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Resistograph investigation of Scots pine wood utility poles in the State Museum at Majdanek

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Abstract: *Resistograph investigation of Scots pine wood utility poles in the State Museum at Majdanek.* Any activity relative to the protection of monuments is determined by the requirements of fidelity and authenticity in the preservation of the place and landscape. On the site of the State Museum at Majdanek, the former infrastructure of the concentration camp has been reconstructed. An element there of are pine wood utility poles.The present research project involved an assessment of their state of preservation with the method of resistography. The poles were subjected to inspection and preliminary acoustic assessment by means of tapping. Resistograph drillings were made radially, perpendicularly to the side surface of the poles, at various heights. A number of the poles have been found to be highly degraded in their sapwood part, which threatens their stability – these poles require immediate replacement. The principal cause of the degradation areactive feeding grounds of European house borer.The results of the research confirmed the effectiveness of resistographyin on-site assessment of the state of preservation of wooden poles.

Keywords: Scots pine wood, natural durability, resistography, wooden pole, protection of monuments, Majdanek

INTRODUCTION

Scots pine ranks first among forest stands in Poland. As much as 58% of the total forest area (ca. 6 m. ha) corresponds to this species, which gives the stock of large timber at 950 m. m^3 [Lasy w Polsce '*Forests in Poland*' 2018].Pinewood, as the species of wood dominant on the Polish market for decades, was and still is widely used [Kozakiewicz 2019]. It served as construction timber for the purpose, among others, of constructing utility poles [Galewski and Korzeniowski 1958].

Pinewood has good mechanical properties; it shows, however, high variability depending also on the burden of inherent defects which result from the wood's anatomical structure [Warywoda 1957, Galewski and Korzeniowski 1958, Wagenführ 2007]. For this reason, construction timber has to be sorted and has to comply with relevant standards. The requirements for utility poles are at present comprised in ISO 15206:2010; formerly they were stated in the overall technical requirements for utility poles to be applied in measurement and classification of timber in PGLLP (http://drewno.zilp.lasy.gov.pl/drewno/Normy/).

Pinewood has medium natural durability (resistance to biotic factors). The resistance to fungi, defined and published in standard EN 350:2016, of pine hardwood zone amounts to 3-4, and that of sapwood to 5 (the lowest durability).In accordance with data quoted in the above standard, pine sapwood is also susceptible to insect attack, including that of European house borer. For this reason, it is advised that wood for external use should be impregnated. The effectiveness of the impregnation is determined, among others, by the penetration depth of the impregnating substance; in previous centuries it was enhanced by perforating the wood surface. Utility poles were impregnated in the same way [Bub-Bodmar and Tilger 1922, Kozakiewicz and Matejak, 2011]. Despite impregnation treatment, unfortunately, wooden utility poles often undergo degradation as a result of biotic factors.

One of the non-destructive methods used to assess the technical condition of wood is resistography. This method was developed in 1985, and then gradually perfected, together with the drilling appliances dedicated to the purpose [Rinn et al. 1990], and finally patented [Rinn 1990].

The usefulness of resistography in analyzing annual growth rings and density profiles of wood was confirmed in many research projects [e.g. Rinn et al. 1996, Winnistorfer et al. 1995, Kubus 2009, Rinn 2012], and so was its effectiveness in evaluating the health of wooden elements [e.g. Bernatowicz and Krajewski1998, Krajewski and Andres 2003].

The purpose of this work is to assess the state of preservation of pinewood utility poles on the site of State Museum at Majdanek by using resistography. The requirements of a museum exhibition and modern technical standards do not always meet. Even if a certain solution is not the best one from the viewpoint of construction health it is often forced in an element of landscape which materially affects the perception of museum space. For these reasons, some of the wooden construction elements in historical monuments are at a higher risk of suffering from the effects of exposure to destructive factors.

MATERIAL AND METHODS

In July 2018, research into the state of preservation of wooden utility poles located on the site of the State Museum at Majdanek was carried out. The work was preceded by an analysis of museum documentation (approximation of the poles' age) and confirmatory identification of wood species.

