ISSN 2413-6212 (Online), ISSN 2227-1252 (Print)
Мости та тунелі: теорія, дослідження, практика, 2017, № 11

МОСТИ ТА ТУНЕЛІ: ТЕОРІЯ, ДОСЛІДЖЕННЯ, ПРАКТИКА

УДК 624.21.095.2.014.:[625.1:629.4.016.5]

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PARAMETERS OF TYPICAL CONTINUOUS STEEL TRUSS SPANS UNDER A HIGH-SPEED MOVEMENT

Purpose. Determination of the stress-strain state of a typical continuous steel truss span by calculation according to national norms and computer simulation in the conditions of passage of high-speed passenger trains. **Methodology.** In this work, the stress-strain state of a continuous truss span of the typical project No. 3 501.2-166 for the possibility of its application in areas with perspective high-speed railway traffic was investigated. Calculation of the specified span structure for DBN V.2.3-14-2006 «Constructions of transport. Bridges and pipes. Design rules» for railroad loading C14 was executed. The cross-sections of the elements of a continuous truss span were calculated and the necessary checks performed. For the given span structure in the software complex a model was developed and the stress-strain state at various speeds of railway transport according to European and national norms was investigated. The acceleration and deflection of a continuous steel truss span were determined and their comparison with normative requirements was performed. **Findings.** As a result of simulation in the software complex for a continuous steel truss span, acceleration and deflection under the action of cargo and passenger load at different speeds of movement were determined. The cross-sections of the elements of a continuous steel truss span were calculated. **Originality.** The results of the study can be applied in the development of national regulatory documents on high-speed rail transport and in the design of bridge structures with continuous truss spans in areas with high and higher-speed railway traffic. **Practical value.** The obtained results of the research will allow to effectively use continuous steel truss spans of typical designs in areas with high– and higher-speed railway traffic.

Keywords: high-speed movement; high speed line; bridge construction; continuous truss span; acceleration; deflection; span; metal bridge; model; railway load; finite element method

Introduction

Today, the topic of high-speed and higher-speed railway traffic is relevant as high-speed trains [1] play an important role in improving the competitiveness of railways compared to automobile and aviation transport [2-5]. Every year, the speed of passenger trains increases, as this is a general need of society. For example, in Europe and Asia, the speed of passenger transportation has increased significantly over recent times and has reached more than 500 km/h in some areas. European and international standards recognize that high-speed traffic is a movement that provides trips between two points with speeds in the intervals of 141…160 and 161…200 km/h. Ukrainian departmental standards represent the high-speed movement of passenger trains, as the movement of passenger trains with velocities in given intervals [4]:

- 141…160 km/h – accelerated movement;
- 161…200 km/h – high-speed traffic;
- over 200 km/h – higher-speed traffic.

At present, many new high-speed railway lines are being designed and built around the world (or existing networks are being upgraded). And bridges are an integral part of the high-speed highway. Thus, they require the attention of engineers in terms of their design and their technical maintenance.

For bridges with spans of more than 100 m metal truss structures are being used. These are complex structures, which require a separate ap-

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Мости та тунелі: теорія, дослідження, практика, 2017, № 11

proach to the solution of the tasks for their application for high-speed and higher-speed motion. The main task in designing such structures is to find optimal geometric sizes, including elements' cross– sections, layout and design solutions.

Analysis of foreign experience in the design of bridges on the HSR and developments of domestic designers shows the feasibility of the following constructive technological solutions:

– for small bridges and overpasses with spans up to 15 m – prefabricated slab and ribbed simple beam spans;

– for multi-sectional beam bridges with spans of 15…33 m spans – slab-girder spans made of monolithic pre-stresses reinforced concrete;

– for bridges with spans 33…55 m – box structures of monolithic pre-stressed reinforced concrete;

– in bridges with spans of more than 55 m – metal two-track structures with main trusses or arch systems with massive concrete and reinforced concrete supports [11].

On bridges, only a non-junction track is used, which reduces the dynamic impact of rolling stock on the bridge, reducing noise and vibration of elements. However, the work of the non-junction track on the bridge is significantly different from the work on the soil, because of the deformability of the bridge when changes in air temperature occur and of the train vertical and horizontal actions. In this connection, additional stresses arise in the rails trat are elements of a coupled system «bridge – a non-junction track». Their size depends, in particular, on the type of bridge deck. In foreign practice, both ballast and non-ballast bridge decks are used. [9, 10, 7, 11].

In Ukraine, nowadays there are no high-speed and higher-speed tracks for railway transport. Trains are driven at speeds up to 160 km/h by railways of general use. At the same time, all bridge structures operated in areas where accelerated traffic of passenger rail transport is being carried out are calculated and constructed in accordance with the existing regulatory documents under the railway load C14.

There are no separate normative documents for designing bridge structures in areas with high-speed and higher-speed traffic in Ukraine. Therefore, today the detailed study of the foreign experience of introducing high-speed traffic and design of bridge structures according to European norms and norms of other countries of the world and adaptation of foreign normative documents to Ukrainian conditions will allow to develop national standards for designing and building bridges for perspective high-speed and higher-speed highways, which will eventually be introduced in Ukraine.

Purpose

Determination of the stress-strain state of a typical simple metal span structure with bearing trusses by calculation according to national norms and computer simulation method.

Methodology

In this work, the stress-strain state of a continuous truss span by the typical design No. 3 501.2-166 for the possibility of using it in areas under perspective high-speed railway traffic is researched. Calculation of the specified span structure for [12] for railroad loading C14 was executed. The cross-sections of the elements of a continuous truss span were calculated and the necessary checks performed. For the given span structure in the software complex a model was developed and the stress-strain state at various speeds of railway transport according to European and national norms was investigated. The acceleration and deflection of a continuous steel truss span were determined and their comparison with normative requirements was performed.

Particular attention should be paid to ensuring high rigidity of spans – vertical, horizontal and twisting (significant reduction of permissible deflections). The values of permissible deflections, angles of the profile fracture and displacement of the top of the supports on the bridges of VSM at speeds up to 350 km/h are standardized.

When designing bridges, it is necessary to pay special attention to the dynamic calculations of bridge structures, including control of resonant phenomena, as well as the influence of flaws of wheels and rails. The peculiarity of the force influence of rolling stock on the bridge is related to the so-called speed effect, or kinematic excitation. The essence of this interaction mode of the bridge and the train is the transfer of variable force influence on the span structure by the cars of the trains through the wheel pairs as a result of moving the temporary load on the bridge. Hazardous resonance oscillations of bridge structures arise when

ISSN 2413-6212 (Online), ISSN 2227-1252 (Print)
Мости та тунелі: теорія, дослідження, практика, 2017, № 11

the period of power influence of the train coincides with the period of the natural oscillations of the train loaded span structure, while the value of the dynamic index to the temporary load from the rolling stock increases significantly. It should be noted that it is dynamic calculations that are key in the design of bridges on the HSR.

According to the results of dynamic calculations, the main dimensions, parameters and dynamic characteristics of span structures are determined. Rational design allows avoiding excessive adverse dynamic responses during operation, as well as ensuring the safety of high-speed trains and the reliability of the work of the structure.

