International Journal for Computational Civil and Structural Engineering, 18(2) 43–50 (2022)

DOI:10.22337/2587-9618-2022-18-2-43-50

COMPARATIVE ANALYSIS OF STATIC AND DYNAMIC PILE TESTS IN DIFFICULT GROUNDS OF KAZAKHSTAN

Ascar Zh. Zhussupbekov [1], Ascar U. Yessentayev [1], Victor N. Kaliakin [2], Irina V. Drozdova [3]

[1] L.N. Gumilyov Eurasian National University, Nur-Sultan, KAZAKHSTAN
[2] University of Delaware, Newark, USA
[3] Saint Petersburg State University of Architecture and Civil Engineering, Saint Petersburg, RUSSIA

Abstract. A comparative analysis of the results of field tests to determine the bearing capacity of a pile at the facilitys in the Nur-Sultan city and Petropavlovsk city. The aim of the study was to carry out a comparative analysis of the results of dynamic and static tests in the two construction site in order to identify the difference in performance. This article provides programs and results of tests with static indentation load and dynamic load on a pile in different two of the construction site under different soil conditions. The results of the comparative analysis are the following: Dynamic tests are needed for a preliminary assessment of the dynamic bearing capacity and the possibility of driving piles in different soil conditions. The bearing capacity of the pile, determined by dynamic tests, is slightly lower than during static tests, the difference between the results is 11 and 17%.

Keywords: static test, dynamic tests, pile, comparative analysis, bearing capacity.

СРАВНИТЕЛЬНЫЙ АНАЛИЗ СТАТИЧЕСКИХ И ДИНАМИЧЕСКИХ ИСПЫТАНИЙ СВАИ В СЛОЖНЫХ ГРУНТОВЫХ УСЛОВИЯХ КАЗАХСТАНА

А.Ж. Жусупбеков [1]***, А.У. Есентаев*** [1]***, В.Н. Калякин*** [2]***, И.В. Дроздова*** [3]

[1] Евразийский Национальный Университет им. Л.Н.Гумилева, г. Нур-Султан, КАЗАХСТАН
[2] Университет Делавэра, г. Ньюарк, США
[3] Санкт-Петербургский государственный архитектурно-строительный университет, г. Санкт-Петербург, РОССИЯ

Аннотация. Проведен сравнительный анализ результатов натурных испытаний по определению несущей способности сваи на объектах г. Нур-Султан и г. Петропавловск. Целью исследования было провести сравнительный анализ результатов динамических и статических испытаний на двух строительных площадках с целью выявления разницы в эксплуатационных характеристиках. В данной статье приведены программы и результаты испытаний со статической вдавливающей нагрузкой и динамической нагрузкой на сваю на двух разных стройплощадках при разных грунтовых условиях. Результаты сравнительного анализа, следующие: Динамические испытания необходимы для предварительной оценки динамической несущей способности и возможности забивки свай в различных грунтовых условиях. Несущая способность сваи, определенная при динамических испытаниях, несколько ниже, чем при статических испытаниях, разница между результатами составляет 11 и 17 %.

Ключевые слова: статические испытания, динамические испытания, сваи, сравнительный анализ, несущая способность.

INTRODUCTION

The 800-bed Astana Medical University Hospital is being constructed on the right bank of the Esil River in the city of Nur-Sultan, Kazakhstan. The total area of the hospital will be 140 thousand square meters. It will house a consultative and diagnostic

Version of record at: https://doi.org/10.22337/2587-9618-2022-18-2-43-50

center, round-the-clock and day facilities with 800 and 110 beds, respectively. The architectural rendering of the hospital complex is shown in Figure 1.

Figure 1. The architectural rendering of 800-bed Astana Medical University Hospital

Figure 2. The architectural rendering of the hospital complex in Petropavlovsk city

The hospital complex in Petropavlovsk city will be equipped with state-of-the-art equipment. Therefore, in order to improve their qualifications, 200 local doctors will undergo training abroad. The hospital is designed for 540 beds, dozens of modern departments. On the territory of the medical complex, there is a take-off platform for sanitary aviation. A separate conference building will be built here. The new multidisciplinary hospital will become a major medical center, attractive for citizens of other countries. The architectural rendering of the hospital complex is shown in Figure 2

