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GEOTECHNICAL SPECIFICATION OF AMERICAN AND KAZAKHSTAN STANDARDS IN PILE TESTING

Askar Zhussupbekov[1], Assel Tulebekova[1], * Talal Awwad[2], Turlybek Mussabayev[1] and Akmaral Tleubayeva[1]

[1]Department of Civil Engineering, L.N. Gumilyov Eurasian National University, Kazakhstan. [2]Damascus University, Damascus, Syria; Saint Petersburg State University of Architecture and Civil Engineering, St. Petersburg, Russia.

*Corresponding Author, Received: 18 Feb. 2019, Revised: 19 March 2019, Accepted: 22 April 2019

ABSTRACT: Pile foundations become more essential during the construction of mega projects of the new capital of Kazakhstan–Astana. Many advanced pile technologies are appearing today. Unfortunately, Kazakhstan Standards have not a recommendation for modern pile design, testing and quality control methods. This paper presents methodic of the testing pile by ASTM D8169 (USA) standard and the State Standard 5686-94 (Kazakhstan). The methodic of testing piles by these standards have some differences. Discussion of using control equipment, technological features of the aforementioned methodic shall be important for the understanding of different points. The paper includes the results of piles of static tests using ASTM standards. The recommendations for the future modernization of Kazakhstan Standards have been given. It was concluded that the tests conducted according to the requirements of American standards which have made them more accurate and reliable.

Keywords: Pile, test, Standard, Methodic Comparison

1. INTRODUCTION

The world practice shows the construction development directly indicating a state economic position throughout the world. It is one of the relevant fields for future advance and development overall. One of the challenging issues of constructions, through the lens of economic efficiency, is designing and laying foundations in difficult soil conditions.

Many scientists have carried out the investigation of pile works in the soil; they are Dalmatov B.I., Mangushev R.A., Fadeev A.B., Roger Frank, etc. [1]

The big attention is paid to a rise of labor productivity, quality and structures safety. The high production rates can be achieved with proper planning and design, efficient equipment and experienced personnel.

Unfortunately, the present Standards have confined the application of modern technology of pile foundation installation, indicating incomplete usage of advanced technology [2].

Nowadays many international projects are being carried out in Kazakhstan. For example, Italian and American companies, which work in the western part of Kazakhstan, have faced some difficulties of non-compliance between Kazakhstan Codes and international ones. Kazakhstan engineers also have some problems in modern projects designing where advanced technologies are generally used [3-4].

The paper presents the analysis of the results of soils field tests by piles on the construction site “The USA Embassy” in Astana city.

The dynamic and static tests of soils on the field were carried out by steel piles according to the requirements of ASTM D8169 (USA) standard and the State Standard 5686-94 (Kazakhstan).

2. FIELD TESTS METHODOLOGIES

2.1 DYNAMIC LOAD TEST ACCORDING TO THE STATE STANDARD 5686-94 (KAZAKHSTAN)

In Kazakhstan, the dynamic test is carried out by using many types of pile driving machine. The special marks every 1 m are painted on its surface along the whole length of the pile before the pile driving but in the last meter every 0.1 m.

The number of blows is recorded for every meter of pile penetration and last meter every 0.1m in the pile driving process. The test pile driving is terminated until the designing refusals (cm/blows). It is necessary to use average refusals for a definition of bearing capacity of piles, which are obtained during the piles re-driving after their "rest". The rest time depends on a soil condition of the site: for clayey soil 6 -10 days, for sandy and gravel soil up to 3 days [5].

The re-driving of test piles is done gradually with three and five blows of the hammer.

A measuring tape is attached on test piles before the beginning of re-driving, with the length of 10 cm, divided by 1 mm. The control of the test pile penetration is conducted with the theodolite.

2.2 STATIC LOAD TEST ACCORDING TO THE STATE STANDARD 5686-94 (KAZAKHSTAN)

The static load test should be carried out for driving piles after the “rest” and for bored piles after achievements of the concrete strength more than 80%. For the static load tests the following equipment is used: hydraulic jack SMJ-158A - 200 ton; caving in-measurers of the type 6PAO.

The distance between the testing pile till anchoring pile is 5d<L_1>2.5m. The pressure in the jack was created by the help of manual oil pump station MNSR-400 with power up to 800 kg/cm², the moving of steel piles was fixed by caving in-measurers of the type 6-PAO, which were installed on both sides of unmovable bearings with the benchmark system.