For calculations of slab, box and ribbed simple beams up to 60 m span, the dynamic effect can be represented as a set of lumped forces that travel along a bridge at a given speed. For truss, arch and frame structures, a dynamic calculation is made taking into account the vehicle-bridge interaction. In order to ensure the stability of the bridge deck, which guarantees the stability of the rail track as a requirement for safety of movement on the railroad, on the HSR bridges the maximum vertical peak acceleration of the span structure at the level of the topside of the track is limited [6, 7]:

– with ballast track – 0,35 g m/s^2;

– with rigid base (ballastless track) – 0,50 g m/s^2.

In the dynamic calculation of the «vehicle – bridge» system, the acceleration at the level of passengers seating in the car, to ensure the comfort of travel should not exceed:

– vertical – 0,15 g m/s^2;

– horizontal – 0,1 g m/s^2.

Eurocode 1990 also defines the limits of maximum vertical displacement from the standpoint of passenger comfort. Passenger comfort during the movement of a car depends on the vertical acceleration [8]. Listed in table 1.

Table 1

Recommended levels of passenger comfort

Comfort levels	Vertical acceleration b_v, m/s^2
Very good	1,0
Good	1,3
Acceptable	2,0

When designing long-span structures, the issues of aerodynamic interaction of high-speed train and structural elements, as well as wind influence, are taken into account. For small and medium bridges, unified design and technological solutions that are specially developed at the initial design stage should be used.

The optimal structural solutions of a unified series of spans should be developed taking into account the results of dynamic calculations on the load from high-speed trains, depending on the track topside on the stage being designed and based on a technical and economic comparison of options.

Individual design is permissible when designing large and extracurricular bridges with large spans, when bridges are located in areas with a complex longitudinal profile, as well as in other justified cases.

The technical conditions for the design and construction of artificial structures on the HSR have their own features [11]:

– to ensure smoothness of trains and comfortable conditions for passengers, the value of the elastic deflection of spans from the static temporary load is limited to a length of 1/2200 span length (on regular railways – 1/600);

– to ensure the rigidity of runways on the HSR in a horizontal plane, it is recommended to limit the elastic deformation to 1/4000 of span lengths, with the maximum relative torsion of the runway structure limited to 1 mm per 1 m of span length (table 2).

In order to assess the impact of the heterogeneity of rolling stock, speed, eccentricity and other factors, additional theoretical and practical tests are required.

Despite the significant achievements of science in the field of computer modeling, the problem is the refinement of the spatial model of the vehicle-bridge interaction system, the possibilities of which would allow a comprehensive assessment of the reliability of artificial structures and the safety of traffic on it.

For further calculation continuous truss span structure with 110+132+110 scheme was selected (shown in fig. 1).

The material of the span structure is D40 steel.

Table 2

The value of the elastic deflection of spans

Regulatory requirements	Limit values of high-speed trains
Maximum deflections	At a speed of 350 km/h:
	δ ≤ 1/1500 L at L ≤ 27 m; δ ≤ 1/2600 L at L = 65 m; δ ≤ 1/2000 L at L ≥ 100 m
	At a speed of 200 km/h:
	δ ≤ 1/1000 L at L ≤ 15 m; δ ≤ 1/1500 L at L = 38 m; δ ≤ 1/600 L at L ≥ 90 m

The calculation was performed according to [12] for C14 load. Forces in the elements of the main trusses from wind and braking were determined. Optimal cross sections were selected and their checks for load C14 were performed. The sections of the main truss elements are shown in fig. 2.

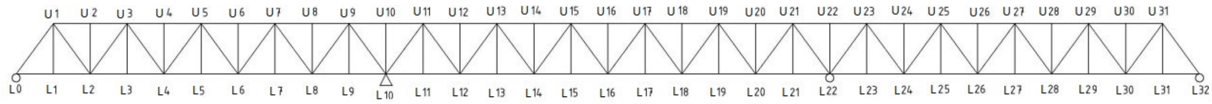


Fig. 1. Calculation scheme

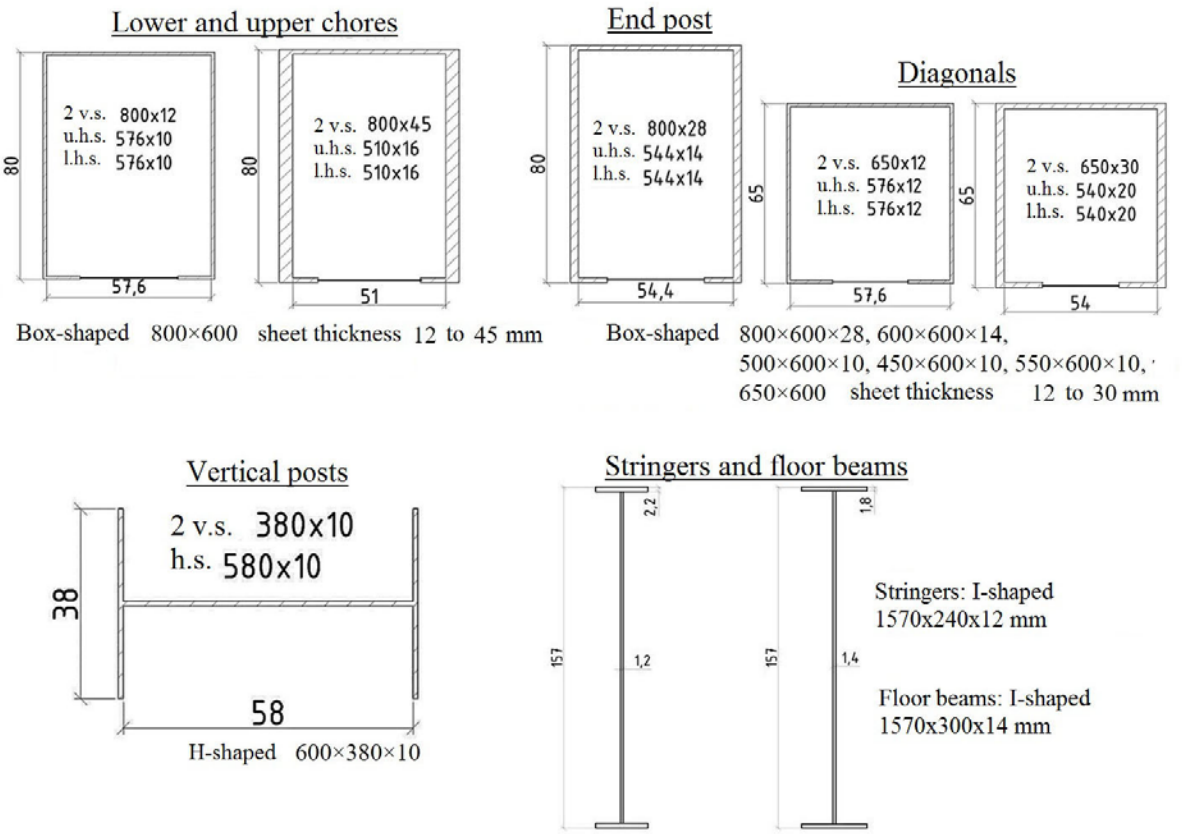


Fig. 2. Main truss elements' cross-section. Results of calculation by [12]

For the software complex calculation, a spatial model of a continuous truss structure with scheme 110+132+110 was constructed, shown in fig. 3, 4. Cross sections for each element according to the performed calculations were applied:

– truss elements (top chord, bottom chord, diagonals, hip verticals and intermediate posts);

– stringers and floor beams;

ISSN 2413-6212 (Online), ISSN 2227-1252 (Print)
Мости та тунелі: теорія, дослідження, практика, 2017, № 11

– ballastless deck slab.

