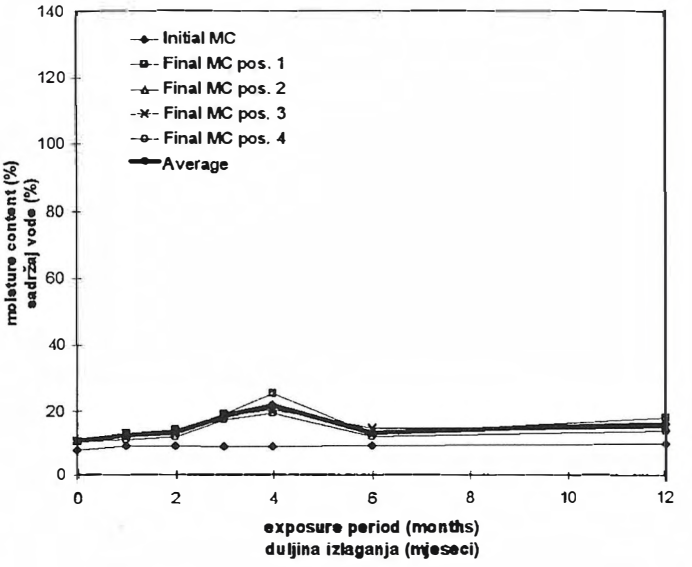

Figure 4. b)
The Moisture contents of L-joints coated with TEAK STAIN and exposed in Zagreb • Sadržaj vode u L-spojevima premazanim SMEĐOM LAZUROM i izlaganim u Zagrebu

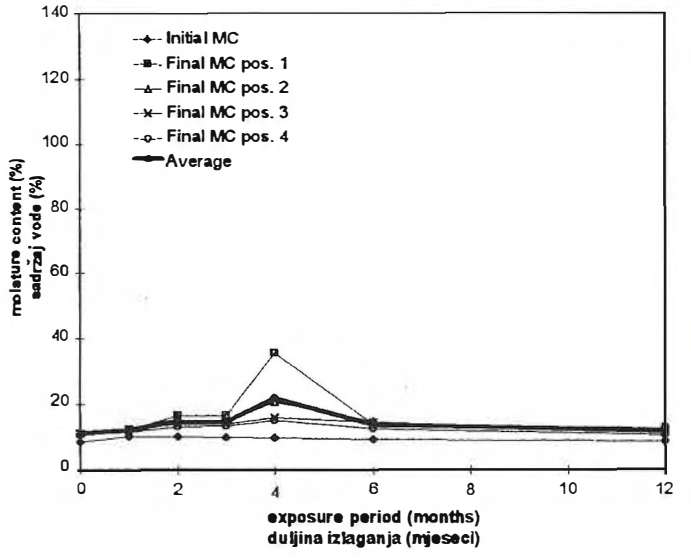

Figure 4. c)
The Moisture contents of L-joints coated with BLACK STAIN and exposed in Zagreb • Sadržaj vode u L-spojevima premazanim CRNOM LAZUROM i izlaganim u Zagrebu

nally a lower colonisation of micro-organisms. The exception between the L-joints were the two L-joints, both coated with black stain, one exposed 4 months in Zalesina, and the other exposed 6 months in Rovinj. Regardless of the mentioned stain vapour diffusivity, the average moisture contents of those two L-joints were unusually high.

Regardless of the type of coat the influence of colour was noticeable during the first two months of exposure, particularly with the L-joints coated with the brown and

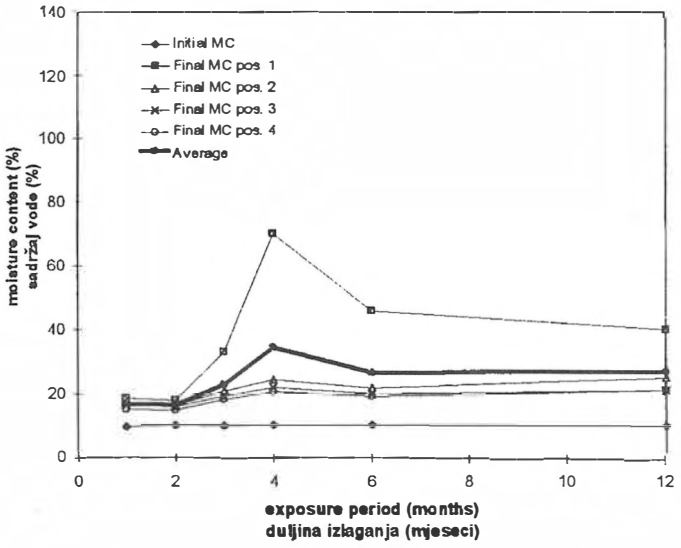

Figure 4. d)
The Moisture contents of L-joints coated with WHITE STAIN and exposed in Zalesine • Sadržaj vode u L-spojevima premazanim BIJELOM LAZUROM i izlaganim u Zalesinama

