МОСТИ ТА ТУНЕЛІ: ТЕОРІЯ, ДОСЛІДЖЕННЯ, ПРАКТИКА

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SOLUTION OF TASK OF THE MOBILE LOADING IN THE DYNAMIC STATEMENT

Purpose. That is the feature of static work of tunnel constructions, that their stress-strain state is formed in interaction with a surrounding rock mass. But the dynamic component of stress-strain state of such constructions is also large, as tunnel constructions are perceived, except for permanent action of surrounding rock mass, spectrum of the dynamic loadings. Analyzing every type of dynamic action, it follows also to give him appraisement from position of reflection in normative documents, as the account of most dynamic actions is only declared in them without development of some methods. **Methodology.** For research of influencing of the mobile loading in the dynamic statement model it is some changed in order to correctly attach loading between columns as an impulse. As well as at the conducted research of the mobile loading in the static statement, in which it was found out, that his influence on the station construction depended on the depth of contour interval, at the solution of the same task in the dynamic statement explored two models – with the depth of contour interval 5 m and 10 m. **Findings.** It is possible to testify from the conducted analysis, that the complex analysis of the station construction with conducting of static and dynamic calculations allows to obtain more complete information about stress-strain state, which allows to estimate the state of elements in different situations, some of which more reliable result in emergency situations and must be forecast. **Originality.** Influencing of the mobile loading in the static and dynamic statements has been analyzed. **Practical value.** The calculations of the underground stations of shallow contour interval are complemented by an important calculation in the dynamic raising, and the results of such complex analysis can be considered more complete.

Keywords: column station; shallow contour interval; mobile loading; dynamic action; stress-strain state

Entry

That is the feature of static work of tunnel constructions, that their stress-strain state (SSS) is formed in interaction with a surrounding rock mass. But, in our turn, the dynamic component of SSS of such constructions is also large, as tunnel constructions are perceived, except for permanent action of surrounding rock mass, spectrum of the dynamic loadings. In this spectrum enter: 1) influence of the mobile motor transport loading (stations and running tunnels of shallow contour interval); 2) mobile loading of train (tunnels on the railways) or metro train (undergrounds); 3) special dynamic loadings (cases of impulsive action in the case of explosion or impact, loading from soil vibrocreep or vibroshrinkage [1-2]).

Complexity of tunnel constructions conduct and of surrounding rock mass by the dynamic loadings considerably higher, than by static, as approach to the solution of dynamic tasks substantially differs from static approach as a result of account of inertia component of the SSS forming. The problem of dynamic tasks solution in the case of tunnel constructions is complicated to those that it follows to take into account added the soil masses, at the same time, taking into account not only an inertia component but also interaction with the elements of construction.

Some tasks and ways of their solution in the field of static or weak dynamic actions were already got and systematized by different authors; however developed general systematization and ways of dynamic tasks solution in the case of underground construction were not elaborated [3-5]. In this field it is difficult to consider basic concepts already in theory developed, but development of methods of practical calculations is actual.

The field of dynamic actions for the stations of underground can be classified like that.

1. Dynamic action of metro train, which is periodic action both on the station support and on basis. Vibrocompression (compression of basis under tray part of the station construction), vibrocreep (phenomenon of increase of movement under the tray of the station construction at action of loading periodic or pulsation) is the results from this dynamic action and strengthening of concrete corrosion.

2. Dynamic action of the land transport, which more active influences on the station constructions of shallow contour interval, more frequent all appears on the stations of the one-arch and columnar types of shallow contour interval (depth of contour interval no more 20 meters).

3. Shock dynamic action in the case of some masses falling within the limits of the station construction. This type of action also more active influences on the station constructions of shallow contour interval, however much some specific cases of shock action also can influence on the deep contour interval station (depth of occurrence more than 20 meters).

4. Impulsive dynamic action. This type of action is small studied in the field of calculations of the station constructions, however is actual for the solutions of their conduct by the special actions [6].