Following this transient loads of load models: C14, HSLM-A1, SW/0, SW/2 were given with corresponding dynamic speed functions (shown in Fig. 5, 6). For models SW/0, SW/2 and C14 – 80, 90, 100 km/h, for HSLM-A1 – 200, 215, 225, 235, 250, 265, 275, 290, 300, 315, 325, 335, 350 km/h.

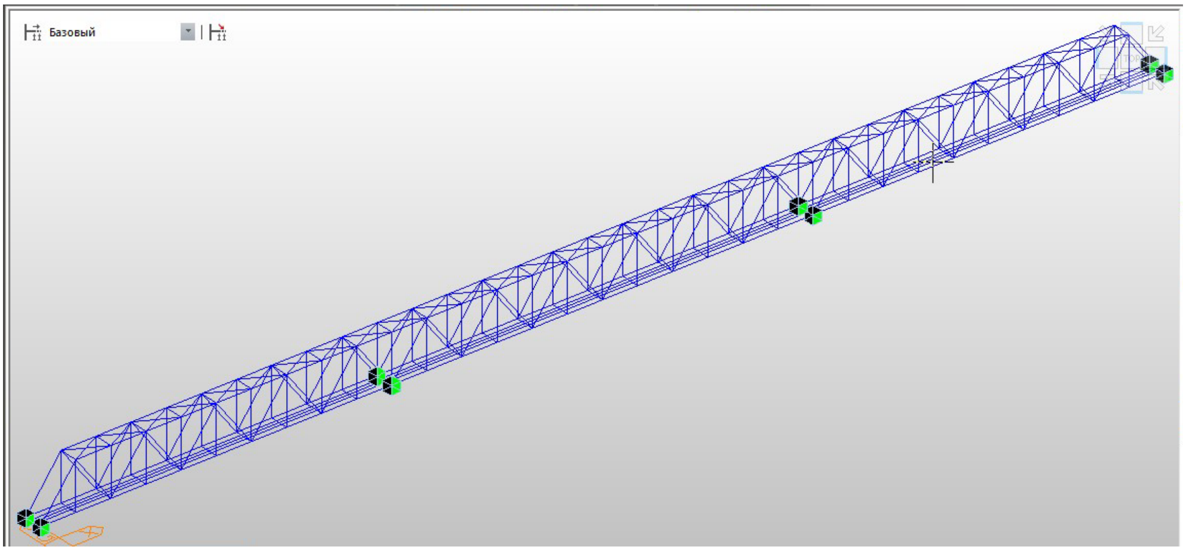


Fig. 3. Schematic of span structure

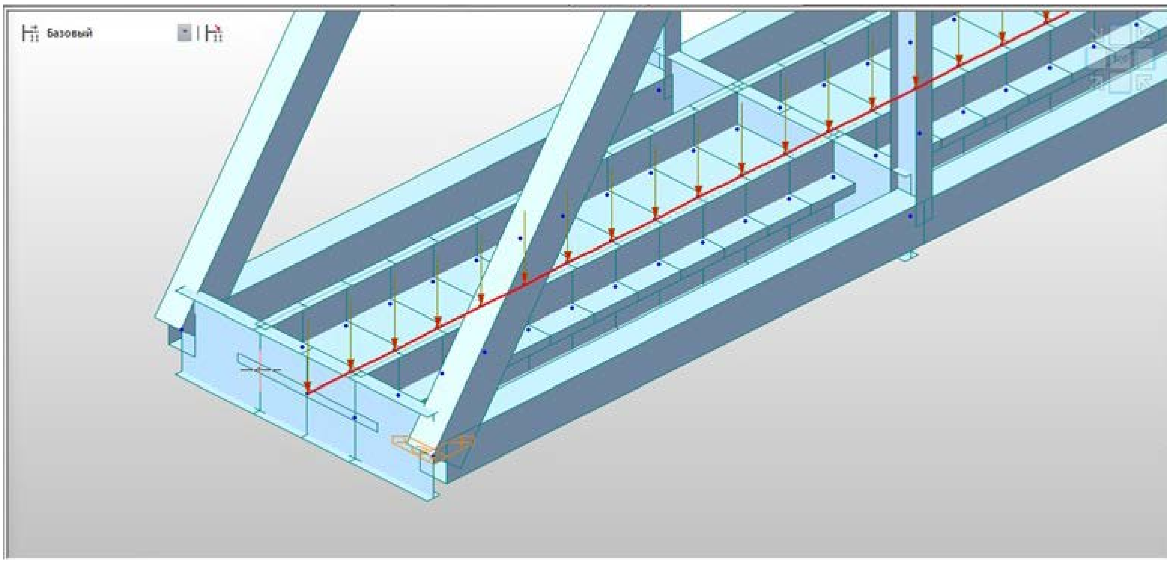
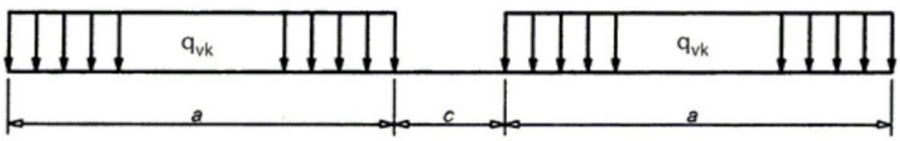
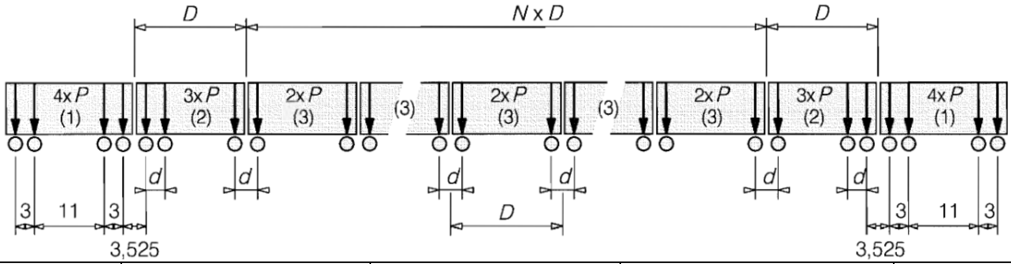


Fig. 4. Schematic of span structure



Load model	mq_{vk}, kN/м	a, m	c, m
SW/0	133	15,0	5,3
SW/2	150	25,0	7,0

Fig. 5. Load models SW/0 and SW/2



Universal train	Number of intermediate passenger cars N	The length of the passenger car D, м	The distance between the axles of the trolleys d, m	Force P, kN
A1	18	18	2,0	170
A2	17	19	3,5	200
A3	16	20	2,0	180
A4	15	21	3,0	190
A5	14	22	2,0	170
A6	13	23	2,0	180
A7	13	24	2,0	190
A8	12	25	2,5	190
A9	11	26	2,0	210
A10	11	27	2,0	210

