ZESZYTY NAUKOWE POLITECHNIKI ŚLĄSKIEJ 2004
Seria: TRANSPORT z. 52 Nr kol. 1621

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CONTRIBUTION TO THE DESIGN OF BALLAST BED CONSTRUCTION

Summary. The paper points out the possibilities of application of dynamic penetration test in the design of construction of sleeper bearing. The results of experimental measurements carried out on a formation level and their mathematical-statistical processing made possible to find the relationship between static and dynamic penetration modulus of deformation and the coefficients, which allow their mutual conversion and using in design methodology.

PRZYCZYNEK DO PROJEKTOWANIA KONSTRUKCJI PODŁOŻA PODKŁADÓW

Streszczenie. Artykuł prezentuje możliwość wykorzystania penetracyjnego badania dynamicznego dla potrzeb diagnostyki konstrukcji podłoża podkładów. Przedstawiono, na podstawie wyników pomiarów doświadczalnych wykonywanych na liniach kolejowych oraz na podstawie opracowań wyników metodami statystycznymi, zależności występujące pomiędzy statycznym modułem odkształcenia a liczbą uderzeń kafara, potrzebnych do wbicia żerdzi wiertniczej na głębokość 10 cm, lub między statycznym a dynamicznym penetracyjnym modułem odkształcenia.

1. INTRODUCTION

To know the values of moduli of deformation E_0 and thickness h of construction layers and subgrade level of sleeper bearing is essential for the design of railways and assessment of bearing capacity of railway tracks. Gesign method of sleeper bearing construction is determined from DORNII method - Fig. 1. The values of moduli of deformation are determined by static loading test (STN 73 6190), which was modified for the needs of ZSR [1]. The modification of the method for the determination of static modulus of deformation consists in the determination of $E_{0,2}$ i.e., determination from the second loading cycle - Fig. 2. The determination of moduli of deformation by the test with a loading circular plate is very time consuming on the railways in use and it requires their closure (a railway carriage - counterload must be present on a railway track). If a railway is under construction this test is a factor which restricts realization of technological procedures of construction work.

Recently it has been possible to note the tendencies to reduce the number of static loading tests for the diagnostics of railway body. More favoured are the tests which are less time consuming and which take into account dynamic regime of materials built in the sleeper

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bearing. Dynamic penetration and beating plate are used very frequently [2, 3, 4]. As a part of prepared amendment of ZSR regulation S4 [1] the possibility is considered to include dynamic penetration test in the diagnostics of railway body and making use of the results of this test for the needs of the design methods of sleeper bearing construction. The philosophy of this approach consists in finding coefficients which would make possible simple conversion of specific dynamic penetration resistance q_{dyn} into static modulus of deformation E_0. The results obtained are presented in this paper.

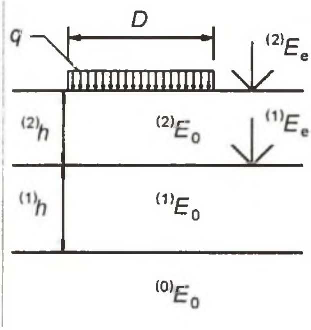

Fig. 1. Scheme of DORNII method
Rys. 1. Schemat metody DORNII

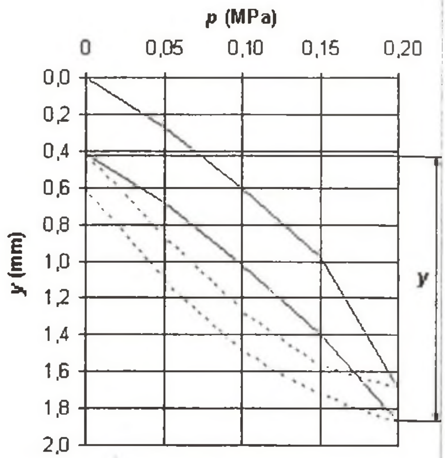

Fig. 2. Determination $E_{0,2}$ from second loading cycle by ZSR
Rys. 2. Ustalanie $E_{0,2}$ drugiego cyklu obciążeniowego na ŽSR

2. ANALYSIS OF E_0 AND Q_{DYN} RELATIONSHIP

This relationship was examined by the methods of mathematical statistics using experimental values characterising deformation properties of soils in sleeper bearing. These properties were experimentally determined by static loading test (E_0) and dynamic penetration (q_{dyn}) carried out on the broad-gauge tracks of Slovakia - Fig. 3. The measurements were performed by the company GEOKONTAKT [3].

The examination included the data obtained at comparable conditions, i.e., the same stationing, the same rail, etc. Totally n = 172 measurements were analysed, from which the following deformation characteristics of construction layers of the body of railway subgrade were determined:

1. from static loading test
   - modulus of deformation determined from the first loading cycle $E_{0,1}$ (MPa),
   - modulus of deformation determined from the second loading cycle $E_{0,2}$ (MPa),
2. from dynamic penetration test:
   - specific dynamic penetration resistance q_{dyn} (MPa).