5. Seismic dynamic action [7].

6. Dynamic action of tectonic processes of the earth's crust. This type of action is less than all studied, as complexity in determination of tectonic forces, their origin, forming and conducts, consists not only in the receipt of analytical dependences but also further their using in practical calculations.

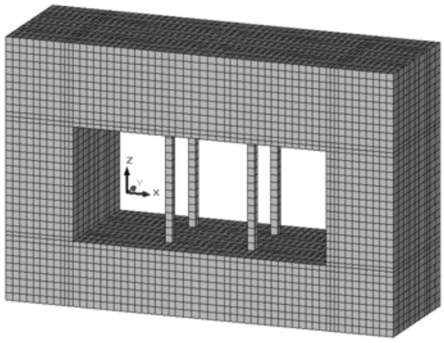
Purpose

Analyzing every type of dynamic action, it follows also to give him appraisement from position of reflection in normative documents (CINR and SCN), as the account of most dynamic actions is only declared in them without development of some methods [8-10].

Methodology

For research of influencing of the mobile loading NK-80 in the dynamic statement FEM-model it is some changed in order to correctly attach loading between columns as an impulse. As well as at the conducted research of the mobile loading in the static statement, in which it was found out, that his influence on the station construction depended on the depth of contour interval, at the solution of the same task in the dynamic statement explored two models – with the depth of contour interval 5 m and 10 m (fig. 1).

a)



b)

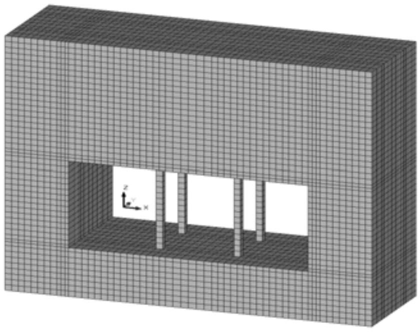


Fig. 1. FEM-model for the NK-80 case (dynamic statement) with the depth of contour interval:
a) – 5 m; b) – 10 m

The NK-80 loading is put on the same distance between columns (fig. 2).

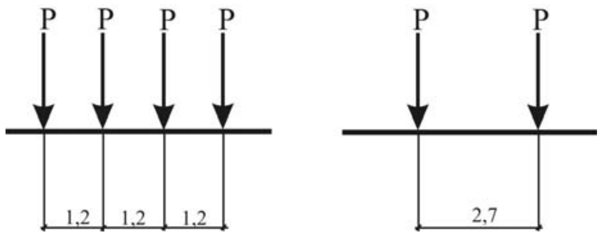


Fig. 2. Parameters of the mobile loading NK-80 (98 kN/wheel)

In order that static statement of calculation on the mobile loading, which is regulated SCN B.2.3-7-2010. «Underground», it follows to convert forces from the wheels of the NK-80 loading on the dynamic influencing. For this purpose we will consider a situation, in which the mobile loading NK-80, which in reality is a large lorry, at the movement gets in small pit. In such situation of loading force NK-80 transformation into the impulses of forces, the values of which can be calculated, set-

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ting duration of interaction of wheel with soil. Transformation to the impulses of all eight forces of the NK-80 loading identical after the value is some simplification, so as at a run-over a greater impulse will get a wheel which got in pit. But such simplification considerably changed for the worse the situation of the NK-80 influencing which is considered as an impulse.

Parameters of impulse of every force NK-80 (dynamic statement):

1. Weight of mass in the load node FEM-model – 100 kN (one wheel NK-80).

2. Duration of interaction – 0,1 c.

3. Value of impulse – 9,8 kN s, is adopted an impulse three-cornered form with a maximum in beginning of interaction.

For the account of the non-elastic behavior FEM-model with damping of vibrations it follows to set the coefficient of non-elastic resistance which is equal 0,09.

