FOLIA FORESTALIA POLONICA

© PAN Series B, Issue 40, 101-109, 2009

# BENDING CREEP BEHAVIOUR OF ORIENTED STRAND BOARD OSB/4 LOADED IN THE PLANE OF PANEL

Ryszard Plenzler, Łukasz Miler

Faculty of Wood Technology
Poznań University of Life Sciences

SYNOPSIS. Three months' duration creep tests in four-point bending were carried out on 12 mm thick oriented strand board OSB/4. Bending samples 600 by 33 mm were loaded in the plane of panel. Twelve samples were divided into three groups, each tested under another stress level: 21, 42 and 53% of the modulus of rupture. The results of the creep tests were approximated using the creep functions of three-, four- and five-element viscoelastic models. Additionally, a destructive test was conducted on 48 samples to obtain the modulus of rupture of OSB/4 loaded in the plane of panel.

KEY WORDS: oriented strand board (OSB), creep, viscoelasticity, creep compliance, creep model, bending, modulus of rupture (MOR), stress

## INTRODUCTION

During the last few decades the interest of the building industry in the use of wood-based panel products as the webs of composite I-beams and box beams or columns has all the time increased. Oriented strand board (OSB) is a relatively new kind of such panel products, designed especially for the building applications and produced in Poland since 1997. The webs of composite structural elements with wood or LVL (laminated veneer lumber) flanges are usually made of oriented strand board OSB/3, predestined for the use under wet conditions or of higher-load capacity OSB/4, predestined for the use under wet conditions too (PN-EN 300). The design of composite structural elements requires not only the knowledge of elastic and strength properties of materials used (wood or LVL and OSB) but also their rheological constants. The elastic and strength properties of the domestic oriented strand board (especially of the OSB/3 type) are already quite well recognised (Szyperska and Nożyński 1999, Wilczyński and Gogolin 1999, Plenzler and Górecki 2002, Plenzler and Pałubicki 2006). The characteristic values of some elastic constants and strengths of OSB panels appropriated for the structural design are inserted into the Polish Standard PN-EN 12369-1.

The creep behaviour of traditional particleboards has been comparatively often investigated during the last decades (Pierce et al. 1985, Dinwoodie et al. 1991, 1992, Zhou et al. 2001). Most creep experiments were carried out in bending, on particleboard samples loaded perpendicularly to the plane of panel. The investigations on the creep behaviour of oriented strand board were similar in a manner but not so numerous (McNatt and Laufenberg 1991, Pu et al. 1992 a, b, 1994, Laufenberg et al. 1999). In consideration of the use of OSB plates as the webs of composite structural elements, where two-dimensional stress state (plane stress) is observed, the elastic, strength and rheological data obtained for oriented strand board loaded in the plane of panel are of the special importance. The creep data for the domestic OSB plates are rather insufficient. Pałubicki and Plenzler (2004) reported creep test results of the OSB plates loaded in the plane of panel in four-point bending. The samples of oriented strand board OSB/3 10 mm thick were investigated for a period of 72 days under four stress levels: 30, 40, 50 and 60% of MOR (modulus of rupture). The values of rheological constants were calculated using the three-parameter creep function of the standard model. The authors stated that the deflections of the samples increased during the creep test nearly linearly with respect to the stress level up to 50% of MOR. The creep process of the samples tested at the stress level of 60% of MOR turned out to be rather nonlinear and some samples failed before the experiment was completed.

This paper presents the results of three months' duration creep test performed on the OSB/4 samples in a similar manner as reported by Pałubicki and Plenzler (2004) for oriented board OSB/3.

## MATERIALS AND METHODS

Polish standards do not define a method of creep tests for wood and wood-based panel products, that applies to oriented strand board too. The PN-EN 310 Standard describes only the method of short-time determination of the modulus of elasticity and strength in three-point bend test. The PN-EN 789 Standard recommends, for the timber structures designers, similar investigation but in four-point bend test. Both standards take into account only one way of loading in bending – perpendicularly to the plane of panel. It was decided to carry out three months' creep test, in four-point bending, on OSB/4 samples loaded in the plane of panel. Three-layered OSB/4 panels with a 12-mm thickness were examined. These panels with dimensions of 1890 × 1250 × 12 mm were produced by the factory of Kronopol-Żary, Poland. Bending samples 600 by 33 mm were cut in such a manner that their longer edge (600 mm) was parallel to the longer sheet edge. The sheet of OSB/4 was resawed into 72 samples, in four groups, along the breadth of the sheet. Four samples, one from each group, were randomly selected from all the pieces to each from the three creep tests, in total 12 samples. Another 12 samples were randomly selected as the reference samples – for the mass control. The odd 48 samples were appropriated to the strength test.