The examination included a survey of the poles with regard to their compliance with the overall technical requirements for utility poles to be applied in the measurement and classification of timber in PGLLP (http://drewno.zilp.lasy.gov.pl/drewno/Normy/).

So-called non-destructive tests were performed with IML 1410 resistograph which had the following characteristics: resolution0.04 mm, drilling depth up to 410 mm, feed rate 60 to 1500 mm/min. The Resistograph 1410 system consists of a drill, a bag with control panel, batteries, printer, and built-in memory. Printouts at 1:1 scale are made simultaneously with the drilling for which special dedicated drills of unique geometry are used, as presented in figure 1.

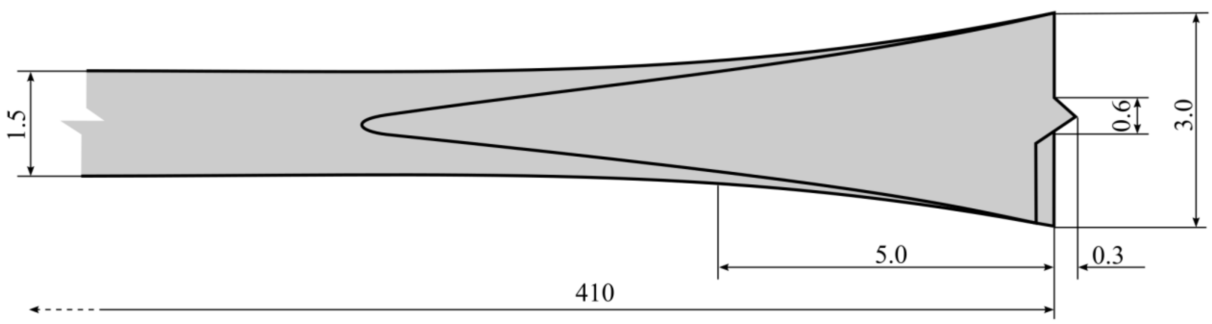

Figure 1. Shape and dimensions (in mm) of the tip of the resistograph steel drill

In total, several dozen bores were drilled in 20 out of 56 wooden poles located on the Museum site. All the drillings performed during the research were made at a feed rate of 200 mm/min. The resultant records of power input (drilling resistance) correlated with wood density were analyzed by using the B-Tools Pro 1.6 specialist program dedicated for IML resistographs. Measurements of wood moisture content were carried out with a MastechMS6900 hygrometer using the resistance method in accordance with EN 13183-2:2002.

RESULTS AND DISCUSSION

The utility poles which are at present located on the site of the State Museum at Majdanek do not date back to the time of World War II; the former poles were dismantled immediately there after and used in rebuilding other objects damaged after the war. The new poles were installed ca. 1962 during the restoration of camp infrastructure. Until then, the power line had been only suspended directly between barrack roofs.

a) b)

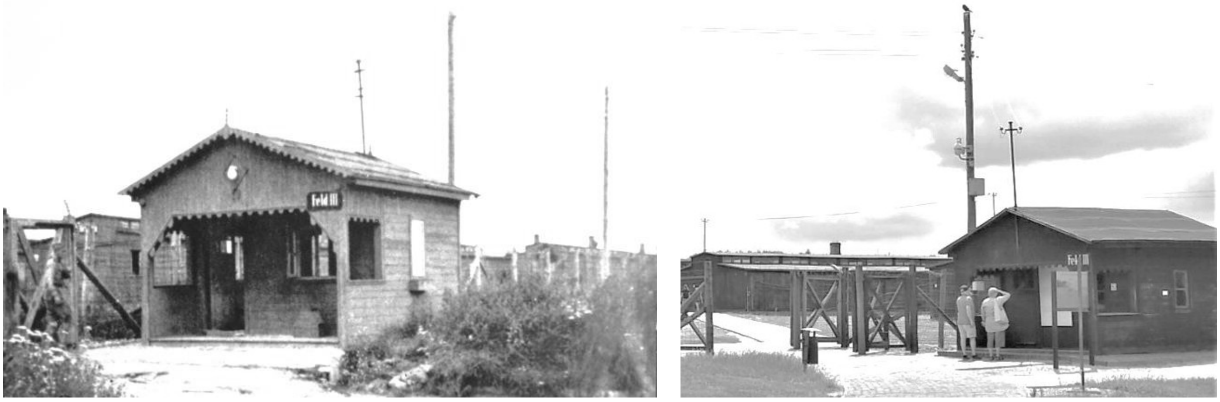

Figure 2. Majdanek camp - view of the entrance to Field III. a) immediately after the liberation in 1944 (reproduction of the plaque from the exhibition at the State Museum at Majdanek), b) current state photo of the same place (2019)