Findings

After the task of the dynamic characteristics FEM-model and parameters of the mobile loading, calculations are conducted, minutes of which are resulted in Addition. On fig. 3 and fig. 4 are produced results of calculation of the deformed state of model on the mobile loading in the dynamic statement.

a) *b*)

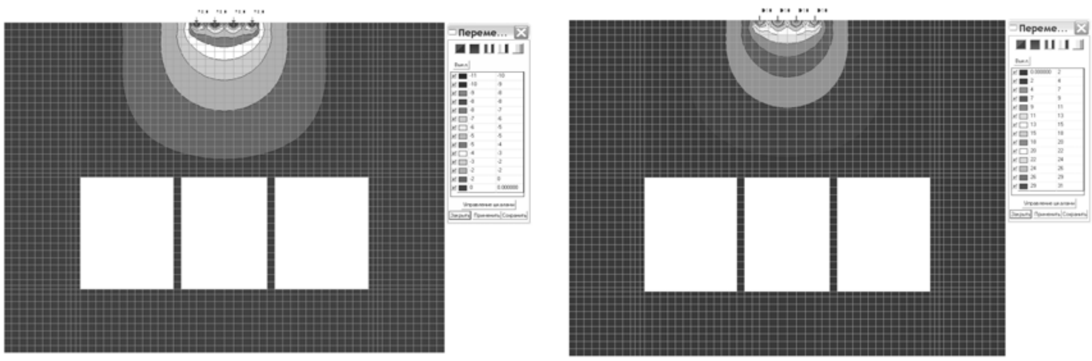

Fig. 3. Vertical movement in FEM-model only from action of the mobile loading NK-80:
a) – static statement; b) – dynamic statement

Horizontal Vertical

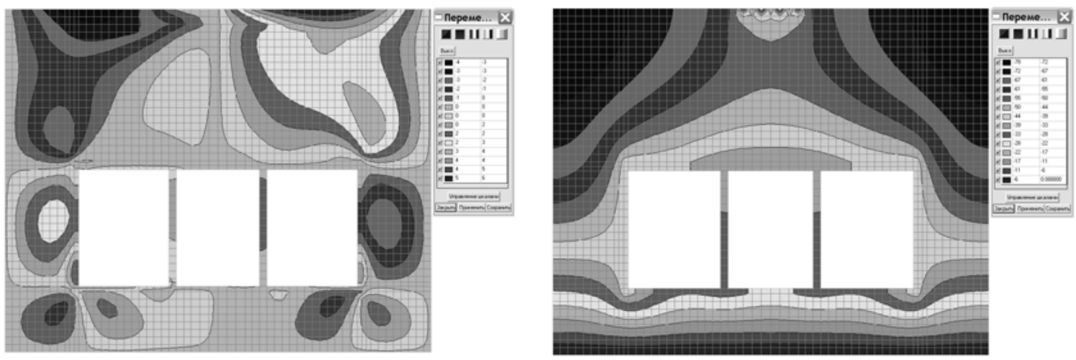

Fig. 4. Isofields and isolines movement in the fragment of model with the depth of contour interval 10 m (fragment of the station support) from own weight and NK-80 action

On fig. 3 are resulted for comparison of value of the vertical movement FEM-model only for the NK-80 influencing in the static and dynamic statement. The comparative analysis of these sizes gives possibility to testify that high-quality the pictures of movement did not change, and in number maximal stresses grew almost in three times (with 11 mm in static to 31 mm in the dynamic statement). Sign «plus» near the vertical movements of the dynamic statement it follows to be perceived not as mathematical sign, and as his absence, so as the dynamic movements from an impulse is given

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on the module, that is related to the specific of vibrations process, which has a scope (double amplitude). Thus, 31 mm is the scope of vibrations, and his half is amplitude, that 15,5 mm, and got in the static statement it follows to compare 11 mm to them. That the increase of movement in the process of replacement of statement of task on dynamic one takes place only on 1,4…1,45 times.

It is also visible from comparison of movement in the static and dynamic statement, it is thus possible to mark the some changed character of their distributing, and also practically identical quantitative level (maximal vertical movement in the static statement – 79 mm against 78 mm in dynamic). It is thus possible to testify that on distributing of movements the change of statement of task did not influence practically.

For more detailed analysis there are the below produced results of the stress state for the static and dynamic statement (only for the case of contour interval 10 m) (fig. 5).