Version of record at: https://doi.org/10.22337/2587-9618-2022-18-2-43-50

1. PILE DYNAMIC TESTS

1.1. Pile dynamic tests in Nur-Sultan

Field tests of test piles C9-30 and C12-30 with dynamic load were carried out from September 21 to September 29, 2020 at the construction site "Construction and operation of the united university hospital for 800 beds at NJSC" Astana Medical University "in the city of Nur-Sultan. In axes X1-X70 and Y1-Y-60. Test piles C9-30 and C12-30 numbered 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17 were subjected to dynamic tests. 18, 19 immersed in the ground to a depth of 8.5 m from the absolute elevation of the bottom of the pit 339.82 ÷ 340.22 m, indicated on the layout of the test piles. Driving and finishing of test piles was carried out from September 21 to September 23, 2020 using a Junttan PM-25HD piling rig with an NNK-8A hydraulic hammer with a shock mass of 8000 kg and a headband weighing 990 kg. When driving the piles, wooden spacers were used inside the metal head to prevent the destruction of the pile head. The drop height of the striking part of the hammer ranged from 0.3 ÷ 0.4 meters

The finishing of the piles was carried out on September 29, 2020 with two successive pledges of three and five blows, after 6 ÷ 8 days from the moment of the end of the pile driving. Before finishing, in order to accurately fix the movement, a measuring tape with a scale of 1 mm was glued to the pile. Observation of the sinking of the piles was carried out using a level.

Failures of piles during their finishing ranged from 0.26 cm to 0.42 cm with a hammer energy of 2.4 t* m.

To determine the bearing capacity, the largest average failure of three and five blows was taken, obtained when finishing the pile after their "rest" (MSP 5.01-101-2003), (SP RK 5.01-102-2013). The data obtained are given in the acts of dynamic tests of piles and are attached to the report

Figure 3. a) Junttan PM-25HD piling rig in Nur-Sultan city, b) test pile

The dynamic test results in Nur-Sultan are in the table 1.

Table 1. The dynamic test results in Nur-Sultan

№	Depth of driving piles into the ground, m	The height of the fall of the striking part during finishing, m	Failure of piles during finishing, cm	Partial value of ultimate resistance of piles, kN	Bearing capacity of piles, kN
1	9,50	0,30	0,34	813	
2	9,50	0,30	0,30	869	
3	9,50	0,30	0,27	919	
4	9,50	0,30	0,22	1025	
5	9,50	0,30	0,30	869	
6	9,50	0,30	0,20	1078	
7	9,50	0,30	0,60	590	
8	9,50	0,30	0,86	783	
9	9,50	0,30	0,46	682	813
10	9,50	0,30	0,70	542	
11	9,50	0,30	0,53	631	
12	9,50	0,30	0,84	789	
13	9,50	0,30	0,40	744	
14	9,50	0,30	0,30	869	
15	9,50	0,30	0,56	620	
16	9,50	0,30	0,30	869	
17	9,50	0,30	0,30	869	

1.2. Pile dynamic tests in Petropavlosk

Dynamic tests were carried out from September 26, 2020, using a Junttan PM-25HD pile driver.

Version of record at: https://doi.org/10.22337/2587-9618-2022-18-2-43-50

The piles in these groups numbered 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17 were subjected to dynamic tests. Additional information related to the piles is available in the report on dynamic testing prepared by KGS Astana LLP .

Figure 4. Junttan PM-25HD piling rig in Petropavlovsk

The dynamic test results in Petropavlovsk are in the table 2.

Table 2. The dynamic test results in Petropavlovsk

№	Depth of driving piles into the ground, m	The height of the fall of the striking part during finishing, m	Failure of piles during finishing, cm	Partial value of ultimate resistance of piles, kN	Bearing capacity of piles, kN
1	10,4	0,40	0,52	745	
2	10,4	0,40	0,54	730	
3	10,4	0,40	0,44	816	
4	10,4	0,40	0,50	761	
5	10,4	0,40	0,56	717	
6	10,4	0,40	0,48	779	
7	10,4	0,40	0,48	779	
8	10,4	0,40	0,52	745	
9	10,4	0,40	0,52	745	746
10	10,4	0,40	0,50	761	
11	10,4	0,40	0,48	779	
12	10,4	0,40	0,56	717	
13	10,4	0,40	0,50	761	
14	10,4	0,40	0,52	745	
15	10,4	0,40	0,56	717	
16	10,4	0,40	0,44	816	
17	10,4	0,40	0,48	779	

1.3. Summary about the dynamic tests

In the Nur-Sultan city:

1. The average load-bearing capacity of test piles in groups C9-30 and C12-30, driven to a depth of 8.50 m at the above construction site is 813 kN.
2. The permissible load on the pile, taking into account the safety factor $\gamma_k = 1.4$ in accordance with paragraph 3.10. of SNiP RK 5.01.-03-2002 “Pile foundations” should thus be taken equal to 580kN.