Three creep tests were carried out, each at another load level. The dead load of 30, 60 or 75 kg cast iron bobs was applied to the samples quasi-statically, through the hydraulic jack. These loads produced at the extreme fibres of the samples normal stress at the level of 21, 42 and 53% of MOR for I, II and III series, respectively. The span size, $l_2$ – between the loading heads was 550 mm and the distance $l_1$ between the inner supports – 380 mm. Bending deflections $f(t)$ of the samples were measured at the zone of pure bending only (Fig. 1) by means of the dial gauges with 0.01-mm accuracy and then converted into the relative deflections $\varepsilon(t)$ of the extreme fibres by using the equation:

$$\varepsilon(t) = \frac{\Delta h}{l_1^2} f(t)$$

where: $h$ – depth of the sample,
$l_1$ – span size between the inner supports.

Next the discrete values of the relative deflections $\varepsilon$ were converted into the values of the creep compliance $J(t)$ by using the equation:

$$J(t) = \frac{\varepsilon(t)}{\sigma_i} \tag{1}$$

where: $\sigma_i$ – actual stress level, to make them comparable with each other. The lifting sling of the mass of 2.45 kg was the preload of each the sample.

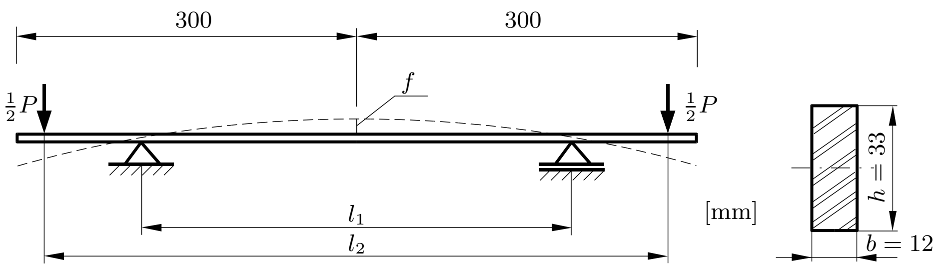


Fig. 1. Diagram of the sample loading and deflection measurement during the creep and destructive tests

The destructive test for the determination of MOR of OSB samples was carried out in four-point bending too, but the span sizes $l_1$ and $l_2$ were somewhat different: 416 and 548 mm, respectively. The load was applied from the FPZ-100 testing machine with unconventional equipment. The rate of loading was so chosen, that the failure of the sample was expected after about 140 seconds (for comparison, the PN-EN 789 Standard recommends the time of 300 ±120 s and the PN-EN 310 – the time of 60 ±30 s). The accuracy of the force measurement amounted 10 N.

## RESULTS AND DISCUSSION

The destructive test, conducted in 25°C on 48 samples showed, that the bending modulus of rupture (MOR) of OSB/4 loaded in the plane of panel amounted 26.2 ±3.15 MPa (average ± standard deviation). This value was almost 4.5% lower than in a similar experiment reported by Plenzler and Pałubicki (2006), presumably due to the higher moisture content (7.1%) of the samples then in the work cited (6%).

The results of three-months' creep tests in the form of discrete values of the creep compliance function (1) were, separately for each sample, modelled with the creep functions of three chosen linear creep models:

– three-element standard model

$$J(t) = J_0 + J_\infty \left(1 - e^{-t/\tau}\right) \tag{2}$$

– four-element Burger model

$$J(t) = J_0 + J_\infty \left(1 - e^{-t/\tau}\right) + \frac{t}{\eta} \tag{3}$$

– five-element exponential model

$$J(t) = J_0 + J_{\infty_1} \left(1 - e^{-t/\tau_1}\right) + J_{\infty_2} \left(1 - e^{-t/\tau_2}\right) \tag{4}$$

where: $J_0$ – instantaneous compliance,
$J_\infty$, $J_{\infty_1}$, $J_{\infty_2}$ – delayed compliances,
$\tau$, $\tau_1$, $\tau_2$ – retardation times,
$\eta$ – viscosity,
$t$ – time.

