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Ground laser scanning of the flyover through the railway for the purposes of its reconstruction

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ABSTRACT The article presents the possibility of obtaining geometric parameters of an flyover passing through a railway using ground–based laser scanning technology using modern equipment Leica ScanStation C10. The practical significance of using the chosen method lies in the fastest and most convenient scanning of the object, reducing production costs and, of course, high accuracy of the spatial data obtained necessary for the reconstruction of the flyover. A study of the use of ground-based laser scanning technology to obtain spatial data of the flyover was conducted, as a result of which the advantages of the chosen method were revealed. Also, based on the data obtained, a comprehensive three-dimensional model and two-dimensional drawings were prepared, such as the facade of the flyover, its plan and drawings of transverse profiles. Thanks to the compiled drawings and models of the bridge structure passing through the railway, the design work on the reconstruction of the facility has become much easier and more efficient. The presented experience confirms the need to introduce modern technologies, namely ground-based laser scanning in survey activities in order to develop and detail design solutions for the reconstruction of flyovers.

KEYWORDS: spatial data; ground laser scanning; flyover (overpass); linear structures; railway; reconstruction

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Научная статья

Наземное лазерное сканирование путепровода через железную дорогу для его реконструкции

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АННОТАЦИЯ Рассмотрена возможность получения геометрических параметров путепровода, проходящего через железную дорогу, с помощью применения технологии наземного лазерного сканирования с использованием современного оборудования Leica ScanStation C10. Практическая значимость выбранного метода заключается в наиболее быстром и удобном выполнении сканирования объекта, снижении затрат на производство и высокой точности полученных пространственных данных, необходимых для реконструкции путепровода.

Проведено исследование применения технологии наземного лазерного сканирования для получения пространственных данных путепровода, в результате которого выявлены преимущества этого метода. На основе полученных данных выполнена подготовка комплексной трехмерной модели и двумерных чертежей, таких как фасад путепровода, его план и чертежи поперечных профилей. Благодаря составленным чертежам и модели мостового сооружения, проходящего через железную дорогу, проведение проектных работ по реконструкции объекта стало значительно проще и эффективнее.

Представленный опыт подтверждает необходимость внедрения современных технологий, а именно наземного лазерного сканирования в изыскательскую деятельность с целью разработки и детализации проектных решений по реконструкции путепроводов.

КЛЮЧЕВЫЕ СЛОВА: пространственные данные; наземное лазерное сканирование; путепровод; линейные сооружения; железная дорога; реконструкция

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INTRODUCTION

In modern scientific literature, the issue of overpasses operation and monitoring of their deformations is considered frequently [1–3], as there are many reasons for changes in their qualitative characteristics. In the process of long-term operation of flyovers, various defects and damages gradually appear, which leads to the problem of their utilisation and large expenditure of resources for reconstruction [4, 5]. Modernisation of bridge structures passing through railways is aimed at improving the reliability performance not only of the whole object, but also of its constituent parts [6].

Documentation for flyover reconstruction includes many components, one of them is drawings of various structures and a three-dimensional model of the object [7]. To obtain such information, the technology of terrestrial laser scanning was chosen.

MATERIALS AND METHODS

Currently, there are various ways of obtaining spatial data on objects, but the most promising and modern direction is terrestrial laser scanning [8–11]. During scanning, the directions of laser beam propagation and the distance to the object points are determined. Terrestrial laser scanning is carried out in order to obtain an accurate and most complete three-dimensional image of the filmed object in the form of a point cloud [12].

The creation of a complex spatial model and drawings for the reconstruction of the flyover on Ofitserskaya Street over the railway in Krasnodar on the basis of terrestrial laser scanning data using Leica ScanStation C10 is considered. In the city this flyover serves as one of the main and always busy entrance routes. The survey was carried out to assess