The first record was performed just after putting the loading, then consequently 4 records with an interval of 15 minutes, 2 records with an interval of 30 minutes and further for every hour until the conditional stabilization of pile settlement. For the criterion of conditional stabilization of pile, the settlement was taken when the speed of settlement of piles on the given stage of loading did not exceed 0.1 mm during the last 1-2 hours of observations. Reloading (unloading) was conducted half stages of the loading.

3. PILES TESTING

The construction site is located on the South-Eastern side of the capital of the Republic of Kazakhstan in Astana (the USA Embassy in Astana), on the right bank of the Esil River (see Figure 1). The city's territory is located on the Kazakh shield and does not have tectonic movements, therefore its territory is not considered as seismic [6].

Fig.1 the USA Embassy in Astana

The geological conditions of the field are as follows: middle quaternary modern deposits of loam, clays with lenses of gravel sand and loam, gravel; alluvial deposits with loams having gravel, sandstone, aleurolite, gruss; aleurolite-alluvial deposits of middle Jurassic rocks (see Figure 2). All of the mentioned layers are under the topsoil. Groundwater level at the depth of 1.2-2.3m, the absolute marks of the level is 349,40÷347,70 m.

All soils are permeable. The permeability coefficients for permeable soils:

- alluvial loam and clays – 0.53m/day;
- gravels – 55.5m/day;
- eluvial loam – 0.0094m/day;
- gruss-gravel 0.21-1.66m/day.

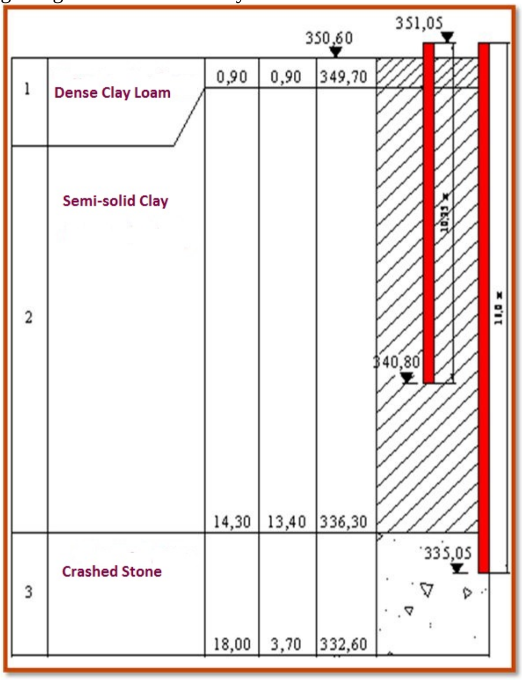

Fig. 2 Geology of the construction site of the USA Embassy in Astana

The project provided for dynamic tests on nine sample steel piles. The length of the steel piles is 12 m. Table 1, Figures 3-6 presents results of dynamic pile test before pile length increasing.

Table 1 Results before pile length increasing

Pile number	Embedded depth in the soil, m	Refusal of the pile at driving, cm	Project refusal of pile, cm	Design load, kN
LT-1	7,00	1,00	1,25	600
LT-2	9,00	1,09	1,25	600
LT-3	10,00	1,14	1,25	600
LT-4	9,25	1,25	1,25	600
LT-5	8,25	1,00	1,25	600
LT-6	10,25	1,25	1,25	600
LT-7	8,00	1,56	1,67	400
LT-8	8,25	1,47	1,67	400
LT-9	7,75	1,67	1,67	400

Before driving, the marks were painted on the surface of steel piles on every 25 cm for the entire length of the pile. From the calculations, it was accepted that during dynamic tests steel piles are driven according to the following preliminary criteria [7]:

- For a design load of 600 kN, the failure is 1.25 cm;
- For a design load of 400 kN, the failure is 1.67 cm.

Table 2, Figures 7-10 presents results of dynamic pile test after pile length increasing. Before driving, the marks were painted on the surface of steel piles on every 25 cm for the entire length of the pile. From the calculations it was accepted that during dynamic tests steel piles are driven according to the following preliminary criteria:

- For a design load of 600 kN, the failure is 1.25 cm;
- For a design load of 400 kN, the failure is 1.67 cm.