The poles were not reconstructed in the original places, which can be seen when comparing archive photographs (figures 2 – 4).It is not only the location of the poles that differs from the original. The present-day route of the power line is also different from that visible in photographs and archival camp electrification plans.

Figure 3. The camp at Majdanek after liberation in autumn 1944. - view of the western fence of the prisoner section with the original overhead power line visible (reproduction of the plaque from the exhibition at the State Museum at Majdanek).

a) b)

Figure 4. The State Museum at Majdanek - view of the western fence of the prisoner section a) condition from 1957 (photo: Edward Hartwig reproduction from PMM collection reference number XVII.7.4.20), b) current condition photo of the same place with a visible overhead power line (2019)

The present position of utility poles on the site of State Museum at Majdanek is shown in Figure 5. The location of new poles has been adapted to current needs and technical requirements. The poles that are in use at present were installed at different times and replaced gradually as damage appeared. They were made in accordance with the regulations and standards which were binding at the time of their reconstruction. The latest replacements were carried out in 2016; the five poles installed at that time were already supplied with the required CE certificates which confirmed their compliance with European standards (ISO 15206:2010).The former, original poles were sunk into the ground; at present they are all raised above ground level and fastened on reinforced concrete crutches. This prevents biodegradation of the poles' lower sections. Moreover, the lower sections have been impregnated with bituminous substances.

An analysis of the wood's structural characteristics confirmed that the poles were made of round timbers of Scots pine (*Pinus sylvestris* L.).

A survey of the poles with reference to the overall technical requirements for utility poles to be applied in measurement and classification of timber in PGLL Prevealed quality discrepancies in three of the 56 poles examined. Two poles had irregular twisting of fibers where the deviation from straight line exceeded 90° measured in the pole's top half, one had two-sided curvature and a rotten knot whose diameter exceeded 60 mm (Fig.6). Most of the poles had marks of resin blazes, in none of them, however, excessively deep streaks were found.