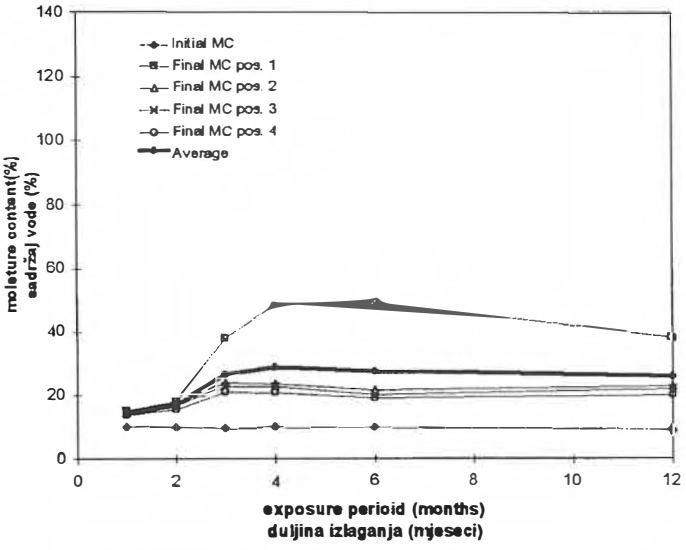

Figure 4. e)
The Moisture contents of L-joints coated with TEAK STAIN and exposed in Zalesine • Sadržaj vode u L-spojevima premazanim SMEĐOM LAZUROM i izlaganim u Zalesinama

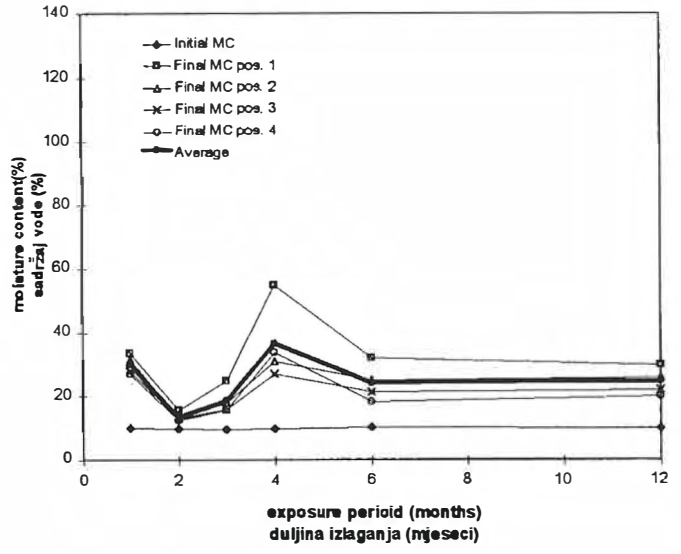

Figure 4. f)
The Moisture contents of L-joints coated with BLECK STAIN and exposed in Zalesine • Sadržaj vode u L-spojevima premazanim CRNOM LAZUROM i izlaganim u Zalesinama

black alkyd paint and exposed in Zagreb and Zalesina (Figures 4.a - c and 4.d - f.).

There were no significant differences between the average moisture contents of the 12 months exposed untreated and treated L-joints coated with stain. At the same time the average moisture contents of the untreated L-joints coated with alkyd coats were higher than the same treated L-joints. Of all the preservative treated L-joints, those coated with white alkyd paint had the greatest average moisture contents (36%.).

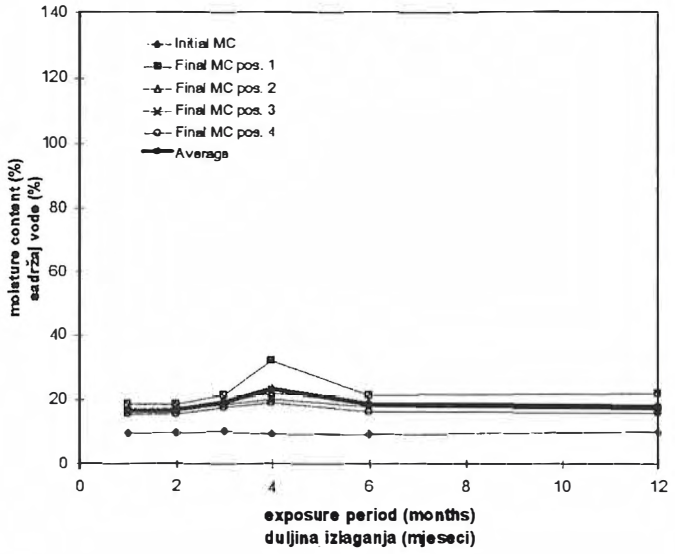

Figure 4. g)
The Moisture contents of L-joints coated with WHITE STAIN and exposed in Rovinj • Sadržaj vode u L-spojevima premazanim BIJELOM LAZUROM i izlaganim u Rovinju