Fig. 6. Load model HSLM-A

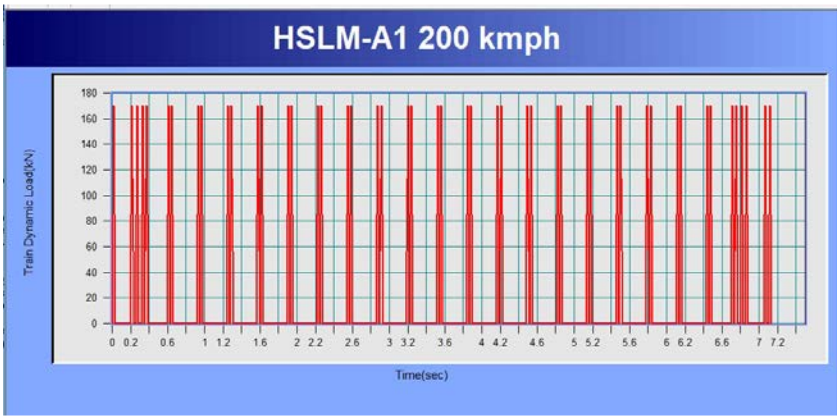


Fig. 7. Dynamic loading function from the load model HSLM-A1 200 km/h

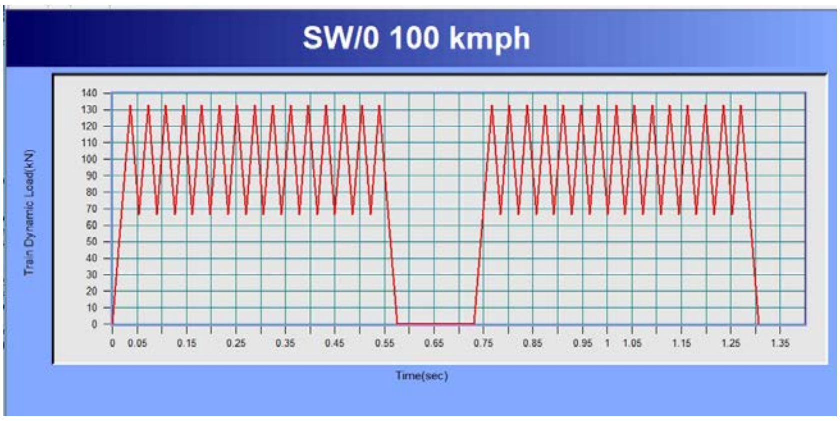


Fig. 8. Dynamic loading function from the load model SW/0 100 km/h

ISSN 2413-6212 (Online), ISSN 2227-1252 (Print)
Мости та тунелі: теорія, дослідження, практика, 2017, № 11

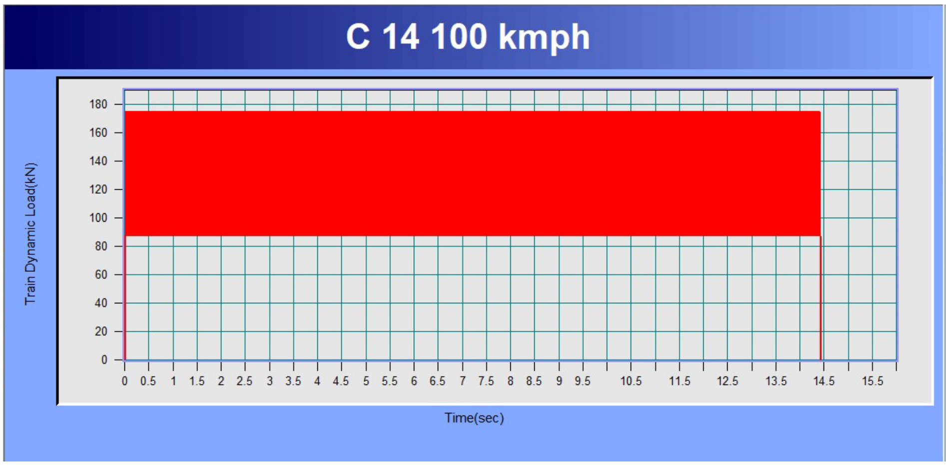


Fig. 9. Dynamic loading function from the load model C14 100 km/h

Fig. 10. Dynamic loading function from the load model SW/2 100 km/h

Results

After calculating the system in the software complex, stress values were obtained in the elements of the truss, Acceleration and displacement were determined for the elements of the truss: at the beginning, at 1/4, at 1/2 parts of each span, and in the middle parts along the axis of the carriageway – at nodes 56, 177, 298 (shown in fig. 11, 12). Graphs of displacements and accelerations are shown on fig. 13, 14.

Figures 15, 16, 17 show the comparison of acceleration and displacement in the elements of the farms with various speed trains.

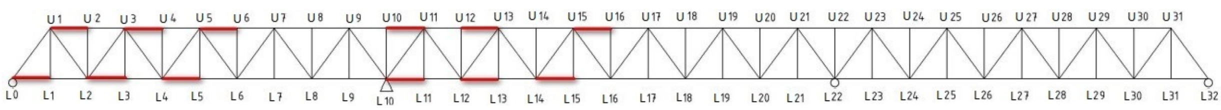


Fig. 11. Truss elements, that need determination of maximum displacements and accelerations

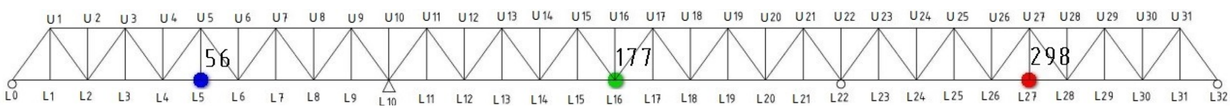


Fig. 12. Middle parts along the axis of the carriageway (nodes 56, 177, 298)

ISSN 2413-6212 (Online), ISSN 2227-1252 (Print)
Мости та тунелі: теорія, дослідження, практика, 2017, № 11

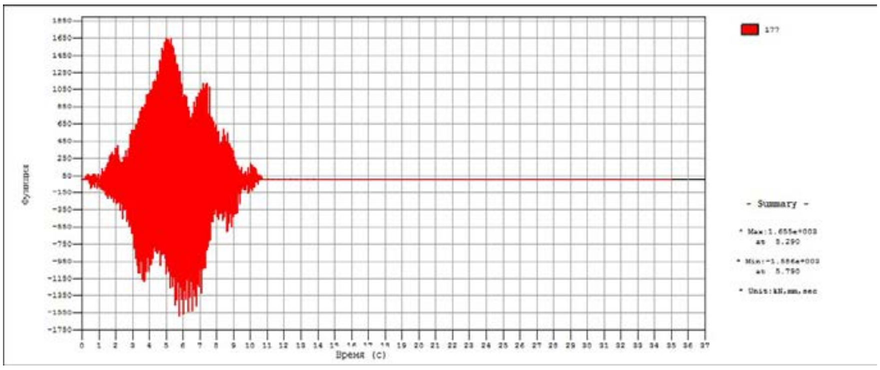


Fig. 13. Maximum acceleration of node 177 for model HSLM-A1 with movement speed of 250 km/h