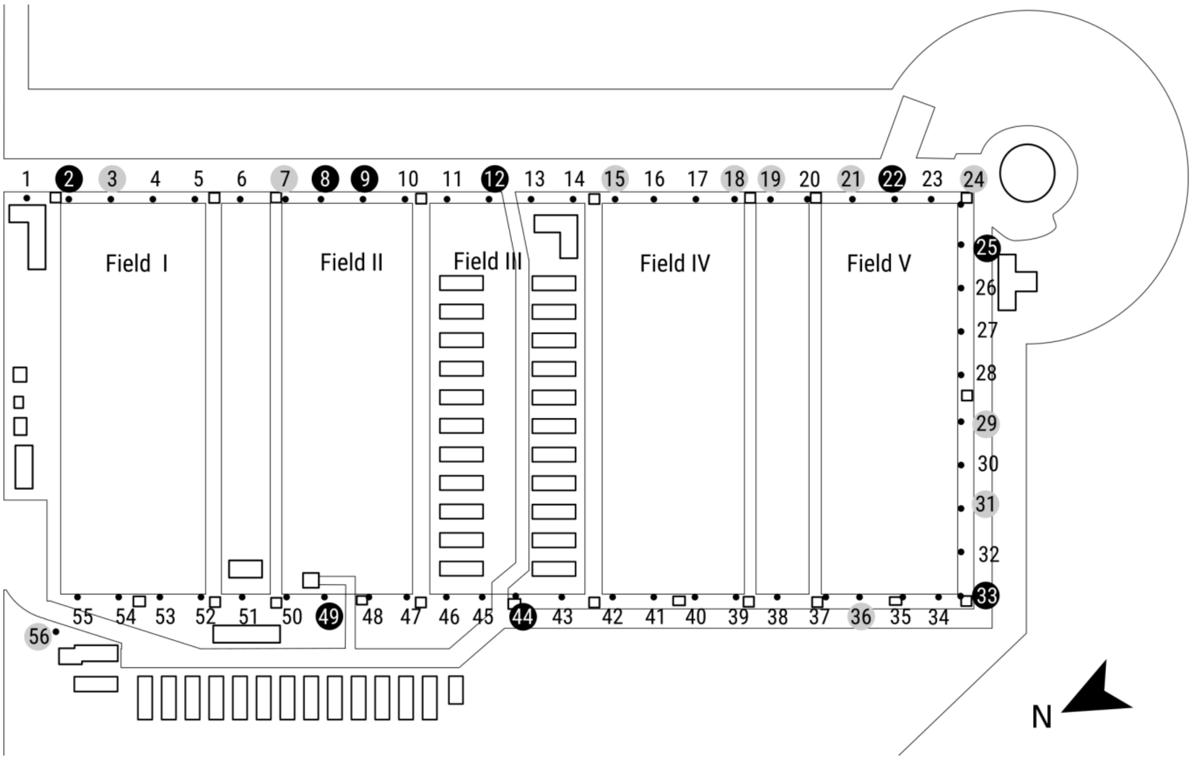

Figure 5. The current arrangement of wooden utility poles on the site of the State Museum at Majdanek - damaged poles are marked in black and the remaining poles (examined with a resistograph) are marked in gray

a) b)