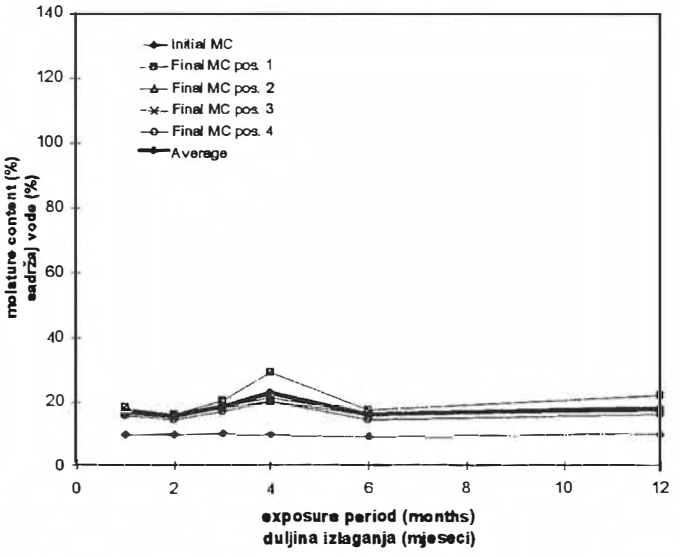

Figure 4. h)
The Moisture contents of L-joints coated with TEAK STAIN and exposed in Rovinj • Sadržaj vode u L-spojevima premazanim SMEĐOM LAZUROM i izlaganim u Rovinju

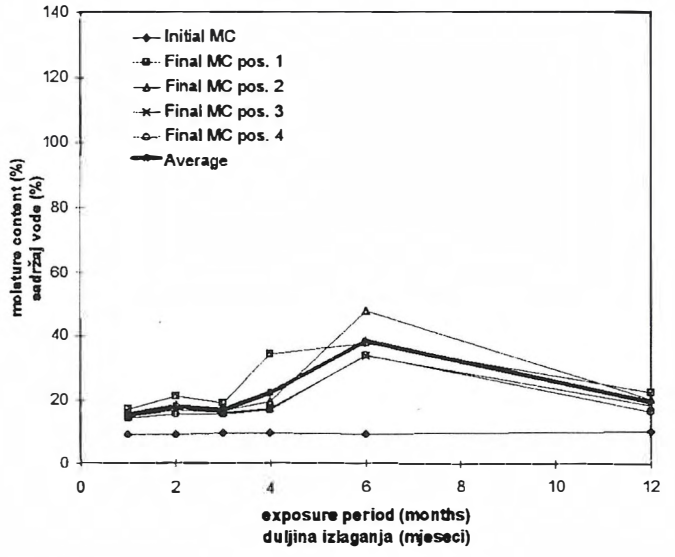

Figure 4. i)
The Moisture contents of L-joints coated with BLACK STAIN and exposed in Rovinj • Sadržaj vode u L-spojevima premazanim CRNOM LAZUROM i izlaganim u Rovinju

4.2. Permeability
4.2. Permeabilnost

In all the exposed L-joints the higher moisture contents caused stronger microbial activity which significantly increased the permeability. Carey suggested (1995) that the "cMA values" between 100% and 175% indicate intensified microbiological activity. If the "cMA value" is smaller than 100% there should be no significant biodeterioration in the L-joint. If the "cMA value" is above 175% and is intolerably high it could

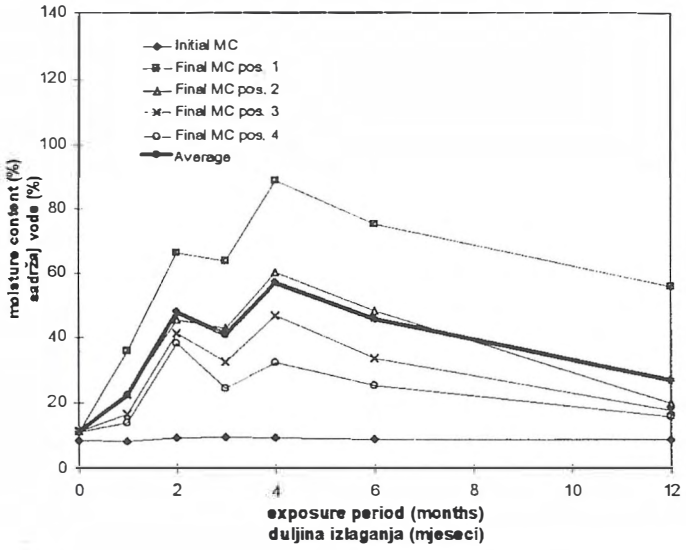

Figure 5. a)
The Moisture contents of L-joints coated with WHITE ALKYD and exposed in Zagreb • Sadržaj vode u L-spojevima premazanim BIJELIM ALKIDOM i izlaganim u Zagrebu