Static statement Dynamic statement

Normal on the axis X

Normal on the axis Z

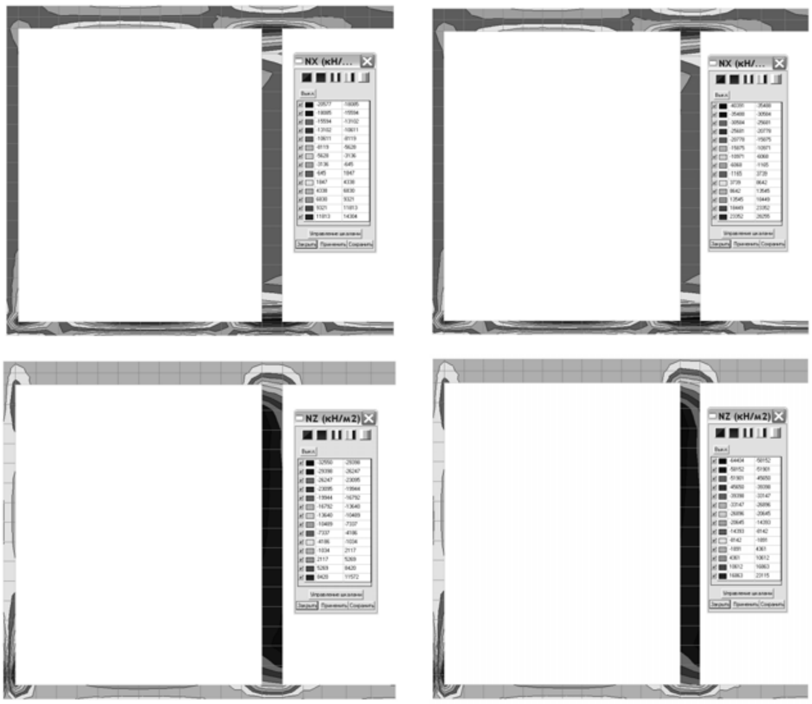

Fig. 5. Isofields and isolines stresses in FEM-models with the depth of contour interval 10 m (fragment of the station support) from own weight and the NK-80 action

It is necessary to notice complete identity of pictures of stresses for two statement, that high-quality both static and dynamic statement are identical, that relationships, so as static force in the dynamic statement is regenerated on an impulse, but not changed place of his supplement.

Except for a complete identity in a high-quality plan, it is necessary to notice considerable quantitative changes in the stress state: the horizontal stresses in the dynamic statement unlike static one was multiplied horizontal stresses in 1,96…2,0 times, vertical – in 1,98…2,0 times, tangential – in 1,95…1,96 times.

If to adopt possible an error in 5 %, it is possible to consider that all components of stresses grew in two times. Thus, if to divide dynamic stresses into stresses in the static statement, we will get the coefficient of dynamic, which is equaled $\mu=2$ and answers the case of blow, which by us was substituted by an impulse.

From distributing of the stress components on fig. 5 it is possible to testify that influencing of the mobile loading NK-80 in the dynamic statement is substantial. After equivalent stresses we will conduct a calculation as a table (table 1), on to the points of stress concentration of the static statement, which did not change the location (fig. 6).

Results of the table 1 testify that influence on the stress state of the station construction NK-80

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(in the dynamic statement) is considerable – the construction gets considerable cracking.

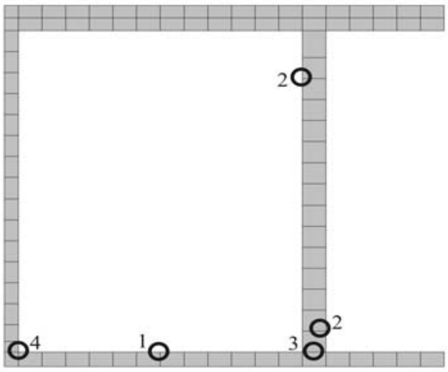


Fig. 6. Points of stresses concentration in the station construction

Thus, a calculation on the mobile loading at the static statement, which SCN «Underground» regulates as obligatory, can be considered verification, and the case of the same loading in the dynamic statement must be complex addition, which allows to forecast possibility of the emergency situations, which related to the large and extracurricular trucks.