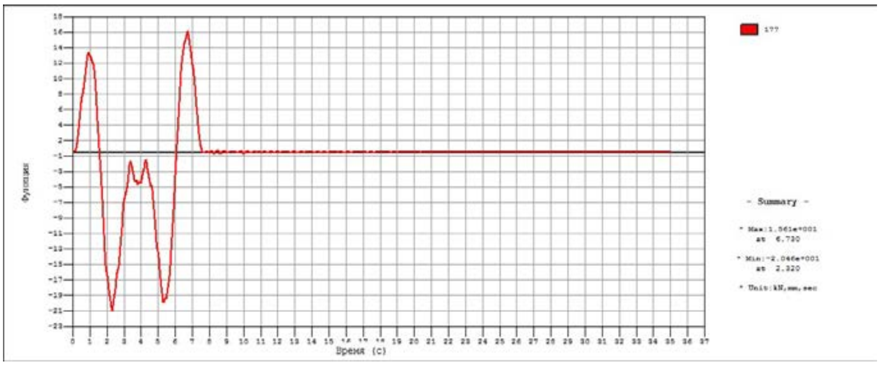


Fig. 14. Maximum displacement in 177 for model HSLM-A1 with movement speed of 350 km/h

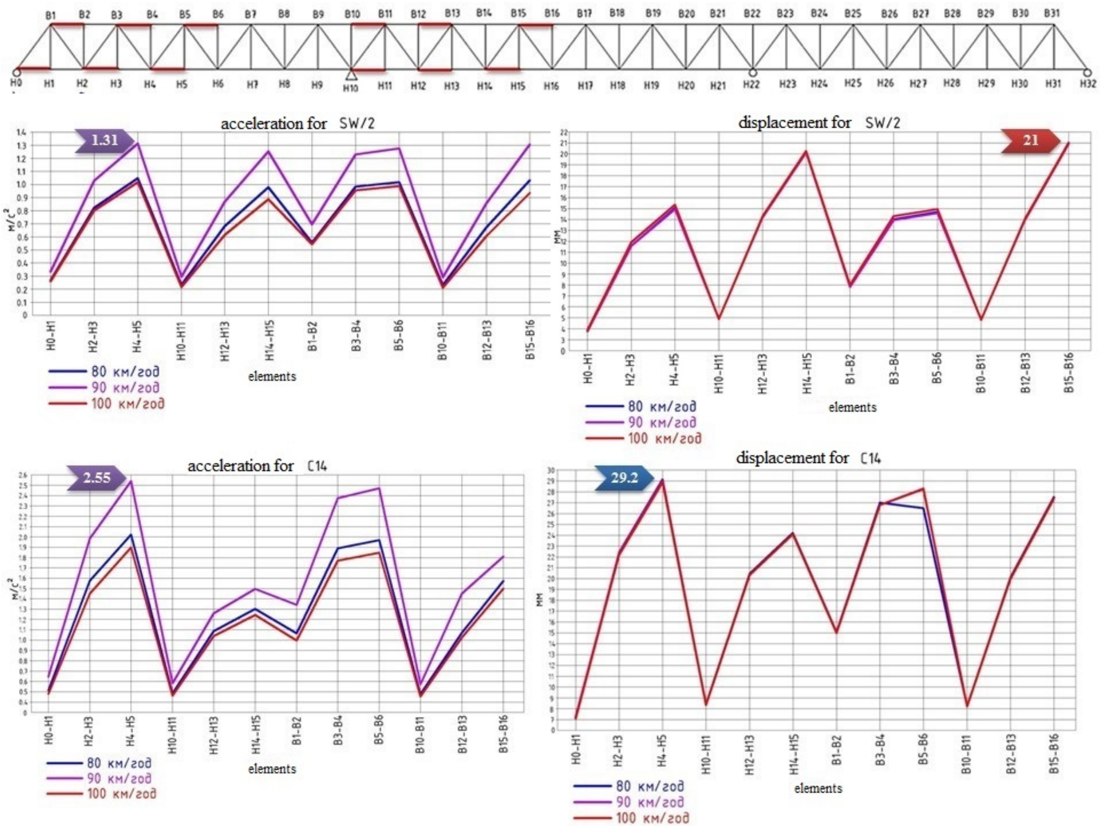


Fig. 15. Graphs of acceleration and displacement in the elements of the trusses at different traffic speeds

ISSN 2413-6212 (Online), ISSN 2227-1252 (Print)
Мости та тунелі: теорія, дослідження, практика, 2017, № 11

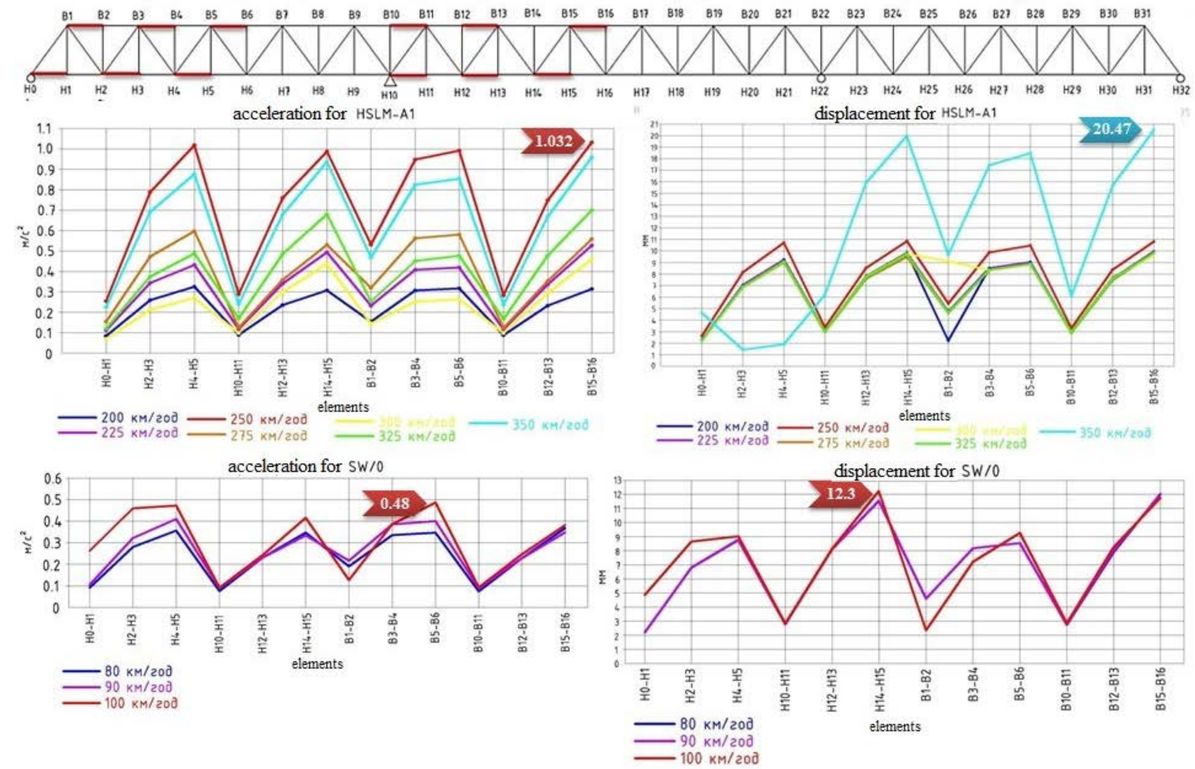


Fig. 16. Graphs of acceleration and displacement in the elements of the trusses at different traffic speeds