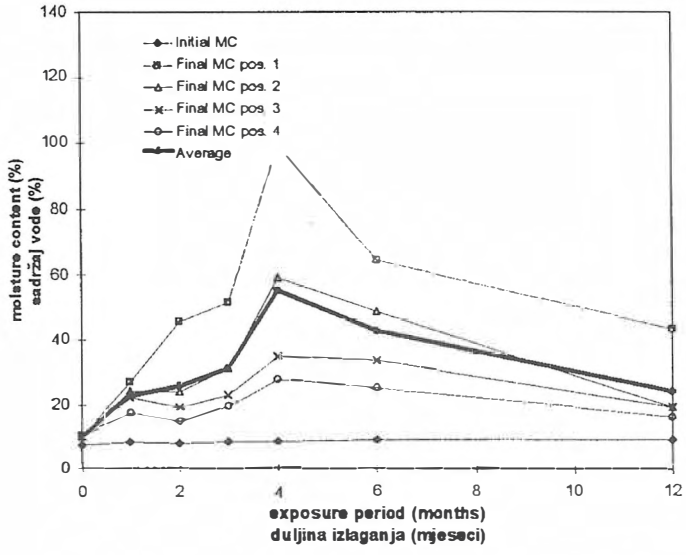

Figure 5. b)
The Moisture contents of L-joints coated with BROWN ALKYD and exposed in Zagreb • Sadržaj vode u L-spojevima premazanim SMEĐIM ALKIDOM i izlaganim u Zagrebu

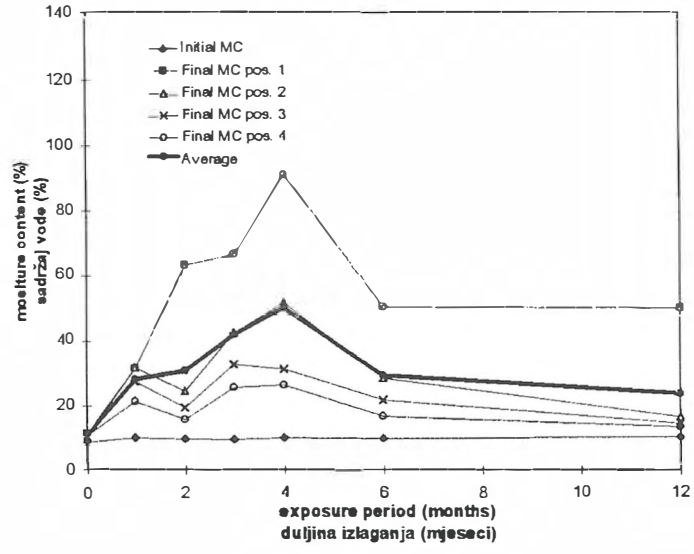

Figure 5. c)
The Moisture contents of L-joints coated with BLACK ALKYD and exposed in Zagreb • Sadržaj vode u L-spojevima premazanim CRNIM ALKIDOM i izlaganim u Zagrebu

be suspected that the high porosityis influenced by other factors than the micro biological activity.

The significance of the increase in permeability has a dual character. The first is a low permeability and nonuniform structural characteristics of fir sapwood (Petrić 1971, Petrić *et al.* 1990, Despot 1991) and the second is the type of coat. Although fir sapwood is more permeable than fir heart-wood, it is at the same time less permeable than pine sapwood (Despot 1991, Petrić 1971). Fir sap-

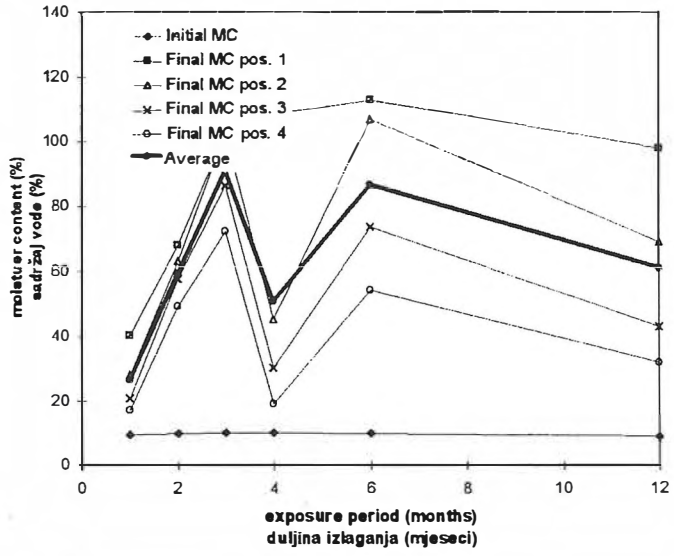

Figure 5. d)
The Moisture contents of L-joints coated with WHITE ALKYD and exposed in Zalesine • Sadržaj vode u L-spojevima premazanim BIJELIM ALKIDOM i izlaganim u Zalesinama