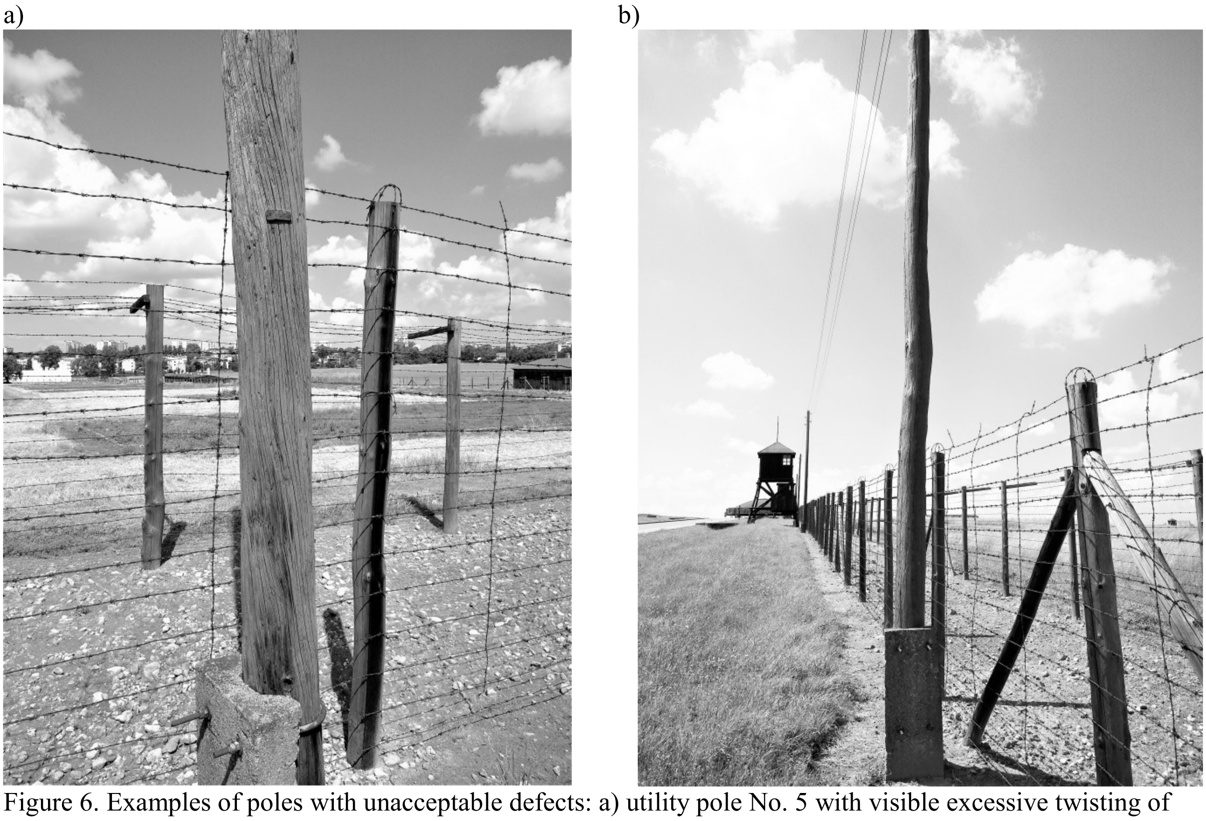

Figure 6. Examples of poles with unacceptable defects: a) utility pole No. 5 with visible excessive twisting of fibers, b) utility pole No. 13 with visible curvature.

The length of electrodes permitted for the moisture content measurements to be taken only in the circumferential sections of the poles. The measurements were carried out in summer, in warm, dry weather. No increased moisture content was noted in any of the examined poles. All the measurements fell within the scope of hygroscopic equilibrium of wood in conformity with the environment conditions. Wood moisture content ranged from 10.1% to 11.2%. The moisture content value from all measurements averaged 10.7% with variability ratio at 2.7%.

Following a preliminary acoustic assessment by means of tapping, 20 poles were singled out for resistograph testing, several of them with distinct beat effect, several others with correct sound, for reference (figure 5). Resistograph tests disclosed pole damage to occur usually at the height ca. 1 m above ground level. The damage was caused by feeding larvae of European house borer (*Hylotrupes bajulus* L.). Despite the lack of serious external damage visible to the naked eye, resistograph tests revealed reduced wood density in eleven poles; in nine of them the reduction was very considerable. In all these cases the damaged area was the sapwood. In three poles, the sapwood at the place of measurement was almost entirely destroyed (no drilling power registered). A typical result for such a case (pole No. 8) is presented in figures 7 and 8. The side surface of the pole showed marks of a resin blaze as well as distinct cracks and a few exit holes of European house borers' galleries. The total width of the damaged area was approximately 11 cm on a diameter of 22 cm. This corresponded approximately to the share of sapwood zone in the trunk of a mature pine tree (Dzbeński et. al. 2000).

The damage to the sapwood zone varied in intensity with the height above ground level. Measurements at different heights showed diversed is tribution of density, well visible on the printouts of pole No. 33 tests (figures 9 and 10).Wood examined nearer its bottom end did not show changes in density. It was only above the concrete crutch holding the pole that reduced density in the sapwood part was clearly observable.