The averaging results of these approximations are summarized in Tables 1-3. From Tables 1-3, it is evident that the worst fitting to the results of the three-months' creep tests was obtained using the creep function (2) of the three-element standard model. The quality of this approximation decreased with an increase of the load level from 21% of MOR (I series) to 53% of MOR (III series). The best fitting to the results of all the creep tests (series I, II and III) was obtained using the creep function (3) of the four-element Burger model. The quality of the approximation with the creep function (4) of the five-element exponential model was slightly worse. The influence of the stress level on the quality of the

Table 1. Creep test results fitted by 3-parameter model (2)

| Series | $J_0$ $\cdot 10^{-4}$ [mm²/N] | $J_\infty$ $\cdot 10^{-5}$ [mm²/N] | $\tau$ $\cdot 10^{4}$ [min] | $R^2$ |
|---|---|---|---|---|
| I | 2.09 | 4.72 | 3.43 | 0.957 |
| II | 1.99 | 4.78 | 2.66 | 0.948 |
| III | 2.16 | 6.10 | 5.01 | 0.931 |

Table 2. Creep test results fitted by 4-parameter model (3)

| Series | $J_0$ $\cdot 10^{-4}$ [mm$^2$/N] | $J_\infty$ $\cdot 10^{-5}$ [mm$^2$/N] | $\tau$ $\cdot 10^4$ [min] | $\eta$ $\cdot 60 \cdot 10^9$ [MPa·s] | $R^2$ |
|---|---|---|---|---|---|
| I | 2.06 | 2.94 | 1.03 | 5.90 | 0.980 |
| II | 1.95 | 3.26 | 0.89 | 5.92 | 0.979 |
| III | 2.06 | 3.14 | 0.50 | 3.52 | 0.981 |

Table 3. Creep test results fitted by 5-parameter model (4)

| Series | $J_0$ $\cdot 10^{-4}$ [mm$^2$/N] | $J_{\infty 1}$ $\cdot 10^{-5}$ [mm$^2$/N] | $J_{\infty 2}$ $\cdot 10^{-5}$ [mm$^2$/N] | $\tau_1$ $\cdot 10^3$ [min] | $\tau_2$ $\cdot 10^4$ [min] | $R^2$ |
|---|---|---|---|---|---|---|
| I | 2.00 | 1.54 | 4.46 | 1.25 | 5.27 | 0.979 |
| II | 1.88 | 1.79 | 4.36 | 0.24 | 3.76 | 0.973 |
| III | 2.00 | 2.65 | 32.22 | 1.21 | 85.76 | 0.975 |

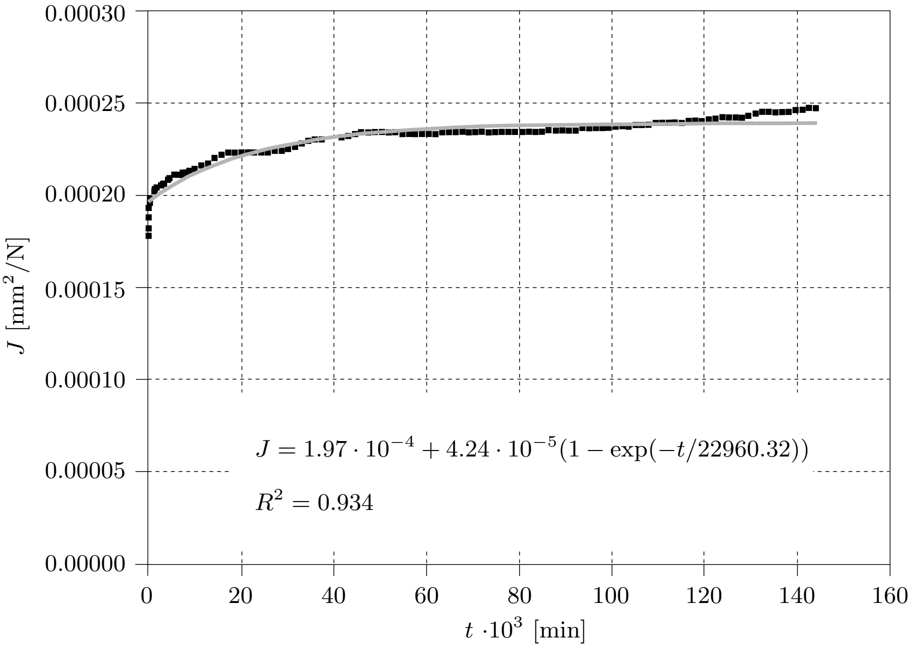


Fig. 2. Typical experimental creep data for a sample of series II (42% of MOR) – fitted by 3-parameter model (2)