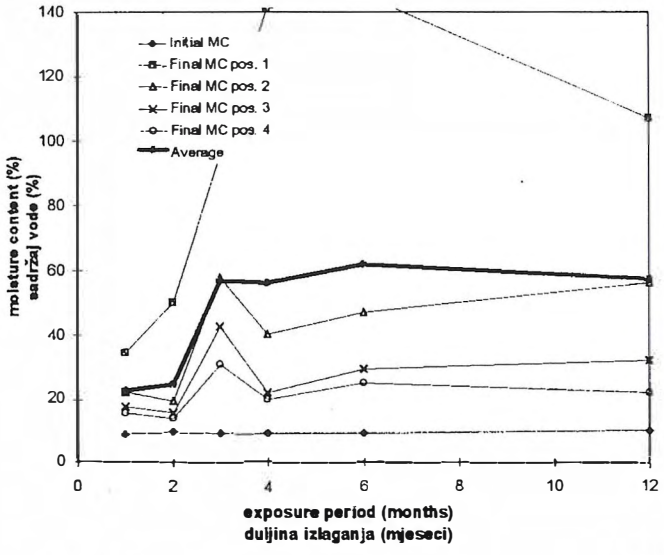

Figure 5. e)
The Moisture contents of L-joints coated with BROWN ALKYD and exposed in Zalesine • Sadržaj vode u L-spojevima premazanim SMEĐIM ALKIDOM i izlaganim u Zalesinama

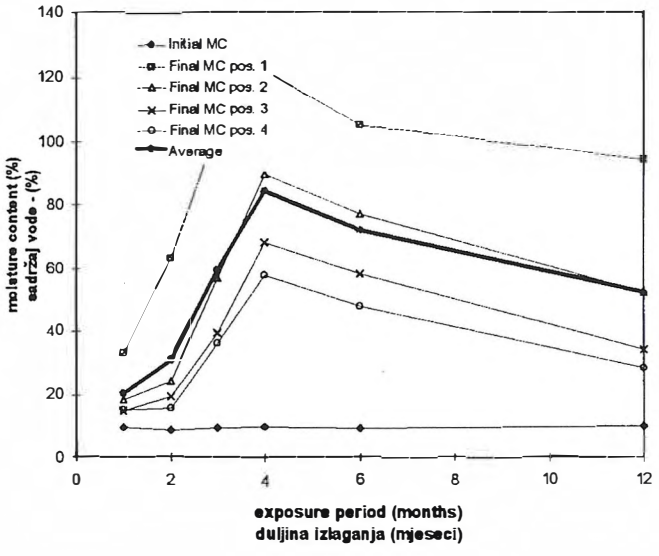

Figure 5. f)
The Moisture contents of L-joints coated with BLACK ALKYD and exposed in Zalesine • Sadržaj vode u L-spojevima premazanim CRNIM ALKIDOM i izlaganim u Zalesinama

wood properties caused the specific distribution of moisture via tenon and influenced on the intensity of the microbial activities in all the exposed L-joints. In mainly all the L-joints, the increased and irregular swelling and shrinking close to the joint, caused strong internal strains in that zone. This produced numerous micro splits and cracks which caused increased permeability. In many cases, the average "cMA value" was above 175% (Table 1 and 2).

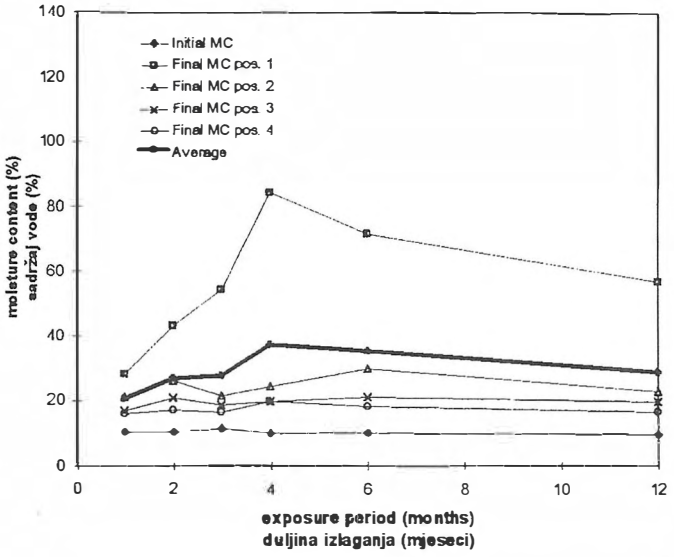

Figure 5. g)
The Moisture contents of L-joints coated with WHITE ALKYD and exposed in Rovinj • Sadržaj vode u L-spojevima premazanim BIJELIM ALKIDOM i izlaganim u Rovinju