These characteristics were obtained for $h \in \langle 0,4;0,6 \rangle$ m.

Fig. 3. Apparatus for dynamic penetration test
Rys. 3. Urządzenie do dynamicznych badań penetracyjnych

Linear and non-linear regression models were used for the examination of E_0 and q_{dyn} relationship. The form of non-linear power model is given by the regression equation:

$$y = a \cdot x^b \tag{1}$$

where a and b are regression coefficients.

The significance of models was proved by *F - test.* Regression coefficients obtained from equation (1) as well as correlation coefficients R for examined dependences are listed in Table 1 - 3. Determination coefficients are given in Fig. 4 - 9, in which measured quantities and their mutual regression are depicted.

Table 1

Results of statistical processing for h = 0,4 m

Regression	n	a	b	$R_{0,05}$	R	Suitable?
$E_{0,1}$ q_{dyn}	172	4,8867	0,7016	0,178	0,6544	yes
$E_{0,2}$ q_{dyn}	172	11,9150	0,6952		0,7026	yes

Table 2

Results of statistical processing for h = 0,5 m [6,7,8]

Regression	n	a	b	$R_{0,05}$	R	Suitable?
$E_{0,1}$ q_{dyn}	172	5,5461	0,6446	0,178	0,5864	yes
$E_{0,2}$ q_{dyn}	172	12,4700	0,6867		0,7079	yes

Table 3

Results of statistical processing for h = 0,6 m

Regression	n	a	b	$R_{0,05}$	R	Suitable?
$E_{0,1}$ q_{dyn}	172	5,9136	0,6408	0,178	0,6066	yes
$E_{0,2}$ q_{dyn}	172	12,8100	0,6966		0,7151	yes