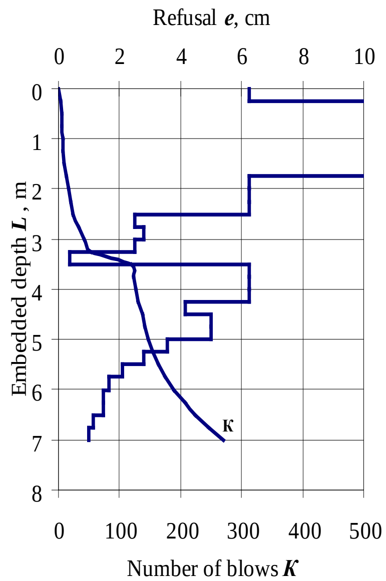

Fig. 3 Graphics before pile length increasing for testing pile LT1

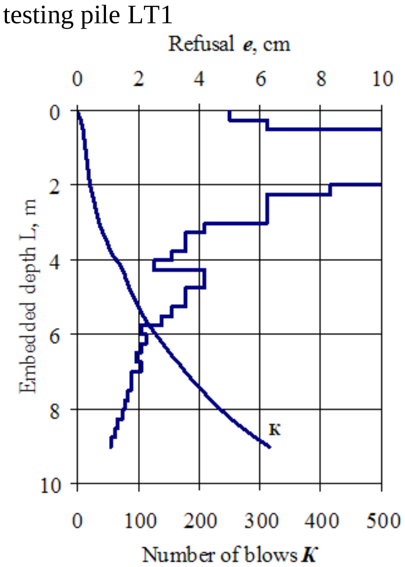

Fig. 4 Graphics before pile length increasing for testing pile LT2

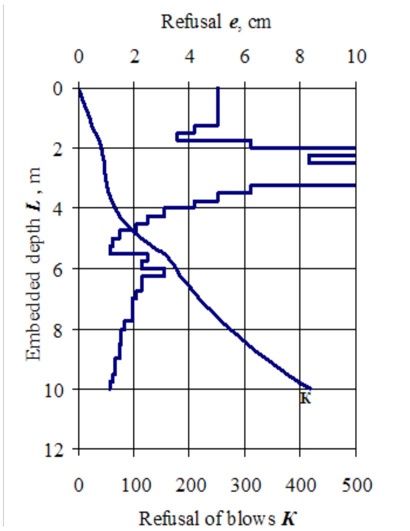

Fig. 5 Graphics before pile length increasing for testing pile LT3

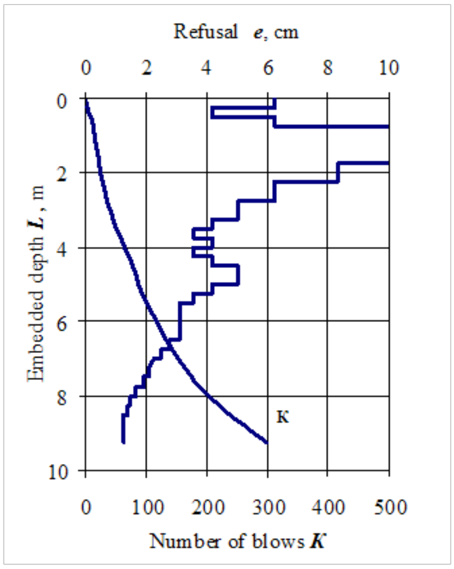

Fig.6 Graphics before pile length increasing for testing pile LT4

Table 2 Results of driving of steel piles after pile length increasing

Pile number	LT-1	LT-4	LT-6	LT-7
Embedded depth, m	7,00	9,25	10,25	8,00
Refusal of the pile at driving, cm	1,00	1,25	1,25	1,56
Settlement, mm	43,03	42,55	40,25	40,88
Design load, kN	600	600	600	400
Applied load, kN	900	900	900	600
Max. load, kN	1200	1200	1200	8000