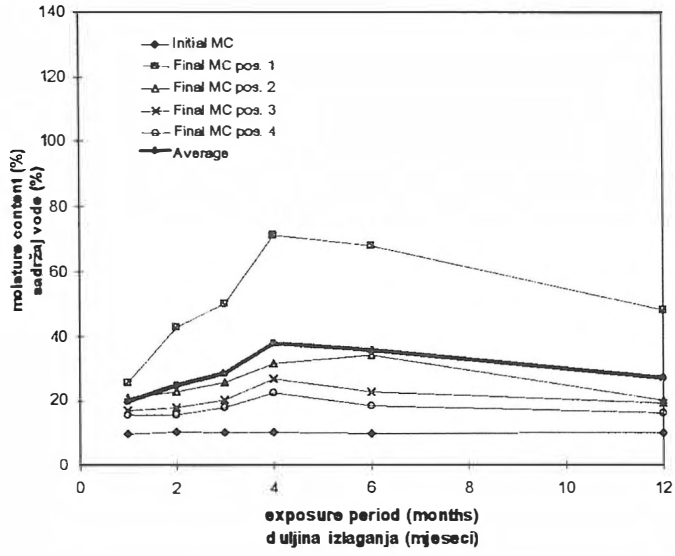

Figure 5. h)
The Moisture contents of L-joints coated with BROWN ALKYD and exposed in Rovinj • Sadržaj vode u L-spojevima premazanim SMEĐIM ALKIDOM i izlaganim u Rovinju

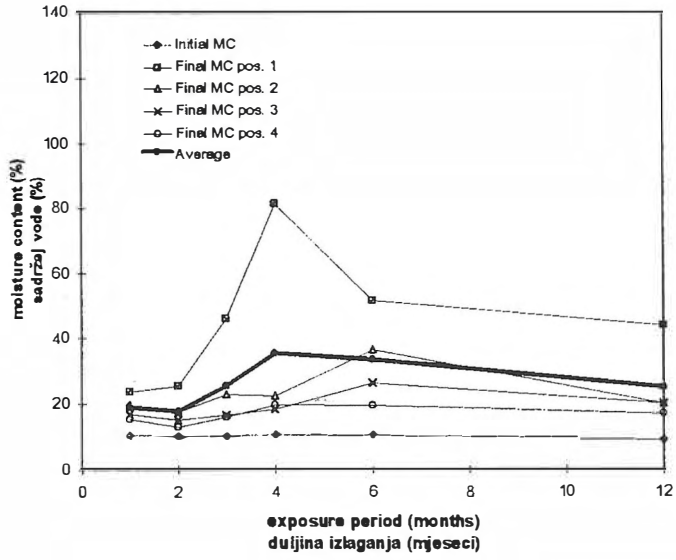

Figure 5. i)
The Moisture contents of L-joints coated with BLACK ALKYD and exposed in Rovinj • Sadržaj vode u L-spojevima premazanim CRNIM ALKIDOM i izlaganim u Rovinju

The alkyd coat (Table 2) delayed water much more than the stain coat did (Table 1), so the microbial activity was stronger and faster in the L-joints coated with alkyd coats. On the other hand due to the mentioned stain vaporous diffusivity, the lower average moisture contents and lower average "cMA values" occurred on the L-joints coated with stain. The highest average moisture contents and beside them the highest "cMA values" occurred particularly in the L-joints coated with white alkyd coat and exposed in Zagreb and Zalesine (Table 2). It happened close to the joint, at positions 1 and 2, but in a few of them (12 months exposed) the increase of the "cMA values" happened at position 4 where the coats of sealant were broken, so water, bacteria and fungi had penetrated inside. Those L-joints were wetter after rain and, therefore, more likely to decay at a faster rate (Carey 1982).

The smallest average "cMA values" occurred in the L-joints coated with the brown (teak) stain and exposed in Zagreb and Rovinj (Table 1).