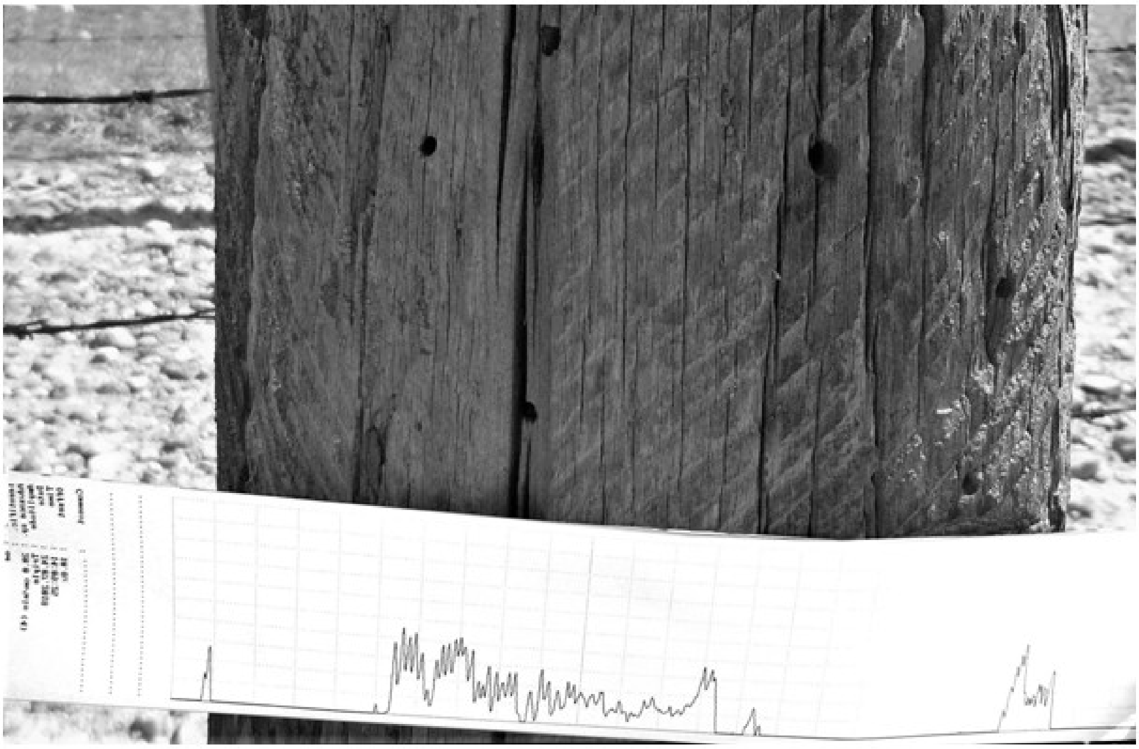

Figure 7. Fragment of utility pole No. 8 with the printout of drilling power correlated with the density profile along its entire diameter at a height (photo: Rafał Krajewski, 2018).

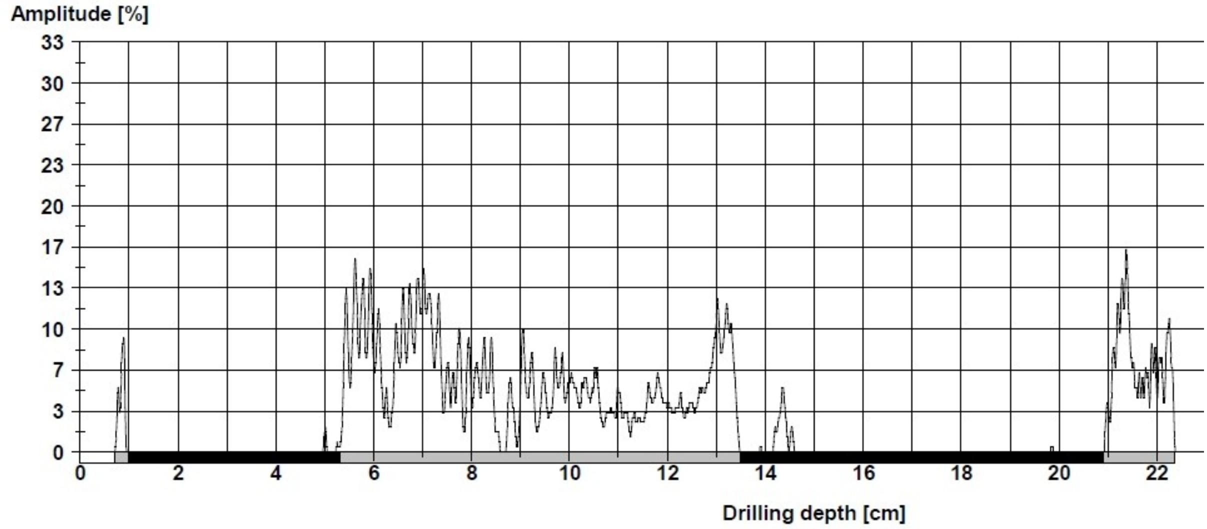

Figure 8. Analysis of the results of resistographic tests of utility pole No. 8 using the B-Tools Pro 1.6 program - the gray shade indicates fragments with typical wood density and black with reduced density

A lesser extent of damage, comprising only a fragment of the sapwood ring, was observed in eight poles, as exemplified in figure 10 (pole No. 33). Bores made at the same height but from different directions did not reveal losses in wood density. No changes in wood density were noted in the bottom sections of the poles (figure 9), despite the damage observed in the upperparts.