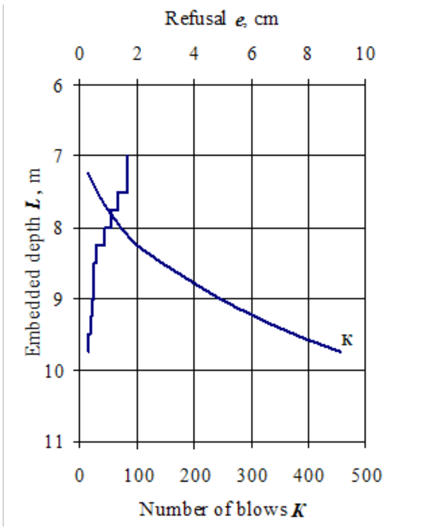

Fig. 7 Graphics after pile length increasing, LT1

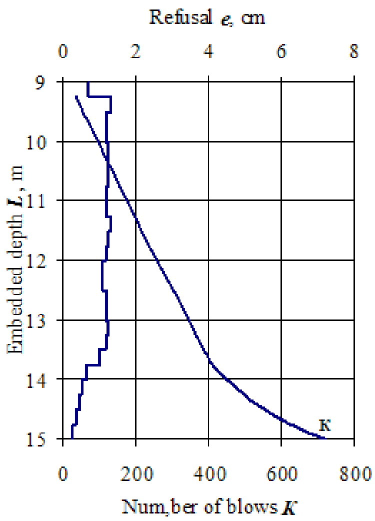

Fig. 8 Graphics after pile length increasing, LT2

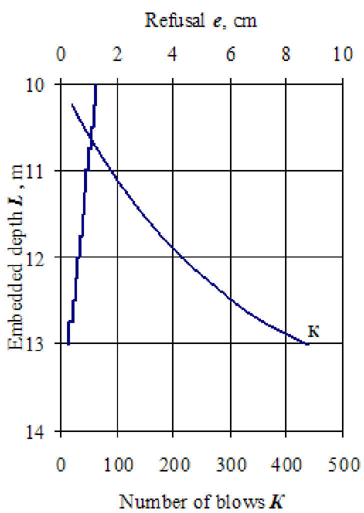

Fig. 9 Graphics after pile length increasing, LT3

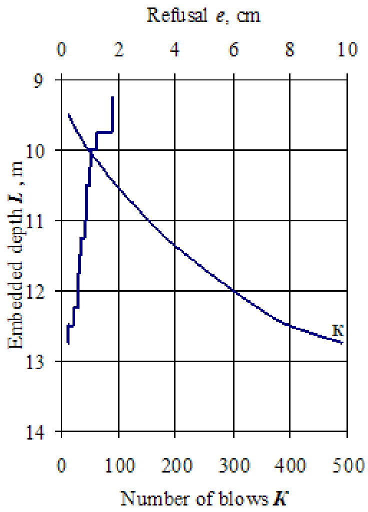

Fig. 10 Graphics after pile length increasing, LT4

The purpose of the static load test is to determine the settlement and bearing capacity of piles.

In order to test the soils, static vertical-pressing loads were used with anchor-support stands consisting of basic and auxiliary beams systems, four anchor piles and anchor strings (clamps).

Special landfills were prepared by driving experimental and anchor piles, installing metal structures of the anchor stand, welding anchor ties to anchor piles. The distance between the testing pile till anchoring pile is $3d < L_1 > 1.5$m.

Static tests of steel piles that were driven according to preliminary criteria, such as pile failure of 1.25 cm to 600 kN and failure of 1.67 cm to 400 kN, showed negative results.

After receiving negative results from static tests, the piles were increased in length and were additionally hammered to the preliminary criteria:

- for the design load of 600 kN, a failure of 0.33 cm;
- for the design load of 400 kN, a failure of 0.83 cm.

The piles were hammered in the same way as the first time, with the same hammer. Static testing of steel piles was carried out after "rest" without consecutive hammering of experimental piles in order to save time.

The results of the static test of steel piles before pile length increasing are shown in Table 3 and Figure 11 [8].

The soil was tested again with static loading after piles length increasing and additional driving of the experimental piles, (see Table 4, Figure 12). The static tests were carried out in the same way as in previous tests.