Table 1

Calculation of equivalent stresses after the fourth theory of durability

Number of point	Stresses, MPa			Equivalent stresses, MPa / Safety coefficient
	Normal on the axis X	Normal on the axis Z	Tangential on the plane XZ	
Point 1	28,5	10,6	-0,7	35/0,6
Point 2	-1,3	-65,2	-0,72	65,8/0,3
Point 3	-41,2	-33,6	-4,8	65,4/0,3
Point 4	-26,0	-52,6	8,6	71,0/0,3

Also we will conduct research of model which is resulted on fig. 1, *a*, with diminishment of depth of contour interval to 5 m. Before we will analyse everything vertical stresses only from the NK-80 action (fig. 7), so as in the case of contour interval 5 m NK-80 already anymore operates on the station construction, that it is visible from shorting of isofield over a vault head and their distribution on columns.

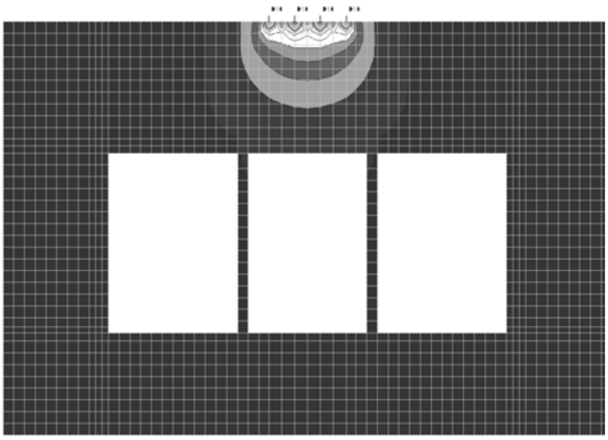
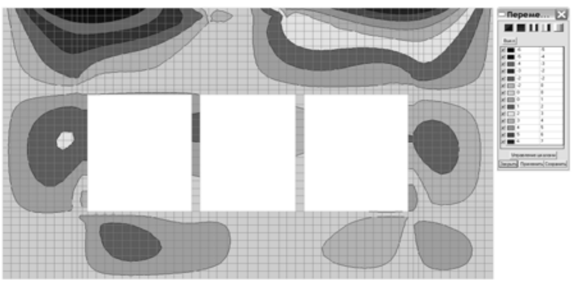


Fig. 7. Vertical movement in a model from action of the mobile loading NK-80 (dynamic statement)

On fig. 8 and fig. 9 results of calculation of the station on the complex loading (own weight + dynamic moving from NK-80) of this model are resulted. However the NK-80 influencing and in this case remains insignificant in comparison with the static statement. It testifies to the insignificant influencing of the NK-80 loading in the dynamic statement on the deformed state regardless of depth of contour interval.

High-quality character of distributing components of stresses unlike a model with the depth of contour interval changed considerably, also the values of stresses quantitatively changed substantially.

Horizontal



Vertical

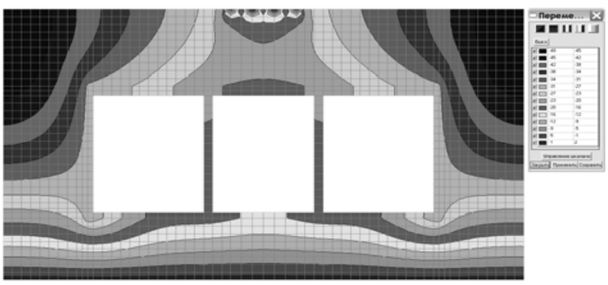


Fig. 8. Isofields and isolines movement in the fragment of model with the depth of contour interval 5 m (fragment of the station support) from own weight and the NK-80 action

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a)

b)

c)