In the Petropavlovsk city:

1. The average load-bearing capacity of test piles in groups C12-30, driven to a depth of 10.40 m at the above construction site, is 746 kN.
2. The permissible load on the pile, taking into account the safety factor $\gamma_k = 1.4$ in accordance with paragraph 3.10. of SNiP RK 5.01.-03-2002 “Pile foundations” should thus be taken equal to 533 kN.

2. PILE STATIC TESTS

2.1. Pile static tests in Nur-Sultan

Field tests of S10-30 driven piles with static, vertical-indentation loads were carried out from December 02, 2020 to January 08, 2021 at the construction site of the Main Building and the Parking lot of the facility “Construction and operation of a united university hospital for 800 beds at NJSC“ Astana Medical University "In Nur-Sultan".

The tests were carried out on four driven test piles C10-30 numbered 29, 40 (Main building) and 62, 66 (Parking), immersed in the ground to a depth of 9.5 m, up to abs. the marks of their bottom are 330.28 ÷ 331.80 m. These test piles are shown in Figure 5.

Field tests were carried out after the piles “rest”, equal to 30 ÷ 60 days after their driving. According to fig. 3. The load on the pile was created using a 100-ton hydraulic jack "Enerpred DU100P150" with a pumping station "Enerpac P462", abutting against a test and loading stand, weighing 120.0 tons.

Version of record at: https://doi.org/10.22337/2587-9618-2022-18-2-43-50

The process is described in detail in the articles previously published. [1,2]. Piles settlement graphs are show in Figure 6.