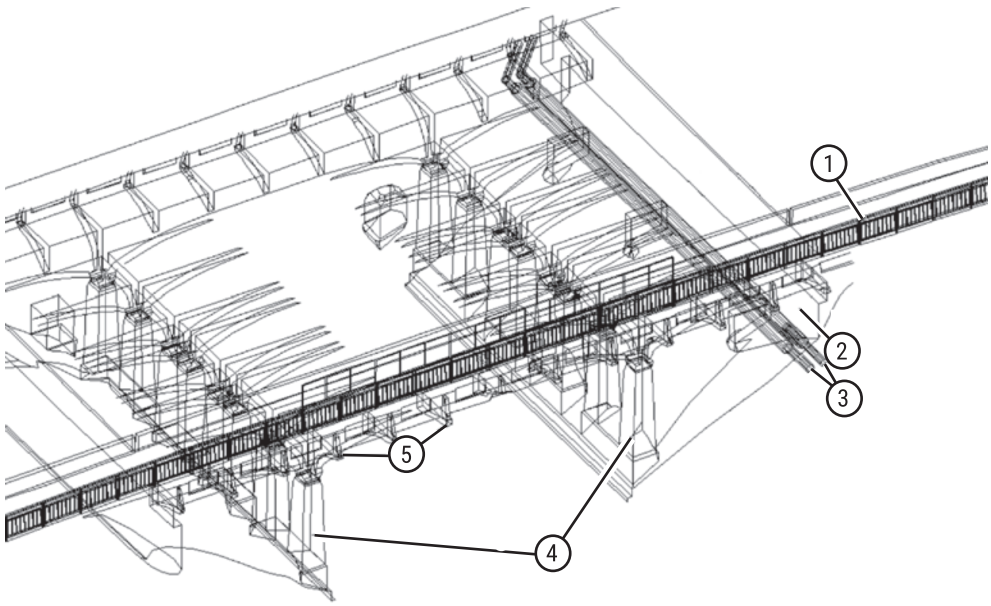

Fig. 1. Three-dimensional model of the flyover: 1 — railing; 2 — support body; 3 — metal pipes in the casing; 4 — reinforced concrete ribs of the superstructure; 5 — support posts

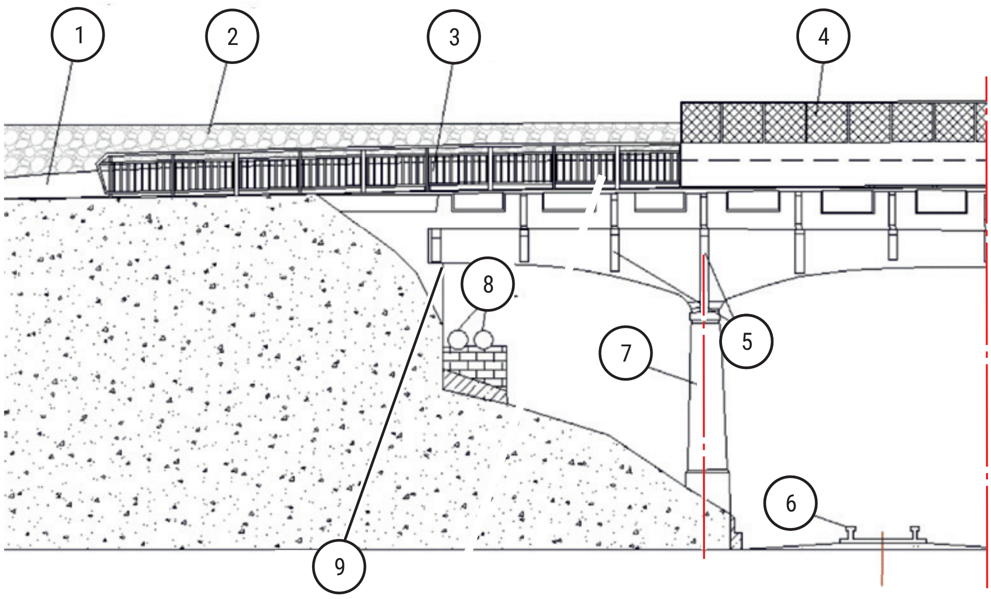

Fig. 2. The facade of the flyover: 1 — reinforced concrete barrier fence; 2 — reinforced concrete communication box; 3 — railing fence; 4 — protective shields; 5 — reinforced concrete ribs of the superstructure; 6 — railway track; 7 — support posts; 8 — metal pipes in the casing; 9 — support body

the technical condition of the flyover building structures, to identify damages and defects affecting the strength and load-bearing capacity of the structure, as well as to carry out further work on its reconstruction.

FINDINGS OF THE STUDY

When flyovers are being reconstructed and design documentation is missing or outdated and inadequate, new spatial data is required.