Resistograph tests are effective in evaluating the state of preservation of wooden elements [Bernatowicz and Krajewski 1998, Krajewski and Andres 2003] but they require a comprehensive approach. In the analyzed case of utility poles, the visual inspection for the occurrence of defects and the test drillings were equally important.

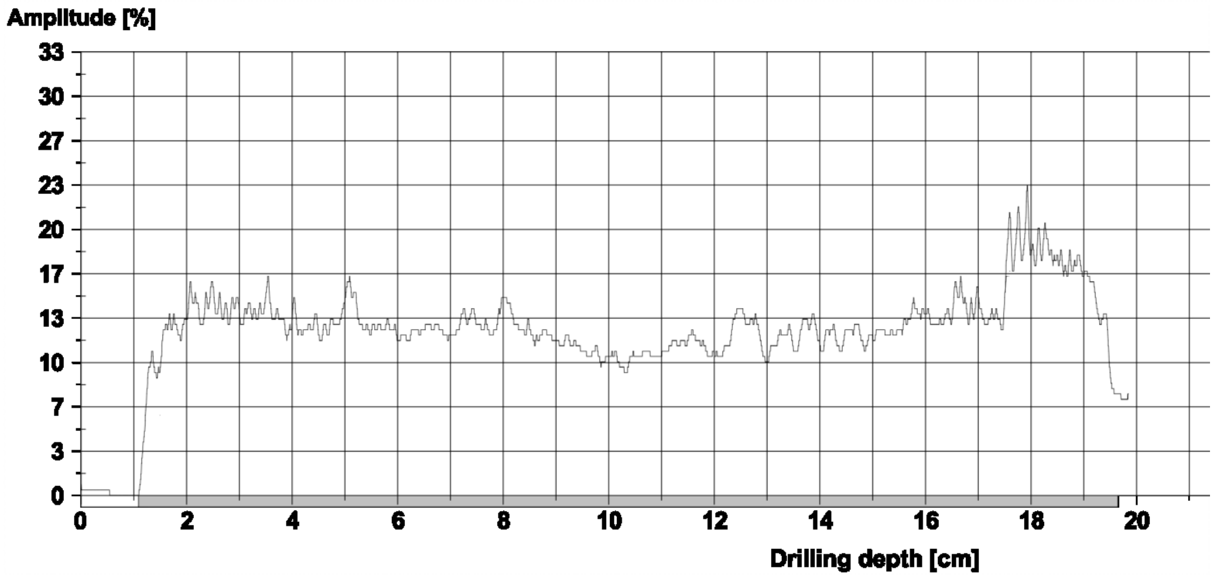

Figure 9. Changes in wood density in utility pole No. 33 - a bore at a height of 100 mm from the bottom end shows no change in density - fragments with a typical (average for pine wood) density level are marked in gray.