Table 3 Results of the static test of steel piles before pile length increasing

Pile number	LT-1	LT-4	LT-6	LT-7
Embedded depth, m	7,00	9,25	10,25	8,00
Refusal of the pile at driving, cm	1,00	1,25	1,25	1,56
Settlement, mm	43,03	42,55	40,25	40,88
Design load, kN	600	600	600	400
Applied load, kN	900	900	900	600
Max.load, kN	1200	1200	1200	8000

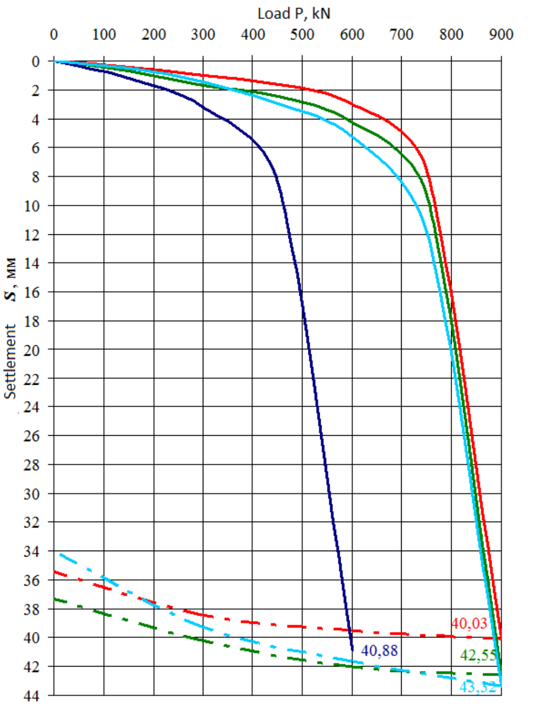

Fig.11 Correlation between settlement S and load P, the results of field static tests on piles before increasing

Table 4 Results of the static test of steel piles after pile length increasing

Number of piles	LT-1	LT-4	LT-6	LT-7
Embedded depth, m	7,00	9,25	10,25	8,00
Driving depth, m	9,75	12,75	16,00	11,25
Refusal of the pile at driving, after pile length increasing, cm	0.31	0.27	0.30	0.78
Number of piles	LT-1	LT-4	LT-6	LT-7
Settlement, mm	4.80	4.96	6.27	3.38
Design load, kN	600	600	600	400
Applied load, kN	1200	1200	1200	800
Max. load, kN	1200	1200	1200	800

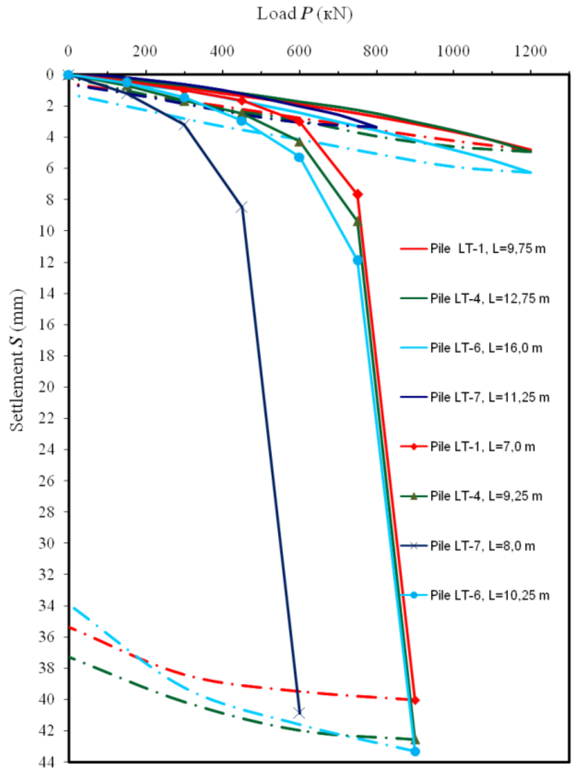

Fig.12 Correlation between settlement S and load P, the results of field static tests on piles after increasing

4. COMPARATIVE ANALYSES

The Kazakhstan Standard has not changed since the 1994 year, ASTM standard was updated in 2007, and therefore latest developments have taken in technology and technical terms and provides for the use of more modern equipment.

The analysis of static and dynamic tests in the construction site “the USA Embassy” shows that the tests with ASTM make them more reliable and give detailed information about the process of testing and results.

After comparing the methods of soil testing with piles according to the American standard, it was noticed that more detailed requirements are presented, most of which are not mentioned in the state standard. There are main differences between the requirements of soils state standards 5686-94 ".

Methods for field testing of piles" and standards of ASTM Standard Test Method for Piles Under Static Axial Compressive Load "are presented in Table 5 [9].

The state standard was regulated only two out of six measurements with reducers provided by ASTM (see Table 6).