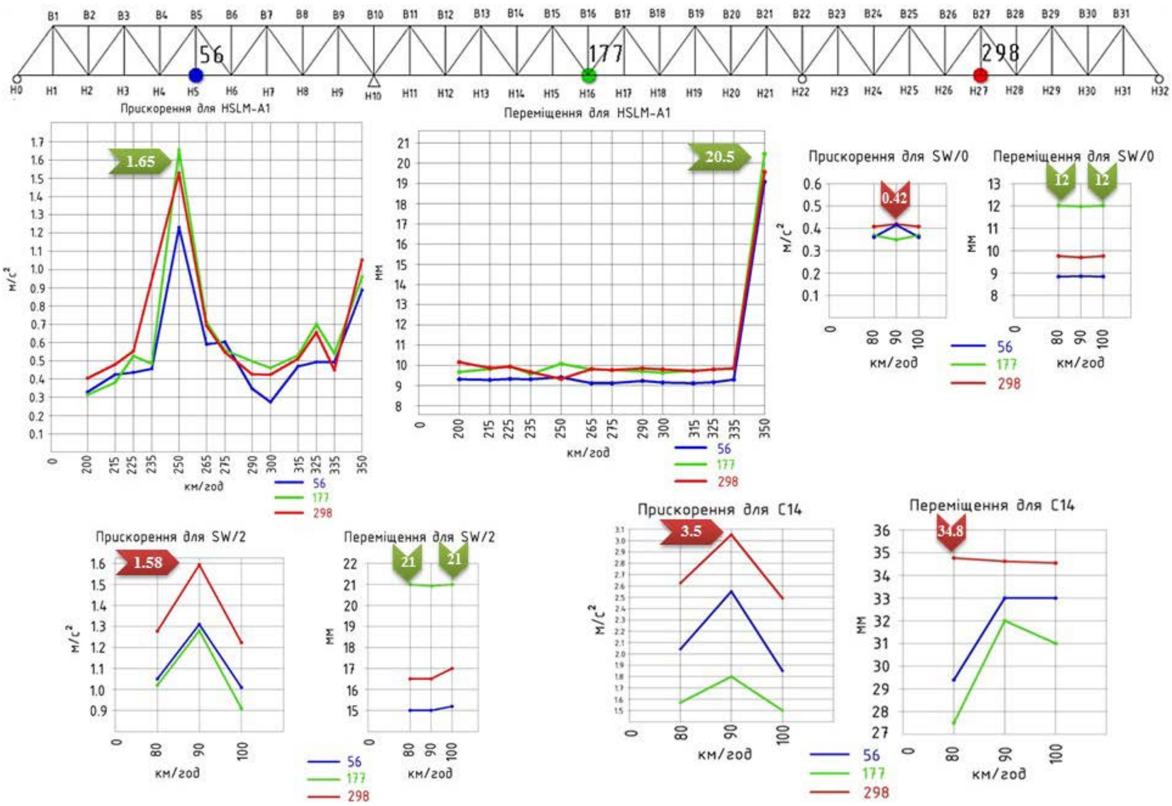


Fig. 17. Graphs of acceleration and displacement in the elements of the trusses
at different traffic speeds at nodes 56, 177, 298

Originality and practical value

The results of the study can be applied in the development of national regulatory documents on high-speed rail transport and in the design of bridge structures with continuous truss spans in areas with high- and higher-speed railway traffic. The obtained results of the research will allow to effectively use continuous steel truss spans of typical designs in areas with high- and higher-speed railway traffic.

Conclusions

On the basis of the performed research of the stress-strain state of a continuous steel truss span and the possibility of its application on stages with high-speed and higher-speed railway traffic, the following results were obtained:

1. When designing bridges at high-speed railways, special attention should be paid to ensuring high rigidity of runways – vertical, horizontal and torsion (significant reduction of permissible deflections). Therefore, in high speed bridges, massive elements must be applied that would satisfy the conditions of high rigidity. It is necessary to pay special attention to the dynamic calculations of bridge structures, including control of resonant phenomena, as well as the influence of flaws in wheels and rails. When designing large-span structures, the issues of aerodynamic interaction of high-speed train and structural elements, as well as wind influence, are taken into account.

2. Methods that use the results of calculating the static load multiplied by the dynamic coefficient F can not predict the resonant effects that arise when the train is passing at high speed. For forecasting of dynamic effects at resonance, methods of dynamic analysis are needed which take into account the load-time dependence within the model loaded with high speed HSLM and real trains. Dynamic factor F is not taken into account for the load caused by real trains; load caused by trains to calculate endurance; load model HSLM; load model «unloaded train». The dynamic effect of the real train can be represented by a set of concentrated forces that are moving.

3. As a result of the calculation of continuous steel truss span according to [12] optimal cross sections were and their checks for load C14 were performed. For truss chors the box cross-section was selected of 600×800 mm with sheet thickness of 12...45 mm, for end post the box cross-section 600×800×28 mm, for diagonals the box cross-section 600×600×14 mm, 600×500×10 mm, 600×450×10 mm, 600×550×10 mm, 600×650 mm with sheet thickness of 12…30 mm, for hip verticals and vertical posts – H-shaped cross-section 600×380×10 mm, for stringers – the I-shaped one 1570×240×12 mm, for floor beams – I-shaped one 1570×300×14 mm.

4. As a result of modeling in the software complex for a continuous steel truss span, accelerations and deflections under the action of freight and passenger load at different speeds of traffic were determined. For freight trains – with a speed of 80 km/h, 90 km/h, 100 km/h. For passenger trains – 200 km/h, 215 km/h, 225 km/h, 235 km/h, 250 km/h, 265 km/h, 275 km/h, 290 km/h, 300 km/h, 315 km/h, 325 km/h, 335 km/h, 350 km/h. All received values of acceleration and deflections are within the established limits. According to EN 1990: Eurocode: Basis of Structural Design, limit values of maximum acceleration from the standpoint of passenger comfort are as follows: 1 m/s^2 – very good; 1,3 m/s^2 – good; 2 m/s^2 – acceptable. And according to EN 1991-2 (2003): Eurocode 1: Actions on structures. P. 2: Traffic loads on bridges, vertical acceleration should not exceed 0,15g m/s^2. According to EN 1990: Eurocode: Basis of Structural Design, vertical displacements to ensure the smoothness of the movement of high-speed trains should not exceed 1/2200 of span length, and for conventional lines, the value of elastic deflection is limited to 1/600 of span length.