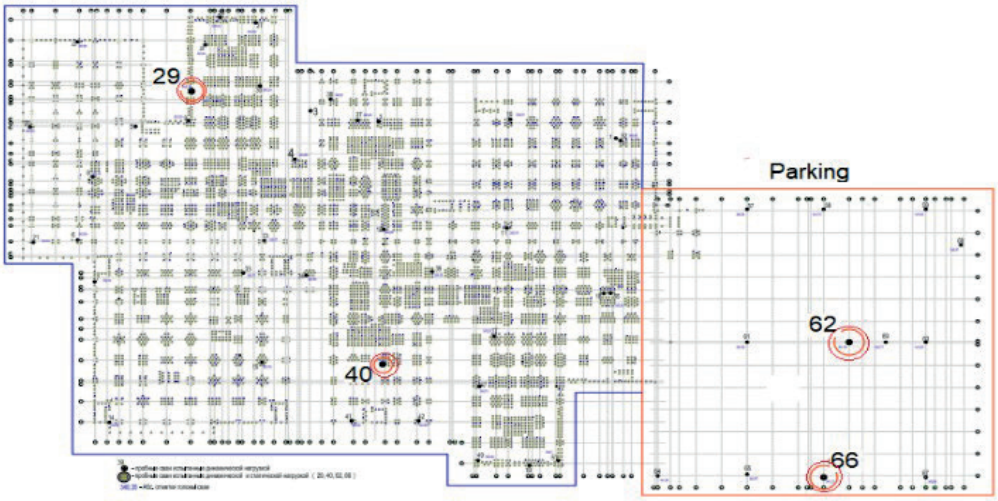

Figure 5. Test pile layout plan

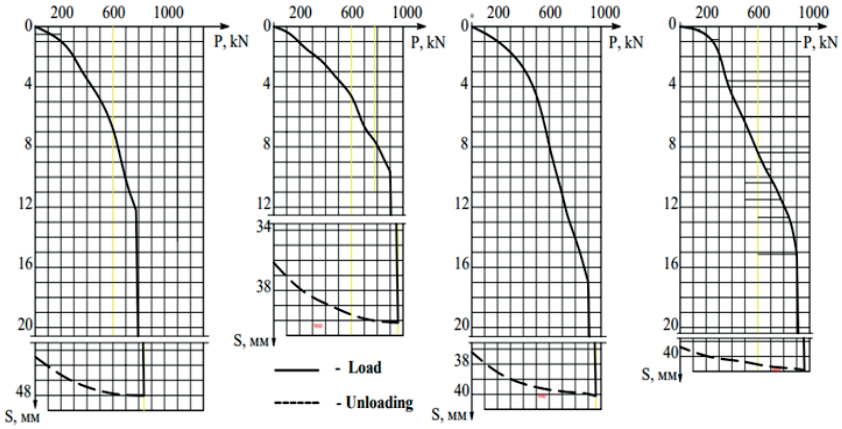

Figure 6. Pile settlement graphs in Nur-Siltan

Static pile tests results in Nur-Sultan:

1) The bearing capacity of the piles test at the locations of the main hospital building and the parking structure were 990 kN and 780 kN, respectively.

2) The permissible pile load, taking into account the safety factor γ_k = 1.2 in accordance with clause 4.4.1.11. SP RK 5.01-103-2013 "Pile foundations" should be taken equal to 750 kN and 650 kN for the main hospital building and parking structure locations, respectively.

Table 3. The static test results in Nur-Sultan

Pile №	Depth of immersion of piles in the ground, m	Maximum applied load, kN	Displacement at the highest applied load, mm	Partial value of ultimate resistance, kN	Bearing capacity of piles, kN
№ 62	9,5	840	48,01	780	780
№ 66	9,5	960	40,14	900	
№ 29	9,5	960	40,12	900	900
№ 40	9,5	960	40,91	900	

Version of record at: https://doi.org/10.22337/2587-9618-2022-18-2-43-50

2.2. Pile static tests in Petropavlovsk

The movement of each pile was measured by two 6PAO deflectiometers with a scale division of 0.01 mm, and by four digital electronic displacement transducers of the type 027DG1, 027DG2, 027DG3, 027DG4 working in conjunction with the aforementioned SLT2 monitoring system.

Figure 7. Loading stand

The devices that are part of the SLT2 system are specially designed to monitor static load testing of piles in accordance with Eurocode 7. This system provides the ability to monitor static load testing of piles at a distance of up to 25 m, and allows personnel (testers) to remotely monitor behind the settlement of the piles and the actual load on the pile without approaching the potentially dangerous zone of the test site structure, where the system is under high pressure and load [3].

The piles were tested with static, stepwise increasing loads. This consisted of five load steps 166 kN (60 bar), next 111 kN (40 bar). The maximum load is 999 kN (pile №170), 1164 kN (piles №203, 157, 126, 492) и 1274 kN (pile №137).

The associated displacements of the piles were 48,10 mm, 39,99 mm, 41,30 mm, 41,33 mm, 42,29 mm и 41,84 mm, respectively.

Each pile was unloaded in steps, with each unloading step being observed for at least 15 minutes.