Exposure periods (months)	cMA in L-joints coated with stain coats															
	< 100 %				> 100 % < 175 %				> 175 % (unaccepted)							
	ZAGREB		ZAL.	ROV.	ZAGREB		ZAL.	ROV.	ZAGREB		ZAL.	ROV.				
	U	T	U	U	U	T	U	U	U	T	U	U				
	w t b	w t b	w t b	w t b	w t b	w t b	w t b	w t b	w t b	w t b	w t b	w t b				
0	♦ ♦ ♦ ♦ ♦ ♦ ♦ ♦ ♦	♦ ♦ ♦ ♦ ♦ ♦ ♦ ♦ ♦			♦	♦										
1	♦ ♦ ♦ ♦ ♦ ♦		♦ ♦ ♦ ♦ ♦ ♦	♦ ♦ ♦ ♦ ♦ ♦	♦ ♦ ♦		♦ ♦	♦ ♦ ♦					♦			
2	♦ ♦ ♦ ♦		♦ ♦ ♦ ♦ ♦ ♦	♦ ♦ ♦ ♦ ♦ ♦	♦ ♦ ♦ ♦			♦			♦	♦ ♦ ♦				
3	♦ ♦ ♦ ♦		♦ ♦	♦ ♦ ♦ ♦ ♦	♦ ♦		♦ ♦ ♦ ♦	♦ ♦			♦					
4	♦ ♦ ♦		♦ ♦ ♦	♦ ♦ ♦	♦ ♦ ♦ ♦		♦ ♦ ♦ ♦	♦ ♦ ♦	♦ ♦		♦ ♦	♦				
6	♦ ♦		♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦ ♦		♦	♦ ♦ ♦	♦ ♦		♦ ♦	♦				
12	♦ ♦	♦ ♦ ♦	♦ ♦	♦ ♦	♦ ♦ ♦ ♦ ♦	♦ ♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦		♦					

Table 1

The "cMA values" of L-joints coated with STAIN coat and exposed at three sites in Croatia (Zagreb, Zalesine, Rovinj) • Koeficijenti mikrobiološke aktivnosti (kMA) u L-spojevima premazanim LAZURNIM premazom i izlaganih na tri mjesta u Hrvatskoj (Zagreb, Zalesine, Rovinj)

Legend:
U - untreated; T - treated; w - white; t - teak; b - black (ebony) • U - nezaštićeno; T-zaštićeno; w-bijelo; t-tikovina; b-crno(ebanovina)

Exposure periods (months)	cMA in L-joints coated with alkyd paints															
	< 100 %				> 100 % < 175 %				> 175 % (unaccepted)							
	ZAGREB		ZAL.	ROV.	ZAGREB		ZAL.	ROV.	ZAGREB		ZAL.	ROV.				
	U	T	U	U	U	T	U	U	U	T	U	U				
	w r b	w r b	w r b	w r b	w r b	w r b	w r b	w r b	w r b	w r b	w r b	w r b				
0	♦ ♦ ♦ ♦ ♦ ♦ ♦ ♦ ♦	♦ ♦ ♦ ♦ ♦ ♦ ♦ ♦ ♦			♦											
1	♦ ♦ ♦ ♦		♦ ♦ ♦ ♦ ♦	♦ ♦ ♦ ♦ ♦	♦		♦ ♦ ♦	♦ ♦ ♦	♦ ♦		♦					
2	♦ ♦ ♦		♦ ♦	♦ ♦ ♦ ♦ ♦	♦ ♦ ♦ ♦		♦ ♦ ♦ ♦	♦	♦		♦	♦ ♦				
3	♦ ♦ ♦ ♦			♦ ♦ ♦ ♦	♦ ♦ ♦		♦ ♦	♦ ♦ ♦			♦ ♦ ♦ ♦					
4	♦				♦ ♦ ♦ ♦		♦ ♦ ♦ ♦	♦ ♦ ♦ ♦ ♦	♦ ♦ ♦	♦	♦ ♦ ♦ ♦	♦				
6	♦ ♦ ♦			♦ ♦ ♦	♦ ♦ ♦ ♦		♦ ♦ ♦ ♦	♦ ♦ ♦ ♦			♦ ♦ ♦	♦				
12	♦ ♦	♦ ♦		♦ ♦ ♦	♦ ♦ ♦ ♦ ♦ ♦ ♦ ♦ ♦		♦ ♦ ♦ ♦	♦ ♦ ♦ ♦ ♦	♦ ♦	♦	♦ ♦ ♦					

Table 2

The cMA's of L-joints coated with ALKYD paint and exposed at three sites in Croatia (Zagreb, Zalesine, Rovinj) • Koeficijenti mikrobiološke aktivnosti (cMA) u L-spojevima premazanim ALKIDNIM premazom i izlaganih na tri mjesta u Hrvatskoj (Zagreb, Zalesine, Rovinj)

Legend:
U - untreated; T - treated; w - white; r - redbrown; b - black • U - nezaštićeno; T - zaštićeno; w - bijelo; r - smeđe; b - crno

5. CONCLUSION
5. Zaključak

The average moisture content and permeability ("cMA values") of untreated and treated fir L-joints, coated with alkyd and stain coats and exposed on three sites in Croatia depended on two main factors. The first was the site's climatic characteristics and the second was the type of coat.

During all the exposure periods the amount of precipitation and the average air humidity was higher in Zalesina than on the other sites, so the highest average moisture contents and the greatest increase of permeability occurred at the L-joints coated with white alkyd paint and exposed in Zalesina.