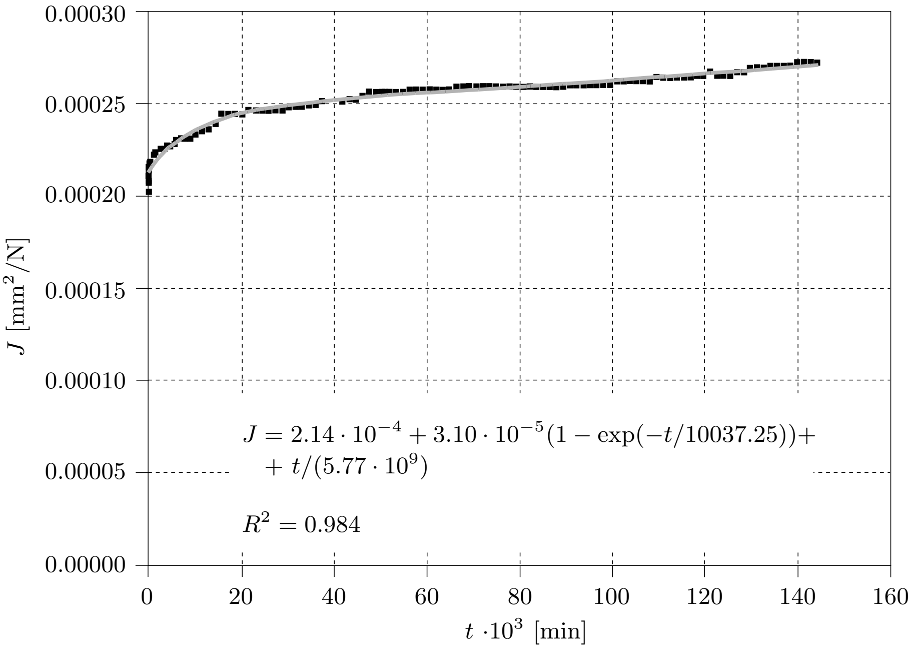


Fig. 3. Typical experimental creep data for a sample of series I (21% of MOR) – fitted by 4-parameter model (3)

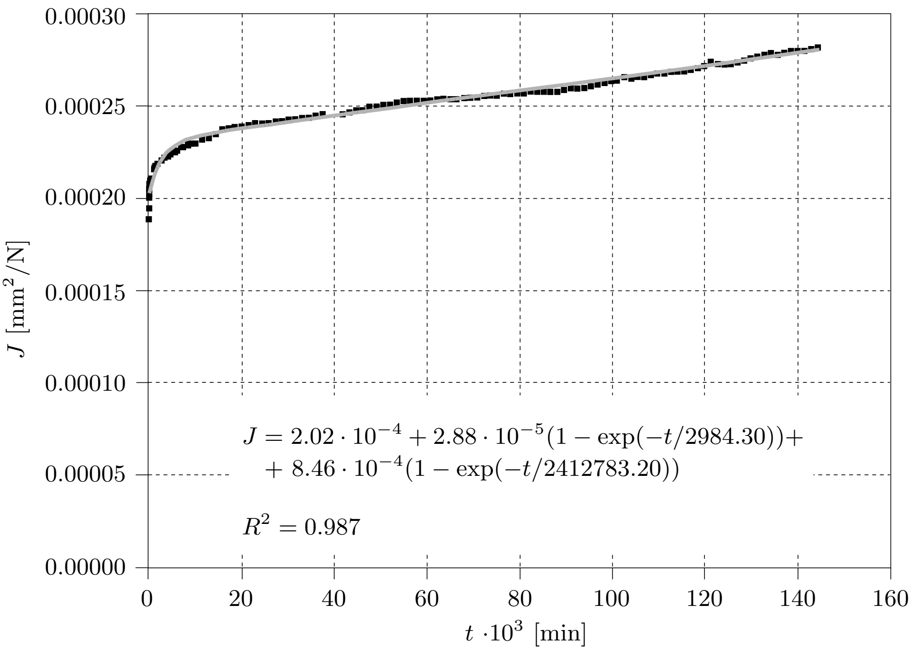


Fig. 4. Typical experimental creep data for a sample of series III (53% of MOR) – fitted by 5-parameter model (4)