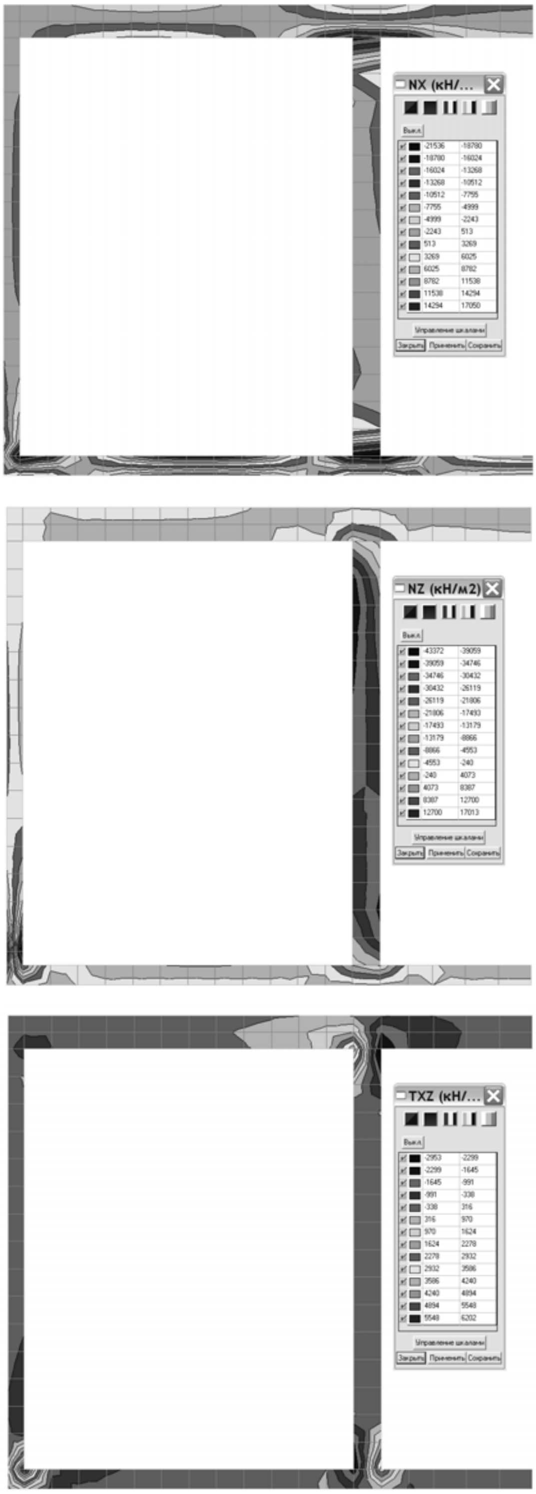

Fig. 9. Isofields and isolines stresses in FEM-models with the depth of contour interval 5 m (the fragment of the station support) from own weight and the NK-80 action:
a) – normal on the axis X; b) – normal on the axis Z; c) – tangential on the plane XZ

However relationships of forming of the stress state in the dynamic statement unlike static is fully kept – high-quality character of isofields and isolines is identical, and quantitatively in the static statement is multiplied stresses on the coefficient of dynamic, which is equaled μ=2, that unlike static was multiplied dynamic stresses in two times. For this case also we will conduct a calculation of equivalent stresses after the fourth theory of strength (power) as a table 2.

Table 2

Calculation of equivalent stresses after the fourth theory of durability

Number of point	Stresses, MPa			Equivalent stresses, MPa / Safety coefficient
	Normal on the axis X	Normal on the axis Z	Tangential on the plane XZ	
Point 1	17,4	4,0	-0,46	19,8/1,1
Point 2	0,3	-43,0	1,52	43,0/0,45
Point 3	-22,6	-16,6	-3,2	34,6/0,6
Point 4	-22,6	-30,2	6,2	47,2/0,45

Conclusions

From findings in table 1 and table 2 it is visible, that dependence of stresses on the depth of contour interval is some nonlinear, so as stresses change disproportionate depending on double diminishment of depth of contour interval.