On the other hand, Zagreb and particularly Rovinj were the sites with the higher average air temperature, with a lower amount of precipitation and a lower average air humidity. Regardless of the type of coat, the average moisture contents and increase of permeability were lower in the L-joints exposed in Zagreb and Rovinj than in the L-joints exposed in Zalesina. Regardless of the site and period of exposure the L-joints coated with stain always had lower average moisture contents and a lower increase in permeability than those coated with alkyd paint. It happened due to the well known stain vapour diffusivity. The influence of the colours of the coats was significant during the first two months of exposure. Then, the dark surfaces absorbed many more heat rays which caused accelerated seasoning, lower moisture contents and a lower increase of permeability. Regardless of the type of coat, the average moisture content and average permeabiliy occurred on the treated L-joints and were lesser than on the untreated L-joints.

The established moisture contents and permeability were important and decisive for the explanation of the processes of colonisation. Those processes and all the results will be presented in the other article.

6. REFERENCES
6. Literatura

1. EN 330: 1993: Wood preservatives Field test method for determing the relative protective effectiveness of a wood under a coating and exposed out-of-ground contact: L-joint method.: 14.
2. Carey, J.K. 1979: A possible method for enumerating Bacteria in wood. Int. Boiodeterioration Bull. 15,(4): 119-123.
3. Carey, J.K. 1980: The mechanism of infection and decay of window joinery. PhD Thesis, University of London.
4. Carey, J.K. 1982: Assessing the Performance of Preservative treatments for Wooden Joinery. Holz als Roh-und Werkstoff, 40, 269-274.
5. Carey, J.K. 1983: Colonisation of Wooden Joinery. Biodeterioration 5, 13-25.
6. Carey, J.K., Bravery, A.F. 1984: Co-operative Research Project on L - joint testing, Progress report to March 1984. International Research Group on WoodPres. Doc. No.,IRG/WP/2211.
7. Carey, J.K., Bravery, A.F. 1985: Developments in the assessment of joinery preservatives. Rec. of the 1985 Ann. Conv. of the Brit. Wood Pres. Assoc.: 3-11.
8. Carey, J.K., Bravery, A.F. 1987: In-service Decay of Timber Joinery and its Eradication, Paper presented at the 7th International Biodeterioration Conference: 8
9. Carey, J.K. Bravery, A.F. 1989: A technique for Assessing Efficacy Against Decay Fungi of Preservative Treatments Applied to Wood, International Biodeterioration 25: 439-444.
10. Carey, J.K. 1995: Personal discussion.
11. Clubbe, C. P. 1980: Colonisation of wood by microorganisms. PhD Thesis,, University of London, Imperial College.
12. Despot, R. 1991: Improvement of Fir-wood permeability cased by bacteria action, MSc thesis, Forestry faculty of Zagreb: 89.
13. Despot, R. 1996: Contribution to understanding of mechanismm of infection and rotting of fir-wood joinery, PhD thesis, Forestry faculty of Zagreb: 386.
14. Fougerousse, M. 1976: Wood preservatives: Field test out of ground contact. Brief survey of principles and methodology.The International Research Group of Wood Preservation, Doc No. IRG /WP/ 269: 34.
15. Le Poidevin, J. 1986: Timber permeability: Significance for Joinery Decay. A thesis submitted for the degree of Master of Philosophy of the University of London.
16. Mendes, F. 1982: Microflora associated with treated exterior joinery. PhD Thesis, University of London.
17. Miller, E.R., Boxall, J., Carey, J.K. 1987: External joinery: end grain sealers and moisture control. Building Research Establishment Information Paper IP20 /87.
18. Miller, E.R. 1995: Personal discussion.
19. Petrić, B. 1971: The Influence of Wood Structure on Permeability of Softwoods. Šumarski list 95, 5-6: 125-140.
20. Petrić, B., Despot, R., Šćukanec, V., Trajković, J. 1989: Protection of Fir wood Joinery, by Double Vacuum method, Drvna industrija 40 (11-12): 231-235.
21. Petrić, B., Trajković, J. & Despot, R. 1990: Variation of fir wood structure from region of Gorski kotar, Drvna industrija 41 (3-4): 43-49.
22. Purslow, D.F., Williams, N.A. 1978: Field trials on preserved timber out of ground contact. (Progress report to 1977) Build. Res. Establ. Current Paper 78/78.
23. Savory, J.G., Carey, J.K., Sttribbling,, M.A. 1977: Laboratory examination of simulated window joinery after out door exposure. Mater. Orga. 12: 315-326.
24. Savory,J.G.,Carey,J.K. 1979: Decay in external framed joinery in the United Kingdom. Journal Institute Wood Science 8 (4): 176-180.
25. Turkulin, H. 1990: Durability of laminated wood joinery. MSc thesis, Faculty of Forestry Zagreb: 312