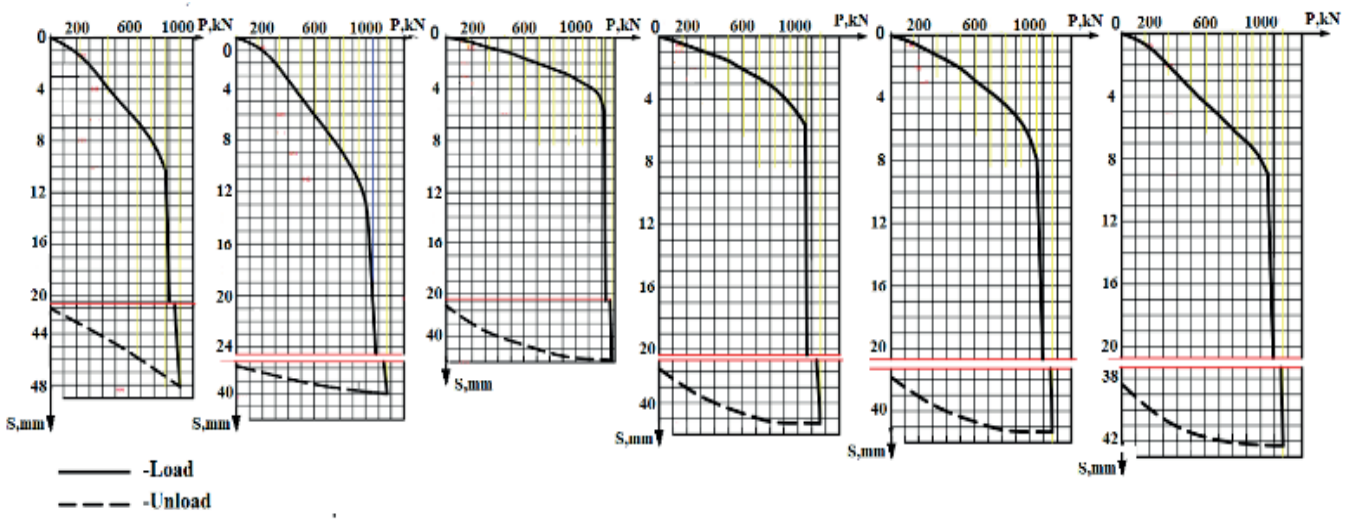

Figure 8. Pile settlements graphs in Petropavlovsk

After complete unloading (to zero), observation of the elastic displacements of the pile was carried out for 60 minutes, with the movement of the piles being recorded every 15 minutes [4,5]

Static pile tests results in Petropavlovsk

1) The bearing capacity of the piles test at the locations of the main hospital building was 995 kN.

2) The permissible pile load, taking into account the safety factor γ_k = 1.2 in accordance with clause 4.4.1.11. SP RK 5.01-103-2013 “Pile foundations” should be taken equal to 829 kN for the main hospital building.

Piles settlement graphs are show in Figure 8

Table 4. The static test results in Petropavlovsk

Pile №	Depth of immersion of piles in the ground, m	Maximum applied load, kN	Displacement at the highest applied load, mm	Partial value of ultimate resistance, kN	*Bearing capacity of piles, kN
№ 170	10,4	999	48,10	917	995
№ 203	10,4	1164	39,99	1053	
№ 137	10,4	1274	41,84	1230	
№ 157	10,4	1164	41,30	1063	
№ 126	10,4	1164	41,33	1093	
№ 492	10,4	1164	41,33	1090	

CONCLUSION

1. Based on the results of dynamic and static tests, it is possible to successfully determine the permissible load for piles.
2. Dynamic tests are needed for a preliminary assessment of the dynamic bearing capacity and the possibility of driving piles in different parts of a construction site under different soil conditions.
3. Static indentation test results must be considered when determining the correct pile length.
4. The bearing capacity of the piles, determined by a dynamic tests, is approximately 11% lower than during static tests in Nur-Sultan.
5. The bearing capacity of the piles, determined by a dynamic tests, is approximately 17% lower than during static tests in Petropavlovsk

REFERENCES

1. **Tulebekova A.S., Zhusupbekov A.Zh., Shakhmov Zh.A., Yenkebayev S.B.**. Opyt provedeniya ispytanij po mezhdunarodnomu standartu ASTM v slozhnyh gruntovyh usloviyah goroda Astany [Experience of testing according to international standard ASTM on problematical soil ground of Astana]. *Vestnik Evraziiskogo natsional'nogo universiteta imeni L.N. Gumileva*, 2012, publ. no. 2 (87), pp. 126-131. (In Russian).
2. **Zhussupbekov A.Zh., Syrlybaev M.K., Lukpanov R.E., Omarov A.R.** The applications of dynamic and static piling tests of Astana. The 15th Asian Regional conference on soil mechanics and geotechnical engineering. Fukuoka, Japan, 2015, pp. 508-508.
3. **Turashev A.S., Lukpanov R.E., Omarov A.R., Zhukenova G.A., Tanyrbergenova G.K.** The applications of dynamic (PDA and traditional) and traditional static piling tests of Astana city. *Vestnik Evraziiskogo natsional'nogo universiteta imeni L.N. Gumileva*, 2015, publ. no. 6 (109), part 1, pp. 244-249.
4. **Yenkebayev S.B**. Comparison results of static and dynamic load test at the construction site of Astana / S.B. Yenkebayev, R.E. Lukpanov, A.Zh.Zhussupbekov // Proc. of Korea-Kazakhstan Joint Geotechnical Seminar. – Incheon, Korea, 2012. pp. 115-121.
5. **Tulebekova A.S., and Zhussupbekov A.Zh**. Geotekhnicheskaya specifika mezhdunarodnyh trebovanij i tradicionnyh standartov pri ispytanii svaj [Geotechnical specificity of international requirements and traditional standards in pile testing]: Monograph. L.N. Gumilyov Eurasian National University. – Moscow: Moscow University Press, 2020, – 111 P. (in Russian).