5. The deflection of the span structure obtained by calculating the simulation method is:

1) In the middle of the carriageway:

– at movement speed of 350 km/h for load model HSLM-A1– 2,05 cm;

– at movement speed of 80 and 100 km/h for load model SW/0 – 1,21 cm;

– at movement speed of 80 and 100 km/h for load model SW/2 – 2,1 cm;

– at movement speed of 80 km/h for load model C14 – 3,48 cm;

2) For truss elements:

– at movement speed of 350 km/h for load model HSLM-A1 – 2,047 cm;

– at movement speed of 100 km/h for load model SW/0 – 1,23 cm;

– at movement speed of 80, 90, 100 km/h for load model SW/2 – 2,1 cm;

– at movement speed of 80 km/h for load model C14 – 2,92 cm.

6. Acceleration of the span structure obtained by calculating with the simulation method is:

1) In the middle of the carriageway:

– at movement speed of 250 km/h for load model HSLM-A1 – 1,65 m/s^2;

– at movement speed of 90 km/h for load model SW/0 – 0,41 m/s^2;

– at movement speed of 90 km/h for load model SW/2 – 1,6 m/s^2;

– at movement speed of 90 km/h for load model C14 – 3,05 m/s^2.

2) For truss elements:

– at movement speed of 250 km/h for load model HSLM-A1 – 1,032 m/s^2;

– at movement speed of 100 km/h for load model SW/0 – 1,21 m/s^2;

– at movement speed of 90 km/h for load model SW/2 – 1,3 m/s^2;

– at movement speed of 90 km/h for load model C14 – 2,91 m/s^2.

7. The calculations do not take into account the effect of the wind and natural oscillations of the span structure. Therefore, taking into account these factors, the cross-sections of the span structure should have greater rigidity to counteract the fluctuations and prevent the occurrence of resonant phenomena that can lead to the destruction of the structure.

REFERENCES

1. Dr. Jean-Paul Rodrigue, High Speed Rail Systems [Virtual resource] / Dr. Jean-Paul Rodrigue // people.hofstra.edu. – 2017. – Access mode: URL: https://people.hofstra.edu/geotrans/eng/ch3en/appl3en/ch3a1en.html.
2. Підтримка інтеграції України до Трансєвропейської транспортної мережі ТЄМ-Т: РК.2 Швидкісний залізничний транспорт. Заключний звіт 2.1, 2010 рік [Електронний ресурс]. – Режим доступу: http://www.ten-t.org.ua/ua/
3. Не по дорозі: що заважає розвитку швидкісного руху в Україні [Електронний ресурс] // news.finance.ua. — Режим доступу: https://news.finance.ua/ua/news/-/304614/ne-po-dorozi-shho-zavazhaye-rozvytku-shvydkisnogo-ruhu-v-ukrayini.
4. ВНД 32.1.07.000-02. Тимчасова інструкція з організації швидкісного руху пасажирських поїздів. Вимоги до інфраструктури та рухомого складу. Державна адміністрація залізничного транспорту України [Электронный ресурс]. Київ : Укрзалізниця, 2002. – 51 с. Режим доступу: https://studopedia.info/1-31887.html
5. Бараш, Ю. С. Аналіз роботи швидкісного руху в Україні [Текст] / Ю. С. Бараш, О. М. Гненний, А. В. Момот // Залізничний транспорт. – 2014. – С. 53-62.
6. EN 1991-2 (2003) : Eurocode 1 : Actions on structures. P. 2 : Traffic loads on bridges.
7. Бенин, А. В. Особенности проектирования и строительства мостов высокоскоростной железнодорожной магистрали «Москва – Казань» [Текст] / А. В. Бенин, Л. К. Дьяченко, В. Н. Смирнов // St. Petersburg state un-ty of the way of communication. – Proceedings of Petersburg Transport University. – 2015. – v. 4 – pp. 15-20.
8. EN 1990: Eurocode: Basis of Structural Design
9. Смирнов, В. Н. Динамическая работа мостов высокоскоростных железнодорожных магистралей при продольных воздействиях поездной нагрузки [Текст] : монография / В. Н. Смирнов. – СПб. Петербург, Гос. ун-т путей сообщения, 2013. – 65 с.
10. Смирнов, В. Н. Расчёт мостов высококоростных железнодорожных магистралей на продольные силы [Текст] : монография / В. Н. Смирнов. – СПб. Петербург, Гос. ун-т путей сообщения, 2013. – 65 с.
11. Новые технологии в мостостроении: мосты на высокоскоростных железнодорожных магистралях [Текст]: сб. трудов / Под ред. В. Н. Смирнова - СПб. Петербург, Петербургский государственный университет путей сообщения, 2013. – 61 с.
12. ДБН В.2.3-14:2006. Споруди транспорту. Мости та труби. Правила проектування [Текст]. – Надано чинності 2007-02-01. – Київ : Мін. буд., архіт. та житл.-комун. госп-ва, 2006. – 359 с.

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ПАРАМЕТРИ ТИПОВИХ МЕТАЛЕВИХ ПРОГОНОВИХ БУДОВ ІЗ НАСКРІЗНИМИ ФЕРМАМИ НЕРОЗРІЗНОГО ТИПУ ПІД ШВИДКІСНИЙ РУХ

Мета. Визначення напружено-деформованого стану типової нерозрізної металевої прогонової будови із наскрізними фермами шляхом розрахунку за національними нормами та методом комп’ютерного моделювання в умовах пропуску швидкісних пасажирських потягів. **Методика.** В роботі досліджується напружено-деформований стан нерозрізної прогонової будови з наскрізними фермами за типовим проектом серії № 3.501.2-166 для можливості застосування його на ділянках під перспективний високошвидкісний рух залізничного транспорту. Виконати розрахунок вказаної прогонової будови за ДБН В.2.3-14-2006. «Споруди транспорту. Мости і труби. Правила проектування» під залізничне навантаження С14. Підібрати перерізи елементів нерозрізної металевої прогонової будови з наскрізними фермами та виконати необхідні перевірки. Для вказаної прогонової будови у програмному комплексі розробити модель і дослідити напружено-деформований стан при різних швидкостях залізничного транспорту за Європейськими та національними нормами. Визначити прискорення та прогини нерозрізної металевої прогонової будови з наскрізними фермами і виконати їх порівняння із нормативними вимогами. **Результати.** В результаті моделювання в програмному комплексі для нерозрізної металевої прогонової будови із наскрізними фермами визначено прискорення і прогини під дією вантажного і пасажирського навантаження при різних швидкостях руху. Підібрані перерізи елементів нерозрізної металевої прогонової будови з наскрізними фермами. **Наукова новизна.** Результати дослідження можуть бути застосовані при розробці національних нормативних документів по високошвидкісному руху залізничного транспорту та при проектуванні мостових споруд із нерозрізними металевими прогоновими будовами з наскрізними фермами на ділянках із прискореним та високошвидкісним рухом залізничного транспорту. **Практична значимість.** Отримані результати дослідження дозволять ефективно застосовувати нерозрізні металеві прогонові будови з наскрізними фермами за типовими проектами на ділянках із прискореним та високошвидкісним рухом залізничного транспорту.