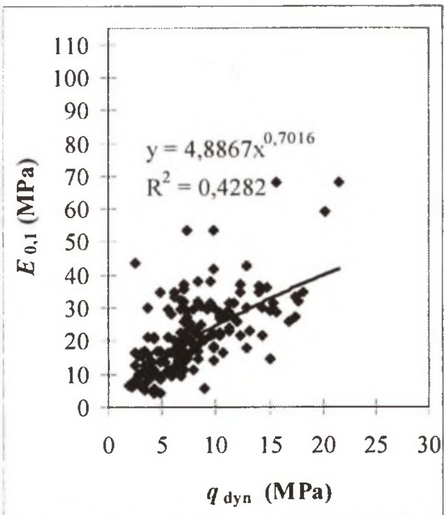

Fig. 4. Non-linear dependence between $E_{0,1}$ and q_{dyn} for h = 0,4 m

Rys. 4. Zależność nieliniowa między $E_{0,1}$ a q_{dyn} dla h = 0,4 m

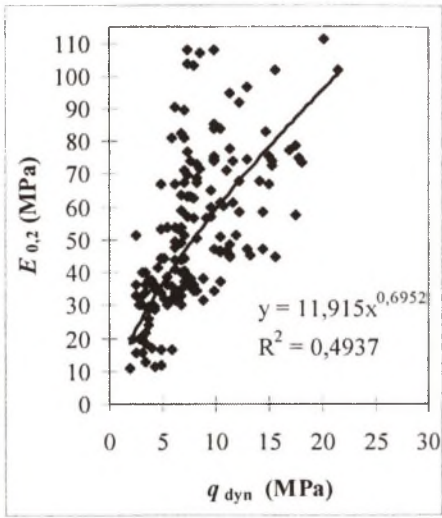

Fig. 5. Non-linear dependence between $E_{0,2}$ and q_{dyn} for h = 0,4 m

Rys. 5. Zależność nieliniowa między $E_{0,2}$ a q_{dyn} dla h = 0,4 m

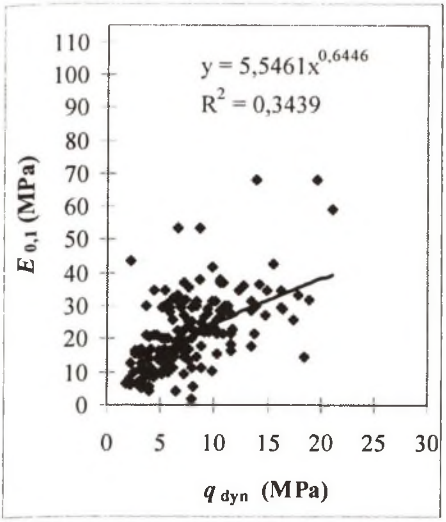

Fig. 6. Non-linear dependence between $E_{0,1}$ and q_{dyn} for h = 0,5 m

Rys. 6. Zależność nieliniowa między $E_{0,1}$ a q_{dyn} dla h = 0,5 m

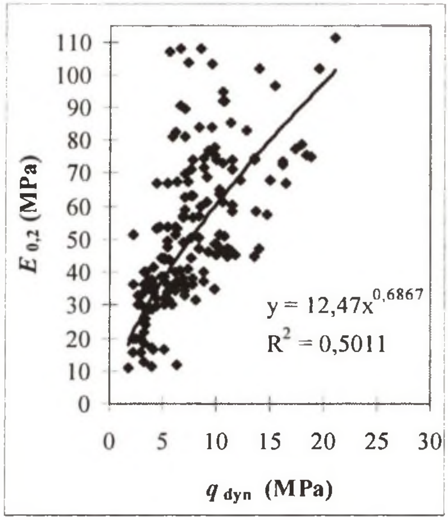

Fig. 7. Non-linear dependence between $E_{0,2}$ and q_{dyn} for h = 0,5 m

Rys. 7. Zależność nieliniowa między $E_{0,2}$ a q_{dyn} dla h = 0,5 m

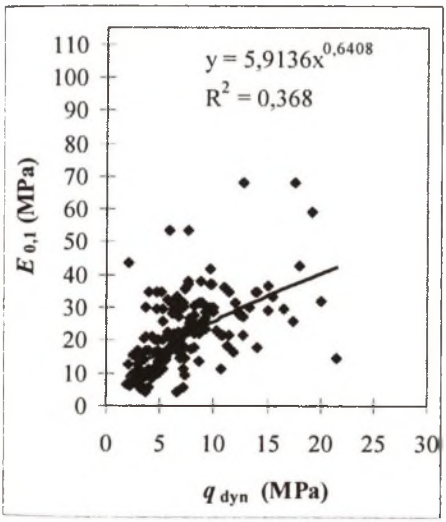

Fig. 8. Non-linear dependence between $E_{0,1}$ and q_{dyn} for h = 0,6 m

Rys. 8. Zależność nieliniowa między $E_{0,1}$ a q_{dyn} dla h = 0,6 m

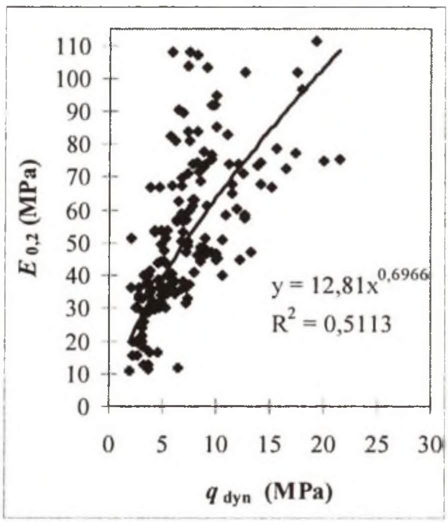

Fig. 9. Non-linear dependence between $E_{0,2}$ and q_{dyn} for h = 0,6 m

Rys. 9. Zależność nieliniowa między $E_{0,2}$ a q_{dyn} dla h = 0,6 m

3. RESULTS EVALUATION AND CONCLUSION

From the presented statistical analysis of deformation characteristics of the construction layers of railway subgrade carried out at the significance level $\alpha = 0{,}05$ follows that:

- the relationship between dynamic penetration resistance and modulus of deformation determined from the second loading cycle of static loading test is statistically significant,
- since Pearson's coefficient of pair correlation is of higher value than critical, it can be stated that there is statistical dependence between dynamic penetration resistance and modulus of deformation determined from the first loading cycle of static loading test, mainly for non-linear regression model (1),
- non-linear form of regression model given by equation (1) in comparison with linear model has higher values of correlation coefficients and it is more appropriate for the conversion of average dynamic resistance into static modulus of deformation.

The type of soil influences the results of dynamic penetration in a considerable way since there is friction between rodding and some types of soils. Gravel, sand, sand clays, loess, are soils in which dynamic penetration achieves the best results. In these soils there is no friction on the surface of rodding or friction is very low and can be eliminated by rotating the rodding. The friction in these soils has to be taken into account only under the level of underground water.

In spite of the fact that the results obtained are promising, the final confirmation of the dependence between modulus of deformation of construction layers of the railway subgrade determined by static loading test from the second loading cycle and specific dynamic penetration resistance determined by penetration test, would need to enlarge the examined set of data by the measurements for other types of soil. This would increase the number of data and it also makes possible to examine the relationship between E_0 a q_{dyn} for various types of water regime of sleeper bearing.

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Abstract

To know the values of moduli of deformation and thickness of construction layers and subgrade level of sleeper bearing is essential for the design of railways and assessment of bearing capacity of railway tracks. The values of moduli of deformation are determined by static loading test, which was modified for the needs of ZSR. The determination of moduli of deformation by the test with a loading circular plate is very time consuming on the railways in use and it requires their closure. Recently it has been possible to note the tendencies to reduce the number of static loading tests for the diagnostics of railway body. More favoured are the tests which are less time consuming and which take into account dynamic regime of materials built in the sleeper bearing. Dynamic penetration is used very frequently. As a part of prepared amendment of ZSR regulation the possibility is considered to include dynamic penetration test in the diagnostics of railway body and making use of the results of this test for the needs of the design methods of sleeper bearing construction. The philosophy of this approach consists in finding coefficients which would make possible simple conversion of specific dynamic penetration resistance into static modulus of deformation. The results obtained are presented in this paper.