The Leica ScanStation C10 scanner provides spatial data with a point position accuracy of 4 mm per 50 metres. On the basis of the obtained information a 3D model, 3D and 2D drawings are created.

Extraction of geometric information from spatial scanning data is performed by point cloud, first it is processed in ReCap and Cyclone programmes. Then the processed point cloud data is exported for modelling in Revit software (*Fig. 1*). Due to the fact that the obtained point cloud is dense, the data from the drawing results are reliable and accurate. As a result, the centres of the supports and the distances between them are identified. Based on the results of modelling the point cloud in AutoCAD programme, drawings were made for the preparation of performance documentation.

The results of terrestrial laser scanning allowed to draw the facade (*Fig. 2*) and plan (*Fig. 3*) of the flyover with indication of qualitative characteristics of its ele-

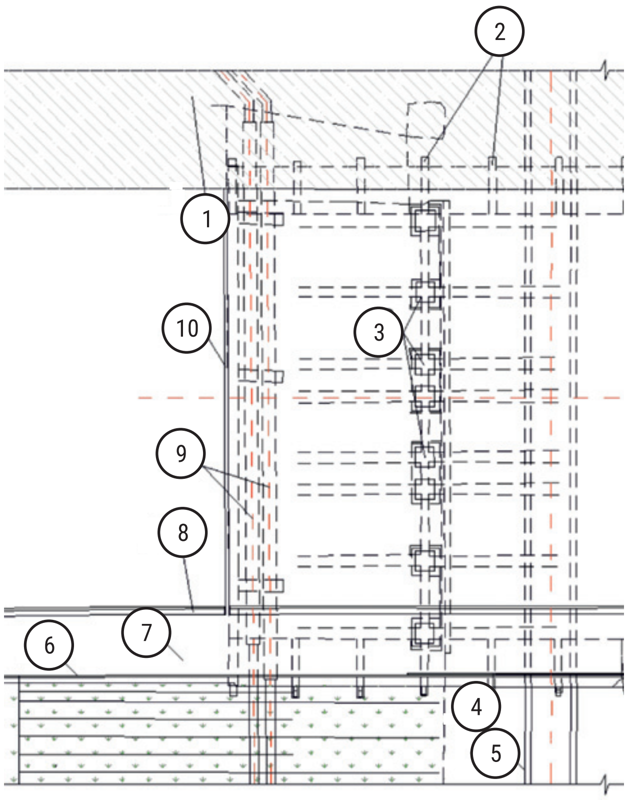

Fig. 3. Plan of the flyover: 1 — reinforced concrete communication box; 2 — reinforced concrete ribs of the superstructure; 3 — support posts; 4 — protective shields; 5 — railway track; 6 — railing; 7 — sidewalk; 8 — reinforced concrete barrier fence; 9 — metal pipes in the casing; 10 — deformation seam

Table

Specification of the fittings for the flyover

Item	Name		Quantity, pcs.	Weight, kg	Total, kg
	Assembly units				
	DSh-BSh-50		2 pcs./(13,93 + 14,07) = 28 RMT		
	Support 1 (4)				
1	∅12 AIII GOST 5781-82*	*L* = 14 000 mm	16	12.432	198.912
2	∅12 AIII GOST 5781-82*	*L* = 145 mm	560	0.129	72.240
3	∅14 AIII GOST 5781-82*	*L* = 450 mm	560	0.545	305.200
4	∅16 AIII GOST 5781-82*	*L* = 420 mm	280	0.664	185.920
	Expansion joint base				
5	∅16 AIII GOST 5781-82*	*L* = 1420–1990 mm	280	2.694	754.320
6	∅16 AIII GOST 5781-82*	*L* = 14 000 mm	48	22.120	1061.760
	Monolithic reinforced concrete, class B25, F200, W8		6.28		
	Filling the gate				
7	∅12 AIII GOST5781-82*	*L* = 1466–1990 mm	280	1.426	399.280
8	∅12 AIII GOST5781-82*	*L* = 14 000 mm	32	12.432	397.824
	Monolithic reinforced concrete, class B25, F200, W8		10.3		
	Materials				
9	Transition zone “MMCreat” or equivalent		m^3		1.18
10	Monolithic reinforced concrete, class B25, F200, W8		m^3		4.47
11	Chemical anchor “BIT-EASF” or equivalent		L		9.76