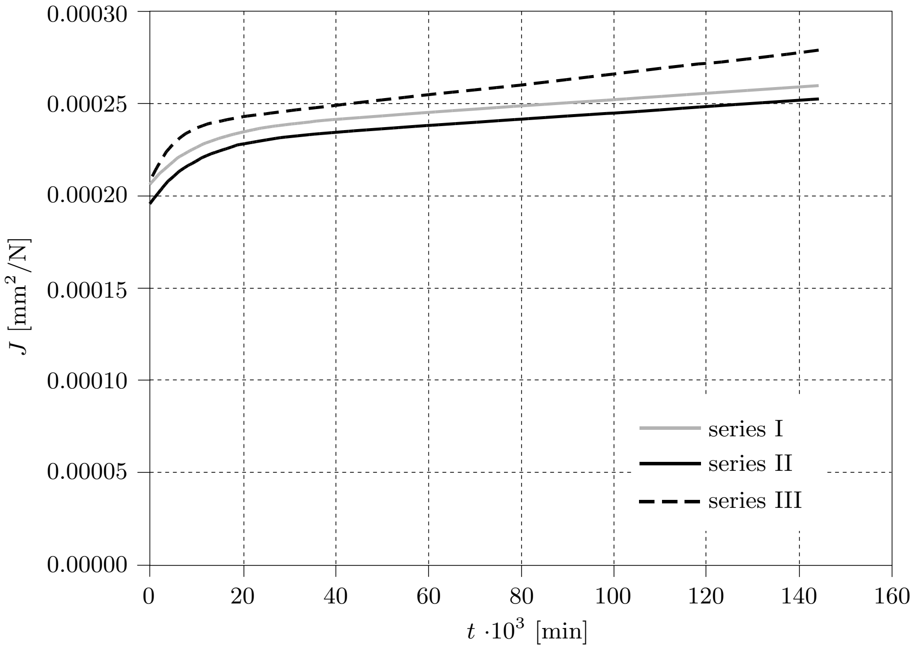


Fig. 5. Averaged creep compliance curves (after an approximation with 4-parameter model (3))

approximation with the models (3) and (4) was not as distinct as in the case of creep function (2) of the standard model. Figures 2-4 show the creep charts of three chosen samples, each at another stress level, after approximations made with creep models (2), (3) or (4). Figure 5 shows three averaged creep curves, each for another stress level, as the effect of the approximation with the use of the four-parameter creep model (3). From this chart, it is evident that the creep compliance curves for I and II stress levels are almost congruent, but the third curve – for the III stress level (53% of MOR) – is different from the others. This phenomenon in the case of the approximation with the creep models (2) and (4) was observed too. The stress level of 53% of MOR exceeds, presumably, the limit of the linear viscoelasticity of OSB/4 plate in received hygrothermal conditions: MC $\approx$ 7%; $t \approx 19°C$ (average moisture content of the samples and average temperature during the creep test). Moreover, one of the samples of the III series failed before this creep test was completed – 10 days after the loading.

## CONCLUSIONS

1. The average value of the modulus of rupture of 12-mm thick OSB/4 bent by the load applied in the plane of panel amounted to 26.2 ±3.15 MPa in the temperature of 25°C and moisture content 7.1%.

2. The bending creep behaviour of oriented strand board OSB/4 loaded in the plane of panel depends on the stress level. For samples tested at stress level of 21 and 42% of MOR the stress-strain-time relationship appears to be practically linear.
3. The creep behaviour of the OSB/4 plate tested at the stress level of 53% of MOR is rather nonlinear. A tertiary creep stage was observed in some specimens of this series and one sample failed before the experiment was completed.
4. The best fitting to the results of all the creep tests (series I, II and III) was obtained using the creep function of the four-element Burger model. The quality of the approximation with the creep function of the five-element exponential model was slightly worse but the worst quality of the fitting was obtained using the three-parameter creep function of the standard model.