It is possible to testify from the conducted analysis, that the complex analysis of the station construction with conducting of static and dynamic calculations allows to obtain more complete information about SSS, which allows to estimate the state of elements in different situations, some of which more reliable result in emergency situations and must be forecast.

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РЕШЕНИЕ ЗАДАЧИ ПОДВИЖНОЙ НАГРУЗКИ В ДИНАМИЧЕСКОЙ ПОСТАНОВКЕ

Цель. Особенностью статической работы тоннельных конструкций является то, что их напряженно-деформированное состояние формируется во взаимодействии с окружающим массивом. Но динамическая составляющая напряженно-деформированного состояния такого рода конструкций также значительная, поскольку тоннельные конструкции воспринимают, кроме постоянного действия окружающего массива, спектр динамических нагрузок. Анализируя каждый вид динамического вордействия, следует также давать ему оценку с позиции отображения в нормативных документах, поскольку учет большинства динамических действий только декларируется в них без разработки каких-либо методик. **Методика.** Для исследования влияния подвижной нагрузки в динамической постановке модель изменена для того, чтобы корректно приложить нагрузку между колоннами в виде импульса. Как и проведенном исследовании подвижной нагрузки в статической постановке, в которой было выяснено, что его влияние на станционную конструкцию зависит от глубины заложения, при решении этой же задачи в динамической постановке исследованы две модели с глубиной заложения 5 и 10 м. **Результаты**. Из проведенного анализа можно свидетельствовать, что комплексный анализ станционной конструкции с проведением статических и динамических расчетов позволяет получить более полную информацию о напряженно-деформированном состоянии, которая позволяет оценить состояние элементов в разных ситуациях, некоторые из которых вероятней приводят к аварийным ситуациям и должны быть прогнозируемые. **Научная новизна**. Проанализировано влияние подвижной нагрузки в статической и динамической постановках. **Практическая значимость.** Расчеты станций метрополитена мелкой закладки дополняются важным расчетом в динамической постановке, а результаты такого комплексного анализа могут считаться более полными.

Ключевые слова: колонная станция; мелкое заложение; подвижная нагрузка; динамическое воздействие; напряженно-деформированное состояние

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ВИРІШЕННЯ ЗАДАЧІ РУХОМОГО НАВАНТАЖЕННЯ В ДИНАМІЧНІЙ ПОСТАНОВЦІ

Мета. Особливістю статичної роботи тунельних конструкцій є те, що їх напружено-деформований стан формується у взаємодії з навколишнім масивом. Але, у свою чергу, динамічна складова напружено-деформованого стану такого роду конструкцій також велика, оскільки тунельні конструкції сприймають, окрім постійної дії навколишнього масиву, спектр динамічних навантажень. Аналізуючи кожен вид динамічної дії, слід також давати йому оцінку з позиції відображення в нормативних документах, оскільки урахування більшості динамічних дій тільки декларується в них без розробки будь-яких методик. **Методика.** Для дослідження впливу рухомого навантаження в динамічній постановці модель змінено для того, щоб коректно прикласти навантаження між колонами у вигляді імпульсу. Як і проведеному дослідженні рухомого навантаження в статичній постановці, в якій було з’ясовано, що його вплив на станційну конструкцію залежить від глибини закладення, при вирішенні цієї ж задачі в динамічній постановці досліджені дві моделі із глибиною закладення 5 і 10 м. **Результати.** Із проведеного аналізу можна свідчити, що комплексний аналіз станційної конструкції із проведенням статичних та динамічних розрахунків дозволяє отримати більш повну інформацію про напружено-деформований стан, яка дозволяє оцінити стан елементів в різних ситуаціях, деякі із яких вірогідно призводять до аварійних ситуацій і повинні бути прогнозовані. **Наукова новизна.** Проаналізовано вплив рухомого навантаження в статичній та динамічній постановках. **Практична значимість.** Розрахунки станцій метрополітену мілкого закладення доповнюються важливим розрахунком в динамічній постановці, а результати такого комплексного аналізу можуть вважатися більш повними.

Ключові слова: колонна станція; мілке закладення; рухоме навантаження; динамічна дія; напружено-деформований стан

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