Table 5 Principal differences between American Standard and Kazakhstan norms [10]

	State Standards	ASTM
The parameter of the experimental stand for the test		
The distance between the testing pile till anchoring pile	$5d<L_1>2.5m$	$3d<L_1>1.5m$
The distance between testing pile till	$5d<L_2>2.5m$	$L_2<2m$
Devices and equipment		
for loading	jack	Jack with Spherical prop
Measurement of load on top pile	manometer	manometer
	-	Dynamometer (more 100 tc) fixed for each jack
Measurement of load on all length pile	-	Tensometer
Measurement of axial displacement of top pile	The transducer of the axial displacement of the cap	The transducer of the axial displacement of the cap
	-	Visual control
	-	Optical instrumental control
Measurement of sway top pile	-	The transducer of sway top pile
	-	Optical control

In practice requirements by American Standard have shown that the results of the test are more safety. Because many control equipment and devices for determination, measurement reverberated are used.

According to both standards, the load on the pile is transferred by a hydraulic jack installed between the pile head and the support beam and is determined indirectly based on the pressure measurement in the hydraulic system "jack-pump". However, the domestic standard does not take into account that when two or more jacks are used where each must be equipped with a manometer or not. There is only one common feature on the manifold. It allows monitoring the work of the jacks and preventing possible irregularities of their work, hence avoids the failure of tests [11].

In some cases, the axial displacement converters may show a multidirectional displacement, which can be explained by the unparalleled support beam and the horizontal plane of the pile head. The State Standard does not give instructions on how to proceed in this case. In that case, the ASTM specifies the installment of side-shift converters to track the development of eccentric loads when the load transfer center is shifted to the axis of the pile. Follow up calculation takes into account the shift. That allows avoiding incorrect test results or their breakdown.

Table 6 Requirements according to the State Standard and ASTM

Requirements according to ASTM	Requirements according to the State Standard
The transducer of force (a measurement of the load on the top of the pile)	not regulated
The transducer of pressure (a measurement of the load on the top of the pile and control of the hydro system	The transducer of pressure (a measurement of the load on the top of the pile and control of the hydro system
displacement transducer (a measurement of the date of axial displacement of pile top)	The transducer of distance (a measurement of the date of axial displacement of the top of the pile)
displacement transducer (a measurement of the lateral displacement of the top of the pile)	not regulated
displacement transducer (a measurement of the date of axial displacement of pile bottom	not regulated
The transducer of force (a measurement of the load on pile bottom)	not regulated

The axial displacement transducer is used to measure the displacement of the lower part of the pile relative to its head. Such measurement will make it possible to determine more accurately the settlement of the soil under the pile tip, and if there are voids in the pile, the transducer differentiates between the actual settlement of the soil and the compression of the low-quality pile. For these purposes, ASTM proposes using a measurement system having a rod displacement indicator mounted on the pile head and a control rod resting instead of the selected point along the axis at the bottom of the pile. In the case of a non-axial installation, it is recommended to install two rods and indicators at the same distance from the axis of the pile on opposite sides [12-13-14].

There are special tubes made for the rods, inside of which the rods can move freely. Tubes are installed in the well and filled with concrete. Rods about the plate (screwed into the nut) that is fixed in the pile.

The force transducer for measuring the lateral resistance of the pile serves to measure the frictional force along the side of the pile along the entire length. Thus, the lateral resistance of the pile can be determined. The number and location of the transducers are determined in the test program and installed along the axis of the pile or pair at the same distance from the axis opposite to each other.

In Kazakhstan, a safety factor of SLT is 1.4 but regarding requirements of ASTM, safety factors are 2. So results which were determined by the requirement of ASTM in construction site "Embassy of USA" are more accurate.

Experience has shown that the tests conducted according to the requirements of American standards which have made them more accurate and reliable, they help to see the full course of the test process. The world experience of the ASTM using during the tests allows us concluding that the requirements, regulated in that standard, are aimed at obtaining test results with maximum reliability.

5. CONCLUSIONS

The process for the adaption of international standards to Kazakhstan ground and construction conditions must be gradual. The first step is to adapt the foreign technical documentation to the national technological environment, to develop an appropriate methodology for assessing conformity to educate builders and designers to develop appropriate training programs, handbooks and manuals, translation to the official language.