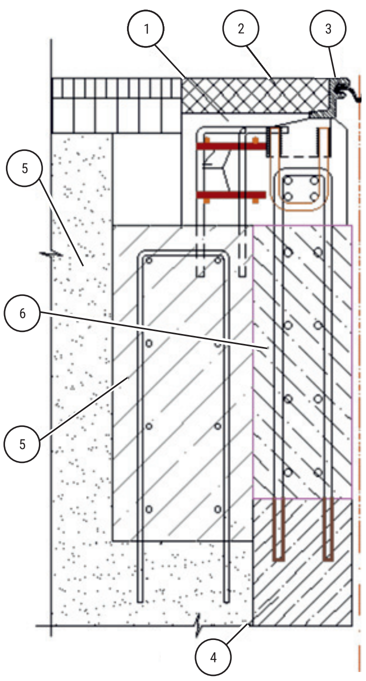

Fig. 4. Design drawing of the expansion joints of the flyover: 1 — monolithic concrete; 2 — transition zone; 3 — extreme load-bearing profile; 4 — cabinet wall; 5 — filling the gate with monolithic reinforced concrete; 6 — monolithic reinforced concrete base for the expansion joint

ments in scale 1:100. Also based on the measurement data, drawings of cross-sectional profiles were made with the determination of slope values and slope directions.

In order to reconstruct the flyover, a condition survey is also required. For this purpose, a construction drawing of the expansion joints (*Fig. 4*) with the accompanying specification of reinforcement for the flyover (*Table*).

CONCLUSION AND DISCUSSION

The article presents the experience of using the technology of terrestrial laser scanning of flyovers, based on the results thereof it can be concluded that the use of this technology for surveying engineering structures is relevant, taking into account its advantages. During reconstruction laser scanning is used to obtain executive documentation, to monitor geometric deviations from the design or permissible parameters for the flyover, as well as to obtain characteristics of its structural elements — flyover condition survey. The obtained data are reliable and can be used for development and detailing of design decisions on reconstruction.

REFERENCES

1. Gura D.A., Shevchenko G.G. Ecological monitoring of deformation of structures using ground-based laser scanning. *Construction – 2010: Materials of the International Scientific and Practical Conference*. 2010;152-153. EDN VVOXZP. (In Russ.).

2. Sukhorukov B.D., Savchynskyi B.V., Zhurbenko M.K. Experience in the operation and monitoring of bridge supports which are subjects to irregular precipitation and careens. *Bulletin of the Dnipropetrovsk National University of Railway Transport named after Academician V. Lazaryan*. 2005;6:186-189. EDN VWACQX. (In Russ.).

3. Bryn M.Ya., Nikitchin A.A., Tolstov E.G. Geodesic monitoring of railway transport infrastructure objects. *Transport of the Russian Federation*. 2010;4(29):58-60. EDN NAXYBX. (In Russ.).

4. Khortsev V.L., Proskura D.V., Gura D.A., Shevchenko G.G. Horizontal and vertical displacements of structures and their causes. *Earth Sciences at the present stage: VI International Scientific and Practical Conference*. 2012;116-119. EDN VMXGTX. (In Russ.).

5. Mukhlis M.R., Bhuiyan Md.A.R. Effect of SSI on seismic response of flyover: a case study. *4th International Conference on Advances in Civil Engineering 2018*. 2018.

6. Makarov A.V., Guluev G.G., Shatlaev S.V. Reconstruction of the overpass as a safety requirement. *Engineering journal of Don*. 2017;2(45):123. EDN ZEOOCF. (In Russ.).

7. Pastushkov G.P., Rasinskaya L.G. *Bridge design: manual*. Vol. 1. Minsk, BNTU, 2017;41. EDN FTXUUC. (In Russ.).

8. Azarov B.F., Karelina I.V. Ground laser scanning as a tool for creating buildings-and-structures' information modeling (BIM). *Geodesy and Cartography*. 2019;80(6):16-23. DOI: 10.22389/0016-7126-2019-948-6-16-23. (In Russ.).

9. Choker H.M., Mustafin M.G. Geodesic support of laser scan technology use for fixing cultural heritage objects. *Geodesy and Cartography*. 2021;82(2):2-10. DOI: 10.22389/0016-7126-2021-968-2-2-10. (In Russ.).