Ключові слова: високошвидкісний рух; високошвидкісна магістраль; мостобудування; нерозрізна прогонова будова з наскрізними фермами; прискорення; переміщення; прогонова будова; металевий міст; модель; залізничне навантаження; метод скінченних елементів

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ПАРАМЕТРЫ ТИПОВЫХ МЕТАЛЛИЧЕСКИХ ПРОЛЕТНЫХ СТРОЕНИЙ СО СКВОЗНЫМИ ФЕРМАМИ НЕРАЗРЕЗНОГО ТИПА ПОД СКОРОСТНОЕ ДВИЖЕНИЕ

Цель. Определение напряженно-деформированного состояния типового неразрезного металлического пролетного строения со сквозными фермами путем расчета по национальным нормам и методом компьютерного моделирования в условиях пропуска скоростных пассажирских поездов. **Методика.** В работе исследуется напряженно-деформированное состояние неразрезного пролетного строения со сквозными фермами по типовому проекту серии № 3.501.2-166 на возможность применения его на участках под перспективное высокоскоростное движение железнодорожного транспорта. Выполнен расчёт указанного пролетного строения по ДБН В.2.3-14-2006. «Сооружения транспорта. Мосты и трубы. Правила проектирования» под железнодорожную нагрузку С14. Подобраны сечения элементов неразрезного металлического пролетного строения со сквозными фермами и выполнены необходимые проверки. Для указанного пролетного строения в программном комплексе разработана модель и исследовано напряженно-деформированное состояние при различных скоростях железнодорожного транспорта по Европейским и национальным нормам. Определены ускорение и прогибы неразрезного металлического пролетного строения со сквозными фермами и выполнены их сравнение с нормативными требованиями. **Результаты.** В результате моделирования в программном комплексе для неразрезного металлического пролетного строения со сквозными фермами определены ускорения и прогибы под действием грузовой и пассажирской нагрузок при различных скоростях движения. Подобраны сечения элементов неразрезного металлического пролетного строения со сквозными фермами. **Научная новизна.** Результаты исследования могут быть применены при разработке национальных нормативных документов по высокоскоростному движению железнодорожного транспорта и при проектировании мостовых сооружений с неразрезными металлическими пролетными строениями со сквозными фермами на участках с ускоренным и высокоскоростным движением железнодорожного транспорта. **Практическая значимость.** Полученные результаты исследования позволят эффективно применять неразрезные металлические пролетные строения со сквозными фермами по типовым проектам на участках с ускоренным и высокоскоростным движением железнодорожного транспорта.

Ключевые слова: высокоскоростное движение; высокоскоростная магистраль; мостостроение; неразрезное пролетное строение со сквозными фермами; ускорение; перемещение; пролетное строение; металлический мост; модель; железнодорожная нагрузка; метод конечных элементов

REFERENCES

1. Dr. Jean-Paul Rodrigue. High Speed Rail Systems [Electronic resource]. Available at: people.hofstra.edu. – 2017. – Access mode: URL: https://people.hofstra.edu/geotrans/eng/ch3en/appl3en/ch3a1en.html.
2. Pidtrymka integhraciji Ukrajiny do Transjevropejsjkoji transportnoji merezhi TJeM-T: RK.2 Shvydkisnyj zaliznychnyj transport. Zakljuchnyj zvit 2.1, 2010 rik [Support for the integration of Ukraine into the Trans-European Transport Network TEN-T: RK.2 High-speed rail transport. Final Report 2.1, 2010]. рік [Electronic resource]. Available at: http://www.ten-t.org.ua/ua/.
3. Ne po dorozi: shho zavazhaje rozvytku shvydkisnogho rukhu v Ukrajini [Not on the road: it hinders the development of high-speed traffic in Ukraine]. [Electronic resource]: https:// news.finance.ua. Available at: https://news.finance.ua/ua/news/-/304614/ne-po-dorozi-shho-zavazhaye-rozvytku-shvydkisnogo-ruhu-v-ukrayini.
4. *VND 32.1.07.000-02. Tymchasova instrukcija z orghanizaciji shvydkisnogho rukhu pasazhyrsjkykh pojizdiv. Vymoghy do infrastruktury ta rukhomogho skladu. Derzhavna administracija zaliznychnogho transportu Ukrajiny* [GNI 32.1.07.000-02. Temporary instruction on organization of high-speed passenger trains. Requirements for infrastructure and rolling stock. State Administration of Railway Transport of Ukraine]. Kyjiv, Ukrzaliznycja, 2002. 51 p. [Electronic resource]. Available at: https://studopedia.info/1-31887.html
5. Barash Ju. S., Ghnennyj O. M., Momot A. V. Analiz roboty shvydkisnogho rukhu v Ukrajini [Analysis of the operation of high-speed traffic in Ukraine]. *Zaliznychnyj transport – Railway transport*, 2014, pp. 53-62.
6. EN 1991-2 (2003). Eurocode 1. Actions on structures. P. 2. Traffic loads on bridges.
7. Benyn, A. V. Djjachenko L. K., Smyrnov V. N. Osobennosty proektyrovanyja y stroyteljstva mostov vыsokoskorostnoj zheleznodorozhnoj maghystraly «Moskva-Kazanj» [Features of designing and building bridges of high-speed railway "Moscow-Kazan"]. *Peterburg. gos. un-t putej soobshhenija – St. Petersburg state un-ty of the way of communication*, 2015, v. 4, – pp. 15-20.
8. EN 1990: Eurocode: Basis of Structural Design
9. Smirnov V. N. *Dinamicheskaja rabota mostov vysokoskorostnyh zheleznodorozhnyh magistralej pri prodol'nyh vozdejstvijah poezdnoj nagruzki* [Dynamic work of bridges of high-speed railway magistrails with longitudinal effects of train load], monografija [monograph]. SPb. Peterburg, Gos. un-t putej soobshhenija, 2013. 65 p.
10. Smirnov V. N. *Raschjot mostov vysokoskorostnyh zheleznodorozhnyh magistralej na prodol'nye sily* [Calculation of bridges of high-speed railways on longitudinal forces], monografija [monograph]. SPb. Peterburg, Gos. un-t putej soobshhenija, 2013. 65 p.
11. *Novye tehnologii v mostostroenii: mosty na vysokoskorostnyh zheleznodorozhnyh magistraljah,* sb. trudov. Pod red. V. N. Smirnova [New technologies in bridge construction: bridges on high-speed railways, Sat. Works. Ed. V. N. Smirnov]. SPb. Peterburg, Gos. un-t putej soobshhenija, 2013. 61 p.

12. *DBN V.2.3-14-2006. Sporudy transportu. Mosty ta truby. Pravyla proektuvannya* [State Standard V.2.3-14-2006. Transport constructions. Bridges and pipes. Design rule]. Kyjiv, Ministerstvo budivnytstva, arkhitektury i zhytlovo-komunalnoho hospodarstva Publ., 2006. 359 p.

Статтю рекомендовано до публікації д.т.н., проф. В. Д. Петренком (Україна), д.т.н., проф. М. М. Біляєвим(Україна).

Надійшла до редколегії 20.08.2017.
Прийнята до друку 25.09.2017.