The experience has shown that the tests conducted according to the requirements of American standards which have made them more accurate and reliable, they help to see the full course of the test process. The world experience of the ASTM using during the tests allows us concluding that the requirements, regulated in that standard, are aimed at obtaining test results with maximum reliability.

The results of research directed to developing of recommendation for modernization of Kazakhstan Codes and oriented to the adaptation of advanced geo-technologies. The modernization will allow completing use of advanced technologies capabilities in existing construction condition of Kazakhstan. Also the methodic of pile test on another load have to consider in future research.

6. REFERENCES

[1] Frank R., Conceptual aspects and basic principles of Eurocode 7: Geotechnical design, Opening lecture, Atti Conferenze di Geotecnica di Torino on Geotechnical Design with Eurocodes, 22-23 November, Torino, Politecnico di Torino, Dipartimento di ingegneria strutturale e geotecnica, pp. 1-21.

[2] A.Zh.Zhussupbekov, A.S.Tulebekova, T.Mussabayev, S. Musina, Features of using control equipment of investigation of soil regarding Kazakhstan norms and Eurocode, 11 International Conferences on Geosynthetics, ICG2018, Seoul, Korea, 2018, pp.13-19.

[3] Awwad T., Kodsi S.A., Shashkin A., Negative Skin Friction Distribution on a Single Pile - Numerical Analysis. In: El-Naggar H., Abdel-Rahman K., Fellenius B., Shehata H., Sustainability Issues for the Deep Foundations. GeoMEast 2018. Sustainable Civil Infrastructures. Springer, Cham, pp. 36-48.

[4] Tulebekova A.S., Zhussupbekov A.Z., Mussabayev T., Mussina S., Features of Investigation of Soil According to Kazakhstan Norm and International Standards. In: Hemeda S., Bouassida M., Contemporary Issues in Soil Mechanics. GeoMEast 2018. Sustainable Civil Infrastructures. Springer, Cham, pp. 142-148.

[5] Awwad T. and Kodsi S.A., A comparison of numerical simulation models to determine the location of neutral plane, Proceedings of the 19th International Conference on Soil Mechanics and Geotechnical Engineering, Seoul, Korea, September 2017, pp. 1947 – 1950.

[6] A.Zh.Zhussupbekov, A.S.Tulebekova, T.Muzdybayeva, R.Lukpanov, Comparative analysis of methodics of testing pile by ASTM and GOST standards, Proceedings of the 4th International Conference on Site Characterization, Brazil, 2012, pp.134-138.

[7] GOST 5686-94. Methods for field testing by piles, Research Institute of Bases and Underground Structures, Moscow, Russia.

[8] A.Zh.Zhussupbekov, A.S.Tulebekova, N.T.Alibekova, I.T.Zhumadilov, Advantages of the pile testing methods according to the USA standards, Proceedings of the 8th Asian Yong Geotechnical Engineers Conference, 8th AYGEC, Astana, Kazakhstan, pp. 51-57.

[9] Standard Test Method for Deep Foundations Under Static Axial Compressive Load, ASTM D8169 / D8169M – 18.

[10] A.Zh.Zhussupbekov,A.Omarov,A.Moldazhanova,A.S.Tulebekova,K.Borgekova,G.Tleulenova, Investigations of the interaction of joint piles with problematical soil ground in Kazakhstan, Proceedings of seventh International conference-GEOMATE 2017, TSU MEI, Japan, 21-24 November 2017, pp.383-388.

[11] Smolin B.S, Zaharov V.V., Puzanov V.V., Features pile load test by ASTM. International Symposium, Russia, pp. 12-16.

[12] A.S.Tulebekova, Control equipment for pile test according to American and Kazakhstan standards, Journal Modern Applied Science, №6, 2015, pp.192-198.

[13] Awwad T., Yenkebayev S.B., Tsigulyov D.V., Lukpanov R.E., Analysis of Driven Pile Bearing Capacity Results by Static and Dynamic Load Tests. In: El-Naggar H., Abdel-Rahman K., Fellenius B., Shehata H. (eds), Sustainability Issues for the Deep Foundations. GeoMEast 2018, Sustainable Civil Infrastructures, Springer, Cham, pp. 77-84.

[14] Kodsi, S.A., Oda, K. & Awwad, T., Viscosity effect on soil settlements and pile skin friction distribution during primary consolidation, International Journal of GEOMATE, Dec., 2018 Vol.15, Issue 52, pp.152 -159.