10. Valkov V.A., Mustafin M.G., Makarov G.V. Application of ground laser scanning to create three-dimensional digital models of the Shukhov Tower. *Journal of Mining Institute*. 2013;204:58-61. EDN RSEQRH. (In Russ.).

11. Valkov V.A., Vinogradov K.P. The technique of automatic modeling of defects of a covering of highways according to mobile laser scanning. *Geodesy, cartography, geoinformatics and cadastres. Science and education: collection of materials of the III All-Russian Scientific and practical conference*. 2019;209-215. EDN LCNURO. (In Russ.).

12. Bryn' M.Ya., Bogomolova N.N., Zhuravlev I.N., Nikitchin A.A. Feasibility of laser scanning at the survey stage in the reconstruction of engineering structures. *Bulletin of Scientific Research Results*. 2020;1:43-53. DOI: 10.20295/2223-9987-2020-1-43-53. EDN IEWCHM. (In Russ.).

ЛИТЕРАТУРА

1. *Гура Д.А., Шевченко Г.Г.* Экологический мониторинг деформации сооружений с использованием наземного лазерного сканирования // Строительство – 2010: материалы Международной научно-практической конференции. 2010. С. 152–153. EDN VVOXZP.

2. *Сухоруков Б.Д., Савчинский Б.В., Журбенко М.К.* Опыт эксплуатации и наблюдения за мостовыми сооружениями, опоры которых подвержены неравномерным осадкам и кренам // Вісник Дніпропетровського національного університету залізничного транспорту ім. академіка В. Лазаряна. 2005. № 6. С. 186–189. EDN VWACQX.

3. *Брынь М.Я., Никитчин А.А., Толстов Е.Г.* Геодезический мониторинг объектов инфраструктуры железнодорожного транспорта спутниковыми методами // Транспорт Российской Федерации. 2010. № 4 (29). С. 58–60. EDN NAXYBX.

4. *Хорцев В.Л., Проскура Д.В., Гура Д.А., Шевченко Г.Г.* Горизонтальные и вертикальные смещения сооружений и причины их возникновения // Науки о Земле на современном этапе: VI Международная научно-практическая конференция. 2012. С. 116–119. EDN VMXGTX.

5. *Mukhlis M.R., Bhuiyan Md.A.R.* Effect of SSI on seismic response of flyover: a case study // 4th International Conference on Advances in Civil Engineering 2018. 2018.

6. *Макаров А.В., Гулуев Г.Г., Шатлаев С.В.* Реконструкция путепровода как требование безопасности // Инженерный вестник Дона. 2017. № 2 (45). С. 123. EDN ZEOOCF.

7. *Пастушков Г.П., Расинская Л.Г.* Проектирование мостов: пособие для студентов. В 2 ч. Ч. 1. Минск: БНТУ, 2017. 41 с. EDN FTXUUC.

8. *Азаров Б.Ф., Карелина И.В.* Наземное лазерное сканирование как инструмент для формирования информационных моделей зданий и сооружений // Геодезия и картография. 2019. № 6. С. 16–23. DOI: 10.22389/0016-7126-2019-948-6-16-23

9. *Шокер Х.М., Мустафин М.Г.* Геодезическое обеспечение использования технологии лазерного сканирования для фиксации памятников культурного наследия // Геодезия и картография. 2021. № 2. С. 2–10. DOI: 10.22389/0016-7126-2021-968-2-2-10

10. *Вальков В.А., Мустафин М.Г., Макаров Г.В.* Применение наземного лазерного сканирования для создания трехмерных цифровых моделей Шуховской башни // Записки Горного института. 2013. Т. 204. С. 58–61. EDN RSEQRH.

11. *Вальков В.А., Виноградов К.П.* Методика автоматического моделирования дефектов покрытия автодорог по данным мобильного лазерного сканирования // Геодезия, картография, геоинформатика и кадастры. Наука и образование: сборник материалов III Всероссийской научно-практической конференции. 2019. С. 209–215. EDN LCNURO.

12. *Брынь М.Я., Богомолова Н.Н., Журавлев И.Н., Никитчин А.А.* Возможности применения лазерного сканирования на стадии изысканий при реконструкции искусственных сооружений // Бюллетень результатов научных исследований. 2020. № 1. С. 43–53. DOI: 10.20295/2223-9987-2020-1-43-53. EDN IEWCHM.

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