СПИСОК ЛИТЕРАТУРЫ

1. **Тулебекова А.С., Жусупбеков А.Ж., Шахмов Ж.А., Енкебаев С.Б..** Опыт проведения испытаний по международному стандарту ASTM в сложных грунтовых условиях города Астаны. Вестник евразийского национального университета им. Л.Н.

Гумилева**,** 2012, – Изд. №. 2 (87), с. 126-131.
2. **Zhussupbekov A.Zh., Syrlybaev M.K., Lukpanov R.E., Omarov A.R.** The applications of dynamic and static piling tests of Astana. The 15th Asian Regional conference on soil mechanics and geotechnical engineering. Fukuoka, Japan, 2015, pp. 508-508.
3. The applications of dynamic (PDA and traditional) and traditional static piling tests of Astana city / A.S. Turashev, R.E. Lukpanov, A.R. Omarov, G.A. Zhukenova, G.K. Tanyrbergenova // Вестник Евразийского национального университета им. Л.Н. Гумилева. – 2015. – Изд. № 6 (109), ч. 1. – С. 244–249.
4. **Yenkebayev S.B**. Comparison results of static and dynamic load test at the construction site of Astana / S.B. Yenkebayev, R.E. Lukpanov, A.Zh. Zhussupbekov // Proc. of Korea-Kazakhstan Joint Geotechnical Seminar. – Incheon, Korea, 2012. – P. 115-121.
5. **Tulebekova A.S., and Zhussupbekov A.Zh**. Геотехническая специфика международных требований и традиционных стандартов при испытании свай : Монография. Евразийский национальный университет им. Л.Н. Гумилева. – М.: Издательство МГУ, 2020, – 111 Р.

Ascar Zh. Zhussupbekov, President of Kazakhstan Geotechnical Society, Dr.Sc., Academic of National Engineering Academy of Kazakhstan, Chair of TC 305 (ISSMGE) on Geotechnical Infrastructures of Megacities and New Capitals, Professor of Eurasian National University; 2, Satpayev Street Nur-Sultan, Kazakhstan, 010008, Phone: +7-701-5118382; email: astana-geostroi@mail.ru

Ascar U. Yessentayev, PhD Student of Eurasian National University; 2, Satpayev Street Nur-Sultan, Kazakhstan, 010008, Phone: +7-776-5730101; email: askaryess777@gmail.com

Victor N. Kaliakin, Professor, Department of Civil & Environmental Engineering, University of Delaware, 360F, Newark, DE 19716, U.S.A.; Phone: +01 302.831.2409; email: kaliakin@udel.edu

Irina V. Drozdova, Dr.Sc., Professor, Saint Petersburg State University of Architecture and Civil Engineering, 4, Vtoraya Krasnoarmeiskaya st., Saint Petersburg, 190005, Russia, Phone: +7(812)495-35-44; email: managment@spbgasu.ru

Жусупбеков Аскар Жагпарович, Президент Казахстанского геотехнического общества, д.т.н., академик Национальной Инженерной Академии Казахстана, председатель ТС 305 (ISSMGE) по Геотехническим Инфраструктурам Мегаполисов И Новых Столиц, профессор Евразийского национального Университета; ул. Сатпаева, 2, г. Нур-Султан, Казахстан, 010008, тел.: +7-701-5118382; email: astana-geostroi@mail.ru

Есентаев Аскар Уалиевич, докторант Евразийского Национального Университета; ул. Сатпаева, 2, г. Нур-Султан, Казахстан, 010008, тел.: +7-776-5730101; email: askaryess777@gmail.com

Калякин Виктор Николаевич, профессор кафедры гражданской и экологической инженерии, Делавэрский Университет, 360F, Ньюарк, Делавэр, 19716, США; Телефон: +01 302.831.2409; email: kaliakin@udel.edu

Дроздова Ирина Валерьевна, д.т.н., профессор Санкт-Петербургского Государственного Архитектурно-Строительного Университета, ул. 2 Красноармейская, д. 4, г. Санкт-Петербург, Россия, 190005 тел.: +7(812)495-35-44; email: managment@spbgasu.ru