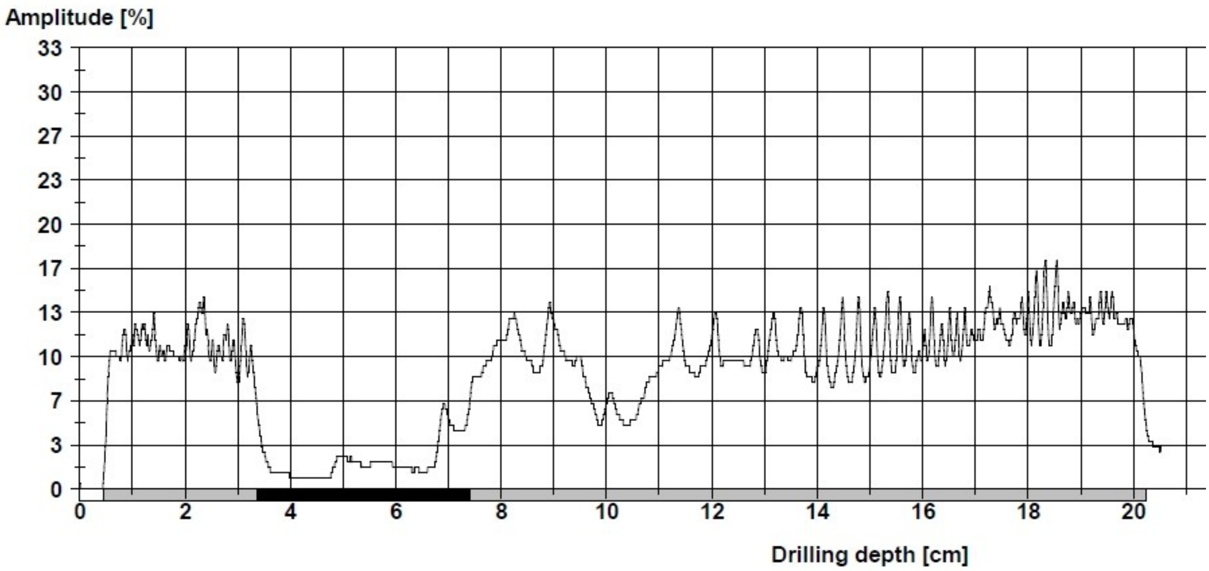

Figure 10.Changes in wood density in utility pole No. 33 - a hole at a height of 700 mm from the bottom end shows local density reduction - the gray shade indicates typical wood density and black shade reduced wood density

It is significant that the sapwood damage observed in the poles begins at the depth ca. 1 cm from the side surface. The thin surface layer of sapwood provides a kind of thermal insulation for the stenothermic (Unger et al. 2013) larvae of the insect, which feed a little deeper.

Some of the poles without visibly or audibly perceptible changes were preventively tested with the resistograph and showed no reduction in wood density.

It is necessary to monitor the preservation of pinewood elements continuously, because of a high risk of them being infested by xylophages insects which cause considerable loss of material. The resistograph method is highly useful in conducting such tests, as it allows for a quick examination of the state of wood constructions.

CONCLUSIONS

On the basis of visual examination and resistograph tests of pinewood utility poles at the site of the State Museum at Majdanek, the following conclusions have been drawn:

1. With regard to the presence of anatomical defects permissible in accordance with overall technical requirements for utility poles, three out of 56 poles examined did not meet the qualitative conditions.
2. The moisture content of the poles' near-surface wood amounted to ca.10.7%, which conformed with the weather conditions existing at the time. By using the acoustic method of tapping, a possibility of internal destruction in more than ten poles was discovered.
3. As a result of resistograph tests, the presence of serious damage of sapwood areas infested by European house borer (*Hylotrupes bajulus* L.) was confirmed, and the extent of such damage was determined in 8 utility poles.
4. The effectiveness of resistograph tests in wooden structures with insect-caused damage requires selecting appropriate places for bores as well as making several diametrical trial drillings at various heights and from various directions.

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Streszczenie: *Badania rezystograficzne sosnowych słupów teletechnicznych na terenie Państwowego Muzeum na Majdanku.* Na terenie Państwowego Muzeum na Majdanku częściowo odtworzono dawną infrastrukturę obozu. Jednym z jej elementów są sosnowe słupy teletechniczne. W ramach niniejszej pracy oceniono stan ich zachowania z wykorzystaniem metody rezystograficznej. W pierwszej kolejności obiekty poddano oględzinom pod kątem spełnienia ramowych warunków technicznych na słupy teletechniczne oraz wstępnej ocenie metodą dźwiękową przez opukiwanie, a także pomiarom wilgotności drewna. W wytypowanych 20 słupach dokonano średnicowych wierceń rezystografem w ich przekrojach poprzecznych na różnych wysokościach. Na postawie analizy danych z rezystografu stwierdzono, że część słupów jest silnie zdegradowana w części bielastej, co grozi utratą ich stateczności – słupy te wymagają natychmiastowej wymiany. Głównym czynnikiem powodującym degradację są aktywne żerowiska larw spuszczela pospolitego, które znalazły tam dogodne warunki bytowania. W ramach podjętych badań potwierdzono przydatność i skuteczność metody resystograficznej do terenowej oceny stanu zachowania słupów drewnianych.

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