## REFERENCES

Dinwoodie J.M., Higgins J.-A., Paxton B.H., Robson D.J. (1991): Creep in chipboard. Part 9: The effect of steady-state moisture content, temperature and level of stressing on the components of creep deflection for a range of boards. Wood Sci. Technol. 25, 383-396.

Dinwoodie J.M., Higgins J.-A., Paxton B.H., Robson D.J. (1992): Creep in chipboard. Part 11: The effect of cyclic changes in moisture content and temperature on the creep behaviour of a range of boards at different levels of stressing. Wood Sci. Technol. 26, 429-448.

Laufenberg T.L., Palka L.C., McNatt J.D. (1999): Creep and creep-rupture behavior of wood-based structural panels. Res. Pap. FPL-RP-574. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory: 20.

McNatt J.D., Laufenberg T.L. (1991): Creep and creep-rupture of plywood and oriented strandboard. Proc. 1991 Int. Timber Engineering Conf. London, 3.457-3.464.

Pałubicki B., Plenzler R. (2004): Bending creep behaviour of OSB loaded in the plane of the panel. El. J. Pol. Agric. Univ. Wood Technol. 7 (1): 7.

Pierce C.B., Dinwoodie J.M., Paxton B.H. (1985): Creep in chipboard. Part 5: An improved model for prediction of creep deflection. Wood Sci. Technol. 19, 83-91.

Plenzler R., Górecki A. (2002): Badania wybranych właściwości sprężystych płyt OSB. Mater. 5 Konf. Nauk. Drewno i materiały drewnopochodne w konstrukcjach budowlanych. Szczecin: 115-120.

Plenzler R., Pałubicki B. (2006): Orientation dependent modulus of elasticity and strength of OSB/4 bent in the plane of panel. Fol. For. Pol. Ser. B, 37: 47-54.

PN-EN 310:1994: Płyty drewnopochodne. Oznaczanie modułu sprężystości przy zginaniu i wytrzymałości na zginanie. Warszawa.

PN-EN 789:1998: Konstrukcje drewniane. Metody badań. Oznaczanie właściwości mechanicznych płyt drewnopochodnych. Warszawa.

PN-EN 300:2000: Płyty o wiórach orientowanych (OSB). Definicje, klasyfikacja i wymagania techniczne. Warszawa.

PN-EN 12369-1:2002: Płyty drewnopochodne. Wartości charakterystyczne do projektowania. Część 1: Płyty OSB, płyty wiórowe i płyty pilśniowe. Warszawa.

Pu J., Tang R.C., Davis W.C. (1992 a): Creep behavior of commercial structural oriented strandboards under high relative humidity. For. Prod. J. 42 (4): 49-54.

Pu J., Tang R.C., Hse C.Y. (1994): Creep behavior of sweetgum OSB: effect of load level and relative humidity. For. Prod. J. 44 (11/12): 45-54.

Pu J., Tang R.C., Price E.W. (1992 b): The effect of hot and humid environmental conditions on the creep behavior of commercial structural oriented strandboards. For. Prod. J. 42 (11/12): 9-14.

Szyperska B., Nożyński W. (1999): Wyniki badań płyt drewnopochodnych o ukierunkowanych włóknach w aspekcie możliwości stosowania ich w budownictwie drewnianym. Mater. Konf. Nauk. Drewno i materiały drewnopochodne w konstrukcjach budowlanych. Szczecin-Świnoujście: 375-381.

Wilczyński A., Gogolin M. (1999): Ortotropia właściwości sprężystych płyty OSB. Mater. Konf. Nauk. Drewno i materiały drewnopochodne w konstrukcjach budowlanych. Szczecin-Świnoujście: 103-109.

Zhou Y., Fushitani M., Kamdem D.P. (2001): Bending creep behavior of medium density fiberboard and particleboard during cyclic moisture changes. Wood Fiber Sci. 33, 4: 609-617.

Received in September 2009

Authors' address:
Dr. Ryszard Plenzler
Łukasz Miler
Faculty of Wood Technology
Poznań University of Life Sciences
ul. Wojska Polskiego 38/42
60-627 Poznań
Poland